Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/97/72840-00003-2		

4. Title and Subtitle	5. Report Date
COMPENDIUM OF GRADUATE STUDENT PAPERS ON ADVANCED SURFACE TRANSPORTATION SYSTEMS	August 1997
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
9. Performing Organization Name and Address Transportation Engineering Program Civil Engineering Department Texas A&M University	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency and Address Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Faculty & Editor: Conrad L. Dudek

Mentors: Marsha Anderson, Ginger Gherardi, Thomas Hicks, Joseph McDermott, Colin Rayman and H. Douglas Robertson

16. Abstract

This document is the culmination of the seventh offering of an innovative transportation engineering graduate course at Texas A&M University entitled, "Advanced Surface Transportation Systems". The seventh offering of the course was presented during the summer 1997 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. 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.

17. Key Words	18. Distribution Statement
Intelligent Transportation Systems, Advanced Traffic Management Systems, Advanced Traveler Information Systems, Commercial Vehicle Operations, Railroad/ Highway Crossing Systems, Advanced Border Crossing Systems, Rural Advanced Traveler Information, Truck Safety, Variable Speed Signs, Multiple-Lane Ramp Meters	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

COMPENDIUM OF

GRADUATE STUDENT PAPERS

ADVANCED SURFACE TRANSPORTATION SYSTEMS

AUGUST 1997

PREFACE

This document is the culmination of the sixth offering of an innovative transportation engineering graduate course at Texas A&M University entitled, "Advanced Surface Transportation Systems," which was presented during the 1997 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. 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, Joseph McDermott, Colin Rayman, and H. Douglas Robertson 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.

Gratitude and appreciation are expressed to Dr. Carroll Messer, Professor of Civil Engineering, Texas A&M University, who helped me pioneer this innovative graduate course in transportation engineering. Dr. Messer was a co-instructor for the course during the first two years it was offered. Other teaching commitments required his attention during subsequent summer terms.

Sandra Schoeneman, Senior Secretary with the Texas Transportation Institute, once again 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. A listing of all the papers that were prepared since the first offering of the course in 1990 is shown in the Appendix of this Compendium.

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

CRITERIA FOR THE SELECTION OF ADVANCED BORDER CROSSING SYSTEMS (ABCS) LOCATIONS

by

Jonathan Bean

Professional Mentor
Colin A. Rayman, P.E.
Ontario Ministry of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

With the passage of the North American Free Trade Agreement in 1994, trade between the United States, Canada, and Mexico has increased considerably. With this increase in trade, traffic volumes have also increased considerably at the land border crossings between the three countries. Stakeholders at the borders including: owners and operators, Customs and Immigration, and road authorities have found that they are unable, with their current physical and staffing resources, to keep up with the user demands at the border crossings. Processing and tolling of vehicles arriving at the border requires a considerable amount of time if performed manually. Delays are, thus, incurred on commercial and non-commercial vehicles. These delays increase the cost required to conduct business which eventually increases the consumer's cost.

To address these operational problems, advanced technologies will be implemented and tested at a few border crossings. The intent is to utilize standard pre-clearance procedures and Electronic Data Interchange (EDI) to facilitate the information exchange between commercial and Customs and Immigration agencies. Dedicated Short Range Communication (DSRC), Weigh-in-Motion (WIM), and other advanced technologies will be used at the border for detection, tolling, and clearance at the border to provide a "seamless" border operation. The collection of technologies used to improve the operations at border crossings is known as Advanced Border Crossing Systems (ABCS).

ABCS implementation, however, is not feasible at every border crossing between the U.S.-Canada and U.S.-Mexico borders. The objectives of this paper were to investigate how ABCS technology is being used currently, its effectiveness, and to identify the characteristics of border crossings that lend themselves to the success of ABCS technology. A literature review was conducted to obtain information in the following areas:

- Border Crossing Stakeholders,
- Advanced Border Crossing Technology,
- Current Border Initiatives,
- ABCS Requirements,
- Expected Benefits, and
- ITS Implementation Philosophies.

A professional contact survey was also conducted to obtain information from those affiliated with border crossings and their operations. From this information a further objective was to develop criteria for the selection of border crossings that would realize the greatest benefit from the use of ABCS technology. The final objective was to apply this criteria to a case study.

The recommended criteria developed from the literature review and professional contact survey included the following:

1. An identifiable problem must exist at the border crossing that can be alleviated using ABCS technology before implementation should be considered.
2. A high truck volume must be present.

3. A high volume of daily or weekly commuters must be present.

4. Physical expansion is either not possible or is less feasible than ABCS implementation.
5. The potential for dedicating a lane for ABCS participants must be present.
6. The geometric site characteristics must be able to accommodate the technology needed.
7. Interagency cooperation must be expected at the border crossing of interest.
8. Market-share must remain undisturbed between border crossings and businesses within the region.
9. User participation must be expected at the border crossing of interest.

The criteria were applied to the Peace Bridge spanning from Buffalo, N.Y. to Fort Erie, Ontario. Based on the recommended criteria, the Peace Bridge was found to be a good candidate site for ABCS implementation.

TABLE OF CONTENTS

INTRODUCTION

With the implementation of the North American Free Trade Agreement (NAFTA) on January 1, 1994, trade between the U.S. with Mexico and Canada has seen an accelerated rate of growth (1). A 1995 study conducted by the Texas Transportation Institute projected that Mexican exports are expected to increase by 65 to 70 percent by the year 2000. At the U.S.-Canadian border there has been a 40 percent increase in vehicle trips since 1984 with 2.7 million trucks, and 18.9 million passenger cars annually using the border crossings (2). Increased trade at the U.S.-Canadian border due to NAFTA is expected to accelerate this growth in the coming years. Other attractions, such as the new Windsor Casino, are expected to increase border crossing volumes by 4 million person trips.

This increase in trade has created operational problems at many of the border crossings especially at those in which a high percentage of the volume is made up of commercial vehicles and commuters (2). Delays due to toll payment and Customs and Immigration clearance have increased the cost of doing business for many commercial entities which eventually costs consumers more. Many businesses, namely the automotive industry, have begun to use "just-in-time delivery and "inventory on wheels" as their method of operation. This type of operation is greatly hindered by border crossing clearance delays. Pre-clearance with customs and immigration agencies using advanced technologies in conjunction with automated tolling have shown promise of operational benefits at border crossings. Advanced Border Crossing Systems (ABCS) is the name given to the use of these advanced technologies to better facilitate the traffic operations specific to border crossings.

The success of ABCS in the early stages will be based on the actual benefits in traffic operation realized at the specific border crossings in which implementation takes place. As implementation takes place on a broader scale, or at a large number of border crossings, the success of ABCS can be measured by its benefit to the commercial industry and commuting traffic using the border crossings. As this broad implementation takes place more global benefits can be realized. With broad implementation, however, the need arises for detailed strategies developed to meet the desired vision and goals of all stakeholders while taking into consideration limited resources. It is not feasible, nor is it desirable, to place ABCS at every crossing between the U.S.-Mexico and U.S.-Canada borders. Before broad implementation can occur there is a need to identify the crossings that have the greatest potential for successful implementation and realization of benefits.

Objectives

The four primary objectives of this paper were to:

1. investigate how ABCS technology is being used currently, and how effectively it addresses operational problems encountered at border crossings;
2. determine specific characteristics of border crossings that lend themselves to the success of ABCS technology;
3. develop criteria for the selection of border crossings that would realize the greatest benefit from the use of ABCS technology; and
4. apply the developed criteria to at least one case study to validate the criteria.

Scope

The primary purpose of this paper is to establish some of the basic criteria that can be used to select feasible sites for ABCS implementation. The paper will focus on crossings located on both borders to the U.S. (Canada and Mexico). Though ABCS may be used on other borders in the world, the criteria that are discussed should only be applied to the U.S. and its bordering countries. The data used to develop these criteria are limited to information given in the telephone surveys and from available literature.

Organization of Paper

This paper is organized into several sections. Following the Introduction section, is the Research Study Design section. The methodology used to achieve the objectives of this paper within the research scope is discussed in this section. The Literature Review follows the Research Study Design. This section is a review of the pertinent literature involving border crossings and advanced technology. Its purpose is to provide a background framework from which a professional contact survey and eventually recommended site selection criteria can be developed. The results of the professional contact survey are discussed, in some detail, in the Survey Results section. The next section, Summary of Findings From Literature and Surveys, is a list of some of the most relevant findings found in the literature and from the professional contact survey. From this summary and the author's personal beliefs, Recommended Site Selection Criteria are developed and presented in the next section. In the next section, Peace Bridge Case Study, these criteria are applied to the Peace Bridge which spans the Niagara River between Buffalo, New York and Fort Erie, Ontario. The Peace Bridge Case Study section is followed by an overall Conclusion section.

RESEARCH STUDY DESIGN

To accomplish the objectives of this paper a three part research study was conducted. The research study consists of a review of the pertinent literature to provide a background framework; a telephone survey of governmental agencies, bridge authorities, and consultants to provide further insight from personal experience and from different perspectives; and a case study to apply the criteria developed.

ABCS Literature Review

A literature review was conducted to provide background information on the following issues:

- Border Crossing Stakeholders,
- Advanced Border Crossing Technology,
- Current Border Initiatives,
- ABCS Requirements,
- Expected Benefits, and
- ITS Implementation Philosophies.

This review yielded information that was useful in providing a starting point for identification of site selection criteria. The development of the telephone interview, discussed below, was at least partially based on the information found in the literature.

ABCS Telephone Survey

A telephone survey was conducted in order to gain insight from several different perspectives on respondents' personal experience with ABCS technology. The survey focused on the technology being used at the border, the benefits of the technology, and positive and negative site characteristics related to implementation of ABCS.

An attempt was made to contact 30 professionals who have experience with the use of ABCS technology. Personnel from state and federal transportation agencies, Customs and Immigration, border crossing owners and operators, and consulting firms from the United States, Mexico, and Canada, were telephoned. The contact list was developed using information given by the author's mentor, Colin Rayman, with additional contacts resulting from discussions with TTI researchers and from the telephone interviews. A seven-question survey was prepared as a guideline for the information to be collected (See Figure A-1 in the Appendix).

Case Study: Peace Bridge

The Peace Bridge, spanning the Niagara River between New York and Ontario, was analyzed with some detail in the form of a case study. The case study was conducted in the context of the recommended ABCS site selection criteria that were developed from the literature review and telephone survey. The purpose of the case study was to verify the criteria by analyzing the site characteristics specific to the Peace Bridge and comparing them to the developed criteria for selecting sites. This case study discusses the feasibility of implementing ABCS at the Peace Bridge.

LITERATURE REVIEW

Border Crossing Stakeholders

Highway border crossings are highly complex operations which involve a wide range of stakeholders. Some of these stakeholders include:

- owners and operators,
- customs and immigration
- road authorities, and
- a number of user groups (commercial carriers, commuters, tourists, etc)

The owners and operators can be either public or private agencies, depending on the crossing. These agencies collect tolls in the currency of either country from both passenger vehicles and commercial trucks. Customs and immigration officials have the duty of monitoring the flow of goods and people, respectively, to ensure that only authorized passage is granted. Road authorities have the interest of maintaining acceptable traffic operations on routes leading to the border crossings and in the immediate vicinity of the crossing. Both commercial and non-commercial user groups are important stakeholders. They are the groups that are directly affected by the level of service provided at the border crossing. Successful operation of the border crossing involves a great deal of cooperation between each of these groups. Implementation of new technology at these crossings will also require the approval and full cooperation of these stakeholders. One of the main issues to resolve in the implementation of the technology is to be able to do so in a manner that achieves the diverse goals of each stakeholder (2).

Advanced Border Crossing Technology

ABCS refers to the use of advanced technology to facilitate operations at border crossings. It is important to note that the ABCS systems are composed of existing technologies integrated in a manner that is geared toward the border crossing context. Advanced systems are designed to provide expedited service to both passenger cars and commercial trucks that have agreed to participate in the program. A program, begun in the early 1990s, was designed to reduce the time drivers actually spend at the borders. Used mostly by commercial entities, the shippers, custom brokers, or carriers transmit by fax or computer a copy of the bill of lading containing a bar code. The paperwork is reviewed by customs while the commercial vehicle is in transit to the border crossing. The decision is made before the vehicle arrives at the border whether the freight can be released immediately or held for secondary processing. When the driver arrives at the border, he or she presents the bill of lading, bar codes are compared, and the freight is either cleared or checked based on the earlier "Pre-Arrival Review" process. A process which at one time took 40 minutes to an hour now takes around one minute (3).

Though the system described above has reduced the time spent at the border by commercial vehicles, there remains the need for even more reduction in delay to a level of almost instantaneous or "seamless" clearance. Newly designed systems will provide not only expedited Customs and Immigration processing (C&I), but also automated tolling, integration with local Advanced Traffic

Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS), enforcement, and Commercial Vehicle Safety and Regulation (CVSR). Table 1 below shows the technologies used for each of these functions.

Table 1. Technologies to be Used at Border Crossings (3,4,5).

Function	Technologies
Automated Tolling	• Weigh-in Motion (WIM) • Automated Vehicle Classification (AVC) • Automatic Vehicle Identification (AVI) • Changeable Message Signs (CMS)
C & I Processing	• Electronic Data Interchange (EDI) • AVI • CMS
ATMS/ATIS	• Highway Advisory Radio (HAR) • CMS • Speed/Occupancy Detectors • Video Monitoring
Enforcement	• AVI • Video Surveillance
CVSR	• EDI • AVI

*Note: Dedicated Short Range Communication (DSRC) is the term used in place of AVI in some references

The use of Dedicated Short Range Communication (DSRC) is used for detection and processing of vehicles through the various plazas at the border. This communication requires that the vehicle's owner register with each border crossing agency prior to the trip. During this registration, the vehicle owner purchases a transponder that is placed within the vehicle. Using the transponder, the needed detection and communication can take place between the border crossing agencies and the vehicle operator. Upon arrival to the border crossing, customs and toll antennas detect the approach of the vehicle and begin processing the information matching the transponder's ID number. Vehicles that have a verified transponder number will be directed to an express lane for faster service. Commercial vehicles are weighed and classified using the WIM/AVC technology. A toll is calculated and debited from the account matching the transponder number (5). For commercial vehicles, uniform information on the shipment will be relayed to C & I processing by the broker prior to the vehicle's arrival at the border through the use of EDI. The transponder number is read using AVI and matched against the EDI information similar to the bar-coding system currently used. Frequent non-commercial users of the border crossing (commuters, tourists, etc.) can also register with immigration to receive expedited AVI service at the border crossing as well (4). CVSR is conducted in a similar manner as the C & I processing for commercial vehicles. Electronic safety records will be available from roadside safety inspection facilities on the approach to the border (5). These records are linked at the border using the AVI transponder code and EDI. Records on the carrier safety risk rating, the driver's commercial license status, special regulated load type (hazardous materials, etc.), and other safety information will be reviewed by border crossing officials and a decision will be made as to whether the vehicle can pass. At each step the vehicle will be monitored using some type of enforcement system involving, at a minimum, AVI and video monitoring. Also at each step CMS will be used to guide the vehicles through each process in the border crossing operation (4). Figure 1 illustrates the border crossing processing operation.

Upon the approach and departure to the border, useful information will be provided to the drivers through ATMS/ATIS technologies. Different types of information such as congestion due to construction or an incident can be detected using video monitoring or speed/occupancy detectors. This information can be relayed to the driver through the use of HAR, CMS, and other more technologically advanced methods, such as in-vehicle navigation systems. The driver can make more informed decisions on route-choice from the information provided by these technologies (6).

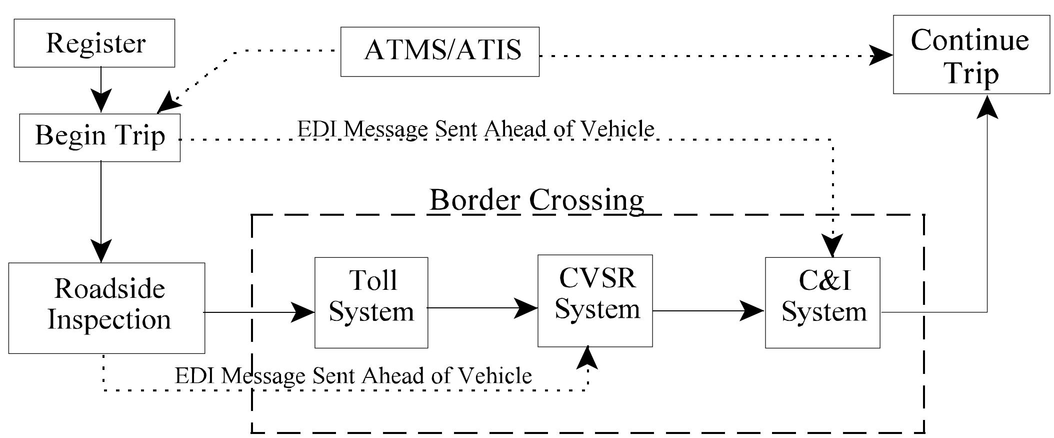


Figure 1. Advanced Border Crossing System Conceptual Layout.

Current Border Initiatives

North American Trade Automation Prototype (NATAP)

The North American Trade Automation Prototype (NATAP) is a set of guidelines developed under NAFTA by the governments of the United States, Mexico, and Canada to harmonize trade procedures among the three countries. The prototype specifies data structures and trade processes to be implemented so that the three countries and the shipping companies using the borders can operate under one set of procedures (7). The main objective of this initiative is to expedite processing at the borders through this common set of procedures. Currently, field operational tests are being conducted at six border crossing locations. These crossings are:

- Ambassador Bridge (Detroit, Michigan/Ontario),
- El Paso, Texas,
- Laredo, Texas,
- Nogales, Arizona (Expedited Processing at International Crossings Project),
- Otay Mesa, California (International Border Electronic Crossing Project), and
- Peace Bridge (Buffalo, New York/Ontario).

Currently the advanced systems at these sites are being tested in a "parallel" fashion to the existing clearance processes used at the border (8). The purpose of these tests is mainly to evaluate the technology and the feasibility of their use at the border crossings. The vehicles still must stop and proceed through the manual processes required from the current systems. Few benefits, therefore, will be seen through these tests. After a lane is dedicated for ABCS use only, benefits can be truly quantified.

Commercial Vehicle Information Systems and Networks (CVISN)

FHWA is implementing a Commercial Vehicle Information Systems and Networks project (CVISN) in order to standardize the flow of commercial information from state to state (9). In the past, motor carriers have been required to visit several state agencies for their required credentialing. CVISN provides motor carriers with a "one-stop shopping" opportunity through the use of EDI (10). FHWA envisions CVISN as "a collection of information systems that will enable the seamless movement of goods and services throughout the United States and North America" (10). This expedited information exchange will be useful for border crossing pre-clearance operations. Credential and safety information will be available at the border from the roadside safety inspections prior to the border. At the border, the AVI used in conjunction with the CVISN electronic data exchange, will be used to identify carriers, vehicles, or drivers, with a poor safety record. Those that are identified as having a poor safety rating will be directed to a secondary inspection station. At this station they will be issued a warning that they will be denied future entry if the safety problems are not cleared through a safety inspection facility participating in CVISN (5).

ADVANTAGE I-75/AVION

Another system designed to expedite the movement of truck traffic uses electronic clearance at truck inspection sites in major urban areas. In order to solve the problem of congestion caused by the increased NAFTA trade, the entire highway should be made seamless as well as the border crossings. A two-year pilot test is currently being conducted along I-75 (ADVANTAGE I-75) in the United States from Detroit to Florida. The test continues into Ontario, Canada (AVION) along Highway 401. The system utilizes the EDI capabilities provided by the CVISN initiative. Truck weight, driver, and safety inspection information is stored on the transponder at a weigh station at the start of the trip. At the next inspection station (possibly in the next state), the information is read from the transponder and a clearance decision is made. The driver is either instructed to bypass the station or pull in for inspection. The information obtained at these stations can also be accessed at the border to prevent unneeded stops (11). This initiative combined with the CVISN technology will provide a major advantage to border crossing clearance agencies especially the CVSR agencies. Many borders crossings do not currently have an efficient method for screening commercial vehicles for credentials and safety regulations (12). In fact, many do not even screen for CVSR at all. The results of the ADVANTAGE I-75/AVION test will be influential in the broad implementation of this type of technology to other major trade corridors.

ABCS Requirements

The success of ABCS is dependent upon several requirements. These requirements include operational and user, geometric, and non-technical requirements. The requirements listed here are those given in the literature, and will be useful in developing the ABCS site selection criteria.

Operational and User Requirements

There are several operational and user requirements of the ABCS that must be incorporated in order to achieve the most efficient automated border crossing design. The key to a "seamless" border crossing is to have an integrated system. An integrated system means that information must be usable by all entities at the border crossing (toll agencies and C&I), by the local ATMS, and by the CVSR agencies. The technologies should also incorporate other initiatives such as CVISN and ADVANTAGE I-75/AVION. Through public-private partnerships, technology standards should be developed to be used at all ABCS locations (13). This will ensure that the technologies are easily transferrable from one border crossing to the next or from the border crossing to any other advanced technology application the vehicle may encounter on the roadway. The overall success depends to a great extent on the amount of participation by commercial and non-commercial users. To provide incentive, therefore, the technology to be purchased by the user should be available at a reasonable cost and dedicated lanes are a necessity to provide the fast service that is expected (4).

Geometric Requirements

Technical requirements are those which directly affect the physical implementation of the technology such as hardware and software capabilities and geometry of the border crossing. The reader should refer to reference 5 for detailed information on hardware and software requirements, for listing them in this paper would be beyond its scope. Hill and Harris (5), however list some of the geometric requirements that may be of interest when deciding which crossings should be selected for ABCS implementation. Following is a list of the relevant requirements given in the paper:

- a single AVI roadside reader and antenna configuration are subject to a maximum of 1500 feet between them;
- the WIM/AVC sensors must be placed around 80 feet prior to the payment point to allow the information to be collected and processed; and
- 800-1100 feet is required between the initial AVI detection and C&I clearance to allow for data processing, deceleration, and the display of the stop or go message from a CMS.

Other technical requirements involve the dedicated lane potential of the specific border crossing. To provide user incentive, as discussed earlier, a dedicated lane must be possible. This, however, is not easily implementable at all crossings. Many of the older international bridges and adjacent facilities are located in older sections of border communities, making physical expansion difficult. According to Lindquist et. al. (6) retrofitting these border crossings to provide a dedicated truck lane is impractical. Where a dedicated lane is possible it is essential that it be provided for as far as possible in advance of the toll barrier and C&I inspection regular-use lanes. This will help to eliminate the problem of queues developing and impeding entry into the ABCS lanes.

Non-Technical Requirements

There other non-technical requirements that need to be addressed before successful implementation of advanced border crossing systems can take place. These issues include:

1. inter-agency relationships,
2. privacy concerns, and
3. market-share maintenance.

Interagency Relationships

As mentioned before, Inter-agency conflicts can hinder the success of ABCS. For an ABCS system to be implemented the state and federal government border entities must be unified with the private organizations and users. The potential for this unification largely depends on the agencies' past relationships and their willingness to cooperate. Relationships among the agencies that administer each crossing differ from one location to another (7). Therefore, it is logical to consider the context at each border crossing separately from others, for the purposes of implementation, while still maintaining technology standards.

Privacy Concerns

Privacy becomes a concern whenever information sharing is involved. Many users become concerned when they realize there is the potential for collecting personal information on origins and destinations and linking this information back to their personal identification. This potential may reduce the public's willingness to support the development and adoption of various advanced border crossing technologies. However, a 1991 survey (13) suggested that Americans have "ambivalent" feelings concerning privacy. Although people want their privacy protected, they realize that in order to receive some benefits they must compromise their privacy to some extent.

Market-Share Maintenance

Another non-technical requirement for smooth implementation of ABCS technology is that sites should be chosen so that current market share is maintained. Providing expedited service at one location may cause an imbalance in the market-share by providing an advantage to the businesses which use that crossing while a competing company uses another crossing not equipped with ABCS pre-clearance technology. This issue would require an in-depth study of current commercial usage of border crossings and the effect ABCS implementation would have on the global and local markets (2).

Expected Benefits

Benefits realized from implementation of ABCS can only be estimated at this time. Upon implementation it is expected that the benefits will accrue to four groups: the users, the toll entities, Customs and Immigration, and custom brokers. Table 2 lists the categories of each of these benefit groups. The amount of benefit realized at a given border crossing is dependent on the current characteristics of the crossing. For example, a crossing with 5,000 total vehicles per day would not benefit as much from ABCS as would a crossing with six million passenger cars and one million trucks per year. Reference 5 gives detailed procedures for calculating expected benefits at a given border crossing.

Table 2. Expected Benefits from ABCS Implementation (4).

Benefits	Categories
Users	‣ time savings ‣ cost savings ‣ convenience ‣ commercial fleet operations
Toll Entities	‣ collection cost savings ‣ increased capacity ‣ toll processing savings ‣ improved management information for staffing, scheduling, planning, performance evaluation, and other decisions ‣ improved customer service quality/public relations
Customs and Immigration	‣ increased third party data entry ‣ automation of records and systems ‣ reduced inspector hours ‣ improved management information for staffing, scheduling, planning, performance evaluation, and other decisions ‣ improved customer service quality/public relations
Custom Brokers	‣ increased third party data entry ‣ automation of records and systems and reduced service costs ‣ improved management information for staffing, scheduling, planning, and other decisions ‣ improved customer service quality/public relations

It is very important that expected benefits be quantified so that the operators, C&I, brokers, and users at a specific border can see the benefit in the system and thus accept the changes that must be made for implementation to take place. The amount of benefit that accrues due to ABCS is largely dependent on the amount of participation by the user. The problem, however, is that the amount of participation is a function of the expected benefits. It is anticipated that acceptance will increase over time as more and more benefits have actually been realized (4).

ITS Implementation Philosophies

Two opposing philosophies exist regarding the implementation strategy of ABCS technology. Some organizations and individuals believe that ITS technology, in general, should be implemented on a global level wherever the technology can be applied. Others believe there should be specific warrants for the use of ITS technology, thus limiting the implementation to locations that have demonstrated a need.

The Heads of Customs of Canada, the United States and Mexico have stated, "It is envisioned that once the Prototype (NATAP) is evaluated, concepts that have proven to be successful will be incorporated into the mainstream systems of all three customs administrations" (4). This statement implies that the Customs departments of all three countries believe that select ABCS technologies should be implemented at all border crossings. This would allow them to expedite the services for complying commercial carriers and commuters while focusing their attention on possible non-compliers. This type of implementation also provides fairness to competing businesses and toll agencies for market share. The cost of global implementation would, however, be considerably higher than selective site implementation.

The Texas Department of Transportation has developed its own ITS implementation strategy to guide the efforts of headquarters and district personnel in the development of ITS projects. As discussed by Lindquist et. al. (6) the strategy holds to the following core principles:

- ITS projects must meet an identifiable public need;
- TxDOT must ensure maximum participation from a broad range of actors in every project to help ensure a wide base of support (both public relations and financial support) and a reduction in possible technological redundancies;
- ITS projects should minimize long-term costs (although approach deployment from a strategic, long-term perspective) and commit to justifiable short-term costs as related to shorter-range priorities; and
- ITS projects should be implemented locally.

This strategy is in direct conflict with the global strategy mentioned previously. It has the advantage of lower overall cost by prioritizing over the short-range. Another difference is that the projects are implemented on a local level. This is advantageous in that the local problems can be better addressed by local entities. However, local implementation may cause the technologies at a particular site to become "orphan" technologies (i.e. the technology used at the particular site can only be used at that site) if strict enforcement of standards are not enforced.

Other implementation strategies could involve a combination of these two extreme philosophies. One possibility is implementation at only sites which warrant the technology with the actual implementation power being at the regional or federal level to maintain standards and consistency in design. The author believes this moderate approach toward implementation should be followed. The strategy that is chosen must take into consideration the benefits weighed against the costs for all stakeholders.

SURVEY RESULTS

The telephone survey yielded some interesting results relative to ABCS technologies, their benefits, and site selection criteria. As mentioned in the study design, an attempt was made to contact 30 professionals who were at least familiar with border crossing operations and advanced technologies. Some complications were experienced while attempting to reach many of the contacts. While a few survey participants were contacted by phone, several answered the survey questions through fax or by electronic mail. Many of the contacts were unable to be reached during the survey period.

ABCS Survey Participants

During the five week study period responses to surveys came from 11 professionals affiliated in some way with the border crossing operation of one or more crossings and/or ABCS technology. Table 3 shows an alphabetical list of the professional contacts who participated and their organizational affiliation.

Table 3. Professional Contact Survey Respondents.

Organization Type	Professional	Affiliation
Bridge Authorities	Anthony Braunsheidel	Peace Bridge Authority (the Peace Bridge spans the Niagara River between Buffalo, N.Y. and Fort Erie, Ontario)
	Allen Gandell	Niagra Falls Bridge Commission
Consulting Firms	Joe Elias	Calspan
	Craig Fundling	Booz, Allen, and Hamilton
	Peter Houser	Signal Processing Systems
Governmental Agencies	Brian Hicks	Transport Canada
	Lee Jackson	U.S. Department of Transportation, Intelligent Transportation Systems and Commercial Vehicle Operations
	Drew Livesay	Montana Department of Transportation, Motor Carrier Services Division
	Bill Nolle	U.S. Treasury Department
	Colin A. Rayman	Ministry of Transportation in Ontario, Intelligent Transportation Systems Office
	Joe Tsai	Ministry of Transportation in Ontario, Intelligent Transportation Systems Office

Survey Responses

This section will list the responses to each of the survey questions. Some of the questions were left blank or were listed as not applicable for some of the surveys. The answers will be listed together with no reference to the professional who gave the answer. The data are presented in this manner to maintain the anonymity of each professional who participated. The answers to the questions are presented under the categorized italicized headings below (12, 14-23).

1. Border Crossing Affiliation and Roles

Question 1 pertained to the professional contacts' experience with border crossings and their particular role in association with the border crossings with which they are affiliated. Of the contacts surveyed, at least one was affiliated with the following border crossings or border crossing regions:

- Ambassador Bridge (Detroit/Windsor)
- El Paso, TX
- Laredo, TX
- Lewiston Queenston
- Montana/Alberta
- Nogales, AZ
- Otay, Mesa CA
- Peace Bridge (Buffalo/Fort Erie)
- Rainbow
- Whirlpool

The professionals' roles varied depending on the crossing and the agency with which they are affiliated. The federal governmental agencies tend to have a role in implementation of the technology, C&I processing, and standards development. The role of the consulting firms is more on the technological level. Their roles involving ABCS range from technology installation and testing to evaluation of benefits and barriers to implementation. The bridge authorities are responsible for the operations and toll collection at their particular bridge.

2. Operational Problems

Current operational problems experienced at the border crossings as listed in the survey responses (question 2), included (the actual responses are given with additional comments in parentheses made by the author):

- Inadequate screening for safety and credentials.
  (Currently, screening commercial vehicles for safety and commercial vehicle operators for credentials is inadequate and evidently non-existent at many border crossings).
- Traffic congestion due to the very low capacity at the toll and Customs and Immigration plazas relative to the traffic demands of the connecting highway and bridges, the sequential processing of traffic through the various plazas introduces additional delays.
  (The throughput capacity provided at the border crossings is restricted by the time it takes to process each vehicle. Currently, the average processing time is one minute).

- The manual paper-based Customs system causes delays and data errors.
(Manual processing requires repeated data entry and keeping up with paper-work. This process can be tedious and creates considerable room for error).
- Limited staff.
(This response is self-explanatory. Where there is limited staff, the processing time will increase when the demand exceeds the capacity).
- Lack of data standards.
(The data can be processed faster if it is standardized. This problem must be overcome for the advanced technology alternative to be successful).
- Unpredictable traffic movement.
(When the traffic movement is unpredictable, it is difficult to optimize the available staff resources).
- Poor integration between trade and C&I. . . they both use electronics, but don't communicate well with each other.
(Poor interagency communication is the root of many of the problems that exist at border crossings. This problem must be solved before successful implementation of ABCS can take place).

3. & 4. Benefits of Technology

An attempt is made, through Questions 3 and 4 of the survey, to obtain qualitative information regarding benefits that have or will be achieved through the use of ABCS. The questions basically ask: Would ABCS benefit the current operations at border crossings, and if so, how? The responses to these questions may be slightly opinionated. A few of the survey respondents deferred answering these questions because of their speculative nature (no in-depth benefit/cost analysis has been conducted). One respondent believed the answer should be somewhere between response a and b. He believed the benefits would outweigh the costs but only slightly. Following are the responses that were recorded for these questions. Table 4 shows the responses to the multiple choice question (question 3). Below the table is the respondents' explanations for their reasoning (question 4).

Table 4. Response to Question 3 of Professional Contact Survey.

Would (have) electronics/advanced technologies help(ed) solve the operational problems at the border crossings with which you are familiar?	**Frequency**
a) Yes, to a great extent (benefits outweigh costs significantly)	7
b) Yes, but only slightly (benefits do (would) not outweigh costs significantly)	0
c) No, not at all	0
Between a and b	1
Deferred answering	3

Yes, to a great extent (benefits outweigh costs significantly):

The answers provided here are those associated with those who answered question 3 as "Yes, to a great extent (benefits outweigh costs significantly)." The answers provide an explanation for the contact's multiple choice selection.

- The reduction in travel time through the gateway provides virtual capacity on the bridge while enabling resources to be focused on the non-compliant elements of the population.
- The solution directly addresses the problem. In other words, the processing capacity of the dedicated electronic clearance lane is from six to ten times the capacity of the manual lane. There are also positive economic benefits and vehicle safety benefits.
- ITS is the only way to achieve electronic processing at land border locations.
- Pre-processing of information and quick ID of non-compliant vehicles/drivers, will eliminate congestion and delays and improve processing.
- The systems will provide toll savings and extra capacity for Customs/INS.
- ABCS Expedite safety and credential screening at locations where this process is currently done manually, and also encourages implementation of this processing at locations where no screening is conducted in any form.

Between a and b

One contact responded that his answer was between selection a and b. His justification was:

- The benefit to cost ratio would work fairly well for a fully operational facility, but with a prototype system the costs currently outweigh the benefits.

5. Implementation Philosophy

Question 5 was designed so that an indication of the implementation philosophy held by each contact could be obtained. Table 5 shows the frequency of responses.

Table 5. Response to Question 5 of Professional Contact Survey.

Electronics/advanced technologies should:	**Frequency**
a) be implemented on a large scale (to most (all) border crossings).	6
b) be implemented at only a few border crossings where certain problems exist.	3
c) not be implemented at all	0
between a and b	1
deferred answering	1

6. Site-Specific Characteristics Leading to Success of ABCS

Several characteristics of border crossings associated with successful implementation of ABCS were given as a response to question 6 of the survey. Physical, operational, and other characteristics were given, and thus will be presented in this manner below.

Physical:

- The limited space available at some crossings makes it infeasible for physical expansion. The high demands at some of these crossings, however, requires an increase in capacity possibly with the use of advanced technologies.
- If there is a bridge, there is constricted traffic flow.
- There must be the potential to dedicate a lane for electronic clearance lanes at the crossing plaza.

Operational:
- The volume of traffic crossing the border was identified by several professionals as an important characteristic of crossings associated with successful implementation of ABCS (volumes must be greater than border crossing capacity or crossings must service greater than 100,000 trucks per year).
- ABCS is useful when the ability for the DOT to screen drivers and carriers does not currently exist at a specific crossing.
- Where limited staff resources are available, ABCS can be useful.
- When implementing ABCS, staff must be trained in used computer interfaces

Other Characteristics:

- A progressive and proactive management style must exist at the crossing plazas.

7. Site-Specific Barriers

Several characteristics of border crossings that hinder the successful implementation of ABCS were given as a response to question seven of the survey. Physical, operational, and other characteristics were given, and thus will be presented in this manner below.

Physical:

- Where there is no ability to dedicate a lane it is impossible to realize the any benefits from ABCS.

Operational:

- When there is a high percentage of crossing violations in existence at a particular crossing it will be difficult to implement ABCS.

Other Characteristics:

- The sharing of information is "tricky" when Customs is involved.
- The degree of cooperation among agencies at the port will dictate successful implementation.
- If there is a lack of interoperability, there is a high probability of an unsuccessful implementation.
- If there is a lack of participation from users it will be difficult to realize the benefits from ABCS.

SUMMARY OF FINDINGS FROM LITERATURE AND SURVEYS

The literature review and professional contact survey yielded some relevant findings that were used to develop the ABCS site selection criteria. The purpose of this section is to provide an easy-to-reference list of the most relevant findings from this research. It is from this list that the recommended site selection criteria, of the next section, were developed.

Literature Review

Following is a list of the most relevant findings from the literature review. In addition to the first section, which contains a general list of findings, the section also contains three sub-sections. These sub-sections contain a list of the requirements for ABCS implementation found in the literature.

- The use of Dedicated Short Range Communication (DSRC) (or AVI), EDI, WIM, AVC, CMS, and other advanced technologies can be used to increase the capacity at many border crossings by expediting the processing at each plaza.
- Several stakeholders exist at border crossings and are responsible for its operations. The needs of owners and operators, Customs and Immigration, road authorities, and a number of user groups must all be considered when developing criteria for ABCS implementation. The full cooperation of each of these entities will be required for successful implementation.
- Several border initiatives such as NATAP, CVISN, and ADVANTAGE I-75/AVION will be helpful in harmonizing trade procedures at the borders through the use of advanced technology and by providing the standards and the means for information exchange.
- Several user benefits are expected as a result of ABCS implementation. These benefits can be grouped into four categories: the users, the toll entities, Customs and Immigration, and custom brokers. Refer to Table 2 for more detail. The amount of benefit depends on the amount of user participation.
- Two extremes in ITS implementation philosophies exist. One states that ITS technologies be placed wherever applicable. In the context of ABCS this would mean placing ITS technologies at all border crossings. Another states that ITS implementation should take place on the local level where an identifiable public need is met. Both philosophies have advantages and disadvantages, however, it is the author's opinion that a moderate approach toward implementation be followed using both philosophies.

Operational and User Requirements

This sub-section lists the operational and user requirements of border crossings for successful implementation of ABCS technology.

- The system design must be integrated so that information and technology is usable by all entities at the crossing.
- The system design must also incorporate other major initiatives, such as CVISN to prevent "orphan" technologies from developing.
- A high percentage of user participation must exist which is dependent on the benefits incurred by the user.

Geometric Requirements

This sub-section lists the geometric requirements of border crossings for successful implementation of ABCS technology.

- Some technologies that will be implemented at border crossings have certain geometric spacing constraints. The geometric constraints are dictated by the specific technology's data processing requirements, the vehicles' deceleration requirements, and the drivers' information processing requirements.
- The potential for a dedicated lane or lanes for ABCS participants is necessary for successful implementation. The dedicated lane will provide incentive for users to participate in the ABCS pre-clearance process.
- There must be sufficient queuing space prior to the plaza so that ABCS participants can bypass regular-use lane queues to enter the dedicated lane or lanes.

Non-Technical Requirements

This sub-section lists the non-technical requirements of border crossings for successful implementation of ABCS technology.

- Cooperation among agencies at the border must be considered when implementing ABCS. The agencies must be willing to work together and share information.
- Privacy must be maintained to the best of each agency's ability, however, privacy must be compromised to an extent for the full benefit of ABCS to be realized.
- Market-share must not be disturbed.

Professional Contact Survey

This section lists the significant findings from the results of the professional contact survey.

- Several operational problems were identified through the survey. These problems included: inadequate screening, insufficient capacity at the border crossing plaza, delay due to sequential processing, data error due to paper based Customs, limited staff, lack of data standards, and poor communication between trade and Customs agencies.
- Of the eight professionals who responded, all believed that the benefits of ABCS implementation would outweigh the costs, while seven indicated that the benefits would outweigh the costs significantly.
- The specific benefits given by the respondents all essentially related to the reduction in travel time, the increase in capacity, and the ability to dedicate staff to more crucial areas in the clearance process.
- Though not statistically significant, the survey indicates that two philosophies do, in fact exist among border crossing professionals. A majority of those surveyed believed that ABCS should be implemented on a large scale (to most (all) border crossings) while a good portion believed that implementation should take place only where certain problems exist.

- Dedicated lane potential, limited space available for physical expansion, high truck volumes, limited staff, inability of DOT to screen properly, trainable staff, and progressive management styles were identified as characteristics associated with border crossings possessing the most potential for successful ABCS implementation.
- The inability to dedicate a lane, the existence of a high percentage of crossing violations, the lack of cooperation between agencies, and lack of participation by users were identified as characteristics of a crossing that would act as barriers to implementation of ABCS.

RECOMMENDED SITE SELECTION CRITERIA

Through the course of the study, it was discovered that there are, in fact, characteristics specific to crossings which are associated with success or failure of ABCS implementation and realization of benefits. The criteria here are guidelines for selecting ABCS sites based on these findings from the literature review and survey results.

1. An identifiable problem must exist at the border crossing that can be alleviated using ABCS technology before implementation should be considered.

The author believes that ABCS technology should be warranted in some way before it should be implemented. Advanced technology is merely a tool that can be used for alleviating certain problems. To say that ABCS should be installed at every border crossing is like saying that a traffic signal should be installed at every roadway intersection. Common problems which occur at border crossings were cited in this study, and are summarized in the Summary of Findings section. Most, but not all of the problems were caused by high truck volumes exceeding the capacity of the border plazas. This problem leads to criteria 2 below. The remaining criteria assume that criteria 1 is true.

2. A high truck volume must be present.

The processing of trucks at the border is responsible for a large portion of the delays experienced at the border. Customs and Immigration inspection, safety inspection, and toll processing based on weight and vehicle classification can all cause considerable delays if a high volume of commercial vehicles is present. Using ABCS will directly address the problem of inadequate capacity by increasing the virtual capacity by six to ten times (17). Based on telephone conversations with transportation professionals, crossings with greater than 100,000 trucks per year should be considered for ABCS implementation.

3. A high volume of daily or weekly commuters is present.

Some crossings are located where daily or weekly commutes take place. People commuting across the border for work, school, shopping, or for social/recreational reasons sometimes experience delays at the border. These commuters could benefit from ABCS by pre-registering through Customs and Immigration and the toll agents at the specific crossing.

4. Physical expansion is either not possible or is less feasible than ABCS implementation due to site-specific constraints.

Given that inadequate capacity is present at a particular crossing border, crossing owners have two options. They can improve operations by adding more lanes and/or staff or they can implement ABCS technology. Some sites have specific constraints that limit the physical expansion that is required for additional lanes. These sites are perfect candidates for ABCS implementation.

5. The potential for dedicating a lane or lanes for ABCS participants must be present.

For an ABCS system to operate successfully a lane must be dedicated for ABCS participants only. This lane dedication provides incentive to users to procure pre-clearance and the required technology to participate. A planning analysis of a particular border crossing must be undertaken to determine how many lanes to dedicate and whether the remaining regular-use lanes are sufficient for the non-commuting, non-participating traffic. The lanes must also be designed so that queuing in the regular-use lanes does not impede entry into the dedicated lane or lanes.

6. The geometric site characteristics must be able to accommodate the technology needed.

Each ABCS technology has requirements such as deceleration length, processing time, and detection time that must be accommodated with the given geometric characteristics at the border crossing. If these geometric requirements are not present, implementation may not be possible, especially if further physical expansion is infeasible.

Successful ABCS technology implementation is dependent on whether:

7. Interagency cooperation is expected at the border crossing of interest;

It is crucial that cooperation exist between the agencies present at the border. An analysis must be conducted at the border crossing to investigate interagency cooperation potential.

8. Market-share will remain undisturbed between border crossings and businesses within the region;

If ABCS is installed at one border crossing and significant benefits are realized, the traffic patterns at this crossing and other border crossings in the region may be affected. Commercial and non-commercial vehicles may change their route slightly to use a border crossing with ABCS instead of the one they normally use if a significant difference in travel time can be obtained. As a result, the market-share between bridge owners may be interrupted. This problem can be expected in regions where "just-in-time" delivery is prevalent due to the predictable travel times needed. The market-share may also be disturbed between multiple businesses. For example, if a company receives the benefit of ABCS at the border crossing that it uses, but the company's competition does not, the company receiving benefits may have an unfair productivity advantage and may steal the less productive business' market-share. The solution to this problem would be to implement ABCS in a manner that at least attempts to prevent either of these problems from occurring. This would require an in-depth analysis of the markets using the border crossing.

9. User participation is expected at the border crossing of interest.

A site chosen for ABCS implementation must have good potential for user participation. User potential is crucial to realize the potential benefits of ABCS. Participation is expected to grow over time.

PEACE BRIDGE CASE STUDY

The following case study will apply the recommended criteria to the Peace Bridge to verify their applicability.

Background on the Peace Bridge

The Buffalo and Fort Erie Public Bridge Authority is referred to as the Peace Bridge. This bridge is located near the center of downtown Buffalo, New York and Fort Erie, Ontario where it crosses the Niagara River. The bridge provides a link for not only passenger cars, but is also a vital land trade border crossing. Currently, approximately $30 billion worth of trade crosses the Peace Bridge each year. This figure marks an increase of 43 percent in commercial traffic between 1990 and 1996. In 1992 the Peace Bridge carried 13.8 percent of all the land trade across the Canada-United States border. In 1996 it carried 61.6 percent of all commercial vehicle traffic on the Niagra Frontier. The current traffic is expected to double by the year 2020 (14).

Currently, the Peace Bridge has the physical and traffic characteristics listed in Table 6. However, a "Capital Expansion Program of historic proportions" is being implemented that will add a new twin span and a pre-arrival facility for commercial vehicle processing into the United States. As part of the project ABCS technology is also being tested (NATAP).

The Peace Bridge is governed, currently, by a ten-member board consisting of five members from New York State and five members from Canada. All capital improvement funds and operating expenses are generated by tolls and rentals of the Peace Bridge and Peace Bridge owned property and buildings. Other stakeholders at the crossing are Customs and Immigration and the commercial and non-commercial users (14).

Table 6. Physical and Traffic Characteristics of The Peace Bridge (4, 15).

Bridge Characteristic	Quantity/Description
Total Length of Bridge and Terminals	5,800 feet
Number of Auto/Truck Toll Lanes	To USA = 0/3
	To Canada = 5/2
Number of Auto/Truck C&I Primary Inspection Lanes	To USA = 10/3
	To Canada = 17/4
Commercial Vehicle Traffic	1,237,653 trucks per year
Passenger Vehicle Traffic	6,382,875 vehicles per year

Application of Recommended Criteria

1. *Identifiable problem?*

More than one identifiable problem does, in fact, exist at the Peace Bridge border crossing. These problems include data errors due to manual paper-based processing, limited staff and geometry that is unable to support the sharp increase in traffic demand seen in the last five to ten years.

2. *High truck volumes present?*

As shown in Table 6, there are over 1.2 million truck crossings per year at the bridge. This volume would be considered high (above 100,000 trucks per year) by most transportation officials familiar with border crossing operations.

3. *High daily or weekly commuters present?*

There is a high non-commercial volume of traffic of over 6.3 million vehicles per year at the bridge. Currently the Peace Bridge has Dedicated Commuter Lanes (DCL) in operation known as (AUTOPASS) which allows pre-clearance of commuters using the border crossing with only a momentary stop to present I.D. required. The fact that this program has been successfully implemented, indicates that ABCS clearance has the potential to be even more successful.

4. *Feasibility of physical expansion?*

The Peace Bridge is located near the center of downtown Buffalo, New York and Fort Erie, Ontario. Because of its urban location, the potential for physical expansion is limited. The current expansion project, however, will include some physical expansion of the roadway approaching the border crossing. A twin span will be added that will provide three additional lanes on the bridge. This addition will only increase the capacity on the approach to the border crossing. Physical expansion of the border crossing plazas (increasing the number of lanes at each plaza and/or increasing the amount of staff for processing) would be very costly and, therefore, infeasible (15). ABCS implementation is, therefore, the better alternative for alleviating the congestion problems currently experienced at the bridge.

5. *Dedicated lane potential?*

There is the potential for dedicated lanes for ABCS participants at Peace Bridge. There currently exists a DCL for autos through the AUTOPASS program. This lane would continue to be used as a dedicated lane, but would be upgraded to incorporate the DSRC technology used for more expedited clearance. For trucks there are two and three lanes in the Canadian and U.S. plazas for tolling respectively and three and four lanes respectively for Customs and Immigration clearance (refer to Table 6). With one lane in each plaza dedicated to ABCS use, at least one lane is left for regular manual processing and toll collection. Figures 2 and 3 show the plaza layouts and the lanes dedicated at each plaza for ABCS use.

6. Geometry accommodates the technology?

Through the current NATAP initiative it will be determined if there are any geometric constraints affecting the implementation of the specific technologies. In reality, the technology can more than likely be redesigned to fit the geometry at the crossing even if there are some geometric characteristics that constrain the standard design. Basically, if all other characteristics at the Peace Bridge are favorable towards implementation of ABCS, the system can be retrofit within the given geometry at the border crossing.

7. Interagency cooperation expected?

This criteria will be the most difficult to meet, although it will eventually be met. According to interviews from professionals familiar in some way with the Peace Bridge, interoperability between agencies is one of the more difficult interagency problems that must be addressed. The stakeholders are not working with a common understanding of the entire process. Through the NATAP initiative it is expected that each agency will begin to think about the border crossing process as one seamless operation in which interagency cooperation is a necessity.

8. Market-share uninterrupted?

The Peace Bridge is located in a region where "just-in-time" deliveries are commonplace. This means that predictable travel times tend to be more important here than in other border crossing regions. The market-share issue is, thus, very important. If the Peace Bridge realizes considerable benefits from ABCS, the market-share between the Peace Bridge and other crossings may be interrupted. A more in-depth analysis than can be conducted here must be undertaken to determine which and how many other crossings should be chosen for ABCS implementation to offset this market-share disruption.

9. User participation expected?

It is expected that users will participate in the ABCS program at the Peace Bridge. This participation is expected to be fairly low at first until users begin to see that they can benefit from the procurement of technology and Customs and Immigration pre-clearance. It is expected that participation will grow from 15 percent of users after one year to 30 percent after two years and 35 percent after three years. This approximation is based on the AUTOPASS program market penetration and experience with electronic toll collection elsewhere (5).

Inferences from Case Study

The case study showed that the Peace Bridge meets or is expected to meet most of the recommended criteria. From this study it can be inferred that benefits will be realized from implementation of ABCS at the Peace Bridge. It is, therefore, likely that the Peace Bridge will be a good candidate site for ABCS implementation. This conclusion is, however, dependent on several assumptions that have been made. The border crossing must experience significant user participation and interagency cooperation. The problems that exist that are likely to warrant the technology, however, unless the assumed criteria do, in fact, exist, the benefits realized from implementation will be limited.

CONCLUSIONS

The site selection criteria developed in this paper provide a starting point for transportation officials responsible for broad implementation of ABCS technology at the Canada and Mexico borders to the U.S. There will need to be more definite decisions made to determine some of the specific definitions within the criteria. For example, what is accepted as an identifiable problem which justifies implementation, and what is considered a high truck volume. The remainder of the criteria will require an analysis on a site-by-site basis. Interagency cooperation, for example is a function of the particular site of interest. A set of detailed warrants should eventually be developed beginning with the criteria recommended in this paper. The actual implementation of ABCS will follow these warrants and will more than likely involve a trial and error process with extensive use of lessons learned from field operational tests. Future research on interagency cooperation, user participation, market-share, and geometric issues should be conducted as the NATAP testing concludes and deployment begins.

ACKNOWLEDGMENTS

This paper was prepared for *Advanced Surface Transportation Systems,* a graduate course in Transportation Engineering at Texas A&M University. The author would like to thank Mr. Colin Rayman of the Ontario Ministry of Transportation for his advice and direction for this paper. Thanks also goes to each of the other mentors who graciously dedicated their time to making this program a success: Marsha Anderson, Ginger Gherardi, Thomas Hicks, Joseph McDermott, and Doug Robertson. Appreciation is also extended to Dr. Conrad Dudek for his organization and guidance throughout the course.

REFERENCES

1. *NAFTA's Impacts.* Texas Transportation Researcher. Texas Transportation Institute. Texas A&M University, College Station, Texas. Winter 1995-96, Vol. 31, No. 4. pg.2.

2. *Study of Institutional Impacts of New Technology Applications.* Final Report. Marshall Macklin Monaghan Limited in association with KPMG Management Consulting, JHK and Associates, and Constance Consultants. May 1994.

3. Hall, K.G. *Canada Expanding Pilot Program Aimed at Speeding Border Crossings.* Traffic World. July 1, 1991. pg. 19-20.

4. *Preliminary Engineering and Design of IVHS/AVI New Technology Applications.* Marshall Macklin Monaghan, JHK and Associates, and Constance Consultants. January 1997

5. Hill, C.J. and M. Harris. *Planning for the Addition of New Technologies at National Border Crossings.* Proceeding of the 1996 Annual Meeting of ITS America. Washington, D.C. 1996. pg. 782-787.

6. Lindquist, E., T.J. Lomax, M. Pincus, and M. Cole. *Texas-Mexico Border ITS Assessment.* Texas Transportation Institute, Texas A&M University, College Station, Texas, Research Report No. 97/01. May 1997.

7. Ericson, N. and N. Johnson. *Getting the Green Light at U.S. Border Crossings.* ITS World. September/October, 1996. pg. 38-42.

8. *Prime Minister Chretien Announces New Canadian-U.S. Initiatives on Border Issues.* News Release. April 8, 1997.

9. *CVISN Comes to Maryland*. CVISN News. June 1996. Volume 1.

10. *CVISN: A Partnership to Keep Maryland Moving.* AASHTO Quarterly.

11. Castaneda, K. *Hitting the Road Issue.* Toronto Star. May 13, 1996.

12. Fundling, Craig, Booz, Allen and Hamilton, Professional Contact Survey and Interview.

13. *Non-Technical Constraints and Barriers to Implementation of Intelligent Vehicle-Highway Systems.* A Report to Congress. Department of Transportation, June 1994.

14. Elias, Joe, Calspan, Professional Contact Survey and Interview.

15. Braunsheidel, Anthony, Peace Bridge Authority, Professional Contact Survey and Interview.

16. Tsai, Joe, Ontario Ministry of Transportation, Intelligent Transportation Systems Office, Professional Contact Survey.

17. Rayman, Colin, Ontario Ministry of Transportation, Intelligent Transportation Systems Office, Professional Contact Survey.

18. Nolle, Bill, United States Department of the Treasury, Professional Contact Survey.

19. Jackson, Lee, United States Department of Transportation, Professional Contact Survey.

20. Gandell, Allen, Niagra Falls Bridge Commission, Professional Contact Survey.

21. Houser, Peter, Signal Processing Systems, Professional Contact Survey.

22. Livesay, Drew, Montana Department of Transportation, Motor Carrier Services Division, Professional Contact Survey.

23. Hicks, Brian, Transport Canada, Professional Contact Survey.

APPENDIX

Advanced Border Crossing Systems (ABCS)
Professional Contact Telephone Survey

To address operational problems at border crossings between the U.S., Canada, and Mexico, advanced technologies are being implemented. The intent is to utilize standard pre-clearance procedures and Electronic Data Interchange (EDI) to facilitate the information exchange between commercial and Customs and Immigration agencies. Dedicated Short Range Communication (DSRC), Weigh-in-Motion (WIM), and other advanced technologies will be used at the border for detection, tolling, and clearance at the border to provide a "seamless" border operation. The group of technologies used to improve the operations at border crossings is known as Advanced Border Crossing Systems (ABCS). Advanced technologies, however, are not feasible at every border crossing. The purpose of this survey is to determine physical, operational, and other characteristics of border crossings associated with the success and failure of ABCS implementation.

Your response to the questions below would be appreciated. Please attach additional sheets as needed.

1. What border crossing(s) is your agency involved with, and what is its role?

2. What are operational problems currently associated with this (these) border crossing(s)?

3. Would (or have) the use of ABCS solve the problems described in question 2?
   A) Yes, to a great extent (benefits outweigh costs significantly)
   B) Yes, but only slightly (benefits do (would) not outweigh the costs significantly)
   C) No, not at all

4. Briefly explain your reasoning to your answer in question 3.

5. ABCS technologies should:
   A) be implemented on a large scale (to most (all) border crossings).
   B) be implemented at only a few border crossings where certain problems exist.
   C) not be implemented at all.

6. What are physical, operational, or other characteristics associated with the border crossings that demonstrate the most potential for successful implementation and realization of benefits from ABCS technologies (i.e. the physical space available, amount of traffic using the border crossing, etc.)?

7. Are there characteristics specific to certain border crossings that would hinder the implementation or success of ABCS? If so, what are they?

Figure A-1. Professional Contact Survey.

Jonathan A. Bean received his B.S. in Civil Engineering from Texas A&M University in December 1995. Currently, Jonathan is pursuing his M.S. in Civil Engineering/Transportation also at Texas A&M, and should graduate in August 1997. Jonathan has been employed since January of 1996 by the Texas Transportation Institute as a graduate research assistant. He has also worked for the Texas Department of Transportation for two summers, for the City of Bryan for 6 months, and for TTI as an undergraduate student worker for 8 months. Current TTI projects with which he is involved include: "An Investigation of Highway-Railroad Grade Crossing Characteristics and their Relationship to the Associated Violation Rates (also my thesis topic)," and "An Evaluation of Automated Enforcement at Highway-Railroad Grade Crossings in Texas." Jonathan has been involved in the American Society of Civil Engineers, Chi-Epsilon, and the Institute of Transportation Engineers. His main areas of interest are: transportation safety, transportation planning, Intelligent Transportation Systems, geometric design, and traffic operations.

INCORPORATING COMMUTERS' CHOICE BEHAVIOR INTO TRAVELER INFORMATION AND ROUTE GUIDANCE SYSTEMS

by

Julia Kuhn Butorac

Professional Mentors
H. Douglas Robertson, Ph.D., P.E.
TransCore

and

Marsha Anderson
Street Smarts

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

In attempts to provide reliable and usable information about route choice alternatives and to increase the efficiency of the existing transportation system, several agencies throughout the world are implementing a variety of technologies associated with the provision of real-time traveler and route guidance information. Although some drivers will not modify their behavior in response to information, and each has his or her own tolerance regarding what is considered to be acceptable delay, the provision of accurate and reliable travel time and route choice information can be used by most drivers to verify knowledge about recurring congestion on primary routes, compare alternative routes, justify an alternative route, modify departure time, or choose to telecommute.

In-vehicle route guidance systems (IVRGS) can identify routes using "shortest-path" strategies. Like transportation planning models, IVRGS operate under the strategy that travelers seek routes that minimize their generalized cost; the route that can satisfy this objective is typically referred to as the shortest path. Travel time is typically used to define the generalized cost incurred by drivers, although distance and costs related to toll facilities or road pricing can also be modeled.

Although IVRGS operate under the assumption that drivers will use the shortest path approach, the reality is that individual drivers choose among competing routes based on a variety of factors. The objectives of this research were to identify the attributes that influence travelers' route choice decisions and to evaluate the propensity of travelers to modify their route choice behavior based on the delivery of route choice information and the characteristics of the individual driver and of the commute.

Based on the findings included in this paper, it is recommended that the information provided to travelers through real-time traveler information and in-vehicle route guidance systems should:

- be provided in a variety of media to address the varying cognitive skills of travelers;
- use the most up-to-date traffic flow conditions;
- allow drivers to make decisions in a timely manner;
- be based on a detailed roadway network to account for arterial street alternatives;
- allow drivers to access information about specific route attributes, such as travel time, travel time variability, the number of traffic signals or stops along the route, congestion, distance traveled, monetary costs, number of turns, hierarchy, and safety;
- provide information about the source and expected length of delay related to an incident;
- allow a driver to verify his or her knowledge about traffic flow conditions on his or her primary route;
- be available both pre-trip and en-route; and,
- allow a driver to either make his or her own route choice decision based on knowledge of route attributes and travel times *or* to accept route guidance information provided by the system.

It is also recommended that future route guidance systems be developed in a manner that allows the system to "learn" individual users' preferences for route attributes, alternative routes, and surface street short-cuts.

The incorporation of these options into a route guidance system will enable drivers to access information that is timely, current, accurate, relevant, reliable, and targeted to the specific needs of the individual driver. These recommendations will allow for the provision of route choice and guidance information in a manner that may influence commuters' choice behavior. The feasibility and implications of these recommendations are discussed further in this paper.

TABLE OF CONTENTS

INTRODUCTION

The emergence of a variety of technological and practical advances during the last 10 years has enabled the development of dynamic, real-time, and multiple path routing strategies that may improve the effectiveness of transit and in-vehicle route guidance systems (1). Several route guidance systems have been implemented and are being tested throughout the world; two in-vehicle route guidance systems (IVRGS) have been tested in the United States: the TravTek system in Orlando, Florida and the ADVANCE system in Chicago.

Each has the ability to influence drivers' route choice behavior and may affect these changes in a different manner and it has been suggested that route guidance systems can benefit the operation of a transportation system in the following ways (2):

- improving travelers' knowledge of the transportation network and mode choices and helping them identify efficient routes;
- reducing congestion;
- linking route guidance systems with traffic control systems and road pricing systems to allow each system to operate more effectively; and,
- discouraging use of routes that are environmentally or politically sensitive.

The effectiveness and application of the last of these, routing in a "system optimal" manner to discourage drivers from environmentally sensitive routes, has been the subject of debate for many researchers and practitioners. Many transportation professionals feel that, even with the promotion of environmentally sensitive/system optimal routing strategies, many drivers may recognize that the advised route is not the best for the individual traveler. For this reason, it is unlikely that any IVRGS will include the routing of private vehicles in a manner that provides overall benefits to the transportation system. However, the first three benefits, as described above, hold a great deal of promise for improving the operation of transportation systems in an era where creative solutions are necessary to address declining funding and increasing single-occupancy vehicle use throughout the nation.

In the IVRGS that have been and are being tested in Europe, Japan, and the United States, routes between specific origin/destination pairs are identified using "shortest-path" strategies. Like transportation planning models, the models that have been used to route vehicles in these systems operate under the strategy that a traveler seeks routes that minimize his or her generalized cost; the route that can satisfy this objective is typically referred to as the shortest path. Travel time is typically used to define the generalized cost incurred by drivers, although distance and costs related to toll facilities or road pricing can also be modeled. However, during the last 30 years, several empirical studies of the factors (in addition to travel time) that affect drivers' route choice behavior have been done. Examples of these factors include:

- a traveler's ability to identify and willingness to use alternative routes;
- the provision of up-to-date traffic information;
- traveler's knowledge about recurring and incident-related congestion;

- the decision-making process used by drivers to choose routes; and,
- route attributes and preferences.

A better understanding of the effects of travelers' decision processes (especially as related to the type and location of the provision of route information) and route attributes on route choice behavior is essential to the successful implementation of route-guidance systems.

Purpose and Scope

A variety of algorithms can be used in IVRGS to identify the "best" route through a transportation network; however, each of these algorithms is based on a purely mathematical definition of a unique route. According to a mathematical definition, two paths between a given origin and destination that do not traverse exactly the same nodes in the same order are considered unique (3). However, this definition does not correspond to the manner in which travelers identify competing routes and subsequently choose between two or more routes. In practice, drivers often make route choice decisions based on prior experience, perceived travel times, and personal preference. In recognition of this disparity, the objectives of this paper were to:

- identify the attributes that influence travelers' route choice decisions and examine the feasibility of including these in an IVRGS;
- evaluate the propensity of travelers to modify their route choice behavior based on the delivery of the route choice information (e.g., how and when the information is provided) and the individual driver characteristics and behavior; and,
- discuss whether IVRGS will attract the number of users necessary to make the infrastructure investments required to provide quality, real-time traveler information.

The central hypothesis of this paper is that the inclusion of commuters' route choice behavior may improve the effectiveness of IVRGS.

The scope of this research is limited to the identification of the attributes that influence travelers' route choice decisions and the propensity of travelers to modify their behavior in response to route choice information. Although transit routing strategies were reviewed, this research primarily focused on IVRGS and the provision of real-time traffic information to commuters in urban areas.

Organization of Report

Following the introduction, this report consists of five primary sections. An overview of the manner in which routes and transportation networks can be modeled and the algorithms that can be used in IVRGS is included in the first section of the report. A discussion of the route attributes that influence commuters' choice behavior is provided in the second section. The influence of real-time travel information on commuters' choice behavior is discussed in the third section. The characteristics of the individual driver, the commute, and the transportation system that affect a commuter's propensity to change routes are also identified. The feasibility of a series of recommendations is provided in the fourth section. Finally, the results of this paper and recommendations for further study are summarized in the fifth section.

OVERVIEW OF THE MODELING OF ROUTE CHOICE BEHAVIOR

Recent studies indicate that unnecessary travel costs more than $80 billion per year in the United States and approximately £600 million in England given the costs of accidents, pollution, and unnecessary vehicle miles traveled (4). It has been theorized that this unnecessary travel may be attributable to the fact that many travelers do not use route choice criteria that minimize cost or time when selecting routes. Some travelers do not have the necessary cognitive skills or access to the appropriate information to select optimum routes, and others fail to follow planned routes because of cognitive deficiencies in formulating or storing route descriptions and deficiencies in the transportation information system.

In attempts to provide reliable and usable information about route choice alternatives and to increase the efficiency of the existing transportation system, several agencies are implementing a variety of technologies associated with Advanced Traveler Information Systems (ATIS). The successful implementation of these technologies depends on an understanding of the factors and decision-making processes that influence travelers' route choice behavior.

The consideration of travelers' route choice behavior can be used to determine the appropriate location and wording of static guide signs and variable message signs and the method in which static and dynamic route information should be conveyed to travelers in both pre-trip and en route applications. The modeling of route choice behavior can be used in planning models to assess changes in travelers' behavior in response to transportation system changes, such as roadway or transit system improvements and road/congestion pricing, and in dynamic, real-time models to determine the extent to which drivers may be influenced by the various methods available of providing information to travelers.

A travelers' route choice behavior can be characterized as the process through which he or she identifies possible modes and routes that can be used to reach a destination, how he or she behaves in unfamiliar environments, what aids are used to identify the appropriate route, and what criteria are used to evaluate a series of alternatives. Consequently, the understanding of route choice behavior requires the evaluation of the following questions (4):

- How do travelers choose routes?
- What do they know about the transportation network (e.g., the available modes, the alternative routes)?
- What travel, environmental, and personal characteristics play a role in the route selection process?

In seeking to answer these questions, this paper provides a summary of the various factors and route attributes that affect a traveler's route choice behavior and propensity to modify route choice and/or departure time. The extent to which these attributes can be incorporated into an in-vehicle route guidance system is also hypothesized.

Definition and Representation of a Route

In the routing algorithms that can be used in IVRGS, the rules by which motorists choose routes need to be defined. In practice, the problem of route choice faced by drivers is very complex because of the large number of possible routes in a transportation network and the complex pattern of overlap among alternative routes (5). Further, realistically representing human decision-making processes regarding route choice in mathematical models is difficult because of limitations in computational resources and the understanding of the cognitive factors, preferences, and habits associated with travelers' behavior.

In recognition of these limitations, the representation of route choice in planning models and IVRGS typically assumes that motorists choose the shortest path. The shortest path between a given origin/destination pair is the path that minimizes the drivers' generalized cost (e.g., travel time, distance, out-of-pocket costs). The representation of route choice in this manner assumes that drivers are:

- aware of the existence of the route;
- able to recognize the route as the shortest/optimal path; and,
- willing to use the route.

However, as discussed in the next sections of this paper, there are several attributes in addition to the minimization of travel time that affect drivers' route choice behavior. The ability to incorporate these attributes is also discussed.

Routing Algorithms

A variety of algorithms can be used in route guidance systems to identify routes between an origin/destination (O/D) pair. The manner in which multiple routes between an O/D pair are identified and the limitations associated with path selection and differentiation in several of these algorithms is discussed below.

In route guidance systems, more than one route may need to be provided to a user. One example of this is the routing of emergency medical service (EMS) vehicles through the use of real-time traffic information provided by Intelligent Transportation Systems (ITS). EMS drivers need to be provided with a variety of route choices because several criteria, such as factors related to travel time variability, in addition to minimizing the travel time may need to be examined to select the most appropriate route. In-vehicle route guidance systems can identify multiple routes between a given origin and destination in order to route travelers in a manner that avoids excessive delays related to an incident or congestion.

Route guidance systems may determine multiple routes between a given O/D pair in one of three ways. First, multiple routes can be identified by calculating all of the possible routes between an O/D pair. According to a purely mathematical definition, two paths that do not traverse exactly the same nodes in the same order are considered unique (3). There can be a multitude of routes between a given O/D pair in even a small roadway network; consequently, this task can be extremely time-consuming and impractical.

Second, multiple routes can be identified by limiting the search area used to identify routes between an O/D pair. For example, in the ADVANCE in-vehicle route guidance experiment the search area was limited to higher functional class roadways (6). Limiting the search area can be accomplished through the application of a "reasonable path" algorithm. Although reasonable path algorithms, such as the one postulated by Dial (7), reduce the number of paths that need to be enumerated, they also do not ensure that routes will be identified in a manner that is consistent with drivers' choice behavior.

Finally, multiple routes can be identified by applying a k-shortest path algorithm. However, this solution also may not yield results that are consistent with drivers' choice behavior. For example, the minimum time path between a given O/D pair may include several roadway links on a highway; however, the second shortest path that is identified may be to exit the highway and then to immediately reenter it (8). Although from a mathematical standpoint these routes are different, from a practical standpoint the second route is clearly unrealistic.

Regardless of the assignment type, the reasonableness of the routes is rarely examined even though the mathematical definition does not correspond to the manner in which drivers identify competing routes and subsequently choose between two or more routes. In practice, drivers often make route choice decisions based on prior experience, perceived travel time, and personal preference, as will be discussed in the next section of this paper.

FACTORS THAT AFFECT TRAVELERS' ROUTE CHOICE BEHAVIOR

A number of factors are thought to influence travelers' route choice behavior in the absence of traveler information or route guidance systems, such as:

- a traveler's ability to identify and willingness to use alternative routes;
- a traveler's knowledge of recurring and incident-related congestion;
- the ability of a traveler to plot out an entire route before leaving the origin point or make decisions at junctions as he or she encounters them; and
- the specific route attributes to which drivers are attracted.

Factors that are related to the use of alternative routes and the provision of route guidance information are reviewed in the next section of this paper. Several of the specific route attributes to which drivers are attracted are identified in this section of the paper. This synopsis is based on a synthesis of several stated preference surveys, evaluation of route guidance systems, and ATIS simulation experiments that have been conducted throughout the United States and Europe. The feasibility of incorporating these attributes into an in-vehicle route guidance system is discussed in the fourth section of this paper.

Introduction

As discussed in the previous section of this paper, drivers' route choice behavior is represented in IVRGS and planning models by the identification of the shortest path. The shortest path is identified as the route that minimizes a driver's generalized cost. A driver's generalized cost is typically a function of travel time and, where applicable, out-of-pocket costs associated with road/congestion pricing or toll facilities.

However, it is well recognized that different drivers select different routes when traveling between the same places (9). This can be partially attributed to the fact that each driver incorporates different features into his or her individual generalized cost function and perceives these features in different ways. Consequently, the different attributes associated with alternative routes do not each have the same importance in a driver's selection of a preferred route. Several researchers postulate that a driver formulates a set of attractive alternatives and selects a preferred route from this set that best satisfies his or her individual needs, personal constraints, and preferences (10).

Although it has been recognized that it is very difficult to make generalized conclusions regarding the validity and relative importance of route choice attributes because of the different manners and contexts in which these attributes have been studied, the intent of this section of the paper is to identify attributes that are commonly cited as influential in drivers' behavior and to make inferences about the feasibility of including these attributes in IVRGS. In the future, it may be possible to customize the route choice information that is provided to individual drivers and to incorporate a variety of route attributes in the generation of route alternatives in order to make ATIS more useful to drivers.

Consideration of Route Attributes

In most studies, the minimization of travel time is recognized as one of the most important factors that influence route choice behavior, especially in home-to-work and work-to-home trips. In fact, some researchers hypothesize that 60 to 80 percent of the routes actually used by drivers can be explained through the incorporation of time and distance in the generalized cost function; the unexplained portion can be attributed to differences in individual perceptions or imperfect information about route costs or errors (9). However, a survey conducted in England revealed that 70 percent of drivers surveyed indicated two or more attributes affected their route choice behavior (11).

In addition, several studies have been conducted that emphasize the need to consider other factors in addition to travel time in order to improve the effectiveness of route guidance information. Two examples of these studies are a survey conducted in Los Angeles in 1992 and the evaluation of the ADVANCE project in Chicago.

In Los Angeles, a.m. commuters were surveyed to determine the route attributes that are considered important in route choice, drivers' willingness to use ATIS, and the effect of advanced traffic information on route choice. Questionnaires were customized and distributed to each individual according to each respondent's origin, destination, and primary route, and each driver was asked to compare a computer-generated minimum path route to his or her primary commuting route. The results of the survey indicated that only 10.5 percent of the drivers used the same route as that generated by the computer, 54 percent of respondents had used the same route as that generated by the computer at one time, and 29 percent had used part of the route (12).

Each survey respondent was also asked to provide reasons why he or she did not use the computer-generated route as his or her primary route. The most common reasons cited were:

- primary route is faster (62.9 percent);
- primary route is shorter (37.8 percent);
- travel time is unpredictable on the computer-generated route (37.1 percent); and,
- primary route is safer (28.7 percent).

Based on the results of the survey, the researchers concluded that, although the comparison of perceived attributes of the primary and the computer-generated routes revealed a bias toward the primary route, a traveler information system that provides commuters with information about the specific attributes of alternative routes could alter drivers' perceptions and subsequently route choice.

Another study that emphasizes the importance of considering alternative routes is based on the findings of the focus groups conducted shortly after the participants had used ADVANCE-equipped vehicles for a 2-week testing period. ADVANCE (Advanced Driver Advisory and Navigation Concept) is a public-private partnership in Chicago, Illinois in which an in-vehicle route guidance system that was designed to provide drivers with *real-time* traffic and navigation information was developed and tested.

Many participants in the focus group felt that the advice provided by the ADVANCE system was not adequate; some of the routes that were provided were longer in time and distance than the driver's primary route. Often the routes were not the most direct and logical; therefore, many of the drivers diverted back to their primary route. These problems were attributed to errors in the database as well as to the algorithm selected to replicate route choice behavior (the ADVANCE system assigned drivers to the minimum path on higher level roadways) (6).

Many participants expressed interest in more driver control over route planning, especially until the information became more reliable and logical and because many of the drivers set their own criteria for selecting a route. These criteria included: minimizing time and/or distance, avoiding signals, the desire to keep moving, avoiding a particular street or street type (e.g., toll facilities, expressways), and avoiding left-turns and/or grade crossings.

A number of additional studies conducted during the last 30 years have investigated the attributes that influence route choice. Rather than describe the specific findings of each study in this paper, a summary of the identified attributes that influence route choice behavior is provided in Table 1. It is intended that the information provided in this table will provide a list of the most common attributes that drivers consider to be important. Where applicable, the relative importance of each of the factors, as identified by the study participants, is also included.

Table 1. Attributes that Influence Route Choice Behavior.

Primary Author	Study Location	Identification/Relative Importance of Factors									
		Travel Time	Travel Time Variability	Signals/ Stops	Congestion	Hierarchy	Distance	Turns	Safety	Monetary Costs	Other
Abdel-Aty	Los Angeles	1	2	4			3		5		
Antonisse	Netherlands	Noted		Noted	Noted	Noted	Noted		Noted		Road Quality Signing, Scenery
Benshoff	England	1	7	4	2		3		5		6 = Most Relaxing 8 = Habit
Bonsall & May	Europe	2	1		1						
Khattak	Chicago	Noted	Noted	Noted					Noted		Scenery
Schofer	Chicago, IL	Noted		Noted			Noted	Noted	Noted		Maintain Speed
Spyridaki s et al	Seattle, WA	1					4		2		3 = Commute Enjoyment
Uerschaer	Germany	Noted		Noted	Noted	Noted					
Wachs	Evanston, IL	Noted		Noted	Noted	Noted		Noted		Noted	Scenery
Wohl-schaleger	Houston, TX	2		4	3			1	5		

Quantification of Route Choice Attributes

As indicated in Table 1, some of the attributes of individual routes that are most commonly cited in the literature as influencing route choice behavior include: minimization of travel time, travel time variability, minimizing the number of traffic signals or stops along the route, minimizing the distance traveled, monetary costs, number of turns, hierarchy, and safety. Other attributes that have been identified include scenery, the desire to maintain a consistent speed, road quality, and signing. The ability to quantitatively or qualitatively describe each in route guidance is described below.

Travel Time

The majority of studies cited minimizing travel time as one of the most important factors influencing commuters' route choice and, as discussed previously, many models base route choice behavior on travel time. One of the difficulties in providing real-time travel information to travelers is the methodology by which travel times are estimated.

Travel time information can be provided based on historical data through the use of a static model. This approach can be used on roadways where there are no incident detection capabilities, such as aerial surveillance, or loop detectors that can be used to estimate current travel times. The primary limitation of using historical travel time information is that it can not account for temporal variations in traffic flow; therefore, this approach cannot account for the effects of differences in departure times or factors that relate to travel time variability. Consequently, information based on historical travel time information may not be as useful to commuters. Commuters are typically knowledgeable regarding travel times associated with recurring congestion and may seek information to either confirm expectations about the commute or to form new expectations based on information about incidents.

Travel time information can also be estimated based on a combination of historical data and the most current travel time information. Up-to-date travel time information can be provided through the use of a variety of monitoring techniques, such as probe vehicles, incident detection algorithms, information from loop detectors, incident reports from police and emergency services, and video surveillance. In order to provide accurate information to commuters, this approach requires significant infrastructure investment and cooperation between traffic management centers and emergency services.

Ideally, the travel times that are provided should be based on predicted conditions. However, the provision of reliable predictive information is extremely difficult in congested networks because actual network conditions in future time segments will depend on the manner in which drivers respond to information and traffic flow conditions.

Regardless of the manner in which travel times are estimated, IVRGS are limited in their ability to identify the shortest path in a network by the level of detail included in the network. The extent to which lower level roadways (e.g., arterials and major collectors) are included in a transportation network is largely a function of the application.

Travel Time Variability

One of the most difficult route attributes for travelers to estimate and account for is travel time variability. Unknown variabilities in travel time have important implications on the ability of a commuter to arrive at his or her destination in a timely manner and on the routing of emergency medical service vehicles. Variability in travel time may be attributable to a variety of factors, such as the presence of incident-related versus recurring congestion, rail crossings, draw bridges, roadway and bridge construction, special events, and the probability of stopping at traffic signals.

To account for unknown variabilities in traffic, drivers may consult a variety of information sources, such as highway advisory radio, changeable message signs, or traveler information systems, in an attempt to predict the travel time conditions that may be expected in subsequent periods; however, predictions of variability based on use of information sources are subject to the most up-to-date conditions regarding special events, construction, or incidents that have recently occurred. Information sources cannot be used to predict the probability of the occurrence of an event that may cause additional travel time delays on a particular route.

Quantification of travel time variability in an IVRGS is difficult. Dynamic, microscopic models can be used to estimate the probability of having to stop at an intersection and to predict the effect of incidents or special events on traffic flow; however, to truly model travel time variability, the probability of a specific event (such as an incident, rail crossing) occurring would need to be modeled and accounted for in the prediction of travel time information.

Signals/Stops

The avoidance of traffic signals and/or stops is cited in most of the reports as influencing route choice behavior; however, as shown in Table 1, avoidance of signals/stops has been identified as a secondary factor in several studies. Several of the route attributes identified in these studies are not independent of one another. As such, avoidance of signals and stops may be related to minimizing the potential for travel time variability, the desire to maintain a consistent speed, and the fact that many travelers plan the routes in accordance with the functional hierarchy of the roadway system. Many studies recognize that a driver selects higher functional class roadways (such as expressways) for the majority of his or her trip and uses local roads near the origin and destination. By nature, higher class facilities are typically associated with higher posted speeds and fewer traffic signals or stop signs per mile.

The possibility of having to stop at a stop sign or a traffic signal can be represented merely by the number of times that a stop sign or traffic signal is encountered on a route. However, this is somewhat of a simplifying assumption because not all drivers who travel through a particular signal have to be stopped. As an alternative, the stop rate of an individual driver at a signalized intersection can be quantified based on an approach developed by Akçelik (13).

One of the difficulties in providing information about being delayed at a traffic signal is similar to the provision of predictive travel time information. To truly account for the time-dependent and physical nature of queues at signalized intersections and their effects in limiting the amount of traffic that can travel downstream, differences in departure times and the manner in which drivers react to queues and delays and the provision of information need to be estimated. For this reason, it may be more practical to provide information about the number of signals along a particular route.

Hierarchy

As discussed previously, many studies recognize that a driver selects higher functional class roadways (such as expressways) for the majority of his or her trips and uses local roads near the origin and destination. Two reasons may be used to explain why drivers rely on hierarchical trip planning.

First, many transportation systems are planned and designed in conformance with the theory that form follows function (14). Higher class facilities are designed in a manner that facilitates mobility, while lower class facilities are designed to serve as access to adjacent properties. As such, the facilities that are used by a driver are related to trip length. Most drivers expect that roadways that serve mobility needs should have higher speeds and capacities than roadways that serve access needs.

Second, behavioral scientists postulate that an individual's level of route cognition is higher in heavily used areas, such as near home or work; subsequently, these areas are relatively limited, scattered, and different for each individual. As a result, on a network-wide basis, each driver's level of route cognition may be relatively low and therefore individual drivers may not be aware of local alternatives (4).

To account for hierarchical trip planning, IVRGS routing algorithms can limit the search area used in identifying alternative routes to higher class facilities. Some of the problems associated with this technique have been described previously in this paper in the description of the ADVANCE focus group.

Distance

As indicated in Table 1, several studies identified travel distance as a secondary factor that influences route choice behavior. Many studies indicate that minimizing travel time is a more dominant criterion in route selection than minimizing the total travel distance. In fact, 80 percent of the respondents of a motorist survey conducted in Houston, Texas indicated that they travel a greater distance to avoid congestion on an occasional basis (15).

Theoretically, distance is more of an influential factor in the selection of the specific destination and the facility types used rather than the route itself. In non-commute trips, such as shopping and recreation, a traveler may choose to shop at a particular location because of its proximity to his or her home or work; however, a commute trip has a fixed origin and fixed destination; therefore, it is logical to assume that the route that minimizes the travel time between two points is not a route that is illogical in terms of total travel distance.

The identification of a route that minimizes total travel distance can easily be computed through the use of a shortest-path algorithm based on distance rather than travel time. The minimization of distance does not account for the effects of recurring and incident-related congestion on travel times; therefore, criteria related to distance may be more applicable in transit-routing situations in which the alternatives between a specific origin and destination are limited by the transit service that is provided.

Turns

Several studies indicate that drivers may select routes that minimize the number of turns (especially left-turns) that must be made to reach a destination. The inclusion of turns in some drivers' route choice criteria may be based on two primary factors.

First, drivers may prefer to follow a simple, direct route between an origin and destination; the incorporation of several turns and subsequently the use of several different roadways increases the frequency of the need for the driver to concentrate more on navigation, the most complex level of information processing required as part of the driving task. Drivers may also select routes that minimize the number of turns because of the additional delays that are typically experienced by left-turning drivers at intersections.

Turning movements can be identified based on the spatial representation of nodes and links in a network model. For example, a turning movement can be identified according to the angle formed by the subsequent link vectors in a network.

Safety

Several studies identified safety as a secondary route attribute that influences route choice behavior; many studies reported that safety is more often cited by females as an important attribute in route choice than males. Most often, in stated preference surveys, drivers indicated a preference for a specific route because it was "safer." There is no recognized definition of a "safer" route; this is a subjective attribute that can be take on a variety of different meanings for each individual driver. Therefore, its quantification is difficult.

One researcher has suggested that a GIS model can be used to construct indices that relate the characteristics of an individual driver to the demographics of a zone (16). However, the development of these indices will also be somewhat subjective.

Monetary Costs

As indicated in Table 1, out-of-pocket costs can also influence route choice behavior. The influence of monetary costs has been the subject of recent debate because several jurisdictions throughout the country are evaluating the effect of congestion pricing systems on traffic flow patterns. The quantification of monetary costs in IVRGS routing algorithms can be based on the representation of an individual driver's value of time. The value of time can be represented through the use of a choice model.

Other Factors

Several other factors have been identified by a number of studies. Many of these factors are largely subjective and therefore difficult to quantify and include in a routing algorithm. These include: scenery, commute enjoyment, and personal habit.

Evaluation of Route Attributes in Current ATIS Applications

A variety of traveler information systems have been and are being implemented throughout Europe and the United States. Several major metropolitan areas, such as Seattle, Atlanta, and Houston, provide access to real-time travel information on freeways through the use of the Internet. In these applications, up-to-date travel time information is often provided through the use of a color-coded map of the metropolitan area that travelers can use to make route choice and/or departure time decisions.

In other areas, such as Boston, Washington, D.C., Cincinnati, and Philadelphia, commuters can also access information about expected travel times through a phone-based system. In these metropolitan areas, an operator or automated message system provides information about a particular route. Although there are no formal routing recommendations included in these systems, an operator may occasionally recommend an alternative route (17). Similar systems will be implemented in the near-future in New York City, Minneapolis, and Detroit (18).

These systems provide drivers with access to real-time traffic information on which to base their decisions, but do not provide any information about other route attributes that are considered important in route choice behavior. Many of these systems provide information only about freeways and drivers may already be familiar with the route attributes associated with these types of roadways in metropolitan areas.

Some jurisdictions also provide travelers with routing information for public transit systems. Ventura County, California, provides an interactive transit routing system on the Internet. Metro, in Seattle, provides transit routing information through a phone-based system and is currently in the process of developing an on-line routing system (19).

Finally, two in-vehicle route guidance systems have been tested in the United States. The first system, TravTek, was tested in Orlando, Florida. As part of the demonstration project, General Motors equipped AVIS rental cars with route guidance equipment. The objectives of the test were to provide navigation advice and information about the location of local attractions, restaurants, and hotels to unfamiliar drivers.

In Chicago, the objective of the ADVANCE system pilot test was to investigate the effects of in-vehicle real-time route guidance advice on drivers that were familiar with the network structure and congestion patterns. Participants were selected from a list of volunteers based on their trip-making intensity and schedule availability. The original proposed project was to include equipping more than 3,000 private vehicles with in-vehicle route guidance systems for 12 to 18 months. However, because of delays associated with project development and scheduling, only 80 households were selected to participate for a 2-week period (6).

Three focus groups that were conducted with participants in the study yielded the following findings in addition to those discussed elsewhere in this paper:

- both the driver and the on-board computer provide unique information and capabilities that can be used in the route choice task;
- a driver's routing criteria may be different for different trips and may even change during a single trip;
- drivers expressed an interest in the development of a computer system that could "learn" each user's route choice criteria; the development and use of this type of system could decrease the likelihood that a large proportion of drivers would divert to a single facility;
- although drivers are knowledgeable about recurring congestion, information about incident-based congestion needs to be provided by the route guidance system; and,
- drivers' familiarity with the network suggests that most drivers will be able to detect and likely resist information about system optimal routes.

The findings from the focus groups emphasize the need to incorporate and provide information about other route attributes, in addition to travel time, to increase the effectiveness of future ATIS applications. These conclusions also support a survey of drivers in several major European cities, which indicated that drivers felt that if they had access to real-time data, they could outperform an in-vehicle route guidance system (2).

Implication of Findings

As discussed previously, shortest path strategies employed in planning and IVRGS routing algorithms assume that a traveler chooses a route that minimizes his or her generalized cost. Generalized cost is based on total travel time and out-of-pocket costs related to toll facilities and/or congestion pricing projects, where applicable.

Although several of the route attributes identified in this section of the paper can be quantified in a static or dynamic model, the incorporation of those attributes into a generalized cost function can be difficult. Incorporation of one or more of the attributes requires specific information regarding the relative importance of each attribute for each individual driver. Some researchers have used the results of stated preference surveys conducted in specific urban areas to develop choice models for use in research settings. However, the choice model developed for one area is typically not transferable to other urban areas because of the unique attributes associated with each transportation system.

It is also difficult to develop a choice model that is representative of all drivers in an urban area because each driver places a different level of importance on different attributes. For this reason, route guidance systems should incorporate the capability to quantify a number of route attributes and to provide information about these attributes to the driver. This will allow the driver to weigh the prevailing traffic conditions and each of the attributes to make an informed route choice decision or to asses the route provided by a guidance system.

CHARACTERISTICS THAT AFFECT TRAVELERS' PROPENSITY TO MODIFY ROUTE CHOICE BEHAVIOR

A number of empirical studies and stated preference surveys have been conducted to evaluate the propensity of travelers to modify their route choice behavior in response to route choice information provided by highway advisory radio, changeable message signs, and travel time information provided on the Internet and on television. These studies have identified a number of factors that may be relevant to a traveler's willingness to modify his or her behavior. Examples of these factors include the method of delivery of the route choice information, the type and extent of information presented to the driver, the driver's familiarity with the network, the characteristics of the commute, and the individual driver characteristics.

A review of the applicability of the factors that influence travelers' propensity to modify their routes in ATIS and ATMS applications, especially in in-vehicle route guidance systems, is provided in this section of the report. These factors were analyzed with respect to their influence on travelers to modify their mode choice (including telecommuting), departure time, and route choice, where applicable.

Provision of Route Information

There are several sources of information available to drivers on which to base route choice decisions. Drivers can rely on "low-technology" sources, such as personal experience, word-of-mouth advice, or reports in the media regarding locations of construction or special events that may affect congestion on specific routes. During the last 37 years, several technologies have been developed and implemented throughout the country to provide drivers with improved information. Examples of these technologies include: traffic information broadcasting systems, highway advisory radio, telephone call-in systems, pre-trip electronic route planning systems, changeable message signs, and in-vehicle route guidance systems.

The primary advantage of using the advanced technologies is that they can provide drivers with up-to-date traffic conditions based on information compiled from a variety of sources, such as aerial surveillance, police, emergency and medical services, probe vehicles, and incident detection algorithms. Improved information about traffic conditions offers the potential to reduce delays and unnecessary travel and can assist drivers with a variety of pre-trip and en route decisions.

Access to pre-trip traffic flow information can enable commuters to make informed decisions about whether to travel or to telecommute, what time to depart, what mode to use, and what route to follow. In non-work trips, access to pre-trip information may also influence travelers' destination choice. Access to en route information can be used in decisions about route and mode choice (e.g., deciding to drive to a park-and-ride lot and transfer to a bus or rail system) and, in the case of non-work trips, destination choice decisions. En route information can be received voluntarily, such as through the use of route guidance systems, or passively (e.g., changeable message signs).

Although there are several advantages associated with the provision of improved information, several researchers have noted some of the associated adverse impacts, such as (20):

- a driver may be unable to process the information to select the optimal route;
- a driver may be distracted by the large amount of available information;
- driver reactions to information may cause congestion to shift from one roadway to another; and,
- the provision of improved information may reduce the variability in drivers perceptions about actual network conditions; therefore, drivers with similar preferences may concentrate on the same routes during the same departure times.

Although sources of improved travel information may offer the potential for travelers to make more informed decisions and may be associated with a variety of impacts, the extent to which a driver actually uses the information to modify his or her behavior has been the subject of several stated preference surveys and simulation experiments. The impact of information provided by in-vehicle navigation systems and by other sources, such as changeable message signs, phone messaging systems, and radio broadcast reports, is discussed below.

Early studies indicated the willingness of drivers to receive and use information about traffic conditions. In a study conducted in England in the early 1970s, the majority of respondents surveyed indicated a preference to receive traffic information about one or two routes, although less than half expressed a willingness to use that information in route choice decisions (11). Another survey conducted in Dallas, Texas in the 1970s indicated that 50 percent of drivers who continued through incident-related congestion would have diverted if they had received additional information (21).

Not surprisingly, a variety of studies report that a large proportion of commuters today receive information from traffic reports. A survey recently conducted among Golden Gate Bridge commuters in the San Francisco Bay Area revealed that 94 percent of commuters receive traffic information reports (22). However, the willingness of a driver to depart from his or her habitual behavior in response to this information is varied. For example, results from the Golden Gate Bridge commuter survey indicated that 45 percent of travelers did not modify their route choice despite receiving advanced information about incident congestion. In addition, a survey of Massachusetts Institute of Technology employee commute patterns revealed that only 19 percent of commuters expressed that route choice decisions were made based on radio traffic reports (10). Although no specific reasons were stated in either study regarding why commuters did not modify their behavior in response to the information provided, it is hypothesized that information received on previous trips had not been up-to-date because of difficulties related to the provision of real-time traffic information. Route choice behavior is a dynamic, feedback process; therefore, the travelers may have assessed the reliability of information accordingly.

Other studies have revealed that a traveler who more actively seeks pre-trip traffic information may be more inclined to use it in his or her decision-making processes. Several metropolitan areas throughout the United States provide real-time travel time information to travelers through the use of phone messaging systems, interactive televisions, and the Internet. A survey of 2,000 users of *SmarTraveler*, a Traveler Advisory Telephone Service in the Metropolitan Boston area, revealed that the information received through the phone-in system had a direct influence on 48 percent of the respondents' pre-trip travel decision-making (23), as follows:

- 14 percent changed departure time;
- 12 percent used an alternative route;

- 2 percent canceled the trip;
- 1 percent changed the route and time; and,
- 20 percent used the information to choose between two or more alternative routes.

Most of the other respondents indicated that the information received had been used to verify that their preferred route would be viable. Another interesting finding from this survey is that 8 percent of the participants contacted other commuters to inform them of delays.

Other studies have been conducted to evaluate the influence of IVRGS on traveler behavior. The actual implementation of IVRGS is fairly limited, especially in the United States; therefore, several universities throughout the world have conducted simulator studies that vary the amount and accuracy of information provided to drivers and ask study participants to make hypothetical route choice decisions.

In general, many of the studies that have been conducted indicate that a driver's willingness to use information to modify his or her route choice behavior depends on the feedback that he or she had received about the reliability, accuracy, timeliness, and/or relevancy of information that was provided on previous trips. These studies also emphasize that the level of detail that is included in the network, the extent to which the information is targeted to the specific needs of the drivers, how up-to-date the information is, and a driver's personal perception of the advice or information that is provided all influence a driver's propensity to use travel information. Finally, several studies indicated that drivers may be more willing to divert if they are provided with the cause and the predicted length of delay related to an incident.

Route Switching Behavior

Several other factors in addition to the provision of real-time travel time and/or route guidance information influence the propensity of travelers to modify route choice behavior, such as knowledge of alternative routes, characteristics of the commute, personal characteristics, and the attributes of the alternative routes (as discussed in the previous section of this report). Several of these factors are discussed below.

Knowledge of Alternative Routes

Several studies indicate that, although a driver may be biased toward his or her primary route, he or she is aware of alternatives and may not be committed to a single route. According to the results of a survey conducted in Dallas, 74 percent of the participants used more than one commute route during the month-long survey period (21).

Other studies suggest that, although drivers may be familiar with alternative routes, less than half may use those alternatives. According to the results of a survey conducted in Seattle, 62 percent of drivers surveyed were very familiar with alternative routes; however, 63 percent of drivers surveyed rarely changed routes between home and work, while 42 percent rarely changed routes between work and home. The difference in time-of-day behavior may be attributed to the need to run errands after work (24).

Characteristics of the Commute

Several studies have also been conducted to evaluate the effects of incident-induced delay on a driver's propensity to modify his or her route choice behavior. As expected, the results of these surveys are varied because different drivers in different metropolitan areas have varying threshold levels for the tolerance of schedule delays.

Both Huchingson et al. and Mahmassani found that the length of delay that drivers are willing to tolerate is directly related to the total trip length: drivers who travel longer distances have a wider "indifference band" to tolerable schedule delay (as summarized in (25)). Mahmassani also noted that each drivers' indifference band is related to prior experience and that all drivers must be willing to accept a certain level of schedule delay to ensure the reliability of on-time arrivals.

A study of Los Angeles morning commuters revealed that 39 percent of the respondents indicated a willingness to divert from their primary route if they encountered an increase of less than 5 minutes from "normal conditions" (i.e., recurring congestion) (7) while a study in Houston indicated that delays of 10 minutes or more are necessary for the average driver to justify alternative routes (15).

On the other hand, a survey of commuters in Seattle revealed that the average response to length of delay that would cause motorists to divert was 16.3 minutes to known routes and 25.5 minutes to unknown routes (the average commute length varied between 31 and 35 minutes) (24).

Finally, a study by Mannering revealed that 52 percent of drivers faced with severe congestion during peak hours never change their primary route (as summarized in (4)).

Personal Characteristics

There are also several individual driver characteristics that can influence route choice behavior such as: age, gender, education, income, personality (i.e., risk-prone, neutral, or risk-adverse), habits, and driving experience.

A review of a variety of studies revealed that, in general, males place a greater emphasis on minimizing travel time, are familiar with a greater number of alternative routes, and are willing to divert sooner than females. On the other hand, females place more emphasis on commute qualities and are less willing to divert. To this end, females are more likely to seek pre-trip route information while males are more likely to use en route information. Several studies also indicated that drivers with higher income and education levels are more likely to use alternative routes and have more flexibility in their departure time than lower income drivers. Finally, several studies also indicate that older drivers, males, and lower income drivers are more willing to use route guidance advice.

FEASIBILITY OF INCORPORATING COMMUTERS' CHOICE BEHAVIOR INTO IVRGS

The decision-making process associated with route choice behavior is a dynamic feed-back process. Information learned on previous trips about areas of recurring congestion, specific route attributes, and the effectiveness of the real-time travel time and/or route choice information provided will influence a traveler's propensity to change his or her route, departure time, and/or mode.

Although it has been shown that some drivers will not modify their behavior in response to information and each has his or her own tolerance to what is considered acceptable delay, the provision of accurate and reliable travel time and route choice information can be used by most drivers to verify knowledge of recurring congestion on primary routes, compare two nearly equal route alternatives, justify an alternative route, modify departure time, or choose to telecommute. In order to provide information that can be used by a variety of drivers, real-time travel time and route choice information should:

- be provided in a variety of media in order to address the varying cognitive skills of travelers;
- use the most up-to-date traffic flow conditions;
- allow drivers to make decisions in a timely manner;
- be based on a detailed roadway network to account for arterial street alternatives;
- allow drivers to access information about specific route attributes;
- provide information about the source and expected length of delay related to an incident;
- allow a driver to verify his or her knowledge about traffic flow conditions on his or her primary route;
- be available both pre-trip and en-route; and,
- allow a driver to either make his or her own route choice decision based on knowledge of route attributes and travel times *or* to accept route guidance information provided by the system.

Several of the existing route guidance and traveler information systems were evaluated using these recommendations to assess their ability to influence commuters' behavior. This analysis is discussed below.

Evaluation of Current Route Guidance and Traveler Information Systems

As discussed previously in this report, a variety of traveler information systems and route guidance systems have been and are being implemented throughout Europe and the United States. Several major metropolitan areas provide access to real-time travel information on freeways through the use of the Internet. In other areas commuters can also access information about expected travel times through a phone-based system. In addition, two in-vehicle route guidance systems have been tested in the United States: TravTek, which was tested in Orlando, Florida and ADVANCE, which was tested in Chicago.

A critique of the Internet sites and the in-vehicle route guidance systems using the recommendations discussed above is presented in Table 2. For the purposes of this research, ten metropolitan areas in the United States were identified that provide up-to-date travel time information on the Internet. A list of the web site addresses for these sites is provided in Appendix A.

Also included in Table 2, is a recommendation for the development of an ideal route guidance system that would include the capabilities necessary to influence commuters behavior.

Table 2. Assessment of Existing Systems.

Recommendations	Internet Traveler Information Sites	In-Vehicle Route Guidance Systems	Ideal System that Accounts for Choice Behavior
Address Cognitive Skills	*Advantages*: Most sites provide a color-coded map and textual information regarding existing travel speeds/times on freeways. Some sites also include significant landmarks and important points of interest on map to provide orientation. Some sites provide aerial views from surveillance cameras to allow users to form expectations of commute based on visual inspection of traffic flow. *Critique:* Although redundant information is provided, it may be difficult to use for individuals with sensory or cognitive impairments, such as color anomalous vision.	*Advantages*: Presented both auditory and visual information. *Critique:* Some users found auditory information to be distracting.	Should allow users to customize how information is provided. System should include flexibility to: present information in both an auditory and visual format, use color-coded information to assist users who have difficulty understanding textual or numerical information, and use easily recognized symbols to assist users with cognitive or sensory impairments. Should also include significant landmarks or points of interest to provide orientation. Should provide easy-to-understand directions while en route so will not interfere with driving tasks.
Use Up-to-date Traffic Conditions / Use Detailed Roadway Network / Verify Knowledge about Primary Route	*Advantages*: Provide information about current travel conditions on freeways. *Critique:* Estimation of current travel conditions (e.g., speed and travel time) limited by extent of freeway system that includes detection capabilities. Do not predict travel times.	*Advantages:* Incorporated most of the roadways in urban area. *Critique:* Estimation of current travel times limited by extent of system that includes detection capabilities. Did not include predictive capabilities. Most travel times in roadway system were based on average conditions. However, most commuters are aware of average conditions on system. Errors in data-base sometimes produced routes that were not the most direct or logical.	Should include up-to-date travel times on freeways and surface streets to allow commuters to verify knowledge of recurring congestion or to identify areas with incident-related congestion. Should incorporate the flexibility to predict travel times.

Table 2. Assessment of Existing Systems (continued).

Recommendations	Internet Traveler Information Sites	In-Vehicle Route Guidance Systems	Ideal System that Accounts for Choice Behavior
Incorporates Route Attributes	*Advantages:* One site provides information about toll facilities. Another site provides directions from a specific origin to a specific destination; however, no estimate of travel time is provided nor can the user customize the route based on attribute preferences. *Critique:* Most sites do not include any information about route attributes or include route planning.	*Advantages:* Routes were generated based on minimization of travel time. Several commuters may include this attribute in route choice criteria. *Critique*: Problems with travel time estimation did not generate routes that were truly the shortest path. Did not allow commuter to incorporate preferences for route attributes.	System should include capability to "learn" each user's preferences for surface street shortcuts and route attributes. System should also include flexibility to allow user to specify a different set of route choice criteria for each trip.
Provides Incident Information	*Advantages:* Some sites provide information about location, cause, and current status of incident that allows commuters to form expectations about effect of incident. *Critique:* Most sites do not include detailed or up-to-date information about status of incidents.	*Advantage:* Effects of incidents may have been accounted for in routing of vehicles based on minimal travel time. *Critique*: See discussion regarding travel times.	Should provide information about location, cause, and status of incident to allow commuter to form expectations about effect of incident on traffic flow. Should also incorporate flexibility for computer to estimate effect of incident on traffic flow and provide this estimate to drivers.
Available Both Pre-Trip and En Route	*Advantages:* Internet sites provide pre-trip knowledge about current status of system. Some sites included cellular call-in numbers for en route information. *Critique:* Although pre-trip information allows user to form expectations about commute, most sites do not allow access to information while en route. Current, pre-trip information for segments near the end of trip may not be useful to commuters.	*Advantage:* Navigational advice provided to driver while en route. *Critique:* Commuter may not have been able to form or modify expectations about commute environment.	System should provide information about route attributes and characteristics that allows commuter to make pre-trip decisions, such as departure and route choice. System should also allow commuter to form expectations about commute before trip has begun, to alter those expectations while en route, and to modify route choice accordingly.

Table 2. Assessment of Existing Systems (continued).

Recommendations	Internet Traveler Information Sites	In-Vehicle Route Guidance Systems	Ideal System that Accounts for Choice Behavior
Can Use to Make Decisions or to Obtain Route Guidance Advice	*Advantage:* Commuter can use general information about nature of commute to make pre-trip decisions. *Critique:* Most of the sites did not include route planning capabilities.	*Advantage*: Objective was to provide navigational advice to drivers. *Critique:* Commuters could not access information about route attributes or current conditions to make own choices.	Enable commuter to use computer as intelligent assistant. Both driver and computer can bring unique capabilities to process. Allow each commuter to use computer for navigation assistance or to make informed decisions.

As shown in the table, many of the Internet traveler information sites and the two in-vehicle route guidance systems that were tested in the United States do not include several of the criteria recommended as part of this research effort. In addition, the hypothetical system that incorporates attributes and characteristics that may influence traveler behavior is significantly different than the systems that are in-place or that have been tested in the United States. For this reason, the feasibility and implications of including these recommendations into a future in-vehicle route guidance or traveler information system is discussed below.

The Incorporation of Route Attributes

One of the primary factors that affects commuters' route choice behavior is the extent to which the information is targeted to the specific needs of the individual. Future acceptance of route guidance systems by commuters may depend on the extent to which route guidance systems can provide commuters with information about specific route attributes and generate routing information based on individual preferences. Several issues that are associated with the feasibility of incorporating route attributes are discussed below.

One of the most important factors that needs to be considered regarding the incorporation of route attributes is the manner in which the information is provided to drivers. In a pre-trip context, a variety of information about route attributes can be provided to drivers; however, consideration needs to be given to the ability of drivers to process and use the information effectively. Careful consideration needs to be given to the media that the information is presented in to ensure that the commuter will not be overloaded by an abundance of information and to ensure that the commuter can incorporate pre-trip knowledge into en route decisions.

Providing information regarding route attributes that commuters can use to make decisions while en route may not be feasible. Attempting to process a significant amount of information about potential routes while driving may affect a driver's ability to attend to the control and guidance tasks associated with driving a car. Like the design issues associated with the placement of static guide signs, careful consideration needs to be given to the design of the on-board system to ensure that the navigation level of driving does not impede the control and guidance tasks. A driver needs to be able to process the information that is presented in a manner that allows him or her to make timely decisions. For this reason, the incorporation of route attributes in an en route context should be delivered in the form of generated routes that are consistent with a driver's preferences.

Generating routes that are consistent with a driver's preferences would require the development of an artificial intelligence system. This type of system would need to allow each driver to specify the relative importance of each attribute for a specific trip. The system would also need to "learn" each user's route choice criteria. The development of a system that could learn a user's choice preferences could avoid massive switching from one congested route to another because, by incorporating individualized route attributes in route guidance, the problems associated with reducing the variability in driver perceptions can be avoided.

Finally, the successful development of a system that can incorporate individualized preferences for route attributes would require significant coordination between each of the agencies in an urban area to ensure that the database that is used to compile the information includes the most up-to-date information about specific route attributes such as traffic signal locations, areas of construction, special events, etc.

The Concept of Real-Time Information

As discussed previously, the propensity of a traveler to use information is dependent on the feedback that he or she had received about the reliability, accuracy, timeliness, and/or relevancy of information that was provided on previous trips. However, based on a review of the literature, it seems apparent that there are several questions that remain about the provision of and usefulness of quality, real-time traveler information. In several urban areas, monitoring capabilities are currently limited primarily to freeways. However, to truly provide reliable information about route choice alternatives to commuters, significant infrastructure investments would be required to equip both surface street and freeway alternative routes with the surveillance equipment and technologies required to assess up-to-date travel time conditions. This investment would likely require significant time and monetary investments in each urban area where IVRGS are implemented.

Although the installation of monitoring technologies on surface streets would provide benefits to the overall operation of the transportation system, it is questionable whether the benefits of wide-spread implementation of such a system could outweigh the associated costs. It is probably more feasible to install monitoring technologies on specified corridors in an urban area as part of overall improvement projects to the facilities. Incurring the costs associated with the installation of monitoring capabilities may be justifiable on the basis of improving the safety and operation of the roadway, with the estimation of current travel times as an ancillary benefit. Until a significant number of surface street alternatives are equipped with monitoring capabilities, travel times on surface street alternatives will continue to be based on average conditions combined with information from police and emergency services regarding incidents. Therefore, commuters cannot truly evaluate differences between routes, nor can a route guidance system accurately identify the optimum actual shortest path through a system.

Regardless of the proportion of the system that is equipped, the real issue that needs to be addressed regarding the provision of real-time travel information is the inability to predict traffic flow characteristics during future time intervals. Providing travelers with current travel times on roadways allows commuters to base route, mode, and departure choice decisions on events that have already occurred; these conditions are likely to change by the time the traveler encounters them. Therefore, is real-time information truly being provided? The process of route choice is a dynamic, feedback process; therefore, determining methods to provide travelers with reliable and accurate information is paramount to the success of route guidance and traveler information systems.

Some agencies now provide information to travelers about the cause and current status of incidents. For example, the traveler information Internet site provided by CalTrans and Maxwell Technologies for Southern California allows users to access information about incidents from a central dispatch service. Information is provided about the time of the incident, the cause, and the status of the police and emergency services (e.g., officer on scene, officer has left scene). Based on previous experiences, drivers can form expectations about the likely duration of the incident and the expected effects; however, there are no technologies in place today that can predict the duration of an incident nor the effects on capacity and hence travel time. Future research efforts should be concentrated on predicting the duration and effects of an incident on capacity from the perspective of improving the safety and operation of existing roadway facilities. As with providing loop detectors and aerial surveillance on surface streets, the ability to predict the duration and effects of an incident can allow for the prediction of travel times as a secondary benefit.

Providing predictive information also requires cooperation between various agencies that provide freight and passenger transportation in a metropolitan area. Estimates of predictive travel time information also need to incorporate the expected effects of delays caused by trains crossing at-grade intersections along arterials, raised drawbridges, the coordination (or lack of thereof) of traffic signals along a corridor, etc. Clearly, the institutional barriers associated with obtaining and coordinating information from each agency need to be addressed before real-time guidance systems can be successfully implemented.

Finally, consideration needs to be given to the reaction of drivers to the provision of travel time information and to observed conditions in the prediction of travel time information. As discussed previously, some drivers will not modify their route, mode or departure choices even if they are provided with advance information about conditions. This could again be attributable to perceptions about the quality of the advice that was received in the past or to a discomfort in switching to a route or mode that is less familiar or unfamiliar altogether. Other drivers may continually be processing perceptions about the commute environment and information received in attempts to minimize total travel time at each junction encountered. To provide predicted travel times, drivers' reactions to information needs to be estimated and combined with information about events related to travel time variability.

Evaluation of the Objectives of In-Vehicle Route Guidance

One of the other issues that remains unanswered in the current literature in regards to the provision of real-time travel information is the identification of the true objectives of route guidance systems. Should the objectives concentrate on:

1. the education of motorists in an urban area such that commuters can use the information to not only make decisions about the appropriate route but also to reduce anxiety and to form expectations about the commute itself;
2. the provision of navigational advice to drivers in unfamiliar areas; or
3. the determination of an optimal routing strategy to reduce congestion on urban freeways and to reduce the effects associated with wide-spread diversion to another facility?

Each of the above objectives requires varying levels of technology and focuses for future research and testing. Based on a review of the factors that affect commuters' choice behavior and commuters propensity to choose alternative routes, research emphasis should perhaps be focused on providing information to allow commuters to become more knowledgeable about the commute environment rather than on optimal-routing strategies. As discussed previously, the decision-making processes associated with route, mode, and departure choice are very specific to each individual traveler, the factors that influence behavior may vary even during a single trip, and commuters are very familiar with areas of recurring congestion in an urban area; therefore, it is reasonable to believe that commuters' acceptance of a guidance system based on optimal routing strategies will be limited.

Commuters' acceptance of a route guidance system may be based on the ability of a system to educate and to provide reliable, timely, and relevant information. For this reason, it is essential that any route guidance systems that are developed and tested in the future include achievable objectives with merits that can be easily perceived by drivers. Based on the research conducted as part of this paper, both short-term and long-term recommendations are forwarded for the future research and testing in the area of route guidance. These recommendations are discussed briefly below.

Short-term Recommendations

In the near-term, research and testing efforts should be concentrated on the compilation of detailed databases that will provide unfamiliar drivers with navigational assistance (which is dependent on the provision of a detailed database and not necessarily on the provision of predictive travel time information) and provide familiar drivers with information about locations of non-recurring congestion related to incidents, construction, special events, etc., and about specific route attributes. This research should concentrate on allowing drivers to form educated expectations about the commute environment and to continue to shape those expectations throughout the commute itself.

Near-term research should be primarily concentrated on providing more reliable information to commuters through the use of existing technology that has been and will continue to be used in most urban areas, such as highway advisory radio, telephone information systems, variable message signs, etc. This research will also provide benefits to the future implementation of IVRGS.

The ability to overcome the institutional barriers associated with the coordination of information from all of the surrounding jurisdictions and agencies that provide passenger and freight transportation and services in an urban area is crucial to the provision of improved information. Without information from each of the affected agencies, commuters will not be able to effectively use the system.

Long-term Recommendations

Based on an analysis of commuters' choice behavior, it seems apparent that commuters would be more willing to receive and react to information that can allow them to make more informed choices or to navigate in unfamiliar environments rather than to incur the costs associated with the estimation of predictive travel times today. There are still several issues that need to be researched related to the effects of incidents and other factors that lead to travel time variability on the actual operations of a roadway before predictive travel time information can be estimated. The feedback received by drivers about the advice during a particular trip is essential to success of a traveler information or guidance system; therefore, until reliable information can be provided, research money should be spent on trying to better educate motorists to make more informed route, mode, and departure choice decisions.

In the long-term, however, a system that includes the flexibility to predict travel times and incorporates artificial intelligence to "learn" each user's preferences should be developed. If the short-term recommendations are achieved, it is expected that institutional barriers regarding agency cooperation and the compilation and continued maintenance of a detailed database will be addressed. In addition, it is also expected that as urban freeways become more congested, more arterial streets will include monitoring capabilities to allow for the safe and efficient operation of the overall transportation system.

Both short-term and long-term research efforts in the area of route guidance and traveler information should strive to incorporate factors that affect commuters' choice behavior and should allow commuters to make informed pre-trip and en route decisions or to seek navigational advice.

CONCLUSIONS AND RECOMMENDATIONS

Individual drivers choose between competing routes based on a variety of factors. Consequently, a better understanding of the effects of route attributes and travelers' decision processes (especially as related to the type and location of the provision of route information) on route choice behavior is essential to the successful implementation and future application of route-guidance systems, especially as the use of these systems becomes more widespread.

Several attributes of a route were identified that influence route choice behavior. These include: travel time, travel time variability, the number of traffic signals or stops along the route, congestion, distance traveled, monetary costs, number of turns, hierarchy, and safety. It is difficult to develop a choice model that is representative of all drivers in an urban area because each driver places a different level of importance on each of the attributes. For this reason, route guidance systems should incorporate the ability to quantify a number of route attributes and to provide information about these attributes to the driver. This will allow the driver to weigh the prevailing travel time conditions and each of the attributes to make an informed route choice decision or to assess the routes provided by a guidance system.

The decision-making process associated with route choice behavior is a dynamic feed-back process. Information learned on previous trips about areas of recurring congestion, specific route attributes, and the effectiveness of the real-time travel time and/or route choice information provided will influence a traveler's propensity to change his or her route, departure time, and/or mode.

Although it has been shown that some drivers will not modify their behavior in response to information and each has his or her own tolerance regarding what is considered acceptable delay, the provision of accurate and reliable travel time and route choice information can be used by most drivers to verify knowledge of recurring congestion on primary routes, compare route alternatives, justify an alternative route, modify departure time, or choose to telecommute.

Based on the findings included in this paper, it is recommended that the information provided to travelers through real-time traveler information and route guidance system applications should:

- be provided in a variety of media in order to address the varying cognitive skills of travelers;
- use the most up-to-date traffic flow conditions;
- allow drivers to make decisions in a timely manner;
- be based on a detailed roadway network to account for arterial street alternatives;
- allow drivers to access information about specific route attributes;
- provide information about the source and expected length of delay related to an incident;
- allow a driver to verify his or her knowledge about traffic flow conditions on his or her primary route;
- be available both pre-trip and en route; and,
- allow a driver to either make his or her own route choice decision based on knowledge of route attributes and travel times *or* to accept route guidance information provided by the system.

It is also recommended that future route guidance systems be developed in a manner that allows the system to "learn" individual users' preferences for route attributes, alternative routes, and surface street short-cuts. The incorporation of these options into a route guidance system will enable drivers to access information that is timely, current, accurate, relevant, reliable, and targeted to the specific needs of the individual driver.

These recommendations will allow for the provision of route choice and guidance information in a manner that may influence commuters' choice behavior.

ACKNOWLEDGMENTS

The author wishes to offer her sincere appreciation to each of the mentors for spending the time to make this program a wonderful learning experience for all of the participants. Special thanks are offered to Dr. Doug Robertson and Ms. Marsha Anderson for their insightful comments and suggestions throughout the summer. The author would also like to thank Dr. Conrad Dudek and Ms. Sandra Schoeneman whose hard work and dedication make this program successful.

Finally, the author would like to thank the following people for taking time to share resources and opinions:

Tom Adler, Resource Systems Group
Catherine Bradshaw, Metro - King County
Dave Hartgen, University of North Carolina
Paul Herskowitz, Michigan Department of Transportation
Catherine Ross, Georgia Institute of Technology
Bill Twomey, SmartRoutes
Carol Zimmerman, Battelle

REFERENCES

1. Lee, C. A Multiple-Path Routing Strategy for Vehicle Route Guidance Systems. *Transportation Research C*, Vol. 2, No. 3, 1994, pp. 185-195.

2. Bonsall, P. The Influence of Route Guidance Advice on Route Choice in Urban Networks. *Transportation*, Vol. 19, 1992, pp. 1-23.

3. Dreyfus, S.E. An Appraisal of Some Shortest Path Algorithms. *Operational Research*, Vol. 17, 1969.

4. Bovy, P. And E. Stern. *Route Choice: Wayfinding in Transport Networks*. Kluwer Academic Publishers, Dordrecht, The Netherlands, 1990.

5. Antonisse, R., A. Daly, and M. Ben-Akiva. Highway Assignment Method Based on Behavioral Models of Car Drivers' Route Choice. In *Transportation Research Record 1220*, TRB, National Research Council, Washington, D.C., 1989, pp. 1-11.

6. Schofer, J., F. Koppelman, and W. Charlton. Perspectives on Driver Preferences for Dynamic Route Guidance Systems. TRB Paper No. 97-0146, *Paper presented at the 76th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 12-16, 1997.

7. Dial, R. A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration. *Transportation Research*, Vol. 5, 1971.

8. Park, D. and L. Rilett. *Identifying Multiple and Reasonable Paths in Transportation Networks: A Heuristic Approach*. Paper Submitted for Publication in the Transportation Research Record, April 1997.

9. Ortuzar, J. And L. Willumsen. *Modelling Transport*. John Wiley and Sons, Inc., New York, 1990.

10. Polydoropoulou, A., M. Ben-Akiva, and I. Kaysi. Influence of Traffic Information on Drivers' Route Choice Behavior. In *Transportation Research Record No. 1453*, TRB, National Research Council, Washington, D.C., 1994, pp. 56-65.

11. Benshoff, J. Characteristics of Drivers' Route Selection Behavior. *Traffic Engineering and Control*, Vol. 11, No. 12, April 1970, pp. 604-606, 609.

12. Abdel-Aty, M., R. Kitamura, P. Jovanis, and K. Vaughn. *Investigation of Criteria Influencing Route Choice: Initial Analysis Using Revealed and Stated Preference Data*. Research Report No. USC-ITS-RR-94-12, Institute of Transportation Studies, University of California, Davis, July 1994.

13. Lecture Notes, CVEN 618, Spring 1997, Texas A&M University, College Station, Texas 1997.

14. *A Policy on Geometric Design of Highways and Streets (1994)*. American Association of State Highway and Transportation Officials, Washington, D.C., 1995.

15. Wohlschlaeger, S. Factors Affecting Motorist Route Choice and Diversion Potential. TRB Paper No. 97-0968, *Paper Presented at the 76th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 12-16, 1997.

16. Hartgen, Dave. University of North Carolina, Charlotte, North Carolina. Telephone conversation conducted July 2, 1997.

17. Zimmerman, Carol. Battelle, Washington, D.C. Telephone conversation conducted July 8, 1997.

18. Twomey, Bill. SmartRoutes, Cambridge, Massachusetts. Telephone conversation conducted July 7, 1997.

19. Bradshaw, Catherine. Metro, Seattle, Washington. Telephone conversation conducted July 2, 1997.

20. Ben-Akiva, M., A. Palma, I. Kaysi. Dynamic Network Models and Driver information Systems. *Transportation Research - A*, Col. 25A, No. 5, 1991, pp. 251-266.

21. Huchingson, R., R. McNees, and C. Dudek. Survey of Motorist Route-Selection Criteria. In *Transportation Research Record No. 643*, TRB, National Research Council, Washington, D.C., 1977, pp. 45-48.

22. Khattak, A. *Behavioral Impacts of Recurring and Incident Congestion and Response to Advanced Traveler Information Systems in the Bay Area: An Overview*. Research Report No. UCB-ITS-PWP-93-12, University of California, Berkeley, 1993.

23. *Summary Findings, Massachusetts Highway Department Independent Evaluation of SmarTraveler Operational Test*. SmartRoute Systems, Cambridge, Massachusetts, 1995.

24. Spyridakis, J., W. Barfield, L. Conquest, M. Haselkorn, and C. Isakson. Surveying Commuter Behavior: Designing Motorist Information Systems. *Transportation Research - A*, Vol. 25A, No. 1, 1991, pp. 17-30.

25. Adler, J., W. Recker, M. McNally. *A Systematic Evaluation of the Impacts of Real-Time Traffic Condition Information on Traffic Flow*. PATH Research Report No. UCB-ITS-PRR-93-6, University of California, Irvine, June 1993.

APPENDIX A

The following provides a list of the web site addresses that were consulted for this research effort.

Metropolitan Area	*Web Site Address*
Atlanta, Georgia	http://www.georgia-traveler.com/traffic/rtmap.htm
Boston, Massachusetts	http://www.smartravler.com/bos-com/
Chicago, Illinois	http://www.ai.eecs.uic.edu/GCM/congestionmap.html
Detroit, Michigan	http://campus.merit.net/mdot/largeview.html
Houston, Texas	http://traffic.tamu.edu/traffic.html
Long Island, New York	http://www.metrocommute.com/
Minneapolis/St. Paul, Minnesota	http://traffic.connects.com/
Southern California	http://maxwell.com/caltrans/
Phoenix, Arizona	http://www.azfms.com/travel/freeway.html
Seattle, Washington	http://www.wsdot.wa.gov/regions/northwest/nwflow/

Julia A. Kuhn Butorac is currently pursuing her M.S. in Civil Engineering at Texas A&M University. Since graduating with her B.S. in Civil Engineering from the University of Idaho in 1993, Julia has been working at Kittelson & Associates, Inc., a traffic engineering and transportation planning firm in Portland, Oregon. At Kittelson, Julia has been instrumental in the development of the travel demand model and the preparation of Transportation System Plans for several small and medium-sized communities and counties throughout Oregon and Washington. She has also been involved in a wide variety of access management plans, mixed-use development studies, traffic impact studies for new developments, and the development of traffic signal, signing, and channelization plans. Julia is active in the Women's Transportation Seminar (WTS) and the Institute of Transportation Engineers (ITE). Her principle areas of interest are transportation planning, neo-traditional development, travel demand forecasting, and access management.

GEOMETRIC AND OPERATIONAL GUIDELINES FOR MULTIPLE-LANE RAMP METERS

by

Marc Butorac

Professional Mentor
Thomas Hicks, P.E.
Maryland Department of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

As the metropolitan areas throughout the nation continue to advance in their application of freeway management strategies, the need to develop high-volume and preferential-lane ramp metering strategies is essential to allow transportation management centers to more effectively manage freeway-related congestion. The traditional single-lane ramp meter design strategy does not provide an effective freeway management tool at on-ramp locations where traffic demands generally exceed 900 vehicles per hour or highly variable arrival patterns exist. In addition, this design strategy limits the benefits of high-occupancy vehicle bypass lanes. To address these problems, freeway managers are experimenting with multiple-lane meters to provide additional operational flexibility.

Due to the small number of states currently using multiple-lane ramp meters and the high-degree of variability in their application, the geometric and operational issues associated with applying, designing, and operating this advanced freeway management system are not fully understood. To address these issues, the geometric, traffic control, and operational characteristics of single-lane and multiple-lane ramp meters were reviewed, and application guidelines for each design strategy were developed. In addition to these application issues, the operation of ramp meters under inclement weather conditions and during non-commuting hours was examined, as well as various performance measures used to evaluate operational ramp metering systems.

The application and operational guidelines developed in this paper were used to evaluate the feasibility of deploying multiple-lane ramp meters on the Capital Beltway and Interstate 95 in the Maryland suburbs of Washington, D.C. From this feasibility study, it was determined that several interchanges along the two freeway sections evaluated could accommodate and potentially benefit from multiple-lane ramp meters.

Based on this research, it was shown that the multiple-lane ramp meters provide superior operational flexibility over the traditional single-lane ramp meters under certain conditions and should always be considered with the future conditions of the facility in mind. In addition, it was found that multiple-lane ramp meters can be operated effectively during inclement weather conditions and non-commuting hours if proper precautions are taken by freeway managers and transportation management centers.

TABLE OF CONTENTS

INTRODUCTION

The application of the freeway management technique of ramp metering has been experimented with in various ways over the past four decades. Since the original ramp metering experiments, conducted in Detroit, Michigan and Chicago, Illinois in the early 1960s, freeway volumes and recurrent congestion have continued to grow and become more problematic on freeway systems throughout the United States (1,2). As a result of this growth, on-ramp demand volumes and the variance in arrival patterns have increased significantly. These changes in freeway operating conditions, combined with the advent of preferential lane treatments, prompted departments of transportation that used traditional single-lane ramp metering (e.g., California, Minnesota, and Washington) to develop more flexible ramp meter systems in the mid-1980s (3,4,5). This resulted in the design and construction of multiple-lane ramp meters with the following four designs: single-lane with a parallel high-occupancy vehicle (HOV) bypass lane, dual-lane with mixed-flow traffic, dual-lane with a parallel HOV bypass lane, and dual-lane with a separated HOV bypass lane (6).

Problem Statement

As metropolitan areas throughout the nation continue to advance in their application of freeway management strategies, the need to develop high-volume and preferential-lane ramp metering strategies are essential to allow transportation management centers to more effectively manage both recurrent and non-recurrent freeway-related congestion. The original single-lane ramp metering configuration does not provide an effective freeway management tool at on-ramp locations where traffic demands generally exceed 900 vehicles per hour. In addition, its design limits the potential benefits of HOV lanes. To address these problems, freeway managers are experimenting with multiple-lane meters to provide additional operational flexibility.

Increasing on-ramp demand volumes, highly variable arrival patterns, and the desirability to provide preferential lanes at entrance ramps, warrant the evaluation of the geometric and operational issues associated with multiple-lane ramp metering systems. In addition, guidelines are needed to properly apply, design, and operate multiple-lane ramp meters.

The research discussed in this paper builds upon the author's previous work regarding the feasibility of designing dual-lane ramp meters in the state of Texas. This work focused on developing geometric, traffic control, and operational design criteria for dual-lane ramp meters on frontage road/freeway slip-ramps.

Research Objectives

The primary goal of this research work was to determine the geometric and operational differences of multiple-lane ramp meters compared to traditional single-lane ramp meter systems, and to identify the geometric and operational issues associated with this freeway management technique. To achieve this goal, the following research objectives were established.

- Determine the geometric, traffic control, and operational characteristics of single-lane and multiple-lane ramp meter configurations.

- Provide a comparative analysis of the two ramp meter configuration strategies and identify the geometric and operational issues of multiple-lane ramp meters.
- Establish general application guidelines for single-lane and multiple-lane ramp meter systems.
- Evaluate the operational and safety issues associated with operating ramp meters during inclement weather conditions and propose operating guidelines for these conditions.
- Identify the on-ramp and mainline operating conditions that characterize on-ramps which could potentially benefit from ramp metering. In addition, propose possible warrants for ramp metering and extended metering.
- Identify various performance measures for isolated (local traffic responsive) and system-controlled ramp meter systems.

The findings of this research were applied to a segment of the Capital Beltway and Interstate 95 in Maryland to determine the feasibility of operating multiple-lane ramp meters at these locations. Metering during inclement weather conditions and non-commuting time periods was also examined both from an operational and driver compliance viewpoint along this segment.

Scope

This research focuses primarily on the existing single-lane and multiple-lane ramp meter systems operated today within the United States. The findings of this research were applied to the section of the Capital Beltway (Interstate 495) between Interstates 95 and 295 in Maryland to determine the geometric and operational issues associated with deploying multiple-lane ramp meters along this freeway section. The feasibility of operating ramp meters during inclement weather conditions and non-traditional periods (i.e., times outside the morning and evening commuting periods) was also evaluated for this segment of freeway.

BACKGROUND

The freeway management technique of ramp metering has advanced significantly from a geometric design, traffic control, and operational standpoint since the original ramp meters were tested in Detroit, Michigan and Chicago, Illinois in the early 1960s (1,2). In Chicago, on-ramps to the Eisenhower Expressway were controlled during peak periods by uniformed policemen who directed motorists through the on-ramp at predetermined headways. Through this early attempt at managing freeway traffic, it was revealed that several operational and safety benefits could be achieved by evenly distributing on-ramp traffic into the freeway traffic stream. From these early successes, ramp metering has evolved into a multi-faceted freeway control strategy that is being refined further as a result of the installation of transportation management centers and other Intelligent Transportation System technologies throughout the United States.

The design and control strategies that were developed in the 1960s and used in various applications throughout the 1970s and 1980s to regulate and distribute on-ramp traffic have been significantly updated during the past 10 years as a result of the introduction of new design techniques, such as multiple-lane ramp meters, and better controller systems. Because of these advancements, freeway managers can now effectively meter a wide-range of freeway on-ramp and freeway-to-freeway connector ramp demand volumes. The multiple-lane ramp meters provide a series of operational benefits compared to the traditional single-lane ramp meters, including the abilities to meter traffic volumes up to approximately 1,800 vehicles of mixed-use per hour; provide preferential lane treatments for high-occupancy vehicles; and reduce ramp meter violations. Given these operational benefits, many agencies are interested in modifying existing ramp meter systems and/or developing new multiple-lane ramp meters.

A brief overview of the primary objectives of ramp metering and the current state-of-the practice in the United States, including the various control techniques and design strategies used is summarized in this section. In addition, the advantages and disadvantages of ramp metering were reviewed to provide a better understanding of this freeway management technique.

Objectives of Ramp Metering

As with many freeway management strategies, ramp metering is designed to reduce recurring congestion, improve on-ramp operations and safety, and maintain the capacity and acceptable operating speeds of the freeway facility. The primary objective of ramp metering is typically to evenly disperse vehicles merging into the freeway traffic stream through the regulation of on-ramps or freeway-to-freeway connector ramps. This uniform distribution of entering vehicles reduces the friction within merge areas and may lower driver workload for vehicles traveling on and merging onto the freeway. The metering of on-ramp traffic also reduces the effect of upstream traffic signals on the on-ramp arrival patterns, and promotes the even distribution of motorists between multiple on-ramp locations (7). Another important objective of ramp metering is to protect capital investments in freeways by attempting to maintain the flow on these facilities at or near capacity flow rates (8).

In addition to the traditional objectives of ramp metering, California, Minnesota, Washington, and other states have found that ramp metering provides incentives for the use of carpools, vanpools, and public transit by providing preferential lanes at ramp meter locations (3). The inclusion of preferential lanes (e.g., HOV lanes) leads to additional time savings and visible indicators to motorists of the benefits of using high-occupancy modes of travel (9). Early research in California showed a 1 to 2 percent increase in carpools relative to total on-ramp traffic following the installation of HOV bypass lanes on Interstate 5 in 1971 (10).

State of the Practice

With the opening of several advanced traffic management centers across the United States over the past decade, the geometric design, traffic control, and operation of ramp meters have become more sophisticated and their application more widespread. As of 1995, there were 23 metropolitan areas in North America that operated ramp meter systems (11). In addition to these 23 metropolitan areas, 10 other cities are in the design or planning stages of developing new ramp meter systems that will be operational by 2001 (11). The existing systems are controlled under fixed-time, local traffic responsive, and system-wide environments and maintain up to three lanes of metered traffic.

Within the United States, 14 states currently operate ramp meter systems: Arizona, California, Colorado, Illinois, Massachusetts, Michigan, Minnesota, New York, Ohio, Oregon, Texas, Virginia, Washington, and Wisconsin (11,12). To date there are approximately 3,000 ramp meters operating within the United States (12). In addition to these states, Florida, Georgia, Maryland, New Jersey, Pennsylvania, and Utah are in the process of installing ramp meter systems.

Control Techniques

Ramp meter systems use three primary control techniques to manage on-ramp traffic: fixed-time, local traffic responsive, and system control systems. Fixed-time ramp control provides the basic function of breaking up platoons of traffic at the on-ramp merge point. A fixed-time controlled on-ramp can either operate in a continuous cycle or under a detection-based configuration. The detection-based fixed-time control configuration uses a one or two detector layout to regulate on-ramp traffic. An inductive loop detector (demand detector) is used to identify the presence of vehicles and a passage detector is used by some agencies to terminate the metering cycle. The metering rate of fixed-time controlled on-ramps is based on average freeway traffic flow conditions and does not regulate volumes based on the current freeway conditions. However, fixed-time controlled ramps provide even distribution of traffic into the freeway stream and reduce merge-related congestion and accidents (11).

The second type of ramp meter control is local traffic responsive. This control system uses mainline detection on the freeway in the vicinity of the on-ramp to determine current traffic conditions and adjusts the ramp metering rates to obtain a specified operating level. By continually measuring the freeway traffic, the controller is able to regulate traffic more effectively than a fixed-time system.

The most sophisticated ramp meter control technique is system (or integrated) control. This control technique is traffic responsive, but is not limited to an isolated on-ramp along a freeway. This control technique evaluates segments of a freeway to determine the best overall metering strategy for an entire section of freeway; for example, a series of ramp meters are programmed together to adjust and maintain freeway traffic volume levels. Under an integrated control mode, the metering rates and strategies are calculated in an on-line real-time process that is able to adjust to existing traffic conditions (13). Metering rates and strategies are updated continuously on a system-wide approach based on the control algorithms selected for the given system. This type of control works well within Intelligent Transportation Systems (ITS), which have sophisticated traffic management centers, because it not only reduces congestion and improves operation, but also provides the ability to improve incident detection and management.

Design Strategies

With the continuous increase in demand volumes on urbanized freeways and the introduction of legislation promoting alternative travel modes to traditional single-occupancy vehicles, several states have developed a series of ramp meter design strategies to provide operational flexibility and preferential lane assignments for carpools, vanpools, and transit. Table 1 lists the current design strategies used throughout the nation (8,12).

Table 1. Ramp Meter Design Strategies (8,12).

Ramp Meter Design Strategy	Description
Single-Lane (Single Vehicle Release)	One vehicle is released per green displayed.
Single-Lane (Multiple Vehicle Release)	Two or more vehicles are released per green displayed.
Single-Lane + HOV	A parallel or separate HOV bypass lane is provided for carpools, vanpools, and transit in addition to the mixed-traffic lane. This lane may provide varying degrees of preferential treatment and control.
Dual-Lane	Two lanes are formed upstream of the ramp meter stop-bar and vehicles are released independently by lane or alternately between lanes.
Dual-Lane + HOV	Two lanes are formed upstream of the ramp meter for mixed traffic and a parallel or separate HOV bypass lane is provided for carpools, vanpools, and transit.

As shown in Table 1, the available ramp meter design strategies provide designers and freeway managers with a significant amount of geometric design and operational flexibility. This flexibility has led to more effective freeway management through ramp metering, and increased the interest in the potential deployment of multiple-lane ramp meters throughout the nation.

Advantages and Disadvantages of Ramp Metering

To provide a better understanding of the operational capabilities and limitations of ramp meters, the advantages and disadvantages of ramp metering were reviewed. Based on research published to date and the telephone interviews conducted as part of this research, the following advantages of ramp metering were identified (7,8,14,15):

- provides reasonably predictable freeway operation through the regulation of vehicular inputs;
- reduces the congestion and driver workload at merge points by distributing traffic evenly into the traffic stream;
- increases mainline capacity and speeds by reducing the potential occurrence of bottlenecks and/or accidents;
- diverts local trips from the freeway, thereby maintaining the functional classification design and operating policies established by the American Association of State Highway and Transportation Officials (AASHTO);
- improves interchange operations through the regulation of freeway-to-freeway connector ramps;
- motivates drivers to convert to high-occupancy vehicles where preferential lane assignments are available;
- provides incident management capabilities for transportation management centers and freeway managers; and
- provides an economical service to the public by protecting the capital investments in freeways by attempting to maintain the flow on these facilities at or near capacity flow rates and delaying more costly improvements or new roadways.

Ramp metering can produce many benefits; however, implementing this freeway management technique can result in several disadvantages, as follows:

- creates potential queue spillbacks into the upstream local streets and interchange terminals, service roads, or freeway facilities under high demand volumes or variable arrival patterns;
- leads to possible equity issues between motorists who are and who are not metered in the urban and suburban areas, respectively;
- diverts traffic onto the local street system which can create additional congestion within business districts and neighborhoods; and
- creates the possibility of delay for motorists at metered on-ramps and freeway connector ramps.

GEOMETRIC, TRAFFIC CONTROL, AND OPERATIONAL CHARACTERISTICS OF SINGLE-LANE AND MULTIPLE-LANE RAMP METERS

The geometric and traffic control characteristics, as well as the operational features of single-lane and multiple-lane ramp meters were reviewed and documented within this section. Using this information, a comparative analysis of the two ramp meter configurations was completed to ascertain the similarities and differences in the geometric, traffic control, and operational characteristics between the two design strategies. From this research and analysis, application guidelines were proposed for single-lane and multiple-lane ramp meters. It should be noted that the information presented in this section is based on a survey of dual-lane ramp metering conducted by the Texas Transportation Institute, the telephone interviews conducted as part of this research (see Appendix A), and the available literature cited.

Geometric and Traffic Control Characteristics

Single-lane and multiple-lane ramp meters employ many similar geometric and traffic control elements; however, the multiple-lane ramp meter design strategy requires additional geometric and traffic control design features to properly function. The obvious difference in the two strategies is the need to accommodate a second lane of traffic on the on-ramp during ramp metered operations. This design element and others are explained in detail below.

The traditional single-lane and multiple-lane (i.e., dual-lane) ramp meter configurations used in California, Minnesota, Washington, and other states have been developed on traditional single-lane on-ramps at diamond and parclo-type interchanges. Figures 1 and 2 show the typical single-lane and multiple-lane ramp meter configurations and traffic control elements used throughout the nation (5,8).

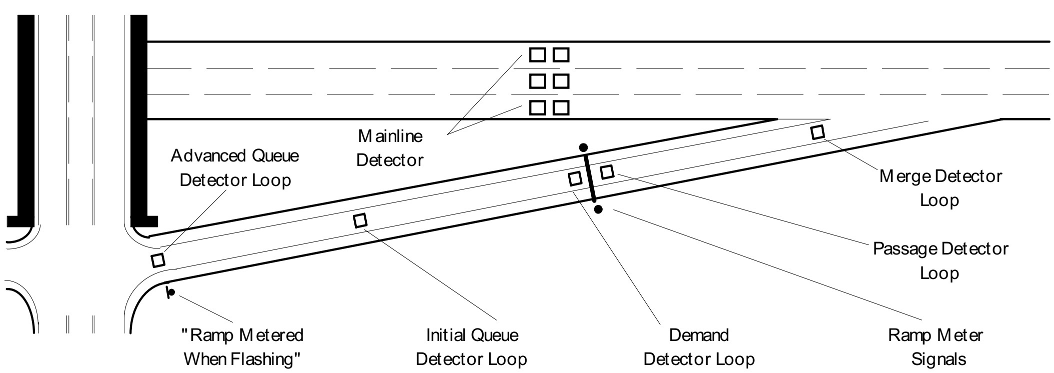


Figure 1. Typical Single-Lane Ramp Meter Configuration and Traffic Control Elements.

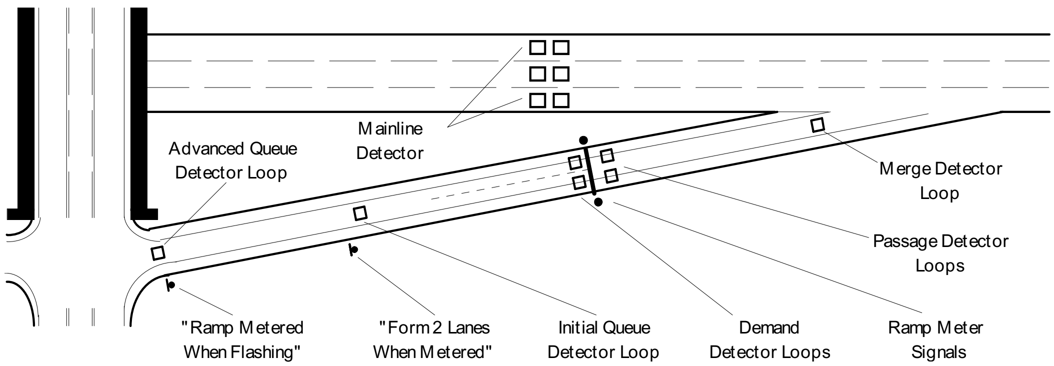


Figure 2. Typical Multiple-Lane Ramp Meter Configuration and Traffic Control Elements.

As shown in Figures 1 and 2, the two ramp meter configurations have similar geometric and traffic control elements; however, the multiple-lane configuration requires several traffic controller advancements and additional pavement width and lateral clearance compared to the traditional single-lane ramp meter. It should be noted that multiple-lane ramp meters can maintain a variety of geometric configurations (i.e., a standard two-lane ramp with a merge point prior to the freeway merge point, connector ramps, etc.); however, this research focuses on the typical multiple-lane ramp meter configuration illustrated above. These geometric and traffic control elements are described below.

Geometric Elements

The single-lane and multiple-lane ramp meters maintain three physical areas: the queue reservoir, the acceleration area, and the merge area. The queue reservoir is the area located between the ramp meter stop-bar and the upstream intersection, service road, or freeway. To develop multiple-lane ramp meters, the single-lane queue storage reservoir is modified with either signage or striping to create two side-by-side storage lanes during metered periods. The queue reservoir can either be striped as one or two lanes depending on the available geometry. Under a traditional on-ramp configuration, the queue reservoir is divided into two lanes through signing that informs motorists to form two lanes under metered operations. As a result, the multiple-lane (dual-lane) ramp meter queue reservoir can accommodate approximately twice the number of vehicles as compared to the traditional single-lane ramp meter.

The queue storage area upstream of the ramp meter stop-bar may maintain either one or two lanes during non-metered periods and should be sufficiently long to accommodate the expected queues during the metered periods. Locations with insufficient storage should be outfitted with queue detectors and control strategies that are capable of increasing the metering rate until queues clear. To estimate the queue during the metered periods, the existing or forecasted on-ramp volumes and freeway volumes must be known. Using the freeway volumes, the expected metering rate during the peak on-ramp arrival period can be determined using a local traffic-responsive, occupancy-based approach. In turn, the expected queue length can be determined using the on-ramp arrival patterns. Once this process is accomplished, the queue storage reservoir required to contain the expected on-ramp demand volumes can be determined.

Under a dual-lane ramp meter configuration, a minimum of 150 feet of queue storage is recommended to allow vehicles to switch lanes when approaching the stop-bar (12). In addition, it is important to note that, even if a sufficient queue reservoir can be developed, the queue reservoir should be designed with queue detectors (i.e., initial and advanced). These detectors will ensure proper operation and safety of the upstream interchange terminal, service road, or freeway, even under unexpected changes in either the freeway or on-ramp arrival patterns and volumes.

Unlike the single-lane ramp meter that can be installed at nearly all on-ramp locations, the dual-lane ramp meter configuration requires additional pavement width to provide space for two lanes of vehicles within the queue storage reservoir. The Oregon and Washington departments of transportation recommend that 24 to 26 feet of pavement be provided within the queue storage reservoir and an absolute minimum width of 22 feet be maintained for dual-lane ramp metering (12). This width allows passenger cars, trucks, and buses to safely queue side-by-side.

The acceleration area is the distance between the stop-bar and the freeway merge point that is necessary for vehicles to accelerate to freeway speed. Some states also require a merge area to allow motorists to find an acceptable gap in the traffic stream. To address the acceleration and merge area requirements on a metered ramp, the Texas Transportation Institute developed mainline operating speed/on-ramp distance relationships to provide guidance to designers. Figure 3 shows the mainline operating speed/on-ramp distance relationships for the recommended acceleration, merge, and acceleration-merge distances (16). It should be noted that the merge area can either be accommodated upstream of the merge point or through the use of an auxiliary lane.

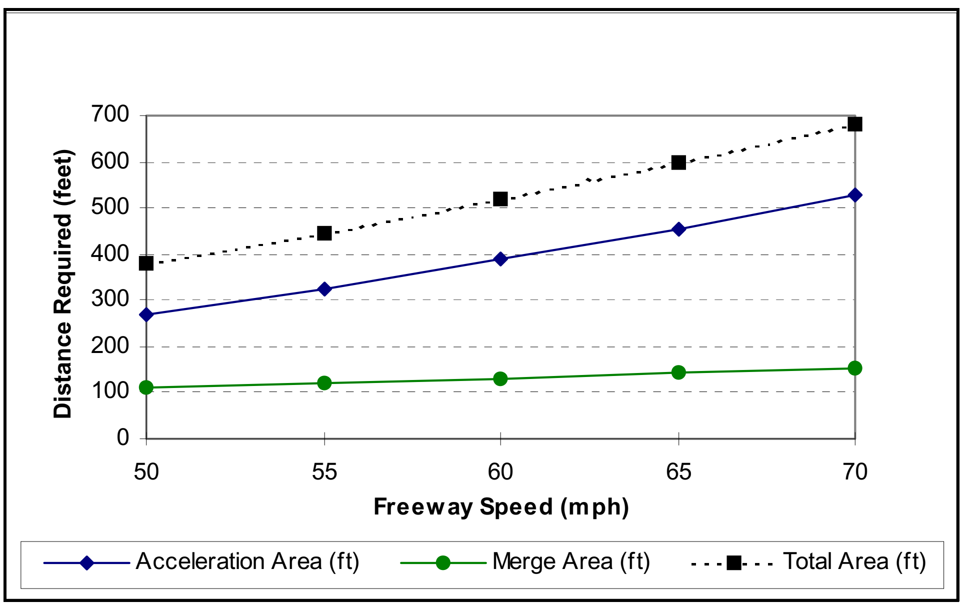


Figure 3. Recommended On-Ramp Acceleration/Merge Area vs. Freeway Speed (16).

As illustrated in Figure 3, an urban freeway with an operating speed of 60 miles per hour requires approximately 390 feet of acceleration area and 130 feet of merge area. Thus, an on-ramp will need to maintain approximately 520 feet between the ramp meter stop-bar and the end of the merging area to provide proper acceleration and merge space.

Traffic Control Elements

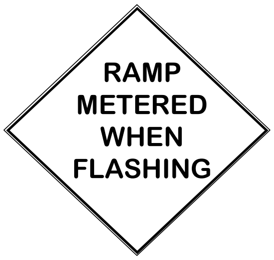
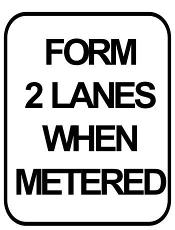
To inform motorists of the ramp meter operations and movement protocols, the metered ramp maintains a series of signs and traffic control devices to effectively communicate the necessary information to motorists and ensure the safety and integrity of the freeway management system. In addition, six sets of loop detectors are required to provide the necessary data to operate fixed-time, local traffic-responsive, or system-controlled ramp meter systems. These include the mainline, merge, passage, demand, initial queue, and advanced queue detectors. Table 2 provides a description of each detector's location and specific application within the control system. It should be noted that the merge, passage, and initial queue detectors are not necessary to operate the three described control systems; however, these detectors provide additional features that several agencies use today to achieve the most effective operations (12).

Table 2. Placement and Application of Ramp Meter Detectors (12).

Detector	Location	Application
Mainline	Located in the freeway upstream and/or downstream of the on-ramp ingress point to the freeway.	Provides freeway occupancy, speed, or volume information that is used to select the local metering rate. These detectors also provide incident detection measurement devices for traffic management centers.
Merge (Optional)	Placed upstream of the merge area in the on-ramp (downstream of the stop-bar).	Used primarily to provide on-ramp volume count data. Minnesota uses it to determine the appropriate time to terminate metering based on the differential between the current on-ramp volume and the fixed-time metering rate.
Passage (Optional)	Positioned immediately downstream of the stop-bar.	Used in California and Washington to determine the duration of the green signal display on the specified lane.
Demand	Placed immediately upstream of the stop-bar in the specified lane(s).	Senses a vehicle's presence at the stop-bar and initiates the green traffic signal display for that specific lane under the selected metering strategy.
Initial Queue (Optional)	Placed approximately half-way between the stop-bar and the on-ramp entrance point in each metered lane.	Adjusts the metering rate to control growing queues within the queue storage reservoir.
Advanced Queue	Positioned near the on-ramp entrance point (typically within 100 feet).	Monitors excessive queues that cannot be contained within the queue storage reservoir. Maximizes the metering discharge rate or discontinues metering to clear excessive queues.

In addition to the detectors used to operate single-lane and multiple-lane ramp meters, a series of warning and regulatory signs are used to convey the intent of the freeway management system. Table 3 provides an illustration of the various ramp meter signs used under single-lane, multiple-lane, and multiple-lane with preferential lane assignment configurations (12).

Table 3. Ramp Meter Signing Conventions (12).

Sign	Placement	Application
	Placed usually on the right-side of the on-ramp near the entrance point.	This warning sign is accompanied by a yellow flashing beacon that is activated during metered periods to alert motorists of the upcoming controlled ramp.
	Placed on both sides normally of the on-ramp at the ramp meter stop-bar. This sign is placed on the signal pole under the post-mounted configuration.	This regulatory sign identifies the ramp meter stop-bar location and is used to align drivers over the demand detector(s) placed upstream of the stop-bar.
	Placed either on the signal pole or with the "Stop Here on Red" regulatory sign under a mast-arm configuration.	This regulatory sign is used to inform motorists of the intended traffic control under ramp metered conditions.
Multiple-Lane Ramp Signage		
	Positioned near the beginning of the dual-lane queue storage reservoir on the right-side of the on-ramp.	This regulatory sign is used to convert the single-lane on-ramp into a dual-lane queue storage reservoir during ramp meter operations.
Preferential Lane Assignment Signage		
	This optional preferential lane assignment sign is located in conjunction with the "Form 2 Lanes When Metered" sign and sometimes repeated near the stop-bar. A similar sign is used to identify separated HOV bypass lanes.	This type of regulatory sign is used to specify lane restrictions at the ramp meter for various carpool occupancies, vanpools, and transit vehicles. Either lane may be assigned.

The final element of the single-lane or multiple-lane traffic control devices is the traffic signal display. As the motorist nears the ramp meter stop-bar, one of two standard signing and traffic signal display conventions is used to inform the driver of the regulatory requirements of the ramp meter and to indicate when the motorist is allowed to enter the freeway facility. Figures 4 and 5 illustrate the typical post and mast-arm ramp meter control conventions, respectively, for multiple-lane ramp meters. It should be noted that single-lane ramp meters use similar control conventions, but provide only a single approach lane.

Figure 4. Typical Multiple-Lane Ramp Meter Post-Mounted Traffic Control Configuration.

Figure 5. Typical Multiple-Lane Ramp Meter Mast-Arm Mounted Traffic Control Configuration.

As shown in Figure 4, the multiple-lane ramp meter post-mounted traffic control convention consists of two separate sets of traffic signals located on the right and left sides of the metered on-ramp. These signals are normally placed within 10 feet, downstream, of the stop-bar and control each lane separately. The upper three-section head traffic signal is intended to inform motorists approaching the ramp meter that it is operational, while the lower two- or three-section head traffic signal is oriented towards the driver at the stop-bar. In addition to the traffic signals, two regulatory signs, "Stop Here On Red" and "One Vehicle Per Green" are affixed to the signal pedestal or nearby to indicate the proper lane control and operation that is to be observed under metered conditions. Under a single-lane design, the signals can be displayed on one or two posts.

The multiple-lane ramp meter mast arm-mounted design illustrated in Figure 5 represents the second ramp meter traffic signal convention that is commonly used. This convention is similar to the traditional traffic signal mounting design used at signalized intersections. The mast arm is typically located within 40 to 70 feet of the stop-bar and has a single three-section head traffic signal over each metered lane. The mast arm design is normally accompanied by regulatory signing in the proximity of the stop-bar indicating the appropriate lane control and operation. It should be noted that the on-ramp illustrated includes an exclusive HOV bypass lane (right side) in addition to the two lanes of mixed traffic.

Operational Features of Single-Lane and Multiple-Lane Ramp Meters

The operational features of single-lane and multiple-lane ramp meters reveal the greatest difference between the two freeway management system design strategies. The single-lane ramp meter cycles at the specified metering rate by either a red-green-red or red-green-yellow-red display sequence when vehicles are present. Most states allow one vehicle to proceed during each green signal display; however, some states have been forced to allow multiple vehicles to be released to accommodate high demand volumes at an on-ramp location. In general, most states will only operate single-lane ramp meters up to a maximum discharge rate of 900 vehicles per hour, which represents a 4-second headway between successive vehicles (12). Agencies have found that headways of less than 4 seconds do not effectively bring vehicles to a complete stop. This can create enforcement problems because motorists continually move through the ramp meter.

The multiple-lane ramp meter design strategies employed throughout the country differ significantly, from vehicles in each lane being released simultaneously to vehicles being evenly alternated between lanes. The existence of a second lane allows multiple-lane ramp meters to meter traffic up to approximately 1,800 vehicles per hour, while maintaining four second or greater headways in each lane. In addition, priority phasing can be given to preferential lanes at a ramp meter. These two capabilities give multiple-lane ramp meters a significant advantage over single-lane ramp meters in operational flexibility. This operational flexibility is further demonstrated under the existence of excessive queues problems.

The two ramp meter design strategies have contrasting operational and traffic control capabilities for dealing with excessive queues. Since single-lane ramp meters can only effectively meter traffic up to approximately 900 vehicles per hour and excessive queues can only be cleared through the discontinuation of metering (12). In contrast, multiple-lane ramp meters can increase the discharge rate up to nearly the saturation flow rate of the on-ramp to clear queued vehicles. This operational flexibility allows multiple-lane ramp meters to continuously regulate and evenly distribute vehicles into the freeway traffic stream, whereas the single-lane design strategy allows a large platoon of traffic to enter the traffic stream. It should be noted that the multiple-lane ramp meter design strategy can accommodate approximately 100 to 130 percent more vehicles within the queue reservoir than the single-lane ramp meter (12).

Comparative Analysis of Single-Lane and Multiple-Lane Ramp Meters

To demonstrate the differences between traditional single-lane ramp meters and multiple-lane ramp meters, a comparative analysis was completed as part of this research on the geometric, traffic control, and operational characteristics of the two design strategies. Table 4 is a summary of this analysis.

Table 4. Ramp Meter Design Strategies Comparative Analysis Summary.

	Single-Lane Ramp Meters	**Multiple-Lane Ramp Meters**
Geometric Elements	• Can be readily designed and constructed on traditional diamond and parclo-type interchanges.	• Requires approximately 24 to 26 feet of pavement within the queue storage reservoir. An absolute minimum of 22 feet should be maintained.
Traffic Control Elements	• Simple control structure.	• Requires additional detection and more advance controllers.
Operational Elements	• Cannot effectively meter demand volumes exceeding 900 vehicles per hour or highly variable arrival patterns with demand volumes exceeding 750 vehicles per hour. • Excessive queues cause lapses in metering or surface street congestion • Preferential lane priority for carpool, vanpools, and/or transit cannot be provided.	• Capable of metering demand volumes up to approximately 1,800 vehicles per hour. • Wider range of metering rates allows for effective queue management. • Preferential lane priority for carpool, vanpools, and/or transit can be provided.

As shown in Table 4, the multiple-lane ramp meter design strategies provide significant operational flexibility over the traditional single-lane ramp meter configuration. Based on the results of the telephone interviews conducted, it was determined that the multiple-lane ramp meter design strategies are thought to be a very successful freeway management strategy by both the departments of transportation and the general public.

Proposed Application Guidelines for Single-Lane and Multiple-Lane Ramp Meters

Using the information summarized in this section, a proposed set of application guidelines was developed for both ramp meter configurations. These application guidelines are listed below.

- Metered on-ramps should maintain sufficient acceleration and merge distances between the ramp meter stop-bar and the end of the on-ramp or auxiliary lane, based on the freeway operating speeds (see Figure 3).
- Proposed ramp metering locations should provide an adequate queue storage reservoir for existing and future on-ramp conditions (i.e., demand volumes and arrival patterns). Ramps that do not maintain adequate queue storage reservoirs should maintain excessive queue management traffic control capabilities.
- Single-lane ramp meters should not be used in locations where the demand volumes are expected to exceed approximately 900 vehicles per hour even after traffic is redistributed between on-ramps within a specific section of freeway that will be metered. In addition, single-lane ramp meters should not be used on locations that maintain on-ramp demand volumes in excess of 750 vehicles per hour and highly variable arrival patterns.
- Multiple-lane ramp meters should provide the proper pavement widths and lateral clearances to accommodate two lanes of traffic within the queue storage reservoir. In addition, preferential lanes should provide proper access to avoid queue spillbacks (i.e., mixed-traffic queues should not block access to the preferential lane).

INCLEMENT WEATHER CONDITIONS AND RAMP METERING

Inclement weather conditions experienced by many of the metropolitan areas in the United States and the typical on-ramp grades associated with diamond and parclo-type interchanges require the evaluation of the effects of ice and snow on ramp metering operations. The inclement weather policies for ramp metering used by several agencies that operate ramp meters in northern states are summarized in this section. The responses summarized were provided during the telephone interviews conducted as part of this research effort. Based on the information ascertained through the telephone interviews, ramp meter operational guidelines for inclement weather conditions were proposed.

Inclement Weather Policies for Ramp Metering

To evaluate the effects of inclement weather conditions on ramp metering systems, departments of transportation in several northern states that currently operate ramp meter systems were interviewed. These northern states were Colorado, Illinois, Michigan, Minnesota, New York, Oregon, Virginia, Washington, and Wisconsin. Staff from these state departments of transportation were interviewed to determine the effectiveness and relative safety of operating ramp meters during either snowy or icy roadway conditions. Table 5 summarizes the current operating policies for inclement weather in the nine states included in the interview process.

Table 5. Summary of Northern State Ramp Metering Policies for Inclement Weather Conditions.

State	Inclement Weather Policy?	Comments
Colorado	No	On-ramps are provided with a high-priority level of snow removal and sanding in the Denver metropolitan area. Therefore, ramp metering remains an effective freeway management technique under poor weather conditions.
Illinois	No	On-ramps are monitored for operational problems by closed-circuit television (CCTV), police, and the *Illinois Minutemen* service patrols. The ramp meters are not shut-off during snowy or icy conditions unless deemed necessary.
Michigan	Yes	Ramp meters are shut-off under either snowy or icy conditions observed on CCTV which may potentially create traction problems for vehicles.
Minnesota	No	Metering is not adjusted during inclement weather conditions; however, the effectiveness of the system decreases significantly under snowy or icy conditions.
New York	Yes	Ramp meters are shut-off under either snowy or icy conditions observed on CCTV. In addition, the department will turn-off ramp meters in the field and from the TMC manually under severe winter storming warnings.
Oregon	No	The Oregon Department of Transportation currently does not have the communication capabilities to shut-off ramp meters during poor driving conditions.
Virginia	Yes	Ramp meter discharge rates are adjusted during inclement weather conditions based on pavement sensors which indicate a clear, wet, or snow/ice covered driving surface. The agency maintains ramp meter operation during inclement weather conditions and provides a high-priority for on-ramp snow removal.
Washington	Yes	On-ramps are typically not metered during snowy or icy weather conditions. The decision to meter is made by the FLOW engineer on duty.
Wisconsin	No	The Wisconsin Department of Transportation does not suspend ramp metering operations during snowy or icy conditions.

As shown in Table 5, the nine states that use ramp meters in colder climates having varying guidelines or policies for operating ramp meters during icy or snowy conditions. The majority of the agencies expressed their concerns regarding the potential for vehicles to lose traction either when stopping at or accelerating from the ramp meter stop-bar. However, many of the agencies do not currently possess the detection capabilities and/or communication equipment to effectively suspend ramp metering operations during snowy or icy conditions. It should be noted that Virginia was the only state identified with an extensive system of pavement condition sensors.

Proposed Guidelines for Inclement Weather Conditions

Based on the ramp metering policies for inclement weather conditions obtained from staff at the nine state departments of transportation, it is recommended that the following guidelines be followed by agencies operating or planning to operate ramp meters in areas that experience periods of icy or snowy roadway conditions:

- Grades in the vicinity of the ramp meter stop-bar should be minimized to avoid vehicles losing traction within both the queue storage reservoir and acceleration areas of the on-ramp. This geometric design detail should be addressed through the placement of the ramp meter signals, since the re-grading of freeway on-ramps is typically not geometrically or economically feasible.
- To maintain effective freeway management during poor weather conditions, metered on-ramps should be plowed and sanded and receive a high-priority in snow removal scheduling.
- On-ramps should be monitored during potential icy/snowy conditions by closed-circuit television, pavement sensors, or other methods to determine when ramp metering may need to be discontinued.

EXAMINATION OF TRADITIONAL AND EXTENDED RAMP METERING OPERATIONS

The potential capabilities of metering on-ramp traffic during non-commuting (or peak) time periods (e.g., mid-afternoon) using the operational flexibility of the multiple-lane ramp meter design strategy is examined in this section. As part of this examination, several state departments of transportation that operate multiple-lane ramp meters were surveyed to determine the current metering periods used throughout the nation. In addition, the thresholds used to initiate metering and/or install new ramp meters were ascertained. Based on this information, the potential advantages and disadvantages of extended metering were examined and guidelines for traditional and extended ramp metering operations were developed.

Ramp Meter Practices

To provide a better understanding of the current freeway management practices regarding ramp meter operation periods in metropolitan areas, the ten state departments of transportation that currently operate multiple-lane ramp meters were interviewed. Based on these interviews, the normal ramp meter operation policies for traditional and non-traditional periods were determined. Table 6 shows the overall and core operational times for the traditional morning and evening commuting periods and extended metering currently employed by various departments of transportation. It should be noted that the core metering period represents the time when all the meters are automatically initialized without regard to freeway conditions.

As shown in Table 6, only Caltrans meters traffic during non-commuting time periods. However, the majority of states interviewed expressed some interest in the possibility of extended metering periods or lunchtime metering. In addition to the traditional metering periods, several states use continuous metering in construction areas where temporary bottlenecks exist to regulate the on-ramp traffic and increase capacity during lane closures. Based on the interviews conducted, it appears that several states are continuing to increase their morning and evening metering time periods to accommodate the widening time period of heavy traffic flows on urbanized freeways.

To initiate and terminate ramp meter operations, freeway managers and transportation management centers use three primary operating thresholds under local traffic responsive and integrated controlled systems. These thresholds include freeway (mainline) occupancy, speeds, and volumes. In addition to these operating thresholds, many agencies employ time-of-day timing plans based on historical on-ramp and freeway information to meter on-ramp traffic. Table 7 provides a summary of the ramp meter operating thresholds used by departments of transportation.

Table 6. Summary of Departments of Transportation Metering Periods.

State	Weekday AM Peak			Weekday PM Peak			Other Metering Periods/ Comments
	Start	Core	End	Start	Core	End	
Arizona	5:30	N/A	9:00	2:00	N/A	7:00	Programmed by time-of-day.
California	See Note	See Note	See Note	See Note	See Note	See Note	Los Angeles maintains continuous metering on several freeways. San Diego and San Francisco maintain more traditional core metering operation procedures.
Colorado	6:20	6:50 - 8:20	8:50	3:00	3:30 - 5:30	6:00	None
Illinois	5:30	N/A	9:30	2:00	N/A	7:00	Continuous metering is used in construction areas and during incidents.
Minnesota	6:00	7:00 - 8:00	8:30	2:30	4:00 - 5:30	7:00	Continuous metering is used in construction areas which create bottlenecks.
New York	6:00	6:00 - 9:00	9:00	3:00	3:00 - 7:00	7:00	Programmed by time-of-day.
Oregon	6:30	N/A	9:30	3:00	N/A	6:00	No mainline detection is available at this time to do extended metering.
Virginia	6:00	6:30 - 9:30	10:00	3:00	3:30 - 6:00	7:30	The metering of the peak time periods has extended to 4 to 4½ hours during the weekday a.m. and p.m. time periods.
Washington	6:00	N/A	9:00	3:30	N/A	6:30	Seven ramp meter locations on Interstate-5 maintain control between 6 a.m. and 7 p.m.
Wisconsin	5:45	6:00 - 9:00	9:15	2:45	3:00 - 6:00	6:15	No extended metering is operated at this time.

* Note The operation times shown above are defined as general operating parameters within the overall system. It should be noted that individual ramp meter locations may operate at different times than indicated.

Table 7. Summary of Ramp Meter Operating Thresholds.

State	Occupancy		Volume (vphpl)		Speed (mph)		Notes
	On	Off	On	Off	On	Off	
Arizona	N/A	N/A	N/A	N/A	N/A	N/A	Time-of-day operation.
California	See Note	See Note	See Note	See Note	N/A	N/A	Operating thresholds based on system-wide volume and occupancy algorithms.
Colorado	17%	15%	1,900	1,900	35	35	Thresholds must be met for three consecutive 1-minute periods.
Illinois	15%	15%	N/A	N/A	N/A	N/A	Operating thresholds based on system-wide volume and occupancy algorithms.
Michigan	15%	13%	N/A	N/A	N/A	N/A	None
Minnesota	N/A	N/A	See Note	See Note	N/A	N/A	Minnesota's volume algorithm is the governing device for metering.
New York	N/A	N/A	N/A	N/A	N/A	N/A	Time-of-day operation.
Oregon	N/A	N/A	N/A	N/A	N/A	N/A	Time-of-day operation.
Virginia	N/A	N/A	N/A	N/A	N/A	N/A	Freeway operator decision based on occupancy indicators and visual inspection.
Washington	See Note	See Note	See Note	See Note	N/A	N/A	Operating thresholds based on system-wide volume and occupancy algorithms.
Wisconsin	18%	18%	1,800	1,800	45	55	The volumes on the freeway are measured every five minutes and the metering is based on the operators review of the operating conditions

As shown in Table 7, the majority of states use mainline occupancy values of 14 to 18 percent, volumes of 1,800 to 1,900 vehicles per hour per lane (vphpl), or speeds of 35 to 45 miles per hour as minimum ramp metering thresholds. However, most of these agencies do not operate fully-responsive ramp meter systems. A number of the states operate ramp meters on a time-of-day basis or under manual control in which freeway managers make metering initialization and termination decisions based on the mainline measures-of-effectiveness and visual inspection. None of the agencies interviewed allow ramp meters to be fully controlled by the computer monitoring system programmed with specific operating thresholds without fixed time-of-day parameters.

In addition to the information collected on the different operating practices used in ramp metering, the process used by states to install ramp meters was evaluated. It was found that the majority of transportation departments do not have a formal procedure for installing ramp meters. Many of the state officials interviewed stated that ramp metering is being implemented on freeways that are already congested. However, California has recently used a guideline that ramp meters be installed when the overall system delay reaches 15 minutes (i.e., the average commuter experiences 15 minutes of delay compared to a motorist traveling at free flow speeds). This guideline is currently being followed in Fresno, California.

Advantages and Disadvantages of Extended Ramp Metering

The primary advantage of extended ramp metering is to provide a consistent regulation of on-ramp traffic and predictable freeway operations. To provide the most effective form of extended metering, ramp meters should be operated within given core metering periods and be capable of initializing or extending the metering period before and after the core metering period based on mainline and on-ramp volume, occupancy, and/or speed thresholds. However, the ramp meter should not be permitted to turn on and off for short periods because this type of sporadic operation could lead to potential increases in ramp meter violations and on-ramp accidents.

The two primary disadvantages of extended weekday metering involve driver expectancy and equity issues. Because motorists have set expectations regarding on-ramp operations (i.e., metered during peak hours only), motorists may either not expect vehicles to be queued on a on-ramp nor adhere to the meter during non-commuting time periods. Another problem with extended metering reverts back to the equity issue between urban and suburban residents. Since the amount of congestion and traffic typically dissipates with distance from the central business district, the amount of time urban residents are delayed by ramp metering significantly exceeds that experienced by suburban residents. Thus, transportation departments could potentially be encouraging urban sprawl rather than increasing land use densities which better complement transportation demand management measures (i.e., carpooling, transit, etc.).

Potential Ramp Meter Warrants and Operating Thresholds

In evaluating the feasibility of installing or operating ramp meters during traditional (i.e., the weekday morning and evening commuting periods) or non-commuting time periods, freeway managers need to first establish thresholds under which either the on-ramp or mainline operating conditions of a freeway can be positively affected by the regulation of on-ramp traffic. However, the development of quantitative thresholds is somewhat difficult as can be shown by the following, somewhat nebulous, ramp metering warrants included in the 1988 Edition of the Manual of Uniform Traffic Control Devices (MUTCD).

Installation of freeway entrance ramp control signals may be justified when the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets, is expected to be reduced with ramp control signals and when at least one of the following instances occurs:

1. *There is recurring congestion on the freeway due to traffic demand in excess of the capacity; or there is recurring congestion or a severe accident hazard at the freeway entrance because of an inadequate ramp merging area. A good measure of recurring freeway congestion is freeway operating speed. An early indication of a developing congestion pattern would be freeway operating speeds less than 50 mph, occurring regularly for a period of half an hour. Freeway operating speeds less than 30 mph for a half-hour period would be an indication of severe congestion.*

2. *The signals are needed to accomplish transportation system management objectives identified locally for freeway traffic flow, such as: (a) maintenance of a specific freeway level of service, or (b) priority treatments with higher levels of service, for mass transit and carpools.*

3. *The signals are needed to reduce (predictable) sporadic congestion on isolated sections of freeway caused by short-period peak traffic loads from special events or from severe peak loads of recreational traffic.*

As indicated in the ramp meter warrants of the 1988 Edition of the MUTCD, no specific on-ramp or mainline volume, occupancy, speed, accident, or delay threshold values had been developed for ramp meter installation. This lack of quantitative metering thresholds has created a disservice to freeway managers trying to obtain funding and approval for ramp metering systems.

An early attempt at establishing minimum peak hour volumes for ramp meters was developed by the Texas State Department of Highways and Public Transportation (now the Texas Department of Transportation). These volume guidelines are shown in Table 8 (13).Table 8. Texas' Minimum Peak Hour Warrant Volumes for Ramp Metering in Metropolitan Areas.

As shown in Table 8, the Texas Department of Transportation provided a fairly definitive set of volume thresholds for installing ramp meters in the early 1970s. However, the original thresholds were abandoned in part due to the inability of single-lane ramp meters to operate at high-volume on-ramp locations from both a traffic control and geometric standpoint. The single-lane ramp meter design strategy did not provide high enough discharge rates or queue storage reservoirs to be installed on freeways that maintained volumes equal to or higher than the volume thresholds presented.

Based on the telephone interviews conducted and available literature, a set of on-ramp and mainline ramp metering warrants were developed for implementing and operating ramp meters during the traditional and non-commuting time periods. These proposed ramp meter warrants are discussed below.

Table 8. Texas' Minimum Peak Hour Warrant Volumes for Ramp Metering in Metropolitan Areas.

Freeway Facility	Metropolitan Area Size (Persons)		
	<500,000	500,000 - 1,000,000	>1,000,000
Four-Lane Freeway	2,600 vph	2,850 vph	3,050 vph
Six-Lane Freeway	3,850 vph	4,200 vph	4,550 vph
Eight-Lane Freeway	5,150 vph	5,550 vph	6,050 vph
Each additional lane above four in one direction.	1,300 vph	1,350 vph	1,500 vph

On-Ramp Warrants

After interviewing various ramp meter operators across the nation, it is evident that nearly all of the departments of transportation use either a minimum on-ramp volume or a combination-based algorithm that compares the mainline and/or system volumes and on-ramp volumes to determine if sufficient traffic is available to provide positive benefits from ramp metering. Based on the minimum values provided by operators, the minimum on-ramp volume threshold for metering lies between approximately 200 and 300 vehicles per hour. This make sense intuitively because these volume levels translate to approximately one vehicular arrival every 12 to 18 seconds on average assuming uniform arrivals. Furthermore, signalized interchange terminals producing this level of traffic would not generate platoons significant enough to impact the operation of the freeway. Thus, one could state that an on-ramp with demand volumes exceeding 250 vehicles per hour could warrant metering, provided mainline freeway conditions could benefit from the distribution of on-ramp traffic.

Mainline Warrants

From the information learned through this research, a freeway on-ramp should be reviewed for potential ramp metering implementation when one or more of the following thresholds is met:

- Freeway occupancy rates during the morning or evening peak commuting time periods is in excess of 15 percent.
- Averaged measured freeway speeds are below 40 miles-per-hour for extended periods of time (i.e., 30 or more minutes in the peak time periods).
- Freeway volumes exceeding 1,700 vehicles per hour per lane in the vicinity of an entrance ramp.
- A high rate of accidents occurs in the influence area of the on-ramp/freeway merging area.

In addition to these thresholds, on-ramps that are evaluated for potential ramp metering should maintain peak hour traffic volumes in excess of 250 vehicles per hour and sufficient length to provide adequate queuing and acceleration areas.

Proposed Guidelines for Traditional and Extended Ramp Metering Operations

Based on the telephone interviews conducted and review of the survey on dual-lane ramp metering conducted by the Texas Transportation Institute, guidelines for operating ramp meters during both traditional and non-traditional periods were developed as part of this research. These guidelines are listed below:

- Ramp meters should only be deployed at locations that provide sufficient area for traffic control devices, vehicular storage, and vehicular acceleration to freeway speeds.
- Extended ramp metering operations should be based on core metering periods, whereby, individual ramp meters can either initiate or terminate metering operations before or after the core metering period based on mainline or on-ramp operating thresholds. However, ramp meters should not be allow to turn on and off based on minor changes in traffic flow conditions (i.e., once initiated, the meter should continue through the core metering period, and conversely, the meter is terminated at the end of the core metering time period or when the threshold values are not met).
- Ramp metering thresholds should be based on measurable values of mainline occupancy, speed, and/or volumes which can predict the starting and ending times of mainline congestion. These metering thresholds, available geometry, and accident rates should be used as guidelines in implementing new ramp meters or providing extended metering on urban freeways..
- On-ramps should not be metered when the demand volumes do not exceed 250 vehicles per hour or mainline freeway conditions cannot be provided with any measurable benefit from the dispersion of traffic (e.g., freeway mainline occupancy levels lower than 12 percent or greater than 35 percent).

PERFORMANCE MEASURES FOR RAMP METERING

To effectively operate ramp metering systems and ascertain funding for the design, construction, operation, and maintenance of this freeway management control device, departments of transportation need to establish performance measures that can easily be calculated and attributed to an operational ramp metering system. The performance measures must take into account the operation and safety of the adjacent arterial street network, on-ramp, and freeway. This section reviews the current surface street and on-ramp and mainline performance measures used by departments of transportation and other possible measures-of-effectiveness for single-lane and multiple-lane ramp metering. Based on this information, a set of performance measures were proposed for multiple-lane ramp meters.

Surface Street and On-Ramp Performance Measures

To properly measure the operating performance of a metered on-ramp, the operation and safety of the surface streets servicing the on-ramp and the on-ramp should be considered. From this research, the following surface street and on-ramp performance measures were identified.

Performance Reliability

The concept of ramp metering *performance reliability* is a measurable value used to evaluate a local ramp meter's ability to maintain the target metering rate established through either local traffic responsive or system control (17). The performance reliability is the percentage of time during metered conditions that the ramp meter can maintain the target metering rate. The potential inability to maintain the target metering rate can typically be attributed to either excessive queues and/or traffic control design or operation problems (e.g., improper placement of demand detectors). Therefore, a ramp meter maintaining a performance reliability of 100 percent meets the objectives of the intended ramp metering policy for a given freeway. However, it should be noted that this proposed performance measure does not indicate whether the overall ramp meter system meets the established freeway management objectives.

Queue Containment

Queue containment provides an indirect measurement of the metered on-ramp's relative safety and adequacy of the geometric and traffic control design features (17). Queue containment is defined as the percentage of time that the vehicular queue on a metered on-ramp is maintained within the area between the ramp meter stop-bar and the point prior to queues interfering with traffic at the upstream signalized interchange terminal, service road, or freeway. The higher the queue containment value, the lower the probability is that queued vehicles will contribute to accidents within the influence area of the metered on-ramp. The Colorado Department of Transportation uses queue containment indirectly by providing excessive queue overrides that prevent queue spillbacks from occurring (18).

Platoon Dispersion

A simple on-ramp measure-of-effectiveness is *platoon dispersion*. This measurement indicates whether or not the ramp meter distributes vehicles evenly into the freeway traffic stream. The effectiveness of platoon dispersion can be represented by the average vehicle headways upstream of the merge point on the on-ramp and through the variance in headways. The New York Department of Transportation uses platoon dispersion as one of their ramp meter measures-of-effectiveness (19). This measure identifies whether or not an agency meets the primary objective of ramp metering; the regulation and dispersion of vehicles into the freeway traffic stream. It should be noted that platoon dispersion is basically a measure of the ramp meter controller strategy used.

Average Control Delay

The *average control delay* at a metered on-ramp is the time a motorist is delayed by the ramp meter signal. This measure of effectiveness is used by several agencies, including the Texas Department of Transportation, to ensure that motorists will tolerate and adhere to ramp meters. Average control delay is somewhat misleading because in many situations the extra delay incurred at the on-ramp represents an overall savings in travel time within a section of freeway. Therefore, this measure-of-effectiveness is not heavily relied upon in evaluating ramp meter operations.

System or Mainline Measures of Effectiveness

The primary ramp metering measures of effectiveness are realized from the mainline or system perspective. The majority of agencies use a combination of the following five measures-of-effectiveness for freeway systems which maintain ramp meters or other freeway management tools: travel speed, travel time, volume, fuel consumption, and accidents. Each one of theses measures of effectiveness have been shown to be enhanced by the installation and operation of ramp meters through traditional before-and-after studies. However, the problem with mainline or system measures of effectiveness, as expressed by several agencies interviewed, is the inability to quantify the incremental benefits realized from ramp metering. Therefore, the five measures of effectiveness (speed, travel time, volume, volume, fuel consumption, and accidents) used to show the benefits of ramp metering can only be subjectively measured due to the dynamic nature of freeway systems and the other freeway management strategies already functioning or being implemented.

Proposed Measures of Effectiveness for Ramp Meters

Based on the information provided above and the discussion with staff from several departments of transportation, it is recommended that all the measures of effectiveness presented continue to be utilized in the proper context. Furthermore, agencies should conduct extensive before-and-after studies to provide proper evidence of the benefits realized from metering urban freeways. An area which all the departments of transportation agreed needs attention is the development of ongoing performance measures that can provide more conclusive evidence of the day-to-day benefits of this freeway management technique, especially with regard to the single-lane versus multiple-lane ramp meter with and without preferential lanes.

APPLICATION OF RESEARCH: RAMP METERS IN MARYLAND

To demonstrate the benefits of this research, the proposed guidelines for applying single-lane and multiple-lane ramp meters, operating ramp meters in inclement weather conditions, extending ramp meter operations to non-traditional commuting time periods, and measuring the performance of ramp meters were used to evaluate the feasibility of operating ramp meters in Maryland. To conduct this research application evaluation, the Maryland Department of Transportation identified eight interchange locations along the Capital Beltway (Interstates 95, 495, and 270) and Interstate 95 for potential deployment of ramp meters. In addition, the department provided geometric and traffic operation data at these interchanges. Using the information provided, each on-ramp was evaluated for metering using the guidelines established through this research.

Study Locations

The research application evaluation focused on eight interchanges locations, comprising 22 on-ramps, along the Capital Beltway and Interstate 95 in Maryland. These interchange locations and on-ramps were selected due to the recurrent congestion experienced during the morning and evening commuting time periods. The location of each study interchange is shown in Figure 6 and the geometric and operational attributes of each on-ramp are summarized in Table 9.

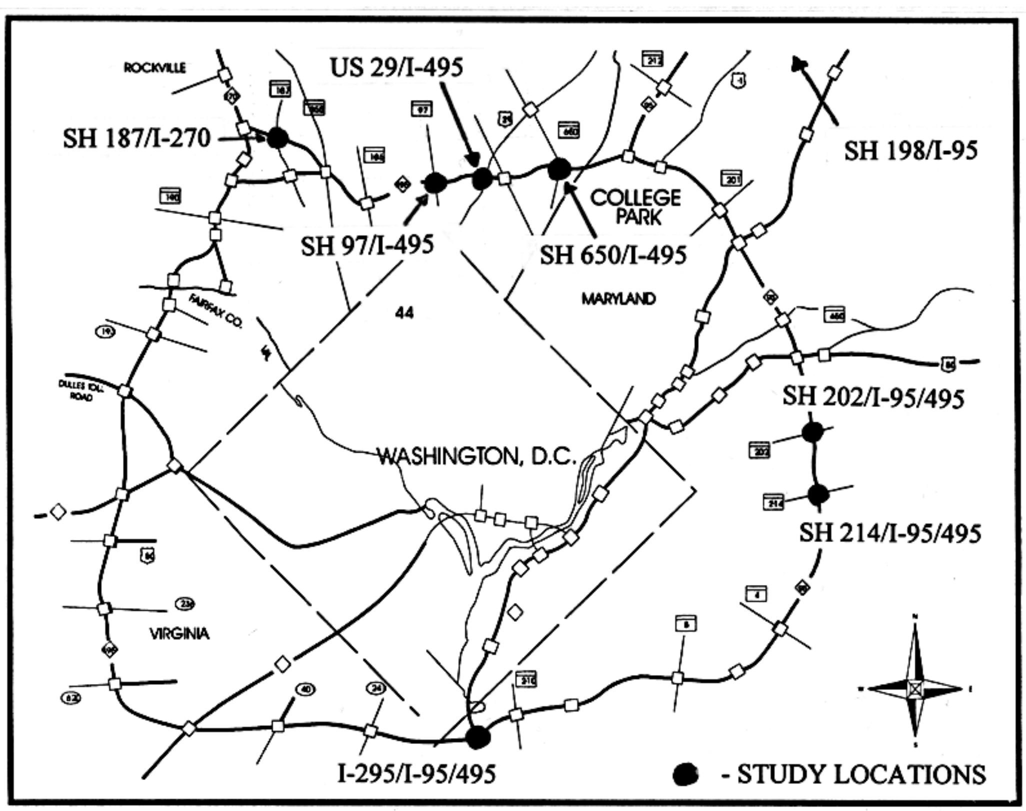


Figure 6. State of Maryland Study Interchange Locations.

Table 9. Study Location On-Ramp Conditions.

Interchange	Direction	On-Ramp Volume (vphpl)		Mainline Volume (vphpl)		On-Ramp Width*	On-Ramp Length
		AM	PM	AM	PM		
Maryland SH 198/ Interstate-95	WB to SB	1,200	750	1,688	1,030	24' + 8'	>3,000'
	EB to SB	700	N/A	1,863	N/A	15' + 8'	1,000'
Maryland SH 187/ Interstate-270	SB to WB	1,550	1,100	1,425	1,233	25'	1,500'
Maryland SH 97/ Interstate-495	SB to WB	720	420	2,061	1,860	22'	1,700'
	SB to EB	650	700	1,859	1,653	22'	800'
	NB to WB	980	1,230	1,979	1,665	22'	600'
	NB to EB	400	650	1,871	1,678	22'	1,600'
US Highway 29/ Interstate-495	SB to WB	1,535	800	1,758	1,608	24'	1,900'
	NB to WB	300	300	1,845	1,633	24'	900'
	NB to EB	400	1,200	1,646	1,490	20'	>3000'
Maryland SH 650/ Interstate-495	SB to WB	450	350	1,346	1,276	24'	1,900'
	SB to EB	950	700	1,641	1,615	24'	900'
	NB to WB	915	700	1,253	1,226	20'	1,200
	NB to EB	900	550	1,748	1,609	16'	>3,000
Maryland SH 202/ Interstate-95/495	SB	900	1,205	865	1,451	24' + 4'	>3,000
	WB to NB	1,325	1,000	1,315	1,454	16' + 2'	1,200'
	EB to NB	600	650	1,390	1,441	16' + 4'	2,500'
Maryland SH 214/ Interstate-95/495	WB to SB	700	500	890	1,540	16' + 2'	1,200'
	WB to NB	550	350	1,328	1,404	16' + 4'	>3,000
	EB to SB	325	930	965	1,423	16' + 4'	2,000'
	EB to NB	825	850	1,346	1,304	16' + 2'	1,300'
Interstate-295/ Interstate-95/495	SB to WB	500	1,975	1,478	1,405	14' + 12'	2,500'
	NB	2,000	1,275	N/A	N/A	24' + 12'	>3,000'

* On-ramp widths represent the existing travel lane width plus the shoulder width.
Note: Appendix B provides more detailed operation and geometric data for each on-ramp.

Ramp Meter Feasibility Study

To properly evaluate the feasibility of managing the recurrent congestion on the Capital Beltway and Interstate 95, the weekday a.m. and p.m. peak hour volumes for the on-ramp and mainline travel lanes, aerial photography, and "as-built" construction plans of each study interchange were reviewed against the guidelines developed in this paper. Each on-ramp was evaluated to determine the proper ramp meter design strategy and examined for appropriate geometric elements and inclement weather monitoring capabilities to operate the selected ramp meter design. Table 10 is a summary of the on-ramp feasibility study results. Appendix B provides a summary of the geometric and operation data used to conduct the feasibility study.

As shown in Table 10, the majority of the on-ramps maintain the proper geometric elements to operate the selected ramp meter design strategy. Several of the on-ramps (i.e., marked single/multiple) will require additional analysis to determine if the single-lane design strategy is sufficient to accommodate the expected arrival patterns at on-ramps that maintain demand volumes between 750 and 900 vehicles per hour. It should be noted that all of the on-ramps could be metered provided that some on-ramps are widened to accommodate the multiple-lane ramp meter design strategy, except for the Maryland State Highway 97/Interstate 495 northbound-to-westbound loop ramp. This ramp does not maintain enough space for vehicles to queue and accelerate up to 60 miles per hour; however, the department may consider designing the acceleration area to 45 mile-per-hour design standards to allow for the installation of a multiple-lane ramp meter.

In addition to the ramp meter design strategy selection and geometric evaluations performed at the eight interchange locations, weather records were reviewed to determine the need to provide ice and snow monitoring at possible ramp meter locations. This area of Maryland experiences a significant number of days during the wintertime months where on-ramps and freeways are exposed to ice and snow. Based on the review of available closed-circuit television units maintained by the Maryland Department of Transportation, four of the eight interchange locations would need to be provided with closed-circuit television, pavement sensors, or other monitoring devices to ensure the operational integrity and safety of metered ramps during inclement weather conditions.

Table 10. Maryland On-Ramp Feasibility Study Results.

Interchange	Direction	Type of Ramp Meter	Adequate Width?	Adequate Length?	CCTV Available?
Maryland SH 198/ Interstate-95	WB to SB	Multiple	YES	YES	NO
	EB to SB	Single/Multiple	Marginal	YES	NO
Maryland SH 187/ Interstate-270	SB to WB	Multiple	YES	YES	YES
Maryland SH 97/ Interstate-495	SB to WB	Single	YES	YES	NO
	SB to EB	Single	YES	YES	NO
	NB to WB	Multiple	Marginal	NO	NO
	NB to EB	Single	YES	YES	NO
US Highway 29/ Interstate-495	SB to WB	Multiple	YES	YES	NO
	NB to WB	Single	YES	YES	NO
	NB to EB	Multiple	NO	YES	NO
Maryland SH 650/ Interstate-495	SB to WB	Single	YES	YES	NO
	SB to EB	Multiple	YES	YES	NO
	NB to WB	Single/Multiple	NO-Multiple	YES	NO
	NB to EB	Single/Multiple	NO-Multiple	YES	NO
Maryland SH 202/ Interstate-95/495	SB	Multiple	YES	YES	YES
	WB to NB	Multiple	NO	YES	YES
	EB to NB	Single	YES	YES	YES
Maryland SH 214/ Interstate-95/495	WB to SB	Single	YES	YES	YES
	WB to NB	Single	YES	YES	YES
	EB to SB	Single	YES	YES	YES
	EB to NB	Single/Multiple	NO-Multiple	YES	YES
Interstate-295/ Interstate-95/495	SB to WB	Multiple	Marginal	YES	YES
	NB	Multiple	YES	YES	YES

Note: The feasibility study results presented in this table are based on the application guidelines developed through this research and the operational and geometric data obtained from the Maryland Department of Transportation and summarized in Appendix B.

Summary of Feasibility Analysis

By using the application and operating guidelines presented in this paper, it was determined that the eight interchanges on the Capital Beltway and Interstate 95 in Maryland could benefit from the installation of multiple-lane ramp meters. The on-ramps at the study interchanges were deemed feasible from a geometric and operational standpoint using either a single-lane or multiple-lane ramp meter. It should be noted that the auxiliary lanes used on Maryland freeways complemented the geometric requirements of metered on-ramps associated with vehicular queuing, acceleration, and merging. Furthermore, it is recommended that the Maryland Department of Transportation investigate the possibilities of extended metering at these interchange locations once ramp meters are installed on the Capital Beltway and Interstate 95.

CONCLUSIONS

This paper was designed to provide a better understanding of the geometric and operation issues associated with multiple-lane ramp meters, and guidelines for applying, designing, and operating this freeway management technique. The application of the multiple-lane ramp meters were compared to the traditional single-lane ramp meter design strategy. Based on the research conducted, it was determined that the multiple-lane ramp meter design strategy maintains several different geometric and traffic control elements and provides superior operational flexibility to the traditional single-lane ramp meter design strategy. The benefits of this design strategy included:

- Multiple-lane ramp meters provide the ability to meter a wide-range of on-ramp demand volumes, ranging from approximately 200 to 1,800 vehicles per hour, compared with the traditional single-lane configuration, which can only effectively accommodate up to approximately 900 vehicles per hour.
- The additional queue storage (queue reservoir) area provided under the multiple-lane design strategy nearly doubles that available under the single-lane design strategy and provides the ability to handle increased on-ramp demand volumes and platoon arrivals from upstream traffic signals more effectively.
- Multiple-lane ramp meter configurations allow agencies to provide preferential lanes to carpools, vanpools, and transit vehicles. This promotes single-occupancy vehicle reduction in accordance with the Clean Air Act (CAA) of 1990 and Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.
- Multiple-lane ramps tend to provide a better self-enforcement environment when compared to single-lane configurations because of the presence of motorists next to one another.

In addition to the application and operational features of multiple-lane ramp meters, it was determined that this freeway management technique can effectively operate under inclement weather conditions and during non-commuting (non-peak) time periods provided the proper precautions are taken by departments of transportation. Also, the procedures for evaluating the need for ramp metering systems and measuring the performance of operational systems were reviewed to provide better guidance to freeway managers and transportation management centers. From these evaluations, it was determine that more definitive on-ramp and mainline warrants are available or can be developed by individual states for ramp metering installations and weekday metering, and several on-ramp and mainline performance measures can be used to evaluate this freeway management technique.

ACKNOWLEDGMENTS

This paper was prepared for *Advanced Surface Transportation Systems*, a graduate course in Civil Engineering at Texas A&M University. The author would like to extend his appreciation to his professional mentor, Tom Hicks of the Maryland Department of Transportation, and the course instructor, Dr. Conrad Dudek, for their guidance and help throughout the development of this paper. In addition, the author would like to recognize the other professional mentors who contributed to this course and paper, including:

- Marsha Anderson, Street Smarts
- Ginger Gherardi, Ventura County Transportation Commission
- Joe McDermott, Illinois Department of Transportation
- Colin Rayman, Ontario Ministry of Transportation
- Doug Robertson, TransCore, Inc.

The author would also like to offer his appreciation to the professionals listed below who provided their time, experience, and opinions which were used to develop this paper.

- Kirsten Benson, Washington Department of Transportation
- Jimmy Chu, Virginia Department of Transportation
- Joe Contegni, New York Department of Transportation
- Gordon Hickman, Colorado Department of Transportation
- Raymond Klucens, Michigan Department of Transportation
- Rich Lau, Minnesota Department of Transportation
- A.P. Cioffi, Illinois Department of Transportation
- Dr. Carroll Messer, Texas A&M University and the Texas Transportation Institute
- Jerry Pfeifer, Arizona Department of Transportation
- Alan Troyer, Oregon Department of Transportation
- Amanda Zacharias, Wisconsin Department of Transportation

REFERENCES

1. Gervais, E. F. Optimization of Freeway Traffic by Ramp Control. In *Highway Research Record 59*, Highway Research Board, National Research Council, Washington, D.C., 1964, pp. 104-118.

2. Wattleworth, J. A., and D. S. Berry. Peak Period Control of a Freeway System - Some Theoretical Investigations. In *Highway Research Record 89*, Highway Research Board, National Research Council, Washington, D.C., 1965, pp. 1-25.

3. *Ramp Metering Policy and Procedure*. Traffic Management Systems, Caltrans. July 1991.

4. *Ramp Metering Overview*, Twin Cities Metro Area. Report Number 07043-0795. Minnesota Department of Transportation. December 1995.

5. *FLOW Operators' Handbook*, Washington Department of Transportation, June 1996.

6. *Ramp Meter Design Guidelines*. Division of Traffic Operations, Caltrans. August 1995.

7. Collins, K. M. *A Guide to Successful Ramp Metering Implementation*. Graduate Student Papers on Advanced Surface Transportation Systems, Southwest Region University Transportation Center, August 1994.

8. *Ramp Meter Design Guidelines*. Traffic Operational Systems, Caltrans. August 1991.

9. Lomax, T. J., and C. A. Fuhs. Geometric Design of Metered Entrance and High-Occupancy Vehicle Bypass Ramps. In *Transportation Research Record* 1385, TRB, National Research Council, Washington, D.C., 1993, pp. 139-147.

10. Uematsu, T. T. *Evaluation of Preferential Lanes for High Occupancy Vehicles at Metered Ramps*. Report Number FHWA/RD-82/121. California Department of Transportation, US Department of Transportation, November 1982.

11. Piotrowicz, G., and J. Robinson. *Ramp Metering Status in North America, 1995 Update*. Final Report DOT-T-95-17. Federal Highway Administration, U.S. Department of Transportation, June 1995.

12. *Survey of Dual-Lane Ramp Metering*. Research Project 1295-7, Texas Transportation Institute, College Station, Texas, May 1997.

13. Blumentritt, C. W., Pinnell, C., and W. R. McCasland. *NCHRP Report 232: Guidelines for Selection of Ramp Control Systems*. TRB, National Research Council, Washington, D.C., May 1981.

14. Anderson, I. *An Investigation of Possible Solutions to the Congestion Cycle*. Graduate Student Papers on Advanced Surface Transportation Systems, Southwest Region University Transportation Center, August 1992.

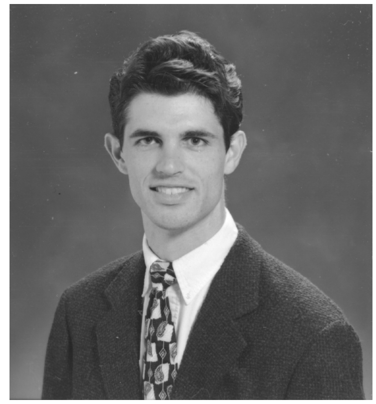
15. Obermeyer, M. *The Design and Operation of Ramp Metering for Freeway-to-Freeway Connection*. Graduate Student Papers on Advanced Surface Transportation Systems, Southwest Region University Transportation Center, August 1993).

16. Messer, C. J., and S. Sharma. *Distance Requirements for Ramp Metering*. Research Report 1392-5. Texas Transportation Institute, College Station, Texas, November 1994.

17. Butorac, M. *Feasibility of the Design of Dual-Lane Ramp Meters in Texas*. Masters of Science, Thesis, Texas A&M University, College Station, Texas, Aug. 1997.

18. Hickman, G. Colorado Department of Transportation. Personal Telephone Interview. July 2, 1997.

19. Contegni, J. New York Department of Transportation. Personal Telephone Interview. July 7, 1997.



Marc A. Butorac received his B.S. in Civil Engineering from the University of Idaho in May 1993. Following the completion of his undergraduate degree, Marc was hired by Kittelson & Associates, Inc. a transportation planning/traffic engineering firm. Marc has managed a multitude of transportation impact studies, highway corridor studies, traffic operations, and signal design projects in the Pacific Northwest. Marc is currently on sabbatical from Kittelson & Associates, and is completing his M.S. in Civil Engineering at Texas A&M University. In addition to completing his classwork, Marc has been employed by the Texas Transportation Institute and is evaluating the feasibility of the design of dual-lane ramp meters in Texas. This experience, combined with his research at the University of Idaho's National Transportation Laboratory, has made Marc versatile in developing mitigation treatments for various access controlled facilities. Marc is currently the Public Relations Director for the Student Chapter of the Institute of Transportation Engineers at Texas A&M University.

ADDRESSING THE INSTITUTIONAL BARRIERS ASSOCIATED WITH IMPLEMENTING ITS AT BORDER CROSSINGS

by

Jon M. Collins

Professional Mentor
Colin Rayman, P.E.
Ontario Ministry of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

Recent advancements in transportation technology and trade legislation have placed an increased emphasis on the efficient operations of border crossings, and have the potential to greatly improve traffic operations at border crossing facilities. This introduction of new technology and legislation has brought to light the interagency problems that can occur at a transborder location. Various agencies have different and at times conflicting needs in order to provide border operations. The problem of different agencies requiring similar information while not cooperating to receive this information from the private sector is also an issue. Without acceptance of this automated features within these agencies this technology will fail.

The objectives of this research were to: identify institutions and environmental conditions involved with border crossings; identify the role institutions have in effectively operating border crossings; identify the institutional barriers toward Intelligent Transportation Systems (ITS) deployment; develop a methodology toward alleviating these barriers; and apply the criteria established to a case border city to demonstrate success or failure at the study location. The agencies involvement in management of the facility was discussed, including the general information required by each agency to provide operations. In addition, the current ITS system components were discussed with emphasis placed on current ITS deployment locations.

This research was undertaken with the goal of answering three questions: "What ITS technologies are currently used by border facilities?", "What are the public and private sector concerns toward ITS deployment?", and "What method can be used to resolve these concerns to allow the effective use of this technology?".

The research was approached through a literature review and a telephone survey of both public and private agencies involved in the operations of border facilities along both the U.S.-Mexico and U.S.-Canada borders at six ITS locations. The six locations were selected based on the current deployment of ITS under the North American Trade Automation Prototype (NATAP). A questionnaire was developed and administered to transportation officials to determine the current institutional concerns regarding ITS for each of the locations. Survey respondents involved both public and private agencies with a return of 13 of the 35 surveys issued.

The results of the surveys indicated that while each border crossing is unique, the basic operations and barriers toward ITS are similar. Below is a listing of the most common concerns.

- Organizational, regulatory, human resources, and technical requirements were the barriers identified through the survey. Organization structural differences between public and private agencies and management practices were major barriers toward ITS deployment.
- Customs and Immigration officials have the most difficulty with the acceptance of ITS due to their roles of security and enforcement. In order to facilitate acceptance of ITS within departments, security measures relevant to ITS at un-manned toll plazas must be adopted and strictly enforced.

- Private commercial shippers are unsure of ITS technology. They see potential benefits associated with the use of advanced technology, but are uncertain of which components will be installed. Different border crossings are equipped with various systems and devices, resulting in a lack of consistency.
- Equity of use between large and small commercial shippers is an important barrier that must be addressed. Allowing larger companies the opportunity to use ITS without involvement of smaller companies is seen as an unequal distribution of the technology.
- U.S.-Canada crossings are operating in a positive environment. Cooperation between agencies within both countries has been positive, but policy and procedure problems still hinder advances.
- U.S.-Mexico crossings are not as advanced in ITS deployment as U.S.-Canada crossings. The problems associated with smaller independent shipping companies and an unclear definition of the benefits hinders deployment at U.S.-Mexico border facilities.

The survey findings suggest that while ITS technology can benefit both users and nonusers at border facilities, management structure and limits on human resources are the primary impediments to effective deployment. Development of an interagency taskforce encompassing officials from both private and public organizations is key to addressing concerns of all ITS stakeholders at crossings. Without a multi-agency taskforce and a common interagency goal, communication between agencies leads to ineffective operations of automated border crossings. The findings demonstrate the need for active federal and state involvement in order to receive participation from commercial vehicle operators. Involvement must be equal between public and private agencies, but have a proactive manager within the taskforce.

TABLE OF CONTENTS

INTRODUCTION

Over the past decade, the transportation industry in North America has witnessed a change in trade relations. The North American Free Trade Agreement (NAFTA) attempts to remove the trade barriers between Canada, United States, and Mexico in order to provide efficient movement of goods and materials across borders. These countries realize that the world is moving toward a global economy, and trade restrictions reduce the economic potential of friendly nations. Throughout Canada, United States, and Mexico, coalitions are organizing around one central theme: better roads and efficient operations mean more trade and money (1).

The introduction of technology associated with Intelligent Transportation Systems (ITS) may further remove trade restrictions by reducing delays and improving operations at border crossings. Private participants of ITS implementation at border crossings believe that there will be no potential customers unless all three agencies, i.e. transportation, customs and immigration, in all three countries agree to implement automated, integrated border crossing systems (2). Thus, there is a clear need to determine who the stakeholders are in a successful trade system in order to address concerns.

NAFTA represents an important milestone in history, encouraging the growth of trade and commerce throughout North America (3). Although the key element of the agreement was the reduction in tariff barriers, it also called on the Customs administrations of the three countries to streamline and standardize their processes with current technology improvements in order to facilitate trade (4). The introduction of electronic data interchange (EDI), integrated databases, automatic vehicle identification (AVI), weigh-in-motion, in-vehicle computers, and electronic sensors are the primary components relevant to application of ITS in order to streamline procedures.

With these advances in technology, a need exists for agencies associated with the operation of border crossings to update their procedures and implement available ITS technology. Unfortunately, the current institutions do not always foresee the potential of ITS and it is these agencies that provide the most resistance toward complete acceptance of ITS at border crossings to aid information exchange (2). The old adage “if it is not broke do not fix it” becomes a common stance against any attempt toward advancement of procedures via ITS. An example of this problem is that Mexican transportation regulations are currently federal, while U.S. regulations are state-based (2). A common format must be established between these nations that is acceptable for all parties.

Unfortunately, problems are also prevalent within the United States. Despite years of federal transportation legislation encouraging cooperative, continuing, and comprehensive planning designed to integrate both planning and operations between agencies, the trend has been toward a greater disaggregation of responsibilities and “double work” to ensure the status and existence of individual agencies. The recent development of the North American Trade Automation Prototype (NATAP) is an attempt toward combining responsibilities of agencies into a common information format that is readable by all parties. Even with the NATAP project, there are still agencies that are not supporters of ITS. Addressing these institutional constraints both externally and internally by applying criteria for institutional changes is critical to the success of ITS at border crossings.

Problem Statement

Current practices used by Customs agencies restrict the capacity of border crossings. The need for documentation of travel information requires cumbersome paperwork and formalities. This documentation is required to ensure that private shipping companies follow regulations pertaining to import and export tariffs. By increasing travel time at border crossings, the costs for goods movement increases. To make the operation of border crossings more efficient and to reduce the travel time and costs associated with the transport of goods, a computerized format should be used.

Many agencies have been developing and operating their own stand-alone automated systems (5). A complete government-wide system must be developed to ensure system compatibility at all crossings. By identifying the organizations that will be using advanced border crossing technologies, improvements in operations within the organizations could be realized through increased manpower efficiency. The successful introduction of an automation process will require the cooperation of all agencies responsible for international trade. Understanding needs of agencies involved in operations of border crossings is required in order to increase the capacity of goods movement between nations and remove opposition to deployment.

Study Objectives

The goals of this report were to present an overview of the basic issues involved in ITS deployment, to identify potential solutions toward addressing these issues, and to provide a recommended procedure for efficient deployment at border crossings. A case study is included to demonstrate the effectiveness of this procedure. The following is a list of tasks for this study.

1. Identify institutions and environmental conditions involved with border crossings and the current role institutions have in efficiently operating border crossings.
2. Identify the issues associated with incorporating electronic data interchange (EDI), integrated databases, automatic vehicle location (AVL), automatic vehicle identification (AVI), weigh-in-motion, onboard computers, and electronic sensors into the operations of crossings.
3. Catalogue these difficulties and recommend approaches to alleviate these problems.
4. Review relationships between institutions and determine how technology can benefit institutions as a whole and individually. This will compare and contrast how border crossings are currently operating.
5. Recommend methods that incorporate ITS into the border crossing arena to aid all institutions in determining a common goal.
6. Propose criteria required for implementation of ITS to improve operations and institutional cooperation.
7. Apply established criteria to a case border crossing and recommend reasons for success or failure at this study location.

Study Methodology

To gather the data required to produce this report, two approaches to locate information were utilized. First, a bibliographic search was performed, drawing information from both the Internet and relevant documents. Information was collected from the United States General Accounting

Office, U.S. Customs, and the Ontario Ministry of Transportation. In addition, a telephone survey of federal, state, government and private organizations was conducted. Personnel interviews of researchers at the ITS Research Center of Excellence, program engineers at the Federal Highway Administration, and private consultants were conducted to gain a perspective of the basic institutional barriers and operational problems at border facilities. A comprehensive list of all sources, including individuals that provided material for this research, is included in the reference section.

Study Scope

Installation of ITS technology at border crossings will benefit both users and nonusers through reduced delays and congestion and subsequent cost savings. The vast information currently available on border crossings required that the scope of this project include only cities which are applying ITS technology. Specifically, the focus was on four locations between the Mexican/U.S. border and two locations along the Canadian/U.S. border. The primary focus was on how these institutions incorporate ITS into policies and operating procedures. The development of trade and transportation information dissemination procedures and policies is also addressed within this report.

Study Organization

A general overview of the issues surrounding ITS deployment is given, followed by specific issues related to crossings at the U.S.-Canada and U.S.-Mexico borders. Recommended procedures for correct ITS deployment in harmony with the requirements of individual agencies at a transborder facility are presented. Examination of the procedures through a case study of the institutional barriers at a U.S.-Canada crossing are also included.

The need for addressing the implementation issues of ITS is provided in Section 1. General information regarding the role federal and state agencies have in border crossing trade practices, operations, and current technologies used at ITS deployment crossings is documented in Section 2.

An overview of institutional issues that hinder deployment of ITS is provided in Section 3. Each general issue is described as they apply to nontechnical barriers to automated installation. The agencies involved and their needs relevant to ITS is discussed in Section 4. The major functions of a transborder facility are outlined, and each agency's role is documented. The current procedures, technologies, and their effectiveness are addressed for the six NATAP locations.

The survey findings and deployment concerns are documented in Section 5. The advantages and disadvantages of ITS are presented along with identification of recent problems encountered between agencies. Conclusions based on the literature and survey findings are documented in Section 6.

The recommended procedures for addressing the institutional barriers identified in Section 3 are presented in Section 7. A case study is presented to demonstrate the effectiveness of the recommendations. The strengths and weaknesses of the procedures are also identified. Recommendations and potential topics for future studies are also provided.

INTELLIGENT TRANSPORTATION SYSTEMS

The role of new technologies in changing the transportation of goods and people is not clear. The new technology is confronted with limits on funding within the public sector and an unclear understanding of the benefits for commercial vehicle operators and private citizens. The role of federal and state agencies in the allocation of funds is continually changing. While the funding concerns will always be complex, ITS technology can benefit users, nonusers, and operators. The following is a listing of the benefits foreseen by public and private sector ITS participants (6).

- Regulating and documenting the physical dimensions of commercial vehicles to ensure that the equipment conforms with preset standards. The age and maintenance records can be recorded for private companies to allow tracking of equipment maintenance.
- Improving operations at gate-regulated facilities by allowing preauthorization clearance of both commercial vehicles and private autos. Random vehicle inspections will continue to be practiced at security check points, but overall operations will improve by a reduction in delays due to congestion at toll plazas and land-based border crossings.
- Developing a working relationship between both private and public agencies. Public agencies will benefit from the information provided from commercial companies by being able to reduce manpower requirements for inspections.
- Improving security by reducing the potential for contraband movement. Development of consistent practices, regulations, and procedures for the transportation of goods will be provided through computerized manifest information. These computerized manifests will allow instant access to cargo information and the weight of the truck.
- Providing benefits to private agencies involved with automation through improved internal operations.

Role of Government Agencies

Federal governments' role in application of ITS involves development of the technology and communication standards, deployment of this technology and maintenance of the roadside features. Federal transportation agencies have developed this technology through partnerships with private vehicle manufactures and enterprises. The initial cost of ITS technology is high and without the lead support of the government, no advances could be made within private industry. Research and development has progressed well, but limited funds slow deployment.

Deployment of roadside communication features and in-vehicle devices is costly, and only a limited number of locations can be funded for testing, reducing the potential benefits to both users and nonusers at all facilities. Roadside communication features are installed by public agencies and private commercial carriers are responsible for the in-vehicle technology installation. Inclusion of ITS technology by commercial vehicles benefits governmental agencies by (7):

- reduced operational inefficiency;
- reduced enforcement procedures;
- reduced volumes of paperwork; and
- reduced administrative complexity.

Maintenance of the roadside features will be an ongoing role that both federal and state government agencies must effectively address if automated technology is to continue to perform up to expectations. ITS technology must be incorporated into the routine maintenance of the roadway. Special emergency maintenance procedures must be developed to reduce operations downtime in the event of the loss of roadside features.

Role of Commercial Carriers

Within the deployment process, the commercial carrier is responsible for the maintenance of in-vehicle technologies. Automated prototype programs, such as the North American Trade Automation Prototype (NATAP), give ITS technology to trucking companies for use during the study period duration. This is an attempt to demonstrate the effectiveness of these products and to show private companies that public agencies are in support of this new technology. Commercial carriers are also responsible for several other actions in order to maintain efficient operations within the program, including the following (8):

- establishment of toll and tax accounts;
- provision of qualified drivers for preclearance programs; and
- development of relationships between drivers, shippers, brokers and inspection agents to ensure close and positive communication.

ITS at Border Locations

Currently there are six border locations testing this ITS technology: four on the U.S. southern border and two on the northern border. These locations coordinate automated systems and the reductions in trade restrictions under NAFTA trade through the North American Trade Automation Prototype (NATAP). The primary objectives of NATAP include (9):

- enhancing overall border crossing system efficiency;
- promoting transportation safety;
- supporting industrial development;
- encouraging tourism;
- enhancing producer access to international and regional markets; and
- improving level of service provided to all transportation users.

The technologies currently being used at NATAP test locations are listed in Table 1.

Table 1. Current Automated Systems Under NATAP (10).

Computer System	Purpose	Technology
Electronic Payment Systems (EPS)	Allows toll payment of both commercial and private vehicles	AVI, EDI, DSRC
Automated Manifest System (AMS)	Sends manifests of imported goods to Customs officials	Telex, AVI, AVL, EDI, DSRC, barcode
Automated Commercial System (ACS)	Allows cargo and driver tracking	AVI, AVL, EDI, DSRC, barcode
Automated Broker Interface (ABI)	Allows broker access to AMS	AVI, AVL, EDI, DSRC, barcode
Commercial Vehicle Operations (CVO)	Removes paperwork and enhances security	Weigh-in-motion
Advanced Vehicle Control and Safety Systems (AVCSS)	Provides safety of commercial trucks	On-board computer monitoring

Electronic Payment Systems (EPS) facilitate commercial and non-commercial travel by enabling travelers and shippers to pay for tolls through the use of smart cards and AVI technology. The system includes hardware and software for roadside and in-vehicle use, driver payment cards or tags, a financial accounting system, and a communications system between vehicles and the roadside. The dedicated short range communications (DSRC) is the backbone of AVI. Communications between the transponders and the towers allow information to be processed prior to entering the border facility. EPS allows drivers to pay tolls without stopping, thus decreasing delays and improving border productivity. The system could include any combination of debit and credit value capabilities. EPS are installed in various configurations, including mainline plazas and EPS only booths. Specific components of the system include automatic vehicle identification, automatic determination of tolls for differing classes of vehicles, automated enforcement of violations, and flexibility in financial payment.

The Automated Manifest System (AMS) links shippers, brokers, and customs agents through the Automated Broker Interface (ABI) and the Automated Commercial System (ACS) and provides data as to the origin, destination, and cargo of a commercial vehicle. These three systems work in conjunction with each other, using bar codes to permit quick approval of repetitive shipments from experienced shipping companies (10).

Commercial Vehicle Operations (CVO) aim to facilitate commercial trucking by encouraging the use of electronic systems as partial substitutes, and eventual complete replacements for, the paperwork required to comply with state and federal regulations (11). These ITS systems include the use of weigh-in-motion technologies, systems designed to immediately notify authorities in case of accidents, and access roadway monitoring systems to enhance safety and improve efficiency. If developed and applied correctly, CVO techniques have the potential to increase the efficiency with which agencies do their job, while at the same time decreasing the time and cost required by trucking firms to comply with the various state and national regulations and requirements (4).

The Advanced Vehicle Control and Safety System (AVCSS) employs devices which provide collision avoidance warnings and automatic braking controls (12). It includes installed sensors in cargo containers that are scanned via computers and uses electronic tracking equipment to check for faulty brakes and other vehicle problems that could lead to accidents.

Among the core technology features, the key is a communication bridge between the public entities and the transportation goods movement providers. Through linking data from the features into a comprehensive and uniform information system, deployment of ITS technologies within commercial vehicles will develop movement toward advances in ITS private auto services. Since deployment of ITS is within its infancy, compatibility with the emerging system architecture is essential to assure interoperability between different border crossing locations.

INSTITUTIONAL ISSUES

The procedures surrounding border crossings have changed recently with NAFTA legislation. North American countries are more apt to allow goods movement across borders and remove trade restrictions to ensure their place in the growing world marketplace. Since as early as 1989, trade restrictions between Canada and the United States have slowly been reduced, allowing companies on both sides of the border the opportunity for new markets (13). Federal governments within both countries have heard the demands from businesses to allow for a free marketplace and have acted positively, resulting in a growth of exports, imports and an overall good relationship between public and private organizations.

Unfortunately, attempts toward similar practices between the United States and Mexico have not had completely positive results due to the large differences in federal requirements between the two countries (14). The differences in definitions and dimensions of cargos and commercial vehicles is only one example of two federal policies in conflict. NAFTA attempts to identify procedures that are acceptable to both countries, but the process is difficult and slow. This difficulty is compounded by the differences in both language and culture.

Even with all the differences between the three countries, NAFTA has brought about growth in trade. Revenue on both sides of the Unites States border due to commerce has increased as much as 40 percent at certain locations with expectations for even higher increases once NAFTA is fully functional in the coming century (15).

Although there is an expected increase in trade, the current operations of border crossings tend to be a limiting factor in increased trading. Organizational, regulatory, human resources, and technology requirements are institutional issues that hinder ITS deployment.

Organizational

The relationship between the public and private sector has not always been positive. Differences in public and private agency structures make defining roles and responsibilities for ITS deployment difficult. Public agencies between countries are also structured differently, compounding the problem. Development of communication lines can be confusing due to structural differences.

Public and private sector participants have different goals and objectives. Public agencies strive to improve operations, whereas private partners must consider profits. This can lead to management conflicts and differences in the expected results of the technology. Public agency managers are required to be more formal in their management approach because of the agency structure. Problems occur when either public or private management is poor, resulting in ineffective communication internally and externally.

Regulatory

Policies and procedures to ensure security of the import nation hinder increased economic interdependence between nations. Differences in federal regulations can cause conflict between public and private agencies in different countries. These conflicts can be detrimental toward development of a uniform automation system.

Trade legislation within one country affects the practices of all three countries. Import and export restrictions are designed to promote nationalism. This opposes the idea of free trade and is problematic to an automated system because this legislation is continuously being changed.

Differences in vehicle safety standards add increased confusion to the regulatory process. Vehicle lengths and weight restrictions differ within the three countries, causing frustration for private trucking companies. Commercial shippers cannot cost effectively transfer goods from one size vehicle to another simply because of weight restrictions. This lack of consistent standards discourages communication between public and private agencies.

Human Resources

Automated systems are intended to increase the productivity of available human resources, but public agencies cannot devote limited resources to learning how to operate this technology. This problem also exists within the private sector. Commercial shippers operate under a profit margin and have to incorporate costly training procedures for in-vehicle components of ITS.

Technology Requirements

Communication standards have not been completely develop to allow for uniform transferring of information. This forces private agencies to be uncertain of the inclusion of different types ITS technology into vehicles. System compatibility between locations increases the problems of acceptance by private shippers. Database input requirements on cargo manifest for one location are not always the same for other locations. The hardware required for automation also differs with location. Private shippers are not willing to invest in several variations of the same technology.

Noninstitutional

Although institutional barriers exist, these barriers are not inclusive of all barriers toward ITS deployment. Disagreements over how an ITS system functions and the costs associated with deployment are also important issues. With the current state of technology, no clear product is capable of providing all features required by both public and private agencies in a cost effective manner. Thus, problems arise as to which type of equipment is needed, be it AVI, AVL, weigh in motion, etc., to operate the facility. Expensive ITS merchandise that provides little in the amount of time savings to local commercial trucking companies is not considered cost effective in the day to day operations of the fleet.

Another noninstitutional problem includes the perceived benefits from both federal or state governmental agencies that fund the deployment of ITS at border crossings. It is difficult for state agencies to justify the need for expensive technologies at a border when the actual state roads leading to the crossing are in need of repairs. Compounded with this equity issue in cost and benefits is the problem of a more active capital investment role that is required by U.S. agencies due to a lack of funds available from the Mexican government. In fact, Secretary Pena said that the NATAP project is a joint effort between the United States and Mexico, but when pressed, he acknowledged Mexico is not allocating money to develop the technology nor to test it (16).

BORDER INSTITUTIONS

The core functions along any transborder facility consist of: equipment management, gate operations, staging, and security (17). Several variations and additions are present at each individual border crossing, but automated technology can aid in all basic functions at a border crossing.

Security of the country is the fundamental principle for a border crossing. Smuggling of both persons and goods between countries is the target of both Customs and Immigration officials. Their role is to check vehicles for illegal goods and persons entering the country and to exercise taxes on legal import products. The operations consist of toll booths and inspection staging areas. These facilities restrict the capacity of the border crossing, but are required to meet the basic principle of security. Recent trends toward streamlining these practices have resulted in more efficient collection of tolls and inspections, but there is still a significant problem with long queues and delays. Based on a review of border crossing operations and automation, the significant stakeholders are presented in Table 2.

Table 2. Primary Agencies Involved with Transborder Facilities

Institutions	Agencies	Purpose
Federal Level	Customs Service	Regulate trade
	Immigration	Regulate immigration
	Department of Agriculture	Regulate food product imports
	General Services Administration	Design and overall operation of border facilities
	Federal Highway Administration	Oversee transportation operations at the border
	U.S. Department of Transportation	Maintain and upgrades facilities
	U.S. Department of State	Report commerce activities
State Level	Department of Transportation	Maintain access roads to crossing
	State Government	Oversee DOT and develop legislative procedures
	Highway Patrol (DPS)	Enforce state and federal laws
Local Level	City Planning and Government	Develop local ordinances regarding border activities
	Metropolitan Planning Organization (MPO)	Oversee organization of border planning and development for twin cities
	Law Enforcement	Aid in enforcement in conjunction with DPS
Alliances	Border Trade Alliance	Recommend criteria for operation improvements
	North American Transportation Alliance	Regulate private trade activity
	Bridge Authority	Operate crossings
Private Level	Customs Brokers	Provide shippers with tariff information
	Shippers	Distribute goods

The Planning Process

Construction of a new or redesign of an existing border facility can be difficult. Add to this intelligent technology, and the process is even more complex. The advances that NAFTA has made in increasing trade will require more capacity at border crossing areas. Decisions must be made as to what to build and at what cost. Recommended agencies that should be involved in the installation of ITS at border facilities is presented in Figure 1.

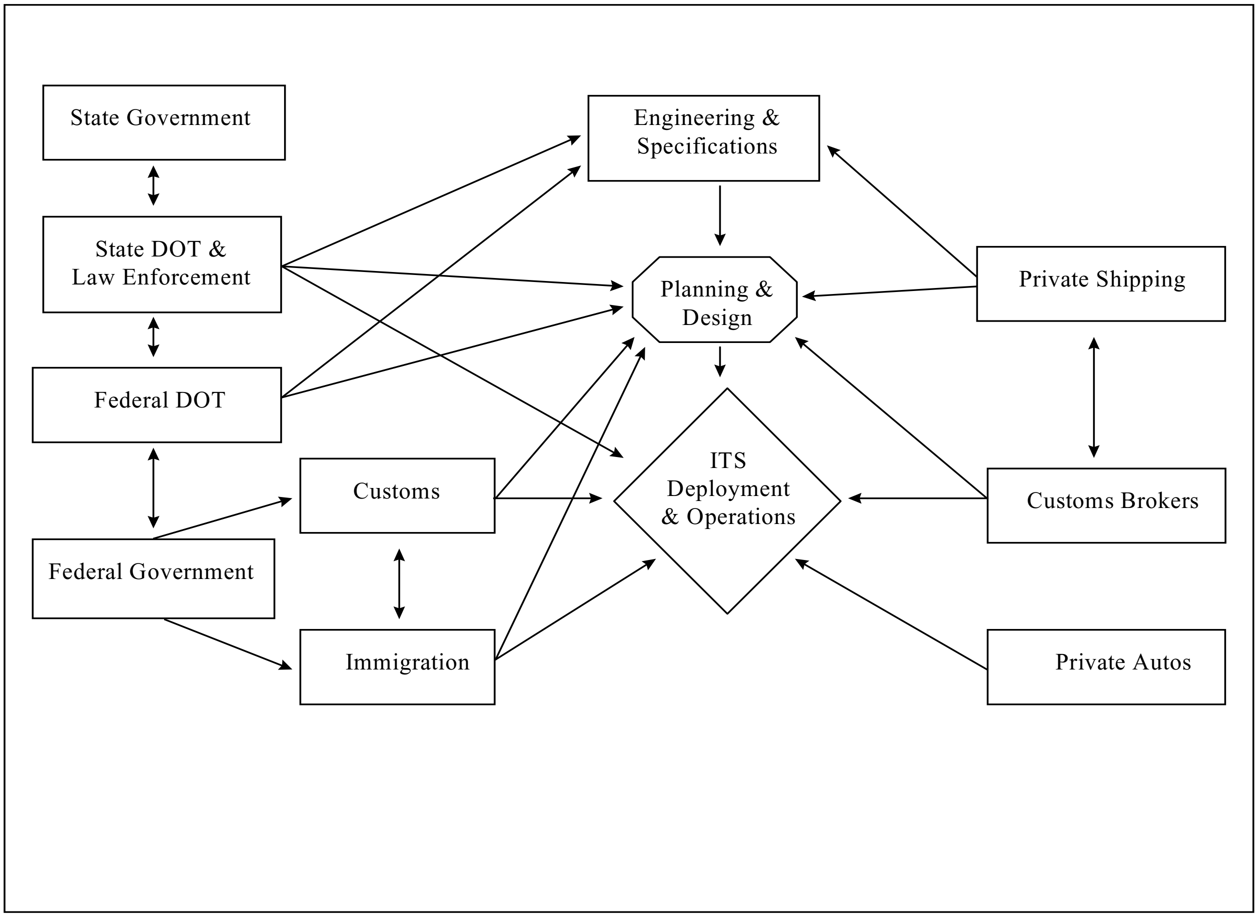


Figure 1. Agencies Required for ITS Deployment at Border Facilities.

Engineering & Specifications

First and foremost, an integrated governmental communication system must be established for the planning and design components of deployment to work. FHWA, General Services, state, Customs, and Immigration officials must develop efficient communication procedures prior to the involvement of the private sector. Without this integrated system, private shippers will feel that involvement within this planning process is inefficient and that the process lacks credibility. This system must have a strong management group capable of gathering needed information in a timely manner from all agencies. A common interagency goal must be developed, in support of the lead management agency or group.

A joint focus group needs to be conducted involving private companies and the federal government focusing on specifications of the software and hardware components of this technology. The Engineering and Specification components of this process consist of determining a common communications format. This process is currently being established at the bridge crossings which were standardized.

The requirement of the public sector in the communication component is to develop and maintain the roadside environment, including transponder stations, central database, and weigh-in-motion systems. Cooperation between federal government agencies, large automotive production companies, and private industry will allow for continual improvements in the accuracy of the hardware and software components of the system.

Design & Planning

The planning process must include the input of the private sector. In the past, the type of facility required was assessed by governmental agencies. This practice cannot continue if ITS is to be effective in improving border crossing operations. Private commercial trucking companies and brokers must be involved with decisions regarding equipment specifications, physical planning, and design. Without the input of the actual users of this technology, no clear need will be established. These commercial trucking companies currently handle day-to-day operations cost effectively and see little need in spending money for new technology. Advances in hardware will always be made, but governmental regulation of communication specifications will need to continue to ensure security of privileged information. If brought in at the planning stage, these companies will have input into the requirements at the facility, thereby increasing demand. Education and involvement is the best marketing technique for ITS.

The inclusion of the private commuter is not regarded as an important part of the design and planning process because of the positive results found within existing ITS locations, but it is still key for governmental officials in determining capacity requirements. Commuters across borders have shown positive support of this technology. Problems arise with community acceptance when this is seen as a benefit for only those that can afford it. Public acceptance must be considered, and proper advertisement of the costs and the overall benefits for both users and nonusers will be necessary.

Deployment & Operations: U.S.-Canada

Canada and the United States are each other's principal trading partner, and they have the largest two-way trading relationship in the world (18). The following sections document the primary agencies involved in operations and the benefits of ITS improvements in operations.

Customs

Current Customs operations along the U.S.-Canada border operate in a cooperative manner due to the large presence of "just in time delivery" and "warehouse on wheels" concepts (19).

Canadian and U.S. Customs agencies work in an understanding accord to promote international trade, facilitate the movement of people and goods across the border, and reduce costs (18).

The rules and regulations for both Customs agencies are very similar, and they promote uniform interpretation and application of cargo origin rules and uniform regulations for certain Customs procedures which aid in deployment of ITS technology (18). System architecture has been revamped between these agencies on both sides of a border to reduce the redundancies of checking procedures (8). The U.S. Customs agency was restructured in 1995 as a three-tiered organization formed of people, processes and partnerships, with the emphasis on service delivery at ports of entry (14). Canadian officials have introduced similar legislation to restructure the agency and procedures through the Customs 2000 initiative (19).

ITS Application. The implementation of ITS technology allows Customs agents to inspect those shipments that have a higher potential for contraband while enabling more mundane shipments faster clearance. Inspection agents will have prior knowledge of cargo before the truck enters the facility, reducing overall inspection time. The changes in regulations and system architecture allow for the inclusion of unmanned toll booths with AVI readers. This reduces manpower requirements and facilitates positive communications between Customs, familiar shipping companies, and brokers. Staging of participating automated vehicles is reduced allowing agents more time to inspect vehicles without ITS technology.

Immigration

Immigration regulations between the two countries are also very similar. Canadian and United States Immigration officials share common interests and issues. The primary purpose of Immigration officials is to regulate the entry of people into a country. Immigration officials are required to question incoming persons about purpose and duration of stay within the country. This can be a time consuming but a necessary task to ensure safety of the country's citizens.

The basic operations within these agencies are similar, except Canadian Customs officials act on behalf of Immigration Canada whereas U.S. Immigration is solely responsible for determination of naturalization requirements (8).

ITS Application. A number of border cities have high commuter traffic resulting in increased congestion along the border. The recent advances in AVI technology have reduced these delays by allowing those commuters that undergo a prescreening process the ability to bypass long standing queues while paying the toll electronically through a toll tag. Similar procedures are available for commercial drivers. Although there are different forms, procedures, and hardware devices for different locations, the preclearance concept remains the same, and it is effective in allowing Immigration's limited manpower to question persons that have not undergone the prescreening process.

Bridge Operators

The Ambassador bridge located at the Detroit-Windsor crossing is owned by a private company (8). The Ambassador bridge is unique because sole ownership forces both countries to conform to the procedures developed by the bridge owner. The other northern NATAP locations in Detroit and Buffalo are controlled by different federal and state governmental agencies. Customs, Immigration, State Department of Transportation, and local governments are all actively involved in the operations of the other NATAP crossings at Detroit and Buffalo.

ITS Application. These owners/operators share a progressive approach which supports the integrated application of advanced technologies (8). This approach involves agency agreements regarding administrative and technical responsibilities for both operations and ITS deployment. The primary reason for the embracement of this new technology is that owners/operators believe the benefits outweigh the cost. In fact, agencies that operate different bridges within the same region have developed partnerships with each other to ensure equality of ITS deployment (8). Deployment of new technology, such as AVI or toll tags, is conducted all bridge locations (8). This is considered sound practice to keep existing traffic patterns.

Brokers

Customs brokers provide the vital link in most commercial transactions by providing a basis for payment of duties (19). Customs brokers are independent private organizations that provide logistics and serve as contact points for private commercial carriers. Their primary role is to advise shippers on tariff classification, cargo shipping rates, duty requirements, and state and provincial sales taxes. Brokers interact with shippers by inputting data into the Customs' computers regarding cargo manifest information and duties paid.

ITS Application. The use of AVI technology is vital to the effective operations of the brokers because it provides the information in a clear and understandable format for both countries' brokers. The manifest information is formatted to international standards and then sent to Customs agents through telecommunication. This information can be provided in advance of the cargo reaching the border, allowing for a reduction in delays.

Commercial Carriers

The primary operation of commercial vehicles along the border involves the common practice of trucking companies delivering goods to their final destination point. Although this method of operation is effective in the delivery of goods, the increased traffic along the border in recent years demands improvements in both infrastructure and operations of these facilities. Unfortunately, infrastructure improvements cannot always be developed to increase capacity in urban areas where space is limited.

ITS Application. Carriers see automated technology as a means to reduce delays at crossings and thereby save transportation costs. The prototype will allow the participants to experiment with new concepts and operating practices without the expense associated with the design of a complete system (18). The benefits of AVI, EDI, and toll tag technologies must outweigh the carrier costs for investments to be made. Participation of commercial carriers within NATAP is strictly voluntary, and the initial in-vehicle cost is minimal to companies.

Deployment & Operations: U.S.-Mexico

The differences between the U.S.-Canada and the U.S.-Mexico border are significant. The Federal Highway Administration identified 913 institutions along the U.S.-Mexico border, including 390 commercial carriers and 280 Customs brokers and freight forwarders (11). These are large numbers in comparison to the U.S.-Canada border.

Customs

Current Customs operations along the U.S.-Mexico border operate in a cooperative manner, but state and federal regulations regarding the size and weight of trucks have caused severe delays at several border crossings. The Customs agencies work in cooperation with their counterparts across the border, but current Mexican commercial shipping practices hinder the effective operations of Customs officials at the U.S. border by noncompliance to size and weight regulations. The rules and regulations for both Customs agencies are different with respect to the requirements for commercial vehicles. Mexican Customs are more flexible with regard to information on the origin and destination of a cargo. As a result, random and extensive Customs inspections occur more frequently at the U.S. port of entry than at the Mexican port of entry.

ITS Application. ITS requires consistency in guidelines in order to operate effectively. This requirement will force the Customs agents to develop standards that meet the requirement of the border countries. Streamlining of Customs operations by the United States will make this standardization process more efficient and allow the use of EDI at NATAP locations.

Due to the differences in vehicle standards, safety is a concern of U.S. Customs' officials at these crossings. The commercial vehicle safety system provides Customs with a method to regulate driver safety information. The capability to alert the commercial vehicle driver whenever there is a critical safety problem or potential emergency is also provided.

Immigration

Immigration regulations between the two countries are very different. The economic differences between the United States and Mexico require Immigration officials along the U.S. border to perform frequent inspections. The basic operations work well with Customs' inspections, but they still require additional delays in order to perform inspections on vehicles that are suspicious.

ITS Application. The number of commuters is not as high as at the Canadian border, but the potential for preclearance processes is still relevant at these crossings. Similar preclearance procedures are available for commercial drivers.

Bridge Operators

Operations and maintenance of these crossings are controlled by joint governmental agencies that report to both the Mexican and United States governments. This differs significantly from the Ambassador Bridge, where operations are controlled by a private company. These agencies must conform to stricter regulations in order to ensure that federal maintenance and operating costs are used more effectively.

ITS Application. Installation of ITS components at the facility will reduce the manpower requirements of this interagency committee. Automated technologies will require improved communication between agencies, resulting from more formal operating policies and procedures.

Commercial Carriers

Commercial vehicle congestion at international ports of entry on the U.S.-Mexico border has increased significantly, partly as a result of reduced trade barriers between the U.S. and Mexico (11). Mexican companies have a different type of operation along the Texas, Arizona, and California borders as compared to their U.S. counterparts. Currently, the cross-border transfer of goods by truck is confusing and variable from one border crossing to another. It involves a mixture of formal and informal relationships between U.S. carriers and Mexican drayage companies (11). Drayage refers to the movement of goods by border-only trucks which pick up a container on one side of the border and drop the container for a final destination truck on the other side of the border. Thus, these trucks cross borders with and without loads. These trucks increase the congestion and overall delays along the border when they are returning to loading areas on the other side of the border without a container in tow.

The Texas-Mexico border is unique in that: (1) 80 percent of the overland trade flow between the U.S. and Mexico crosses in Texas because seven of the largest U.S. exporting states to Mexico are in the Northeast and Midwest U.S., and the shortest route to Mexico is through Texas; (2) commercial transportation between the two countries is changing; NAFTA may hasten that change, but it is not the precipitating event; and (3) border infrastructure is being upgraded, and there is an opportunity for ITS technologies to be implemented along with the other improvements to the transportation system (6). This fact makes deployment of ITS at these locations vital to the overall success of NATAP.

ITS Application. The "seamless" border crossing imagined by both NAFTA and ITS developers will slowly decrease the amount of drayage vehicles at a border crossing. While this will reduce congestion, it will also be detrimental to the local economy and to companies that are dependent on this type of operation. Local drayage companies must develop the ability to deliver goods over a long haul and not serve as the conventional "middle man".

NATAP Locations

Currently there are six locations where ITS technology is being applied in some form at border crossings. These crossings have been given funding by federal governments for NATAP installation. Each site is unique in both operations, physical design, and traffic volumes. It is beyond the scope of this project to address all of these features, but an understanding of how these facilities operate with ITS is important to addressing the institutional issues at border crossings. NATAP deployment cities evaluated within this report are shown in Figure 2.

Figure 2. Six NATAP Locations.

Each of these cities has different components of ITS and they are also at various stages of deployment. Typically, the northern border crossings at Detroit and Buffalo are further along due to similar regulations between the United States and Canada. The southern crossings have had the most institutional barriers toward deployment due to regulations, cultural differences, commercial operating practices, and a general lack of knowledge by all parties involved as to the benefits of NATAP. An example of this problem is in El Paso, where a commuter preclearance prototype was initially planned but was rejected by the public because of the issue of equality (6). The private commuters believed that this technology would only benefit those that could afford the technology. Marketing of the preclearance program was not conducted to demonstrate the benefits in reduced delays for both users and nonusers.

Buffalo, New York

NATAP deployment is underway at the Peace Bridge between Fort Erie, Ontario and Buffalo, New York. Preliminary tests on both commercial and commuter drivers proved successful and the current six-month testing of the prototype is underway (20). Customs and Immigration officials were key toward acceptance. An agreement was reached between both U.S. and Canadian agents to allow this test. If successful, the prototype is expected to be expanded to a larger group of shippers and commuters who qualify for the program. Early in the NATAP process at this location, there was poor communication between Customs' officials and the private trucking industry. Private agencies were unsure of the requirements of NATAP and Customs officials did not always respond in a timely manner. System interoperability was the common request of commercial trucking companies, and no clear system was presented that would work at all locations. Though this was seen as a problem at first, this location can be looked upon as a model of how multiple agencies can work together to form partnerships united under a common goal of increased efficiency.

Detroit, Michigan

The system results are positive, although caution is considered here as deployment of some features is still early. Technologies used at this crossing include AVI devices within the ACS for commercial vehicles and transponder tags for commuters. Commercial trucking companies are larger in size and have already streamlined their own operating procedures. These larger companies have accepted ITS at this location, but are still apprehensive toward full implementation for fear of unwisely investing in this technology completely. The commuting public has accepted this technology and has increased the overall support for the system. The use of toll tags is well established at this location, indicating that acceptance by the commuting public occurs over time. Customs' and Immigration officials on both sides have responded positively to the system.

Laredo, Texas

Electronic cargo seals, AVI, and brake monitoring systems are some of the technologies used at this facility. Currently government officials consider that the costs outweigh the benefits of ITS at this location but this is due to the amount of carriers participating within the system. It is expected that once the system is fully operational, the reduced delays will make the system viable.

Problems encountered at Laredo include a general unwillingness of commercial operators to change their freight shipping patterns. Southbound traffic at this location is high from 1 to 5 p.m. daily with delays of over five hours to cross the border (6). It was suggested to commercial operators that a change to earlier shipments would reduce the congestion, but the response to this basic request was almost nonexistent. This solution deals more with manual processes but demonstrates the general lack of acceptance toward innovation. A change in the overall perception of the problem needs to occur at this crossing in order for ITS to work. The general thought is to build new infrastructures in order to eliminate the problem.

El Paso, Texas

Customs operations have had to make significant changes in order to accommodate the large increase in traffic at the El Paso border (17). Reductions in manifest requirements and an AMS have been incorporated into operations allowing more efficient movement of common commercial cargos. This system was developed in conjunction with Mexican Customs and has shown positive results. Customs brokers continue to use the system to relay information to Customs officials. The reduced data system has brought about a trusting relationship between brokers, shippers, and Customs.

An internal problem with this system is that Customs does not have the manpower required for efficient data input into the system. This issue is currently being addressed, but Customs agents have to serve the dual purpose of both inspection and inputting data. This facility has also allowed more technological advances within the NATAP program to be implemented. Involvement with the U.S. Treasury has also shown positive results by integrating their systems into the Customs ACS (21).

Barriers to trade at this facility deal primarily with local commercial operating procedures and a general mistrust of the technology of ITS within the private agencies. Involvement of smaller commercial shippers has also not been adequately addressed in the implementation of ITS. Small commercial shippers see little incentives to applying ITS within their own fleets. This issue must be addressed by involving these stakeholders in the future.

Capital improvements and ITS applications have been added to the facility at El Paso with additional design improvements currently underway. The source of funds for implementation is a significant problem. State officials are considering support, but their support is mainly focused on physical improvements of the crossing area. Funds tend to be allocated toward physical infrastructure rather then investing in ITS to address the problems. This fact stems from the local lack of trust of new technology benefits mentioned previously.

Nogales, Arizona

AVI and EDI technology is currently in use for commercial shippers who registered in NATAP. The procedure is known as "Prepass" in the NATAP process (6). Participating carriers have radio frequency transponders (DSRC) that work in conjunction with the operating system. A taskforce was initiated to deploy this technology. The primary concerns of the group focused on the involvement and support of the Mexican Customs brokerage industry and the need for Mexican agencies to coordinate their efforts in the clearance of cargo.

The Nogales project includes restructuring of operating procedures and management of personnel within U.S. Customs and Immigration. The change in procedures, brought about by federal regulations, allows officials more time to inspect non-routine shipments. Education of inspection officials regarding this new technology has been important to acceptance. It is hoped that these procedural changes increase the efficiency of the port and will serve as an example of new inspection procedures for other crossings.

Otay Mesa, California

NATAP use includes AVI tags and EDI for commercial vehicles. Driver preclearance for both commercial and commuter drivers is operational with positive results. The primary concern at this facility is the limited number of Customs' officials. ITS deployment has been hindered by this lack of manpower, resulting in limited effectiveness of operation. Customs' officials have recently added new technology, which enables Customs to X-ray entire trucks to determine the cargo (16). This has increased the capacity of the limited manpower at this facility allowing agents to do more with less. Immigration officials employ radio frequency tags, antennas, and other automatic vehicle identification devices in a program known as Secure Electronic Network for Travelers' Radio Inspection (SENTRI) (2). To date, this operation has proven effective and has provided a framework for installation of other forms of automation within the Immigration agency. This program allows Immigration officials the ability to segregate traffic into low and high risk groups and reduces the amount of inspection time.

Overall, this crossing has seen some of the potential benefits in reduced congestion and inspection times with ITS, but the primary agencies which required the most change for acceptance were the Customs and Immigration agencies. Each of these agencies had to restructure their procedures to adapt ITS. Poor communication was seen as contributing to interagency problems. The solution used to address this problem was a multi-agency taskforce consisting of Customs, Immigration, Federal, and State governments on both side of the border.

Sweetgrass, Montana

Though this location is not currently under the NATAP process, it is currently attempting to install automated technology. There has been positive communication on both sides of the border at the state/provincial level, but communication between federal agencies has been nonexistent.

SURVEY RESULTS

This survey findings are documented in this section. Of the 35 surveys sent out, 13 agencies responded with general concerns regarding the lack of acceptance of ITS technology by Customs and Immigration officials. Based on the literature review and the survey responses, several issues associated with ITS and the institutions at border crossings are presented within this section. Significant institutional barriers have been found that are impeding the implementation of technology at the border, including the large number of federal, state, and local agencies involved with conflicting objectives. Examination of the institutions involved with ITS at border crossings was made through a survey to determine successes and failures toward implementation of ITS. The agencies where ITS solutions were not readily accepted into practice were identified within this survey in order to target ITS applications to better meet their needs. An example of the questionnaire can be found in the Appendix. The respondents to the survey included officials from:

- Federal Highway Administration
- Ontario Ministry of Transportation
- ITS Installation Consultants
- Niagara Falls Bridge Commission
- U.S. Immigration
- Commercial Shipping Consultants
- U.S. Treasury
- Transport Canada
- Toll Systems Administration
- ITS Installation Consultants
- U.S. Customs
- ITS Researchers
- Peace Bridge Authority

The following issues were addressed in the questionnaire:

- successes and failures of ITS in improving transportation across boundaries at each location;
- recurring concerns and problems that agencies have encountered;
- "lessons learned" from the development and deployment of the systems;
- difficulties experienced in conveying the benefits of ITS to both public and private institutions;
- advancements in communications between institutions; and
- future plans for ITS and interagency cooperation.

Key Considerations for Deployment of the ITS Structure

Based on the results of the survey, border plazas usually pursue implementation of some combination of the core automation features, eventually leading to a complex ITS. This deployment of features must be supported by common physical (hardware/software) components and institutional relationships which contribute to successful implementation of more than one core feature (22). Below is a listing of some of the most important findings from the survey (23-36) .

- Data systems must link equipment with central software/database systems.
- Communication must exist between public and private sectors, without necessarily relinquishing control. This will require formal interagency agreements for information sharing.
- Information sharing/coordination between countries is essential.
- Proactive management of limited resources must achieve agency objectives.

- Potential customers and information providers including commuters, private sector goods movement agencies, and public sector entities responsible for border operation, safety, and security is critical to success.
- Commercial vehicles, private autos, ITS, and non-ITS users must be considered to facilitate smooth and efficient transfer of people and goods at a transborder crossing ITS deployment.
- Exchange of information between: U.S., Mexican, and Canadian Federal Governments must be consistent; state and provincial transportation agencies must optimize operations; and cross border agencies must ensure compliance and accuracy of data from freight transport modes, receivers, and border operations centers.
- Education of ITS technology must be provided in a top down format for public and private agency employees removes technology and privacy fears for acceptance; the differences in needs and goals of agencies reducing redundancies in procedures.
- Culture and language differences require a standardized, uniform data format.
- Institutional, regulatory, or legal barriers to interagency cooperation or ITS service integration must consider: border agencies in order to optimize system performance and the use of scarce financial resources; border agencies, user groups (commercial and private), and interested public; border agencies with different missions, goals, and needs; and border agencies and oversight agencies.

Organizational

- The inspection philosophy of federal agencies in both Canada and the United States has been difficult to change to conform to the required procedures for ITS applications. One respondent stated that U.S. Customs and Immigration required the most change toward acceptance of automated technology. This respondent further stated that although these agencies were not completely receptive toward ITS, there were no major interagency problems. Cooperation between agencies was rather positive, and the difficulty was in having these government agencies accept an un-manned inspection booth. Similarly, one respondent suggested that there was a lack of understanding of exactly what is required by other agencies involved at a crossing. Inflexibility of internal agency guidelines was a common barrier for ITS. The solution to this problem was that one agency had to assume the lead for deployment and facilitate discussions between agencies. Typically, this occurred due to a higher governmental agency requesting the change. One example is the U.S. Customs Administration federal regulations mandating changes in inspection procedures to conform with NAFTA policies.
- Customs and Immigration officials were receptive toward ITS, but federal and state DOTs required significant changes in agency structure, resulting in poor operations by Customs and Immigration agents. The DOTs are more concerned about the development of standards and are not as actively involved in implementation and operations. ISTEA legislation within the U.S. catalyzed the trend toward federal DOT involvement in implementation, and the U.S. Treasury also realized the need for identification and screening technology. Currently, institutional involvement is voluntary, and private commercial industry must be able to clearly see the actual benefits of ITS. The result of ISTEA and NAFTA legislation along with the NATAP have resulted in a "synergy" between the treasury department and the federal DOT.
- Establishment of the core infrastructure features must permit optimal operations and management of border crossing plazas through the use of currently-available technologies and strengthened institutional ties. In the near-term, implementation and management of the core

infrastructure features is expected to be led by the public sector. Development of governmental management capabilities is expected to occur in an evolutionary manner. Management within the private sector is expected to install ITS systems and educate operators of technology.

Regulatory

- International conflicts in the implementation of NAFTA trucking rules are also seen as creating impediments to international institutional cooperation. A research study conducted by the Texas Transportation Institute suggests two interrelated solutions: the diverse actors in the trade and transportation industry must be included in both the problem identification and planning stages for ITS applications in this complex environment; and increased education of the public of the potential of ITS for border-specific and other transportation problems must be made a priority (6).
- Manifest information differs between countries. Mandatory cargo and vehicle information for all three countries differs slightly. Problems occur when an information field within the ABS and ACS is not reported due to a computer input error. This requires increased delays for commercial carriers that must retrieve the missing information at the facility.

Human Resources

- The installation of ITS technology has the best chance of success at locations where current availability of manpower within Customs and Immigration is limited, causing severe delays to the motoring public. The amount of help this technology would offer these agencies was an issue. Conversely, the potential for loss of jobs due to technology was also expressed.
- Telecommunications and automation software used by the customs brokers follow international standards, but the vast number of pre-arrival manifest sent still requires individual verification by Customs agents. This leads to frustration by truckers who expect reduced clearance time because the information was sent prior to their arrival. Customs officials must operate based on the demand at the crossing. When vehicle demand at the crossing is high, agents are required to inspect vehicles, resulting in a lower priority given to shippers that send information by telecommunication.

Technology Requirements

- Commercial carriers expressed concern over various types of automation. The toll tags and AVI readers were not always compatible between locations, forcing companies to use certain facilities even though an alternative route may reduce delays, resulting in travel time and cost savings.

Noninstitutional

- There is a lack of communication about the status of, need for, cost of, and benefits from ITS technologies between and within federal, state, and private agencies (12). Progress is being made at some locations that have overcome some of the interagency communication problems. A clear problem exists in disseminating information as to the benefits of this technology for private trucking companies (6). The difficulty is that smaller firms do not believe that this technology will be cost effective for them. Based on the current state of applications these firms may be correct in this assessment. A supply-demand relationship must be developed on a site-specific level to demonstrate the need for and cost to these smaller commercial carriers (6). Currently, there is little information as to the actual benefits of these systems, and private commercial fleets are not willing to invest in possible "trend" technology.

- The costs are not clearly understood by all agencies involved. Concern over equity of capital investment costs by federal and state transportation agencies among the three countries was an issue in deployment. U.S. state transportation agencies have encountered problems funding improvements for Mexican commercial shipping companies. Improving only one side of the border gives minimal incentives for NATAP participation by Mexican drayage companies that cannot use automated technology on the other side of the crossing.

Summary of Findings

The interaction of both infrastructure and institutional constraints at border crossings can be difficult. Development of infrastructure without consideration of the institutional issues can lead to poor operations and increased cost of these projects (11). Also, where borders crossings in urban locations have minimal possibilities for infrastructure improvements due to the limited space available. It is at these locations that institutional barriers must be recognized and mitigated to improve the operations of the transborder area. The institutional barriers and the agencies that are significantly affected by barriers are summarized in Table 3.

Table 3. Summary of Border Institutional Barriers Identified.

Institutional Barriers Toward Deployment	**Border Crossing Agencies Affected**				
	Federal Transportation	**State Transportation**	**Local Government**	**Customs & Immigration**	**Private Shippers**
Organizational	✔	✔	✔	✔	✔
Regulatory				✔	✔
Human Resources				✔	
Technology Requirements				✔	✔
Noninstitutional	✔	✔	✔	✔	✔

Common barriers to deployment within the survey results included:

- the initial high cost of deployment and determination of funding sources within and between agencies;
- manpower, resources, priorities, and regulation imbalances between agencies; and

- procedure duplication between agencies and restrictions on operating procedures to ensure individual agency operational territories. Agencies are unwilling to implement ITS technology for fear of eliminating the existence of internal departments.

CONCLUSIONS

Movement toward deployment of the previously defined core ITS infrastructure will occur in an evolutionary fashion, building upon existing border plaza hardware/software/communications systems and institutional relationships. Border areas should be working toward development of these capabilities, with a special emphasis on laying the foundation for future ITS advancements through selection of open-architecture systems and institutional cooperation. Time frames and priorities for deployment should be developed based on the specific needs of the border and coordinated with the project planning, programming, and development processes currently underway.

NAFTA and NATAP must overcome obstacles in implementation. The problems of cultural differences and regulations between the three member countries results in a trade environment that can be complex. Although the key element of NAFTA was the reduction in tariff barriers, it also called on the administrations of the three countries to streamline and standardize their processes. The introduction of NATAP with new technology such as EDI, AVI, in-vehicle computers, and electronic sensors is a positive step in standardization of information.

Security of the country is the fundamental principle of a border crossing. In order to ensure that the integrity of a country is not compromised, inspections are required. This method of operation restricts the capacity of the facility. Border crossings have the difficulty of dealing with both infrastructure and institutional constraints; development of infrastructure must also include institutional issues. Without these two coexisting, poor planning and effectiveness of projects will occur.

Urban border cities have minimal possibilities for infrastructure improvements. Institutional barriers must be recognized and mitigated to improve the operations. These areas will continue to grow requiring more facilities.

RECOMMENDATIONS FOR ITS DEPLOYMENT

To aid in ITS deployment, specific measures can be defined to evaluate the border facility itself and to gauge progress in implementing the technology. The criteria recommended in Table 4 were developed by the author based on the literature review and the survey findings. The criteria suggest an interagency cooperation and an overall understanding that this technology should benefit all entities involved.

Table 4. Recommendations for the Removal of Institutional Barriers of ITS at Border Crossings.

The ITS Deployment Criteria:	
1.	Define an interagency structure to accomplish the mission of ITS deployment.
2.	Develop policies and procedures for coordination between agencies in regards to the sharing and dissemination of information electronically.
3.	Access roads, border facilities, and ITS technology should be planned, operated, and priced as if they were parts of a single system.
4.	Equity of the system should also be considered to ensure community acceptance.
5.	Despite limited resources, the border crossing can effectively resolve the conflict between interagency goals if it adopts a strategy of ITS system management that is tailored to the amount of goods and people movement at each specific crossing.
6.	Continual improvements and education in both operations and technology should be included within the border crossing.

- *Define an interagency structure to accomplish the mission of ITS deployment.*

Existing stakeholders, state, local, federal governments and interagency councils should be included within this structure. Private commercial trucking companies must be incorporated into this structure. The structure should be developed to ensure that security and privacy of information is not compromised and that equity of use is consistent with the current trucking patterns.

- *Develop policies and procedures for coordination between agencies in regards to the sharing and dissemination of information electronically.*

Involvement with local and national trucking associations would be beneficial for acceptance of information exchange between local commercial trucking companies and border agencies.

- *Access roads, border facilities, and ITS technology should be planned, operated, and priced as if they were parts of a single system.*

Development of physical improvements must be coordinated with operational improvements of this new technology. Land use and transportation should be better coordinated to enhance accessibility while reducing system delay. Conscious effort should be applied to the operations of the facility within the planning and design stage.

- *Equity of the system should also be considered to ensure community acceptance.*

The transborder ITS system should be designed to provide convenient access, to facilitate the transborder movement of people and goods, and to provide a "seamless" crossing that is in harmony with the community and the natural resources of the area.

- *Despite limited resources, the border crossing can effectively resolve the conflict between interagency goals if it adopts a strategy of ITS system management that is tailored to the amount of goods and people movement at each specific crossing.*

Specifically, the border crossing agencies should emphasize the operational improvements that enhance the movement of goods and people during peak hours. ITS technology should be adopted along with physical improvements at the facility where possible. Operational improvements in procedures within public agencies and among both private and public agencies should also be considered to improve operations.

- *Continual improvements and education in both operations and technology should be included within the border crossing.*

This must be a joint effort between both public and private agencies to ensure that the demands of all stakeholders are effectively addressed. These improvements should be conducted in a timely manner to ensure positive results and acceptance by all involved. Education in both operations and new technology should be conducted on a consistent basis to receive all the benefits of these technological advancements with minimal educational costs. Continual education will result in a demand responsive atmosphere from the private sector.

A Case Study: Application of Deployment Strategy

Upon completion of the criteria, a case study was performed at the Nogales, Arizona border crossing. This case study will demonstrate the abilities of the established criteria and the effectiveness these criteria have at removing the institutional barriers associated with automation at border crossings. The Nogales location was chosen because of the advancements through interagency relationships that have been made.

Background

Nogales, Arizona, is a culturally and economically diverse twin city that is separated from Nogales, Sonora, Mexico by the U.S.-Mexico international boundary. The primary industry in Nogales is the transportation and distribution of goods. Nogales is an entrance point to the United States trading corridor connecting Tucson, Arizona and Mexico City, Mexico.

Define an interagency structure to accomplish the mission of ITS deployment

The Joint Working Committee (JWC) was established in 1994 to aid state and local agencies in evaluating the stakeholders involved between Arizona and Sonora to plan, design, finance and build an economically viable transportation system (28). The goal of this committee was to improve transborder processing between the United States and Mexico. This goal is in harmony with effective ITS deployment.

Develop policies and procedures for coordination between agencies in regards to the sharing and dissemination of information electronically.

The Nogales JWC identified a barrier between both interstate and international communication. The technology and knowledge that different state agencies had between the U.S. border states of California, Arizona, New Mexico, and Texas was significant. Combined with this problem of communication was the difficulties associated with application of technology within the Mexican border states of Baja, Sonora, Chihuahua, Coahuila, and Tamaulipas. The engineers within Mexico have limited available funds for design and operations of border facilities. These engineers have the unique ability to maximize both personnel and material resources in achieving the construction of facilities. Combining the expertise on both sides of the border was considered an ideal method to maximize limited resources (28).

The result of this was the Border Technology Exchange Program (BTEP) encompassing officials from all border linked states (28). The policies developed from the BTEP included the establishment of a permanent technology exchange program managed by federal officials. This program includes procedures for technical assistance to ITS participants and method for technical and legal compatibility (28).

Access roads, border facilities, and ITS technology should be planned, operated, and priced as if they were parts of a single system.

The State of Arizona and State of Sonora have strong geographic, cultural, and economic ties. Recently, these neighboring states have significantly increased trade through the improvement of transportation infrastructure and increased transportation services. The significance of NAFTA, and the need to develop plans for infrastructure improvements in support of increased trade, has resulted in a cooperative study between the States of Arizona and Sonora. The Arizona-Sonora Transportation Infrastructure Study was conducted to provide an assessment of the current international transportation infrastructure and recommend actions to be taken for improving these facilities (28). Physical, operation, and technology improvements are discussed within the transportation infrastructure study (28).

Equity of the system should also be considered to ensure community acceptance.

The economic dependence of Nogales, Arizona and Nogales, Sonora on the transportation industry can be seen in the active role private citizens play in improving the infrastructure of the border. Private company involvement with the implementation of the "Expedited Process at International Crossings" (EPIC) for commercial vehicles at the Mariposa port of entry in Nogales has been positive (28). Commercial shippers and both communities actively participate in the process.

Despite limited resources, the border crossing can effectively resolve the conflict between interagency goals if it adopts a strategy of ITS system management that is tailored to the amount of goods and people movement at each specific crossing.

The Joint Working Committee was designed to specifically address issues related to the border infrastructure and to enhance operations through the use of new technology and physical improvements. This committee has identified operational problems on both sides of the border and is attempting to address the concerns about the Mariposa port of entry (28).

Continual improvements and education in both operations and technology should be included within the border crossing.

Enhancing the Border Technology Exchange Program through the addition of technical courses, conferences, and seminars provides material and skills for the development of a more efficient transportation system. One of the recommendations from the Arizona-Sonora Transportation Plan was to conduct annual workshops for the purpose of sharing technology information (28).

Future Research

Throughout this study, one issue did not seem to be identified through the literature review or the survey: the needs of the consumer. The public sector is trying to develop positive relationships between agencies that will foster the development of ITS technology. Unfortunately, the role of the private sector is not always considered.

The private sector will be the final consumers of the product, and no one has stopped to ask the consumers what should be required of this technology, or even if it is needed at all. Larger trucking companies may realize benefits, but what about the smaller companies or the local drayage carriers along the U.S.-Mexico border. An independent analysis must be conducted to see what demand exists for the technology. If demand for this product is low and the public sector deems this technology unnecessary, a marketing analysis that targets smaller independent firms should be conducted.

REFERENCES

1. Castaneda, K. Hitting the Road Issue. *Toronto Star Newspaper*, Toronto, Canada. May, 1996.

2. Helliker, P. Otay Mesa Field Operational Test Status. *Southern Border FOT Status of International Border Electronic Crossing Report*. CALSTART, San Diego CA, August 1996.

3. Gore, A. Memorandum on Implementing an International Trade Data System. Washington, D.C., September, 1995.

4. Heads of Customs Conference. Conference Proceedings. Ottawa, Canada, October, 1995.

5. Hallenbeck, M. et al. Identifying and Surmounting Barriers to Implementing IVHS Commercial Vehicle Operations Systems. Seattle, WA, April 1994.

6. Lindquist, E., T. Lomax, M. Pinus, and M. Cole. Texas-Mexico Border ITS Assessment. Texas A&M University Research Center of Excellence, College Station, TX, May 1997.

7. Lasky, J. Logistics Technology in Mexico. Livingston Trade Services. June 1995.

8. Marshall Macklin Monaghan, KPMG Management Consulting, JHK & Associates, and Constance Consultants. Study of Institutional Impacts of New Technology Applications. May 1994.

9. Tsai, J. Intelligent Transportation Border Crossings Systems, Ministry of Transportation of Ontario. Prepared for XIIIth IRF World Meeting, Toronto, Ontario, Canada, 1997.

10. Sadegh, A. An ITS Training and Technology Exchange Program for the I-95 Corridor Coalition. ITS Seventh Annual Meeting, June 1997.

11. Lindquist, E. Crossing the Border to ITS Deployment, *ITS International Report*, March/April 1997.

12. Hallenbeck, M., J. Koehne, R. Scheibe, D. Rose, and J. Leech. Western States Transparent Borders Project: Institutional Barriers and Recommended Action-Washington. Seattle, WA, August 1993.

13. Register of United States Barriers to Trade. www.dfait-maeci.gc.ca, 1997.

14. Medelowitz, A. U.S.-Mexico Trade: Concerns About the Adequacy of Border Infrastructure. General Accounting Office Report to Chairman, Washington D.C., May 1991.

15. Beier, F. Institutional Barriers to the Adoption of Electronic Data Collection and Interchange as it Relates to Commercial Vehicles. University of Minnesota, St. Paul MN, December 1993.

16. Aguilera, M. C. High-Tech Border Cargo Plan Hailed. *San Diego Source News & Report.* San Diego, CA, December 1995.

17. Giermanski, J. Standards as Non-tariff Barriers: NAFTA's Impact. Institute for International Trade, Texas A&M University, Laredo, TX, February 1994.

18. North American Trade Community. Report to Heads of Customs. Prepared by Information Exchange and Automation Working Group. June 1995.

19. Marshall Macklin Monaghan, JHK & Associates, Constance Consultants. Preliminary Engineering and Design of IVHS/AVI New Technology Applications. Mississauga, Ontario, Canada, January 1997.

20. Current and Future Federal Applications of Tagging and Tracking Technology. Summary of Proceedings, Volpe Center, June 1996.

21. Gantz, D. Maximizing the Regional Benefits of North American Economic Integration. North American Trade Law, www.natlaw.com, 1997.

22. Keng, W. R., S. Govind, and C. M. Walton. Institutional Issues Impacting the Implementation of Intelligent Vehicle Highway Systems for Commercial Operations in Texas. Southwest Region University Transportation Center, Austin TX, February 1995.

23. Rayman, C. ITS Manager, Ontario Ministry of Transportation. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

24. Tsai, J. Ontario Ministry of Transportation. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

25. Lindquist, E. Research Scientist, Research Center of Excellence, Texas Transportation Institute. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

26. Houser, P. Signal Processing Systems. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

27. Nolle, B. U.S. Treasury. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

28. Rico, I. International Transportation Programs Engineer, Federal Highway Administration. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

29. Bransheildel, A. Peace Bridge Authority. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

30. Fundling, C. Booz, Allen, and Hamilton. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

31. Gandell, A. President, Niagra Falls Bridge Commission. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

32. Elias, J. Calspan. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

33. Jackson, L. U.S. Department of Transportation ITS/CVO Division. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

34. Livesay, D. Operations Manager, Montana Department of Transportation. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

35. Hicks, B. Transport Canada. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

36. Brady, D. Transcore. Advanced Border Crossing Survey Respondent, Texas A&M University June 1997.

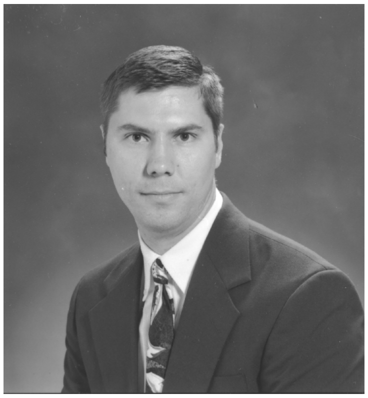
ACKNOWLEDGMENTS

Sincere appreciation is given to the mentors that participated within this program: Marsha Anderson, Ginger Gherardi, Thomas Hicks, Joseph McDermott, Colin Rayman, and Doug Robertson. Their insight into the future of transportation has given the students a positive outlook towards their careers. Deepest gratitude to Colin Rayman for providing the direction for this paper through his individual mentorship. Texas Transportation Institute has also given graduate students the unique opportunity to apply the theory and knowledge gained from classrooms to real world problems. Those researchers whom made significant contributions to this paper were Mr. Lewis Nowlin, Ms. Angelia Parham, and Mr. Eric Lindquist. Finally, special thanks to Mr. Karl Passetti and Mr. Aaron Hottenstein for their constructive criticism throughout the research of this project. As always, Dr. Dudek and Ms. Sandra Schoeneman have excelled in their efforts to increase the success of this program.

APPENDIX

Advanced Border Crossing Systems Survey

1. Which border crossing(s) is your agency involved with and what is its role?
2. What are some of the operational problems currently associated with this (or these) crossing(s)?
3. Are electronics/advanced technologies currently being used at the crossing(s)?
4. What forms of advanced technologies (Intelligent Transportation Systems) are in operation at your border crossing?
5. Would (have) the use of electronics/advanced technologies help(ed) solve the operational problems at the border crossings in which you are familiar (those listed in question 2)? Please Explain.
6. What are the physical, operational, or other characteristics associated with the border crossings that demonstrate the most potential for successful implementation and realization of benefits from electronics/advanced technologies (i.e. the physical space available, amount of traffic using the border crossing, etc.)?
7. Are there characteristics specific to certain border crossings that would hinder the implementation or success of electronics/advanced technology use? If so what are they?
8. What other agencies are currently involved with the operation of ITS at the border crossing with which you are most familiar?
9. Of the above agencies, which required the most change in order to effectively operate with new ITS technology?
10. What institutional changes took place within these agencies?
11. Do you believe there have been institutional barriers towards implementing ITS?
12. What institutional barriers do you feel have caused the most difficulty?
13. What interagency problems have arisen from differences in needs for ITS?
14. What solutions were used to correct these disputes?
15. What positive communication between agencies has developed due to ITS deployment?



Jon M. Collins received his B.S. in Civil Engineering from Texas A&M University in August of 1996. Jon is currently pursuing his M.S. in Civil Engineering at Texas A&M University. Jon has worked for DeShazo Tang & Associates, Inc. in Dallas, Texas as a summer intern in their traffic engineering section. He has been employed by the Texas Transportation Institute since September 1994, as both an undergraduate and graduate research technician. Topics relevant to his work at TTI include Bus Stop Design Simulation, Weaving on Frontage Roads, and Determination of Operating Speeds on Urban Arterials. His current area of research is in Design Consistency of Rural Two-lane Roadways. Jon has had a variety of opportunities to conduct data collection throughout the United States while working for TTI. University activities he is involved in included: Institute of Transportation Engineers, American Society of Civil Engineers, Student Engineering Council, and ITS America. His work interests include: geometric design, computer simulation modeling and public transportation issues.

IMPROVING INFORMATION FOR THE PRIVATE AUTO - TRANSIT TRIP: AN APPLICATION OF THE NATIONAL ITS ARCHITECTURE

by

Michael P. Dixon

Professional Mentor
Doug Robertson, Ph.D., P.E.
TransCore

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Dr. Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

Current transportation services rarely provide the unfamiliar traveler with sufficient information to determine which parking facilities are full, when to begin the trip, what transit agency services would be best to employ, and how to combine the transit and highway services into a feasible itinerary. This problem is even more apparent when the initial mode is the private auto and the others are transit related.

One of the current emphasis in the transportation arena has been the development and implementation of Intelligent Transportation Systems (ITS). The ITS concept can be used to facilitate the intermodal trip for the infrequent traveler by providing an ISP. However, the current ITS architecture does not address its application to the extent necessary for deployment of an ISP.

The research discussed in this paper was intended to address these two problems by describing a process for determining what information flows and services will be needed to support an ISP objective and what agencies might provide these information flows. In this research the ISP objective is to be able to support the development of a pre-trip itinerary for a private auto - transit trip in response to an infrequent traveler request. However, the process presented could be used for other ISP objectives as well.

The ultimate goal of this paper was to enable individuals not familiar with ITS nomenclature and architecture to understand what information is needed and what the bases are for developing interagency relations. This goal was achieved through the development of a process with multiple steps. The initial step included such tasks as formalizing the ISP objective, determining the traveler information needs, defining an ITS architecture relevant to the ISP information needs, and defining the urban area characteristics. The other steps included in the process were the determination of potential information flows and providers, the categorization of information flows, and the determination of the significant information flows and providers.

This process provides a direct link between the National ITS Architecture and its application in urban areas. Furthermore, the process allows local operational and administrative personnel to more easily understand who the information providers are without extensive use of the architecture documents themselves.

Demonstration of this process was given through a hypothetical situation and an actual situation showing that the process would be quick, intuitive, and effective for application in the real world. The process is quick because the information needed is readily available; it is intuitive because it associates information providers, the primary concern, to actual agency services in the urban area; and it is effective as it relates the desirable information flows to the possible information provider agencies, within the urban area. This provides a basis on which agency relations and cooperation can be sought; the individuals involved would know what information is needed from which agencies to increase infrequent traveler access to points of interest in an urban area using the private auto and transit transportation modes. This is an initial step to the development of an ISP for the infrequent traveler.

TABLE OF CONTENTS

INTRODUCTION

Problem Statement

The transportation system is comprised of many components including cars, buses, and commercial vehicles, highways/streets, transit, and rail. These components represent different services provided in the transportation system. The transportation system is not only comprised of different components, or services, but agencies as well. These different services and agencies create functional borders that tend to break up or inhibit the interoperability of the transportation system as a whole. This inhibited interoperability becomes more apparent to an individual requiring services from multiple modes of transportation and transportation related agencies.

An example would be the case where a infrequent traveler desires to make a trip from a suburban area with no transit service to the central business district (CBD); where an infrequent traveler is defined as an individual with little prior knowledge of existing transportation services between an origin and destination. In large urban areas, completing this suburban to CBD trip may require the traveler to cross several municipalities and perhaps use the services of more than one transit providers.

Information describing the transit services is often available to the traveler, but it is seldom obtained from the same source. Furthermore, if the information describing transit service for the metropolitan area as a whole is available from one source it does not take into account the traveler's desired departure time, especially when the initial phase of the trip is made by a private auto (1). This demonstrates that current transportation services do not communicate information in such a manner as to allow the traveler to make informed decisions related to his or her multi-modal trip itinerary when one mode is the private auto and the others are transit related.

There are various reasons that travelers desiring private auto - transit trip information cannot easily obtain the necessary information to facilitate such a trip. One reason may be the lack of coordination between the operating agencies -- highway and transit alike. Traditionally highway agencies have functioned independently of transit agencies creating a disconnected transportation system with limited communication between the two systems.

Figure 1 shows a diagram describing a hypothetical urban area where a user that desires to make a trip from point A to point B would like to determine how best to complete the trip. The traveler must decide whether to use Freeway 10 or Freeway 20, the time of departure, the appropriate light rail transit (LRT) to catch on the freeway alignments, and what bus to transfer to in the CBD to complete the trip. For an infrequent traveler in a typical large urban area this is no small task.

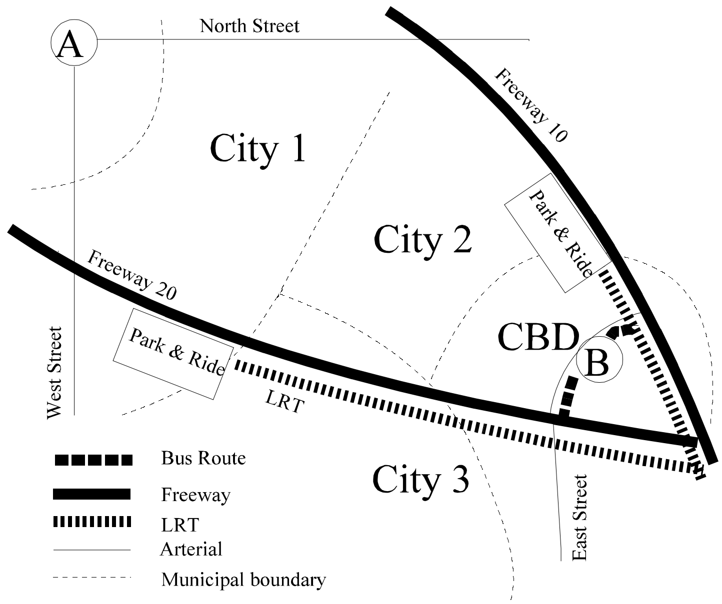


Figure 1. A Hypothetical Urban Area.

Current practice supplies little information to users in order to allow them to make informed decisions with respect to their trip itinerary (1). As a result, traveler choices are often severely limited. Rarely does the traveler have sufficient information to determine which parking facilities are full, when to begin the trip, what transit agency services would be best to employ, and how to combine the transit and highway services into a feasible itinerary. The problem becomes even more pronounced in the case of an infrequent traveler whose information needs are even greater.

The problem is perplexing, at best, and is not easily resolved, especially in light of the many operating agencies that are often involved in urban transportation systems. Transportation efficiency could be significantly increased if highway and transit operating agencies could communicate, and thus operate, in a more coordinated manner. Trips involving the private auto may be difficult to incorporate transit modes due to the low accessibility of transit information for the urban area as a whole including park and ride information. Similar problems exist between transit systems where their respective databases do not take into account overlapping routes of different transit systems, among other important items of information such as incident effects.

These problems experienced in providing information to travelers often result from under staffed agencies having to operate with ever shrinking budgets. As a result creative methods and practices are needed to improve transportation services given agency staffing and budgetary constraints.

One recent area of emphasis in the transportation arena has been the development and implementation of Intelligent Transportation Systems (ITS). A recent project underway in the Washington DC Metropolitan Area is an effort to provide traveler information, describing among other things the services to be provided, the agencies providing the services, and the respective data types to be provided by the agencies. Some services are provided by as many as ten agencies; while some of those agencies provide multiple services, giving rise to a very complex situation. All of this is an effort to provide Washington DC travelers with accurate real-time traveler information (2).

ITS technologies can be used to facilitate the intermodal trip for travelers. This is accomplished through a central information service provider, or ISP. However, a recently developed National ITS Architecture does not address ITS applications to the extent necessary for direct regional and or local application (3). An element of the problem that is addressed within the ITS architecture is the data flow between the architecture subsystems (i.e. Emergency Management, Roadway Subsystem, Transit Management, Information Service Provider, etc.); however these subsystems and their respective data flows were never superimposed over a hypothetical urban area, with its operating agency/jurisdictional boundaries (3).

As a result the existing National ITS Architecture is somewhat distanced from actual implementation. It defines possible data flow between subsystems (which may or may not correspond to different operating agencies) but may not provide sufficient guidance towards the actual implementation of an intermodal ITS supplying information to an infrequent intermodal traveler (3).

Figure 2 graphically describes the general information flows and services supporting the traveler in making trip decisions. This figure demonstrates the existing information flows and services (solid lines and boxes) and the desired information flows and services (dashed lines and boxes). The existing information flows represent the current situation where the traveler must request information of each service. On the other hand, the desired information flows are those needed to support an information service provider (ISP), which would eliminate much of the traveler's workload in creating a viable trip itinerary. The arrangement of the desired information flows would have the various transportation services acting as information providers to the ISP.

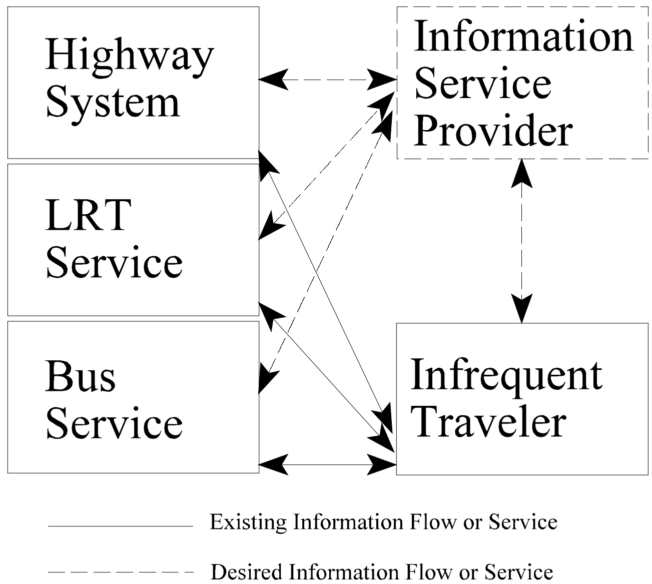


Figure 2. Demonstration of Information Providers.

The list below summarizes some of the current problems in U.S. urban transportation systems related to the provision of information describing private auto - transit services to the infrequent traveler.

- The infrequent traveler must go to several independent information sources to put together a combined private auto - transit trip.
- The National ITS Architecture does not give sufficient guidance on how to determine the information providers and desired information flows for large urban areas in order to fully meet the infrequent traveler needs.
- The National ITS architecture provides suggested data flow and services with little guidance on determining which agencies should collect, fuse, and disseminate the data.

Research Objectives

The research objectives that are listed below are in direct response to the above problem statement summary and were the focus of this research paper. The research objectives were the following:

- <u>To develop a general process for identifying important agency relationships</u> Achievement of this objective seemed to be the logical first step to facilitate information exchange between transit, traffic management, and other service providers and a hypothetical information service provider. This was based on the information needs of the infrequent traveler in a typical urban area desiring to make a combined private auto - transit trip from one point to another in an urban area. However, the process can be used to support other ISP purposes.

- To identify the typical information providers relative to the specific information needed by the infrequent traveler. Relation of the information providers to the information needed of them was stated in terms familiar to transit and highway systems operators and administrators to aid them in understanding what cooperative interagency efforts might need to be arranged and for what reason (i.e., what information). This required investigation into current operations in several urban areas in addition to accurate interpretation of the ITS architecture documents.
- To demonstrate how this process can be applied to the transportation systems of today: Demonstration of the process showed how the research results (the process developed) could be used in creating an optimal information source for the infrequent traveler desiring to make a private auto - transit trip. The process could be used to determine what agency relations/coordination must be developed.

Scope of Research

The ultimate goal of this paper was to enable individuals not familiar with ITS nomenclature and architecture to understand what information is needed and what the bases are for developing interagency relations.

The research discussed in this paper concentrated on resolving the information availability problems experienced by an infrequent traveler wishing to develop a trip itinerary including travel from a suburban area with no transit to locations where several transit options exist (as detailed in Figure 1). Infrequent travelers were considered as opposed to all travelers since their information needs are on a larger scale. Therefore, meeting the information needs of the infrequent traveler would most likely meet the needs of the other travelers as well.

The problem of determining what information is needed and where it will come from was the focus of the research. This was done by applying the relevant portions of the ITS architecture to this research. The relevant architecture was then applied to a hypothetical urban area similar to Figure 1, taking into account the information needs of the infrequent traveler.

The end result of this research was the development of a process to identify the desired information and the information provider to support an ISP objective in an urban area. A relation of the desired information items to the different types of agencies likely found in an urban area was also introduced. This research did not consider factors contributing to communication difficulties such as differences in ideology, budget constraints, technology availability, etc.

The ISP objective, in terms of this research, was the pre-trip development of private auto - transit trip itineraries for the infrequent traveler. This ISP objective embodied the scope of research, enabling the researcher to apply this scope to the process of specifying information providers and desired information items.

A direct link between the ITS architecture and its application in urban areas was provided through this research allowing operational and administrative personnel at the regional and local levels to more easily understand what the information needs are without extensive use of the ITS architecture documents themselves. Understanding the information needs provides a basis on which agency relations and cooperation can be sought since the actual individuals involved would know what information is needed from which agencies in order to support the ISP objective.

Research Methodology

In response to the above stated problems and research scope a research methodology was developed. The next five sections describe a general process for approaching the problem of providing a convenient and useful ISP service to the infrequent traveler. Below is the list of tasks that were performed to explain and demonstrate the process:

- Task 1: Identify the Infrequent Traveler Needs.
- Task 2: Examine the Current Practices and National ITS Architecture and Define a Hypothetical Urban Area.
- Task 3: Identify the Potential Information providers.
- Task 4: Determine the Significant Information Flows and Providers.
- Task 5: Summarize the Process.
- Task 6: Apply the General Process to an Actual Urban Area.

TRAVELER INFORMATION NEEDS

Transportation is a service provided to the population in general. Businesses use the transportation system as a means to transport goods and services while private individuals use the system to facilitate personal trips. The purpose of the task discussed in this section was to establish exactly what the traveler needs are for personal trips. These needs were based on a combination of the guidance provided in the ITS architecture documentation, reports discussing traveler needs, and the research scope.

The needs of travelers are different depending on the characteristics of the trip, the transportation system, and the traveler. Variables associated with the trip might be the trip length, time of departure, and trip frequency. The location of the points of origin and destination (O-D), the operating agency boundaries between the O-D, the plausible modes of transportation, available parking, and travel time are examples of transportation system variables. Variables associated with the traveler may be urban area familiarity, health, and mobility.

Traveler information can be categorized under two headings: en-route travel information, and pre-trip travel information. The mediums used to communicate these categories of information is quite different with en-route information being communicated via changeable message signs, highway advisory radio, cell phones, in-vehicle devices, etc; while pre-trip information is communicated using personal computers, kiosks, television, telephones etc. From these examples it should be readily apparent that there may be some differences in information needs relative to en-route and pre-trip traveler information. A study of Orange County commuters indicated that rerouting information was much more useful prior to beginning the trip, or as pre-trip information (4).

A study by the Texas Transportation Institute in 1977 on freeways in Houston, Texas was performed surveying travelers routing behaviors. This study determined that most travelers choose their routes based on convenience, directness, and smallest relative travel time of the route alternatives. Motorists indicated that they desired route guidance, level of congestion, and locations of incidents to evaluate route alternatives. Study results also indicated that driver familiarity plays a large role in routing decisions. An unfamiliar driver would be much less likely to divert from the freeway than a driver familiar with the area. Information system credibility is a significant issue as well, because travelers must be convinced that a change in route would save them time in the end (5).

Traveler information can also be categorized in terms of its update frequency. Consider two categories: static information and dynamic, or real-time, information. Transit and parking information are almost always static, not changing to reflect the changes in the traffic patterns or parking availability, while freeway operations information often changes to reflect variations in speed or flow or the detection of an incident. Clearly real-time information is preferable to static information in many cases, although the actual benefits of utilizing real-time information varies substantially with the dynamic operations of the transportation system. Regardless of what the actual benefits of real-time information are, surveys of motorist information needs or demands have indicated that travelers would prefer real-time information (6).

The observations recorded in Orange County, California were in agreement with the study performed by the Texas Transportation Institute in 1977. According to the Orange County Transportation Authority (OCTA) information that is most sought after by travelers is the following, by order of importance (4):

Real Time Information:
- locations and extent of traffic delays and congestion
- travel times of alternative routes/modes from point of origin to final destination
- expected arrival time of next transit vehicle
- roadway/weather conditions
- major highway status summaries (e.g., speeds, volumes)
- parking availability at park and ride lots and/or commuter rail stations

Non-recurring Event Information:
- planned roadway construction or major repairs and resultant expected delays and/or detour information

Static Information:
- transit schedules
- general travel directions
- transit fares

The above specific bulleted items of information may be provided by one source or several sources. For example, traffic delay information can be obtained from a traffic control center, a motorist's cellular phone, or the news media. Also information from one source may be more important than another (e.g., freeway information may be more important than surface street information, especially in the case of a longer trip). Additionally, some information items may need to reflect changes in another item, such is the case with traffic delays, travel times, transit vehicle estimated time of arrival, and transit vehicle travel directions, which are effected by one or more of the items listed above.

The National ITS Architecture: Theory of Operations document also provides some input related to the traveler information needs. According to the document the pre-trip travel information needed by the traveler is the following (7):

- incident details
- alternative routes
- parking lot occupancy
- traffic conditions for ramps, occupancy estimates, car pool lanes
- pollution levels
- link times and queue delays
- transit schedules and deviations
- fare, parking, and toll charges
- various special event and commercial or public service information

A review of the two bulleted lists above reveals that there are many information items that are in common or cover similar areas and as a result it can be assumed that the National ITS Architecture and OCTA study are more or less in agreement. At this point it is necessary to state what the information needs of a typical user population are. For this a statement of conditions is needed to clarify the traveler and trip characteristics. Travelers emphasized in this research can be described by the following user and trip characteristics:

- infrequent traveler
- safe efficient transportation is desired
- pollution levels have little effect on the trip itinerary
- trips are longer in duration and distance
- trip origin may be in a suburban area
- trip destination is in an urban area with access to transit
- both private auto and transit are to be used

Based on the above items, the traveler information needs should be defined to account for travelers unfamiliar with the particular trip, who want to make efficient use of private auto and transit modes. Infrequent travelers were selected as the focus group for the research establishing the relevance of items of information that might seem trivial to commuters or other types of familiar drivers.

It is assumed that pollution levels will have little effect on trip or mode choices and the respective routes. Furthermore, the assumption of a longer trip duration and distance makes additional efforts for pre-trip planning more economical. The statement that the traveler may originate from a suburban area makes the no transit option for the initial portion of the trip reasonable since there could be a large number of residences that would not have access to transit.

With the previously stated assumptions the traveler information needs to be used in this research can be derived from the previous listings of traveler information needs. The traveler information needs used in this research are as follows:

- locations and extent of traffic delays and congestion
- travel times of alternative routes/modes from point of origin to final destination
- expected arrival time of the next transit vehicle
- roadway/weather conditions
- major link status summaries (e.g., speeds, volumes)
- parking availability at park and ride lots and/or commuter rail stations
- planned roadway construction or major repairs and resultant expected delays and/or detour information
- transit schedules and deviations
- general travel directions
- transit fares, parking fees, and toll charges
- various special event and service information

The order of the above items of information is not significant in this case. This is because the scope of this research varies from the traveling habits of the general public which, in the U.S., tends to prefer the use of the private auto. The above information is displayed to summarize the overall information needs of the traveling public. Information needs of both private auto users and transit users seem to be adequately represented in the list.

To meet these information needs various data must be collected from several sources. All of these sources are most likely separated by communication impediments where the sources may be different operating agencies (e.g., bus agency, rail agency, departments of transportation (DOTs)). Some items listed above require data from more than one source, such as the item containing transit fares, parking fees, and toll charges. The data for this item would be obtained from toll authorities, transit agencies, and parking facility administrators. Bringing together these data alone would be no small task, and becomes much more complex when presented with the option of various highway/street routes to be taken to meet potential transit services (3).

SUMMARY OF SELECTED CURRENT SERVICES

This section of the research discussion provides a summary of how current services provided in two different urban areas meet the needs of the traveler. Need for the research was established based on this summary which also provided a more in depth knowledge of highway and transit system functions. Knowledge of the system functions allowed the determination of the extent to which current services meet multi-modal infrequent traveler information needs for pre-trip planning.

Southern California

The Southern California traveler information accessed by the author via its web site provides links to web sites describing transportation operations in several Southern California counties: Los Angeles County, Orange County, Ventura County, Riverside County, San Bernardino County, and San Diego County. San Diego County information was not considered as it covers a different urban area from the other counties. Traveler information on the web site provides links to bike, transit, and highway information. The highway information includes only the local freeways and is updated every minute with potential accidents, prevailing speeds, and road closures. All of which can be viewed on an area map or in a list of freeway segment conditions (8).

Fares, estimated travel times, schedules and route maps describe transit operations. The transit information can be accessed via the METROLINK, LA rail, and local municipality home pages. The Ventura County Transportation Authority (VCTC) maintains a home page that offers a transit route building service. This service will put together a feasible itinerary that accounts for the majority of the transit systems in Ventura, L.A., Orange, Riverside, and San Bernardino counties. The route builder also considers airport shuttles and provides walking distances and instructions to the various transit stops that need to be accessed (9, 10).

There are several transit agencies involved in the transit operations in this region. The three major operators are L.A. MTA, the Orange County Transportation Authority (OCTA), the Ventura County Transportation Authority (VCTA), Riverside County Transportation Authority, San Bernardino Association of Governments, local municipality transit agencies, and the Southern California Regional Rail Authority (SCRRA) which is a conglomeration of all the previous agencies (excluding the local municipalities).

The transit options include shuttle busses used in the downtown area of L.A. and between major hotels and the LAX airport; busses operated by the individual transportation authorities and local municipalities, light rail operated by the L.A. MTA; and a heavy commuter rail operated by SCRRA. It is readily apparent that the mentioned systems vary markedly in terms of their coverage areas. The shuttle busses are limited to hotels, airports and downtown L.A. while the L.A. MTA light rail system spans L.A. County, and the heavy rail operated by SCRRA spans several counties (10).

One can put together an itinerary employing several transit systems using Internet services provided by some of the operating agencies. The transit route builder, provided by the VCTA, includes transfers that must be made, fares that need to be paid, departure and arrival times, and walking maps to the transit boarding sites for a submitted origin and destination (9). METROLINK provides a service similar to VCTA's router; the difference is that theirs does not consider any other transit systems and it provides all possible alternative itineraries, leaving the final decision to the traveler (10).

The METROLINK and L.A. MTA web sites both provide information describing parking (total number of spaces and required fee), points of interest accessed by nearby rail stations, and connecting bus and rail lines (10). None of the route building services described integrate parking information or highway information into their itineraries. Both transit services use static data for transit information and separate links to real-time information for highway operations(10).

Atlanta

Information for this urban area was obtained from the Atlanta Traveler Information Showcase web site. All modes of transportation, except bike or pedestrian facilities, are represented in a variety of ways.

Highway information is communicated using a map interface that visually informs motorists of trouble spots on the freeway network using color coded icons and dots. The colors represent various ranges in speed, and the icons represent accidents and roadwork. Motorists can access more detailed operational information concerning a desired freeway section by clicking the corresponding link on the map. Detailed accident information is available in text also. The highway information also provides a route planning function that allows the user to indicate origins and destinations in the form of an address or point of interest. The description of the route is in text and provides detailed information that includes all turn movements and the name of all roadways used (11, 12).

Other motorized modes that are represented on the Atlanta ATIS web site are bus, rail, and long distance modes such as Amtrak, Greyhound, and airlines at Hartfield Airport. Other modes that are available are taxi, limousine, and auto rental services (13, 14).

There are two transit agencies that operate in the area, the Metropolitan Atlanta Rapid Transit Authority (MARTA) and Cobb Community Transit (CCT). MARTA operates both light rail and bus systems while CCT operates only busses. MARTA and CCT information includes parking, points of interest, connectors, rail distances and travel times, and schedules and fares. Maps are provided to help locate MARTA train and bus stations and to display the points of interest and MARTA parking facilities. This site uses tables to describe MARTA's bus/rail fares and schedules. All of the transit information is supported by static data which does not reflect changing traveling conditions. No transit route building is provided (14).

Both the Southern California and Atlanta, Georgia information sites do describe transportation operations to a degree, including both highway and transit data. However, little is done to truly bring the highway and transit information together into a database that does not require the prospective traveler to search for options manually. The route building functions offered by both services do reduce the manual efforts to a degree, but fail to integrate highway and transit information in a way that allows multi-modal trip planning for the infrequent traveler. Furthermore, all of the transit information is static because it does not reflect traffic pattern variations due to inconsistencies such as congestion, inclement weather, accidents or road work. Transit route planning provided by the VCTC in Southern California does successfully consider many transit agency services but remains isolated from the highway system information.

The information problems in the two summarized cases are associated with the exchange of freeway information and surface street information, emergency information, weather information, information associated with the travelers trip purpose (e.g., business hours, business address, etc.), transit related information, and parking information. While some of these items may be integrated with a common ISP, the majority of the problems associated with information exchange remain, inhibiting the flow and availability of information relevant to a traveler creating a trip itinerary.

ITS ARCHITECTURE DEFINITION

Definition of an ITS architecture is discussed in this section accounting for the National ITS Architecture services and information flows and the stated traveler needs. The ITS architecture definition is discussed reviewing the steps taken to define the architecture and describing the architecture itself to the extent necessary. The architecture that results from this process is referred to as the Defined ITS Architecture.

Defining the applicable ITS architecture provides a more complete picture of the most likely information providers and associated information that are needed to support the ISP objective. Included in the discussion are the steps taken to define the information sources and the information flows between the sources. ITS architecture documentation commonly refers to these sources as subsystems and terminators; however, since all of them provide or represent some service, they are referred to as its services.

First it is necessary to strengthen the readers understanding of what the National ITS Architecture is.

> "The National ITS Architecture provides a common structure for the design of intelligent transportation systems. The architecture defines the functions (e.g., gather traffic information or request a route) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle), the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows (e.g., wireline or wireless). In addition, it identifies and specifies the requirements for the standards needed to support national and regional interoperability...."(15)

The National ITS Architecture is a collection of efforts detailing how various operational subsystems can be operated as a system. There are several volumes of reports explaining the architecture in detail.

The National ITS Architecture was used as a template containing the necessary services and information flows some of which were needed to support the ISP objective. Once the template was understood its various elements were assessed and those that were not directly applicable to this research were discarded. In one case an element had to be added, this is discussed in further detail later in this section.

Several general steps or considerations were made in order to define a reasonable ITS architecture for this research. The steps are as follows:

- Eliminate the unnecessary services and their respective information flows (i.e. Roadside System, Vehicle Subsystem, Planning Subsystem, etc.).
- Combine services where appropriate (e.g., the information service provider operator and Information Service Provider.).

- Eliminate superficial information flows and add those relevant to this research (i.e., information not pertinent to the research scope, requests for information, etc.).

For some of these steps the supporting reasoning is readily apparent; however, for others this may not be the case. Therefore, the reasoning behind each of the steps and their respective modifications to the architecture is stated in the following discussion to allow the reader a greater understanding of how the ITS architecture was defined.

Eliminating Unnecessary Services and Information Flows

The first step was to eliminate a major portion of the architecture elements unnecessary to this research. The following items are types of services referred to in the ITS architecture as subsystems or terminators. When an item is mentioned as being eliminated, or not included, then it should be understood that the related information flows are eliminated as well. The subsystems, or services that were eliminated were the following:

- Financial institution (i.e., bank or credit card information): The service provided by this element was outside of the scope of this research since monetary transactions do not necessarily have to be made during the pre-trip planning process. It would be considered an added convenience but not an addition to the travelers body of knowledge or understanding of the urban area transportation system operation.
- Vehicle: The scope of this research does not include the possibility of en route trip planning which would be the primary reason for this element's inclusion in the final ITS architecture.
- Personal Information Access/Remote Traveler Support: These elements would be of interest if this research were concerned with the actual technology used to provide the information to the traveler; however, this is not the case. This research remained independent of the medium by which travelers can receive the required information.
- Planning: This element is intended to aid in the improvement of the transportation system with the primary function of providing planning information and support for facilitating the deployment and operation of ITS services (15). It was not intended to support a traveler information service, but to acquire information from the service.
- Intermodal Transportation Service Provider: The services provided by this element are also outside of the scope of this research, although the name does sound promising. This element focuses on the transportation modes of air, ferry, and heavy rail (e.g., those which do not form part of a transit operation) all of which are outside the scope of this research (15). Although they could play an important role in a traveler's decisions ,the scope of research includes only transit options such as bus, light rail, commuter rail, and the private auto option.
- Fleet and Freight Management: This element was not included for the obvious reason that it deals with the movement of goods and/or services while this research is concerned with the movement of people.

Combining Services

The second step performed by the author of combining services where appropriate made some modifications to the National ITS Architecture based on some reasonable assumptions. The modifications and their respective assumptions are described below.

- ISP Operator: This element was included in the National ITS Architecture to represent the human element of the ISP (15). However, for the sake of simplicity the assumption was made that the Information Service Provider subsystem includes the human element as well.
- Media and Media Operator: These two elements were combined to represent communications with other services that may have information of interest to a traveler. However, keep in mind that these two services are distinctly different, as defined in the National ITS Architecture. The Media service only includes output devices or systems such as printers, visual displays, highway advisory radio, and FM sub-carrier information systems. The media Operator service is associated with TV/radio broadcaster operators, traffic reporting service operators, private citizens, etc. Combining these two services basically establishes an element representative of miscellaneous services that may have relevant input for an ISP (15).

Eliminating and Adding Information Flows

The final step in modifying the National ITS Architecture to fit the scope of research was to eliminate superficial information flows and add those relevant to this research

- Information requests: All of the information flows from the ISP to the various services were classified as superficial for this research since it is a given that the ISP needs to request the information and this research is more concerned with the information coming to the ISP rather than how it is requested.
- Information flows from the ISP to other elements: These flows were not considered since they do not directly enhance the information available to the traveler and this research is not concerned with the medium by which the traveler receives the information (i.e., kiosks, the Internet, etc.).
- Road Conditions: This information flow was added to the architecture since in many urban areas, this information may influence the traveler to switch routes and/or modes of transportation due to hazardous roadway conditions (e.g., fog, ice, snow, wind, rain, etc.). The National ITS Architecture only defines this information flow as reaching the roadway subsystem (15). No information flows containing this information are defined at any other point.
- Other routes map data: This data flow is sent by the map update provider to the ISP and contains a new copy of the digitized map data used to select other, i.e. non-vehicle and non-transit, routes (15). Since this research was focused on transit and private auto modes of transportation this data flow was deemed irrelevant.

After all of the modifying steps were completed the Defined ITS Architecture for this research was representative of a one way network describing where the ISP would acquire the necessary information required to support the ISP objective (see Figure 3).

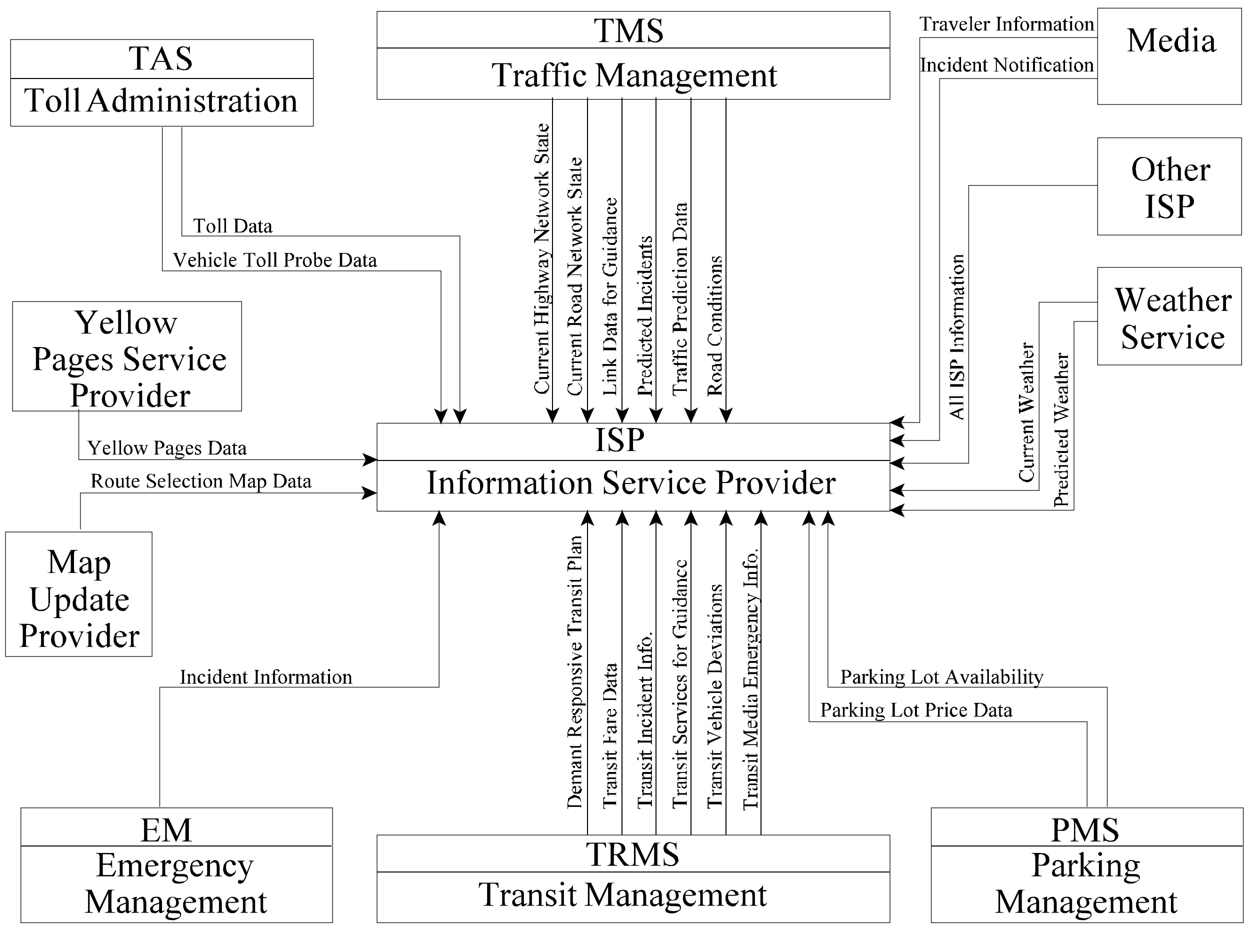


Figure 3. Defined ITS Architecture

Definition of Information Flows and Sources

The data to be exchanged through the information links varies but in some cases is quite similar. Following are brief explanations of what information is to be exchanged between the ISP and the respective ITS services. Also following is a table of traveler information needs relating them to the specific ITS architecture information flows. These definitions were taken from the National ITS Architecture documentation with some modifications for the sake of brevity, understanding, and compatibility with the scope of this research.

After the steps taken to modify the National ITS Architecture were completed each service and the associated information flows were defined. Definition of the architecture elements establishes a common understanding of the ITS services and each information flow. All of the communication or information flow is from the various ITS services to the ISP, which gathers information, processes it, and disseminates it to users upon request. This is the basic definition of an ISP, the remaining ITS services and associated relevant information flows are defined in the following discussion.

Traffic Management

The Traffic Management service is usually provided within a traffic management center or other fixed location. This subsystem communicates with in-field equipment to monitor and manage traffic flow. Incidents are detected and verified and incident information is communicated to the ISP. The subsystem supports demand management policies that can alleviate congestion and influence mode selection; monitors and manages maintenance work; manages reversible lane facilities; and communicates with other Traffic Management Subsystems to coordinate traffic information and control strategies in neighboring jurisdictions (15). The relevant information flows are the following:

1. Current highway network state: This information flow contains data describing traffic conditions on freeway sections in the freeway network served. It consists of the following data items: road section travel time and delay (in addition to free flow travel time) (15).
2. Current road network state: This flow contains data describing traffic conditions on road sections in the surface street network served. It consists of the following data items: travel time and delay (in addition to free flow travel time) (15).
3. Link data for guidance: This data flow contains data for use in determining which other ISP('s) must be contacted to obtain data describing road and freeway sections in geographic area(s) outside that served by the local ISP. It consists of the following data items: roadway segment identity and corresponding ISP identity (15).
4. Predicted incidents: This data flow contains details of known incidents due to take place in the future (e.g., recurrent congestion, sports events, etc.). It contains the following data items: incident location, incident type, incident severity, incident description, and incident traffic impact (15).
5. Traffic prediction data: This data flow contains output from a predictive model process showing predictions of traffic data for route segments on the road and highway network served. The data flow consists of the following items: route segment volume and delay predictions, route segment queue delay predictions, and route segment occupancy predictions (15).
6. Road conditions data: This data flow contains details describing the physical road and weather conditions effecting the traveler (e.g., ice, fog, rain, snow, etc.) (15).

Transit Management

The Transit Management service provides the capability for furnishing travelers with real-time travel information, continuously updated schedules, schedule adherence information, transfer options, and transit routes and fares. Transit incidents are also managed through this service (15). Associated information flows relevant to the ISP objective are the following:

7. Demand responsive transit plan: plan regarding overall schedules and deployment of the demand responsive transit system (15).
8. Transit fare data: this data flow contains details of the fares being currently charged for transit services (15).
9. Transit media emergency information: this data flow contains information about an incident or emergency that has been detected on board a transit vehicle or at a transit facility following

input from a transit user, transit vehicle driver, or automatic detection. It consists of the following data items: transit driver emergency request, transit user emergency request, transit vehicle location, transit incident details, incident location, incident start time, incident duration, and incident severity (15).

10. Transit services for guidance: This data flow contains a complete set of all the transit routes and the services that run upon them, including timings, etc. that are provided by the transit system from which the data was requested. The data contains the details of the transit routes(s) that fulfil the origin-destination requirements of a particular transit user or traveler's request and is in the form of on-line driver and traveler guidance data. The data flow consists of the following data items: transit route number, transit route segment numbers, transit route segment costs, and transit stop scheduled time. The route segment can be separated by transit stops, or other definitive location, to account for fares that vary according to distance (15).
11. Transit vehicle deviations details: this data flow contains details of the deviations of transit vehicles from their published routes and schedules. The data flow consists of the following data items: transit vehicle estimated time of arrival, transit vehicle deviation update, transit vehicle location, transit vehicle schedule deviations, transit vehicle passenger loading, and transit vehicle running times (15).

Parking Management

Parking management provides the capability to communicate parking availability and parking fee information, and supports the detection, classification, and control of motorists seeking parking (15). The relevant information flows are the following:

12. Parking lot availability: this data flow contains details of the number of spaces available in the lot. The data flow consists of the following items: parking lot identity and parking lot spaces (15).
13. Parking lot price data: this data flow contains the prices being charged by each parking lot for each of its spaces, together with the time and date for which they apply. It consists of the following data items: parking lot identity, parking lot price, charges for prospective usage period, application time, and charges for vehicle (15).

Toll Administration

The Toll Administration service provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees. The service sets and administers the pricing structures and includes the capability to implement road pricing policies in coordination with the Traffic Management Subsystem and to communicate the prices to the public (15). Information flow supporting the ISP objective are the following:

14. Toll data: current toll schedules for different types of vehicles (15).
15. Vehicle tolltag probe data: this data flow contains the smoothed average vehicle travel times for the route segment between two toll collection points, and the identity of the route segment (15).

Media

This service represents the miscellaneous entities from which the ISP may collect traffic flow information, incident information, special event information, or any other travel impacting events. An entity may be a TV/radio broadcaster, traffic reporting service operator, private citizens, an output device such as a printer or visual display, or a system of some kind (e.g. a Highway Advisory Radio (HAR) or a FM sub-carrier information output system). The output devices may notify the ISP of an event impacting the transportation system that has not yet been recorded (15). The relevant information flow associated with this redefined service are the following:

16. Traveler information: this data flow contains information that the media has that might be of interest to travelers planning trips. This may include but not be limited to such things as special events, sports events, etc. (15).
17. Incident details: this data flow contains data about an incident that has been reported by a member of the traveling public to the media operator by mechanisms that are outside of ITS (e.g., car phone). The data flow consists of the following items: incident location, incident severity, incident type (15).

Weather Service

An external source of current and forecast weather conditions. This externally derived weather data is integrated with the other information collected and disseminated by the ISP to support travel planning (15). The relevant information flows that are communicated from this service to the ISP are the following:

18. Current weather: this data flow contains details of the current weather conditions, e.g. temperature, pressure, wind speed, wind direction, humidity, precipitation, visibility, light conditions, etc. (15).
19. Predicted weather: this data flow contains details of the predicted weather conditions, e.g. temperature, pressure, wind speed, wind direction, humidity, precipitation, visibility, light conditions, etc. (15).

Other ISP

This service is intended to provide information flows from peer information service providers. It is representative of cooperative information sharing between providers as conditions warrant (15). The information flow relevant to the ISP objective is the following:

20. All ISP information: coordination and exchange of all types of information on behalf of an ISP user (15).

Yellow Pages Service Provider

This service represents organizations that provide any service oriented towards the Traveler. Example services that could be included are gas, food, lodging, vehicle repair, points of interest, and recreation areas. The interface with the Service Provider is necessary so that accurate, up-to-date service information can be provided to the traveler for scheduling purposes (15). The associated information flow is described as follows:

21. Yellow pages data: this data flow provides information on yellow pages services in two forms comprising that of general interest and more specific items. This service will provide access to information regarding hotels, restaurants, and other points of interest (15).

Emergency Management

The Emergency Management service operates in various emergency centers supporting public safety including police and fire stations, search and rescue special detachments, and hazardous material response teams. The service tracks and manages emergency vehicle fleets possibly using automated vehicle location technology and two way communications with the vehicle fleet. It also provides incident information to the ISP to communicate such details as estimated duration, severity, etc. (15). The relevant information flow associated with this service is the following:

22. Incident information: this information provides notification of the existence of an incident, expected severity, location, and nature of the incident. This data flow consists of the following items: incident number, incident location, incident start time, incident duration, incident type, incident severity, and incident traffic impact (15).

Map Update Provider

This service represents a third-party developer and provider of digitized map databases used to support the ISP services. It supports the provision of databases that are required exclusively for those used for display by operators and at traveler information points, e.g. kiosks, Internet, etc. (15). The associated information flow relevant to the ISP objective is described as follows:

23. Route selection map data: This data flow contains an update of the digitized map data used to produce vehicle based routes for trip planning and on-line guidance purposes (15).

Table 1 relates the information flows described to the specific traveler information needs introduced in the Traveler Information Needs section. The numbers preceding the information flows listed correspond to the numbers assigned to each information flow when they were defined for easy referencing. This demonstrates the extent to which the defined ITS architecture information flows support the traveler information needs. It should be noted that all listed items have more than one ITS architecture information flow assigned. It should also be noted that some information flows can be used to meet several of the traveler information needs.

Table 1. Traveler Information Needs Related to ITS Architecture Information Flows.

Traveler Information Needs	Information Flows
locations and extent of traffic delays and congestion	3. link data for guidance 4. predicted incidents 5. traffic prediction data 17. incident details 20. all ISP information 22. incident information
travel times of alternative routes/modes from point of origin to final destination	1. current highway network state 2. current roadway network state 3. link data for guidance 5. traffic prediction data 15. vehicle tolltag probe data 20. all ISP information
expected arrival time of the next transit vehicle	3. link data for guidance 5. traffic prediction data 9. transit media emergency information 10. transit services for guidance 11. transit vehicle deviations details 15. vehicle tolltag probe data 20. all ISP information
roadway/weather conditions	6. road conditions data 18. current weather 19. predicted weather 20. all ISP information
major link status summaries (e.g., speeds, volumes)	3. link data for guidance 5. traffic prediction data 20. all ISP information
parking availability at park and ride lots and/or commuter rail stations	12. parking lot availability 20. all ISP information
planned roadway construction or major repairs and resultant expected delays and/or detour information	3. link data for guidance 7. demand responsive transit plan 20. all ISP information
transit schedules and deviations	7. demand responsive transit plan 9. transit media emergency information 10. transit services for guidance 11. transit vehicle deviations details 20. all ISP information

Table 1. Traveler Information Needs Related to ITS Architecture Information Flow (Continued).

Traveler Information Needs	Information Flows
general travel directions	10. transit services for guidance 20. all ISP information 23. route selection map data
transit fares, parking fees, and toll charges	8. transit fare data 10. transit services for guidance 13. parking lot price data 14. toll data 20. all ISP information
various special event and service information	16. traveler information 20. all ISP information 21. yellow pages data

HYPOTHETICAL URBAN AREA

This section should be referred to as a portion of the initial step in the proposed process where the urban area is defined and the characteristics are specified. In the following discussion the hypothetical urban area is described including statements of how it represents typical U.S. urban areas.

The urban area that was used for the sake of this research was made to reflect the typical characteristics of U.S. urban areas as per the current practice discussion given previously. The basic characteristics considered were transit modes (bus and rail), highway elements (freeway and surface streets), parking facilities, municipality (city) boundaries, alignments (rail and highway), and extent of transit system services (rail and bus). The hypothetical urban area is shown in Figure 4.

The transportation system was designed to be representative of one belonging to an urban area in the U.S. so that the research results might be more credible. The characteristics that should be noted are points A and B signifying a potential travelers origin and desired destination; the overlapping of LRT routes 1 and 2 close to the CBD area; the extent of the LRT system (remaining inside County 1); the potential traveler has no access to transit at point A; and the busses from County 2 serve the LRT system of County 1. For simplicity the bus route numbers were assigned to all of the bus routes consecutively, not accounting for the fact that those in County 2 belong to a separate system. The most noteworthy item of all is that the traveler has various options available for accessing point B. For an infrequent traveler, picking the best route from A to B to suit their needs may prove difficult.

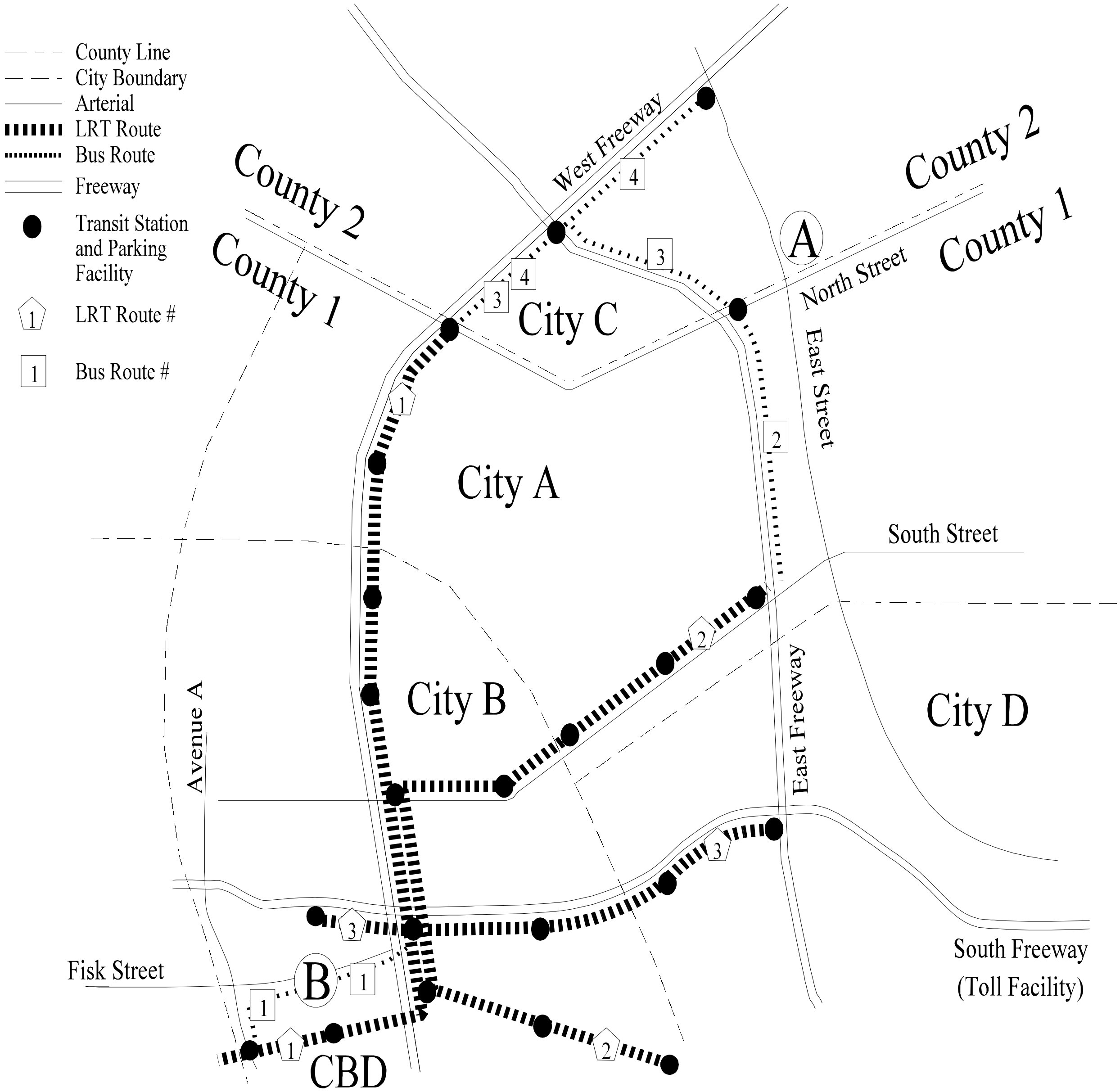


Figure 4. Hypothetical Urban Area.

POTENTIAL INFORMATION PROVIDERS

Once the hypothetical urban area characteristics were established it was possible to determine the potential information providers. These information providers were the agencies providing services relevant to the ISP objective within the urban area. The relevance of an agency service was established if it coincided with the definition of a ITS service included in the Defined ITS Architecture.

The specific services included in the Defined ITS Architecture were also stated relating them to agencies that could possibly provide the services listed in the left hand column of Table 2. To demonstrate the process of specifying the potential information providers, types of agencies were assumed to provide the various ITS services and then listed in the right column of Table 2. The types of agencies and the respective ITS services they were assumed to provide were consistent with those listed in the report for the Washington DC Metropolitan Area (2). Establishing the types of agencies that might provide the ITS services enabled the researcher to associate actual agencies within the hypothetical urban area to the various ITS services as shown in Table 3.

Table 2. Subsystems and Potential Providers.

Service	Type of Potential Providing Agency(s)
Toll Administration	Private/Public Toll Authority/DOT
Traffic Management	State DOT/City DOT/County DOT
Yellow Pages Service	Private
Emergency Management	Highway Patrol/Local Police/Fire Department
Transit Management	Transit Authority (local, county, and regional)
Parking Management	Transit/Private/DOT
Weather Service	U.S. Weather Service
Media	Local News Media and Advertisers
Map Update Provider	Private/Public
ISP	Private/Public

Table 3. Hypothetical Urban Area Service Providers.

Service	Operating Agency Name	Service Area
Toll Administration	Toll Administration	South Freeway
Traffic Management	State DOT	County 1 and 2
	City A DOT	City A
	City B DOT	City B
	City C DOT	City C
	City D DOT	City D
Yellow Pages Service	Yellow Pages Service	County 1 and 2
Emergency Management	Highway Patrol	All freeways and toll facilities
	City A Police	City A surface streets
	City B Police	City B surface streets
	City C Police	City C surface streets
	City D Police	City D surface streets
Transit Management	County 1 Transportation Authority	All County 1 transit operations (bus and LRT)
	City C Transit	Bus routes 3 and 4
Parking Management	County 1 Transportation Authority	All park and ride facilities in County 1 except those on the county line
	State DOT	Park and ride facilities on the county line and in City C
Weather Service	Weather Service	County 1 and 2
Media	Media	County 1 and 2
Map Update Provider	Map Update Provider	County 1 and 2
ISP	County 1 ISP	County 1
	City C ISP	City C

The agencies providing the services in the hypothetical urban area are listed in the middle column with descriptions of their operating areas in the right column of Table 3. These agencies were given simple meaningful names to avoid confusion and their service areas were chosen to reflect common characteristics in typical urban areas. For example some urban areas may have a centralized traffic management center while the agency in charge of emergency management may vary by the location of the emergency with respect to the facility type and city. A case in point would be the highway patrol which usually covers freeways while local police usually cover surface streets in their particular jurisdictions. Please note that fire departments were not included in the hypothetical urban area because their relevant services are similar to those provided by the local police department and their inclusion would not have added value to the discussion.

In many cases an agency status as public or private was not specified since, in the case of this research, the relation of the agency service area to that of the urban area under study was of primary importance. For an agency service to be relevant in this process its service area must overlap that of the specified urban area.

The intent of the overall process proposed in this paper was not to evaluate cooperative efforts among operating agencies or to evaluate operating efficiencies, but to summarize what information exchanges need to take place between the operating agency services and the ISP. It was assumed that information flows linking the ITS service, such as Transit Management, to the ISP will need to exist between the ISP and each of the individual operating agencies providing the ITS service (e.g., County 1 Transportation Authority and City C Transit). The hypothetical transit system appears to be decentralized where no single agency is expected to possess all transit related information for all transit agencies. It can be assumed that it is the responsibility of the proposed ISP to collect the information from the various agencies and to synthesize it for redistribution to the traveling public similar to the Washington DC Metropolitan Area Traveler Information efforts (16).

Some agencies may provide more than one service. Such is the case for the State DOT in the hypothetical urban area where it provides a Parking Management service for the park and ride facilities and Traffic Management service for the entire urban area freeway network. In this case the State DOT is the potential information provider for two ITS services. Conversely, some services may be provided by more than one agency. For example, there are two agencies that provide parking management services, the County One Transportation Authority and the State DOT, therefore there are two potential information providers of parking data to describe park and ride parking in the urban area. Thus each potential information provider is represented by an agency/ITS service combination as demonstrated (e.g., State DOT/Traffic Management, State DOT/Parking Management, County Transit Authority/Transit Management, County Transit Authority/Parking Management, etc.).

Figure 5 represents a modified ITS architecture reflecting operating agency involvement in providing the relevant information flows. In Figure 5 information flows between the services were combined and relabeled for ease of understanding. For example, all of the information flows between Transit Management and the ISP in Figure 3 were combined in Figure 5 and relabeled "Transit Management Data," describing information flow between the agencies and the ISP.

The potential information providers were summarized by combining the middle column with the left hand column in Table 3 illustrated in Figure 5 where each combination is represented by the source agency and the ITS service mentioned in the arrow label. There are 20 potential information providers (i.e., 20 agency/ITS service combinations).

Problems with information communication will remain unless the information flows shown between the particular agencies and the ISP shown in Figure 3 are provided. Providing these information flows will increase traveler accessibility to the agencies service and increase the mobility and efficiency of the traveler. The types of information flows possibly needed from these information providers were described previously in the Defined ITS Architecture discussion where the information flows are organized according to the respective ITS service (i.e., Traffic Management, Toll Administration, etc.).

This discussion of the proposed process has established and organized the potential information providers for the proposed ISP. The information flows shown in Figure 5 are needed between the operating agencies and the ISP in order to create an ISP with the necessary information to support the ISP objective and meet the traveler needs.

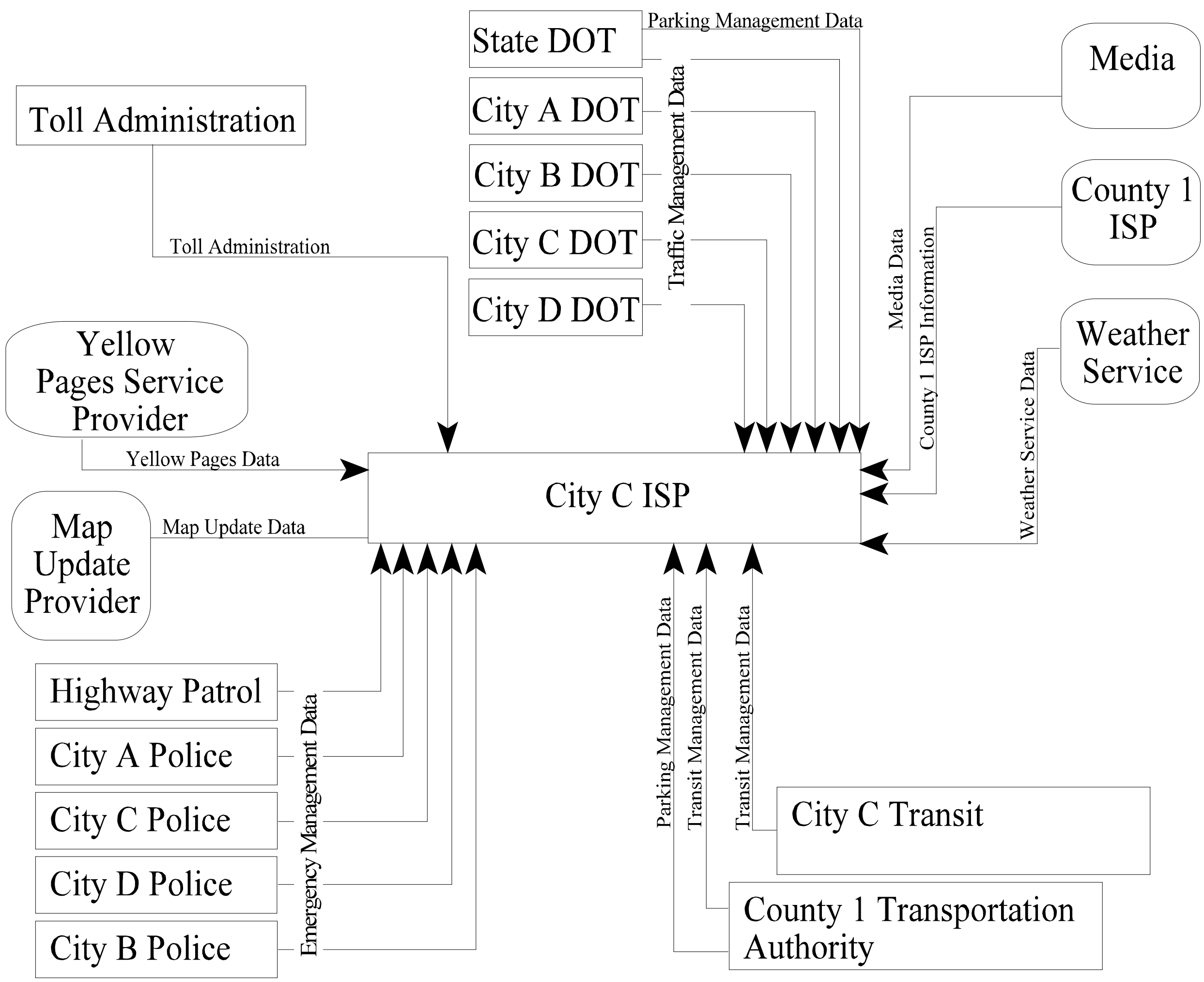


Figure 5. ITS Architecture of Agency Involvement.

SIGNIFICANT INFORMATION FLOWS AND PROVIDERS

Two steps of the proposed process are discussed in this section one is the categorization of the relevant information flows; and the final step is the determination of the significant information providers. These two steps in the process evaluated the potential information providers and the relevant information flows. These evaluations were based on the importance of the information flows and the need for the respective ITS services.

The line of reasoning used to establish the importance, or significance, of the ITS services, information flows, and associated potential information providers is summarized as follows:

- If the ITS service was not available in the urban area then the service and its associated information flows were not significant.
- If the service was available in the urban area but the relevant information flows associated with that service were not important (i.e., not required) then the service is not important, which indicates that the potential information providers associated with that service are deemed insignificant.

Categorized Information Flows

At this point a second look should be taken of the Defined ITS Architecture. Realize that the information flows specified in this architecture are for an ideal case, as described by the National ITS Architecture, to support the ISP objective. However, some of this information is required while others are more optional when trying to support the ISP.

To truly determine what information providers are significant, one must also consider the importance of the associated information flows. This was done by separating the information flows into two categories: Required and Optional. The 'required' information flows are those that are essential to support the ISP in developing feasible trip itineraries. For efficient evaluation of the relevant information flows the ISP objective and traveler information needs established previously were combined into the concept of a feasible trip itinerary whose definition is as follows:

> A trip schedule that meets the cost and time constraints of the traveler and the scheduling constraints of the transportation system.

The optional information flows are those that supply useful pertinent information that may have an effect on the travelers trip choices, but are not necessary for the ISP to function properly in generating a feasible itinerary. Eliminating all of the optional information flows would create a system with the minimum requirements for meeting the needs of the infrequent traveler.

Notice that a category for irrelevant information flows was not included. This category was not necessary since the Defined ITS Architecture was specified based on the relevance of the various services and their information flows. Therefore, all of the information flows included in the architecture were already determined to be relevant in the context of this process.

Categorization of the information flows was based on the definition of a feasible trip itinerary, the Defined ITS Architecture, and the hypothetical urban area agency ITS services. The assumption in these efforts was that no previous arrangements had been made for communications between the ISP and the various agencies, representative of a proposed ISP. However, this assumption would also be useful for an existing ISP exists where it may be desirable to reevaluate the current system.

Following is the categorization of the defined architecture information flows, in parentheses, with brief discussions of the reasoning behind the categorization. Also a summarization of the categorization is presented in Table 4.

- current highway network state (required): This information would ensure accurate travel time estimation for the private auto portion of the trip, accounting for variable operation of freeway facilities.
- current road network state (required): This information would be needed for the same reasons specified for item one above, although the importance of the freeway data may be greater depending on how much of the trip requires use of surface streets verses freeways.
- link data for guidance (required): This would be needed in order to gather information concerning relevant road and highway section from the correct ISP's if any others serve in the urban area or neighboring areas.
- predicted incidents (required): This information flow would help reflect the effects of congested conditions due to predictable traffic variations.
- transit fare data (required): Including fare information would enable the traveler to prepare to pay for the transit services and evaluate alternative itineraries based on cost.
- transit services for guidance (required): This information would help develop a feasible trip itinerary by describing fare variations based on portions of routes used, route numbers, and stop schedules, etc.
- transit vehicle deviation details (required): This information updates routes and schedules making a feasible itinerary possible in the event of transit system disruptions.
- parking lot availability (required): This information ensures that the traveler can feasibly transfer from the private auto to transit at a park and ride facility.
- parking lot price data (required): This information allows the traveler to assess the costs of alternative trip itineraries as was the case for transit fare data.
- current weather (required): Current information describing weather conditions in an urban area would help the traveler to determine which types of bus facilities are more desirable to provide shelter during periods of inclement weather (i.e., a traveler does not want to wait for a bus in the rain or extreme heat). This information can also be used to make qualitative adjustments to alternative trip itineraries based on possible traffic operation variations due to inclement weather.
- predicted weather (required): This information flow would allow the traveler to make a qualitative assessment of a trip itinerary taking into consideration the variation of traffic operations in response to different weather conditions. This would be important in areas where traffic conditions are near the critical capacity where traffic operations would break down if external factors appeared such as rain, snow, heavy winds, etc.
- yellow pages data (required): In many cases the infrequent traveler may not know the business hours and/or address of a destination(s). In this case the information that could be provided by

a yellow pages service provider would be essential, making the ISP much more useful in creating feasible trip itineraries.

- toll data (required): This information would be needed in order to determine the out-of-pocket costs of an alternative trip itinerary.
- vehicle tolltag data (required): This information would provide estimates of travel times on roadway/highway segments enabling the ISP to account for private auto travel times in the development of alternative trip itineraries. It appears that in current practice travel time estimates are mostly derived from loop detector data; however, some agencies in a few urban areas use vehicle probe data from toll tags which allows a more direct, and thus more accurate, method of estimating travel time (17).
- incident information (required): This information would be used to estimate the effects of incidents on different routes/trip itineraries enabling the ISP to evaluate the feasibility of various combinations of routes and itineraries.
- all ISP information (required): For the hypothetical urban area this information flow must be used so both ISP resources can be used to produce a trip itinerary.
- traveler information (required): When large events occur in an urban area they can have a significant impact on the transportation system operation. Therefore, this information could have a considerable impact on what trip itineraries are output by the ISP.
- incident notification (required): Using this information flow provides another means for collecting incident information. However, it comes from the media and the driving public and, therefore, has a larger coverage area. This would be useful especially in cases where transportation facilities are not instrumented in a way that would allow for efficient automated detection of incidents.
- traffic prediction data (required): During normal functions of the highway/roadway network these data would not be required; however, once an incident has occurred, use of these data would be very useful and could possibly be the difference between making and missing a bus or train.
- road conditions data (required): This would be of particular value when considering traffic operation variations in response to road surface conditions (i.e., wet, icy, snow, dry, etc.). The general weather information is also useful in this regard but lacks the detail that this information flow contains. Estimates of travel times can be obtained from highway and road network state data and vehicle tolltag data, but road conditions data for freeways would also reflect surface street conditions as well (i.e., it is unusual that instrumentation used for estimating travel times would be available for surface streets).
- route selection map data (required): Presenting the information using geographic representations that accurately describe the urban area is necessary for quick access to information and quick visual communication of route directions.
- demand responsive transit plan (optional): This would not be required since there is no demand responsive transit system available in the hypothetical urban area.
- transit media emergency information (optional): Much of the data contained in this information flow would not be of particular interest to the traveler. Furthermore, the information flow, transit vehicle deviations details, is probably more applicable to the development of a feasible itinerary.

Table 4. Categorization of the Relevant Information Flows.

Relevant Information Flows	Category
current highway network state	required
current road network state	required
link data for guidance	required
predicted incidents	required
transit fare data	required
transit services for guidance	required
transit vehicle deviation details	required
parking lot availability	required
parking lot price data	required
current weather	required
predicted weather	required
yellow pages data	required
toll data	required
vehicle tolltag data	required
incident information	required
all ISP information	required
traveler information	required
incident notification	required
traffic prediction data	required
road conditions data	required
route selection map data	required
demand responsive transit	optional
transit media emergency information	optional

Only two of the information flows were categorized as optional: demand responsive transit data and transit media emergency information (see Table 4 and Figure 3). These information flows were optional as demand responsive transit was not available and the other was accounted for by a more useful information flow (see previous discussion). Keep in mind that this categorization was based on the hypothetical urban area transportation system services (i.e., no demand responsive transit) and the assumption that the other stated information flows are available. Furthermore, it should also be noted that the categorization of information flows will vary between urban areas as the characteristics will most likely be different.

Significant Information Providers

Significance of the information flows and information providers was established by following the line of reasoning stated at the beginning of this section. All of the ITS services were represented, to some degree, in the hypothetical urban area transportation operations and all of them could provide at least one required information flow. Therefore, all of the potential information providers were deemed significant as were their corresponding required information flows.

One look at the 'required' information flows would indicate that a transportation system that has such information at their disposal would seem to be very advanced in comparison to the Atlanta and Southern California transportation systems. If the existing agencies currently do not possess information needed for the various information flows then some resources must be spent in determining how, or if, such information can be provided. The issues addressing the development of such information are beyond the scope of this research. However, this research does provide the reader with a more detailed picture of where the information should come from and what the information should be.

PROCESS SUMMARY

The previous five sections describe a general process for approaching the problem of providing a convenient useful ISP service to the infrequent traveler for the purpose of planning multiple mode trip itineraries prior to the initiation of the trip. There are various sources of information to help ascertain what information is needed to provide such a service. However these sources do not discuss the process used to relate these information needs to the specific agencies in an urban area, thus locating the information providers for future information exchange. There needs to be documentation for the lay individual who is not completely familiar with the ITS Architecture in all its complexity.

The discussion in this paper guides the reader through the steps in a process to define the information flows and associated providers needed for the achievement of the ISP objective. In brief terms this process does the following: defines the traveler needs, creates an applicable ITS architecture, and relates this architecture to an urban area and its various transportation related operating agencies.

These steps are summarized in this section allowing the lay individual, or investigator, to relate their respective urban area to the National ITS Architecture to provide pre-trip planning services for infrequent travelers. From this the investigator will be able to determine the information needs relative to a proposed ISP and the various agencies that could support the 'required' information flows in that urban area. The summary is presented in the form of a flow chart (see Figure 6) and accompanying discussion to facilitate understanding of the previous steps taken and the reasoning process involved.

Initial Step

ISP Objective

The initial step includes four tasks or efforts. The first task, determine the ISP objective, could be considered a given or changed to reflect more appropriate goals. The reader should note that an ISP would normally have a broader objective, or multiple objectives, as is the case for the Washington Metropolitan Traveler Information service (2).

Traveler Information Needs

The second task in the initial step is to define the traveler information needs. These can be based on local studies of traveler information needs or on previous studies performed in other areas, as was the case for this research. If the later type of source is chosen exclusively, comfort can be found in the fact that the approach taken in this research should provide ample opportunities for one to modify the outcome based on knowledge of the urban area in question.

Define the Relevant ITS Architecture

The next task addresses the definition of an applicable ITS architecture. It is recommended that the ITS architecture be limited to one way information flows toward the ISP and only include information flows that are relevant to the ISP objective and traveler information needs. Following these recommendations will maintain the efficiency of the process.

The Defined ITS Architecture developed in this research was taken from the National ITS Architecture in a comprehensive manner where all relevant information flows, services, etc. were included. Therefore, the Defined ITS Architecture should be a sufficient starting point for the reader to consider the various aspects of the National ITS Architecture and can be used to provide information on all relevant information flows to the ISP if the ISP objective is similar to that stated in this research. If the ISP objective is different then it is suggested that the investigator refer to the National ITS Architecture to reevaluate the information flows communicated between the ISP and the various ITS services, and the ITS services themselves, to determine their relevance to the ISP objective.

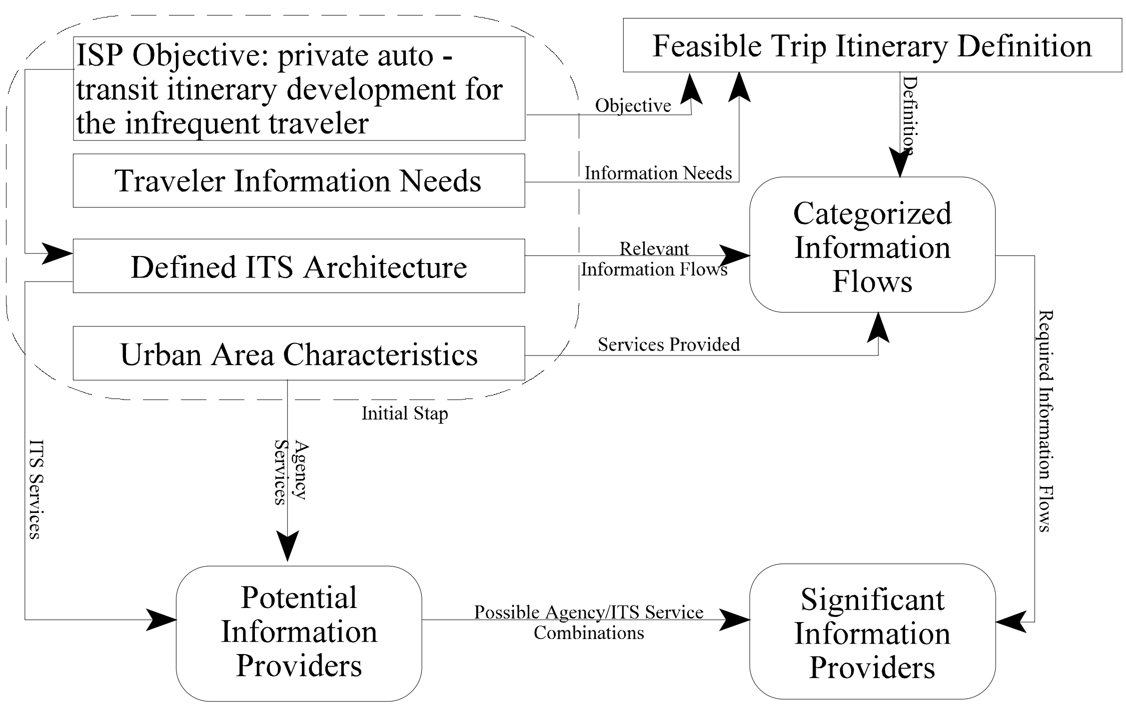


Figure 6. Process for Determining Significant Information Providers.

Urban Area Definition

The urban area characteristics should contain information describing the boundary of the intended service area. This should describe which municipalities, counties, unincorporated areas, etc. are included in the urban area.

One should also describe agency operational boundaries and services provided in such a way that these services can be related to the ITS services in the Defined ITS Architecture. These operational boundaries can be the city limits of incorporated areas; the extent of the various rail and bus systems; the coverage area of traffic management centers, emergency management services, toll authorities; the administrators of the various park and ride facilities; the coverage area of other ISP's in the area; potential radio and television media in the urban area; map provider area of responsibility; and potential sources of weather information; and other ITS services relevant to the investigator's ISP objective.

At this point it should be understood that the actual boundaries of operation are not important. What is important is knowledge that the operational boundaries do coincide with at least a portion of the specified urban area. This is because the process does not consider the geographical relationships between the various agency operational boundaries; it considers only the fact that an agency does operate in the urban area and the respective services that it provides.

Potential Information Providers

This step is performed to determine the probable information providers are for accomplishing the ISP objective. The probable providers are related to the ITS services they provide creating agency/ITS service combinations to describe which agencies provide the ITS services (e.g., State DOT/Parking Management, State DOT/Traffic Management, etc.).

The effort involved in this step of the process is to create the agency/ITS service combinations based on the ITS services proposed in the Defined ITS Architecture and the various agencies operating in the urban area. These combinations are created by matching agencies with ITS services corresponding to current services that they provide.

If a particular service is not currently provided and most likely will not be provided in the future then that service should be skipped. Such a situation may result for ITS services such as Toll Administration, Other ISP, etc. These ITS services will be eliminated in the final step of this process.

Categorized Information Flows

As of yet, no opportunity has been afforded to the investigator for modifying the sets of information flows and ITS services included in the Defined ITS Architecture. Such an opportunity is essential and is provided in this step to allow additional flexibility and to ensure that the project results are reasonable. The relevance of the various information flows to the objective has already been established earlier in the process when the Defined ITS Architecture was developed. However, modifications may be necessary because some information flows may not be required to support the

ISP objective and traveler information needs. At this step the investigator must synthesize the traveler needs established in the initial step, and the ISP objective. The synthesis must be done in a way that will result in the fewest, most intuitive constraints possible, similar to the definition of a feasible trip itinerary. Then the investigator categorizes the relevant flows establishing those that are required to meet the established criteria and those that are optional.

The information needed to establish which Defined ITS Architecture information flows are required are the following: the constraints synthesizing traveler needs and the ISP objective, services provided in the urban area, and relevant information flows as indicated in the Defined ITS Architecture. When this information is available, the information flows can be categorized in such a way that the 'required' flows will be separated from the optional.

Significant Information Flows and Providers

Once the 'required' information flows have been determined and the possible agency/ITS service combinations have been identified a list of significant information flows and providers can be created. This is done by relating the 'required' information flows to their respective services (e.g., current highway network state and Traffic Management or transit vehicle deviations and Transit Management).

The line of reasoning used to establish the importance, or significance, of the services, information flows, and associated potential information providers is summarized as follows:

- If the ITS service was not available in the urban area then the service and its associated information flows were not significant.
- If the service was available in the urban area but the relevant information flows associated with that service were not important (i.e., not required) then the service is not important, which indicates that the potential information providers associated with that service are deemed insignificant.

Some of the information flows dictated by this process may not be feasible to provide based on technological, resource, and/or institutional constraints. This process does not account for the feasibility of the various information flows since the goal of this process was to determine what type of information was needed from which agencies, the first step in creating an effective ISP. This knowledge is the basis for interagency agreements and negotiations, allowing decision makers to have good knowledge of what information flows would be necessary to support the ISP objective.

APPLICATION

The ultimate goal of this paper is to enable individuals not familiar with ITS nomenclature and architecture to understand what information is needed and what the bases are for developing interagency relations for developing an effective ISP. In pursuit of this goal an actual urban area was chosen as a mock application of the process described in the Process Summary. The urban area chosen was the metropolitan area surrounding and including Seattle, Washington. The reason for choosing this site was that it included several counties, many communities, and the necessary information was easily accessible via the Internet.

The discussion describing the application of the proposed process to this urban area is limited to the application of the process described in the previous section, Process Summary (as illustrated in Figure 6). The information used is limited to that which could be feasibly obtained and in some cases does not represent all operating agencies in the chosen urban area. Furthermore, agency names used in this discussion may not be the same as the actual names. These information limitations could be removed by accessing a Seattle area phone book and determining the agency names by city/community.

Some of the agencies may not be interested in supporting an ISP; however, it is essential that all of them be included in name throughout this process. After this process has been finalized the agency proposing the ISP service should then occupy itself with encouraging the interest of all agencies determined to be significant information providers.

Initial Step

The initial step of the process is to define the objective, the traveler information needs, the ITS architecture, and the urban area and its characteristics. The urban area considered for this application ranges from Tacoma, in Pierce County to the south, to Everett, in Snohomish County to the north, and from Seattle, to the west, to Issaquah, to the east. The ISP objective, Defined ITS architecture, and traveler information needs were assumed to be the same as was stated for the hypothetical urban area; however, in a real application all of these assumptions must be checked to ensure compatibility with the urban area and the desired ISP objective.

For the Seattle urban area this process must account for numerous agencies ranging from the Washington State Department of Transportation (WSDOT) to individual municipality agencies such as the Bellevue Fire Department. As mentioned previously the actual names of the individual agencies were not used in the case of the municipalities. The names used were sufficient to identify the area and the agency type (e.g., Bellevue Police Department, Bellevue Fire Department, etc.). There were 36 cities and three counties considered in this process along with the WSDOT and private enterprises (18, 19). It was assumed that each city employed three related agencies which are the following: a department of transportation, a police department, and a fire department .

It was understood that some of these services could be contracted out to the county (e.g., police and fire) or do not exist as a specific agency being incorporated into public works (i.e., department of transportation). If it is determined that the county provides services by contract to several cities then this will only serve to simplify the problem. If a specific agency does not exist then a follow up will have to be made to determine what agency or individual supervises the related work. In effect, the intent is to find the entities that perform the service even if it is only one of many functions the entity performs.

The researcher assumed that each county employed four related agencies, three of which were the same as those provided by the cities while the fourth was a transit agency. Performing some quick math the number of public agencies that were considered is 108 city agencies, 12 county agencies, the state DOT, and the interested private agencies, totaling 121+ agencies.

Determine Potential Information Providers

To determine the potential information providers the agency/ITS service combinations need to be established. The city police and fire departments both provided one service, Emergency Management, and the departments of transportation provided one service, Traffic Management. Therefore, for the cities there were the same number of potential information providers as there were agencies, 108, since each agency only provided one service. For the counties the transit agencies provided two services, Transit and Parking Management. All of the other agencies provided only one ITS service each. Therefore, there were three more agency/ITS service combinations than there were county agencies, (15 agency/ITS service combinations). The WSDOT provided two services, Traffic Management and Emergency Management.

No agency provided the Toll Administration service since no such service exists in the urban area. Furthermore, it was assumed that the service, Other ISP, did not exist in the urban area. Therefore there was no need to determine agency/ITS service combinations for either service.

The remaining agency/ITS service combinations involved private enterprises and could be treated by assuming that there was one agency for each combination. This was possible since it was not known which private enterprises would be selected to support the related information flows. In a sense, the results of this process would enable the organizing agency to post a request for proposals where interested enterprises would participate in competitive bidding for the provision of the related information flows. Therefore, these remaining agency/ITS service combinations were specified as private/Media, private/Map Update Provider, and private/Yellow Pages Service Provider. Given the previously stated combinations the potential information providers were enumerated as shown in Table 5.

Table 5. Enumeration of Seattle Urban Area Potential Information Providers.

Agency/ITS Service Combination Type	Quantity
City Police/Emergency Management	36
City DOT/Traffic Management	36
City Fire/Emergency Management	36
County Sheriff/Emergency Management	3
County Fire/Emergency Management	3
County DOT/Traffic Management	3
County Transit Agency/Transit Management	3
County Transit Agency/Parking Management	3
State DOT/Traffic Management	1
State DOT/Emergency Management	1
Private/Media	1
Private/Weather Service	1
Private/Map Update Provider	1
Private/Yellow Pages Service Provider	1
-/Other ISP	1
-/Toll Administration	1
Total Potential Information Providers	**131**

Categorize Information Flows

The same reasoning described for the hypothetical urban area can be used for the Seattle urban area where all of the information flows were categorized the same except the information flow related to demand responsive transit. Demand responsive transit was available in the Seattle urban area it is an integral part of the transportation system, especially for the physically impaired (18).

An information flow categorized as 'required' does not necessarily signify that it would be included in the final system; to the contrary, through additional study it may be decided that some information flows are infeasible or undesirable to support. For current transportation systems this may be the case for the information flow, current road network state, since few if any surface streets have been instrumented with the necessary equipment to provide such data. However, it may be determined that such data can be provided but only for the larger, more densely populated municipalities. These are issues that should be considered in the development of a system that would achieve the ISP objective specified in the process; however, they are beyond the scope of this research.

Determine Significant Information Flows and Providers

Significant information flows and providers were determined for the Seattle urban area based on the input of the categorized information flows and the potential information providers. The relation of the categorized information flows and the potential information providers completed the picture by associating the possible agency/ITS service combinations with 'required' information flows. The services that did not have any agency providers, current or future, were eliminated (e.g., Toll Administration and Other ISP) together with their associated 'required' information flows. Those agency/ITS service combinations that were not supported by a 'required' information flow could have been eliminated in this step of the process as well; however, all combinations for this application supported a 'required' flow.

After relating the categorized information flows to the potential information providers the remaining agency/ITS service combinations each represent a significant information provider. The agency specified in the combination can now be noted as a desirable source for information describing the related to the ITS service specified in the combination.

Due to the magnitude of agencies involved only a partial report of the significant information providers was provided. This report is detailed in Table 6 enumerating the agency/ITS service combination types, one example providing agency in the Seattle urban area, and the corresponding 'required' information flows for the achievement of the ISP objective.

Typical Agencies and Required Information Flows

Table 6 can also be used to determine what information would be needed from typical agencies in an urban area relevant to the transportation system, accomplishing the second objective of this research. The typical agencies are listed in the left column as part of the agency/ ITS service type and the associated information is in the right column. The relationship of the types of agencies to the information flows enables quick understanding of the type and amount of information needed from the agencies. Understanding these information requirements gives the individual a greater appreciation of the problems associated with developing an effective ISP enabling them to more effectively participate in the development of ISPs that truly meet travel needs.

The bulk of the information is in Table 6; however, there are two missing elements, the ITS services Toll Administration and Other ISP. The service Other ISP simply communicates information requested from neighboring ISPs when conditions warrant and can be provided by public and private agencies alike.

Toll Administration is an ITS service that communicates toll data, which relays the cost schedule associated with toll roads, and vehicle tolltag probe data, which relays the processed travel time data with the associated route segments. Toll Administration is an ITS service that, in practice, can be provided by either public or private agencies. A public agency might be a State DOT or a Toll Authority.

Table 6. Seattle Urban Area Information Providers and Corresponding Information Flows.

Agency/ITS Service Combination Type	Urban Area Example	Significant Information flows
City Police/Emergency Management	Bellevue	Incident Information
City DOT/Traffic Management	Bellevue	• current highway network state • current road network state • link data for guidance • predicted incidents • traffic prediction data • road conditions
City Fire/Emergency Management	Bellevue	incident Information
County Sheriff/Emergency Management	King County Sheriff Department	incident Information
County Fire/Emergency Management	King County Fire Department	incident Information
County DOT/Traffic Management	King County Department of Transportation	• current highway network state • current road network state • link data for guidance • predicted incidents • traffic prediction data • road conditions

Table 6. Seattle Urban Area Information Providers and Corresponding Information Flows (Continued).

Agency/ITS Service Combination Type	**Urban Area Example**	**Significant Information flows**
County Transit Agency/Transit Management	Pierce Transit	• demand responsive transit plan • transit fare data • transit incident information • transit services for guidance • transit vehicle deviations • transit media emergency info.
County Transit Agency/Parking Management	Pierce Transit	• parking lot availability • parking lot price data
State DOT/Traffic Management	WSDOT	• current highway network state • current road network state • link data for guidance • predicted incidents • traffic prediction data • road conditions
State DOT/Emergency Management	WSDOT	incident information
Private/Media	KING 5	• traveler information • incident notification
Private/Weather Service	CNN (Internet)	• current weather • predicted weather
Private/Map Update Provider	ETAK	• route selection map data
Private/Yellow Pages Service Provider	ETAK	• yellow pages data

CONCLUSIONS

The results described in the Significant Information Flows and Providers discussion coincide with the system specifications put forth by a recent study for the Washington Metropolitan Traveler Information Service, essentially validating the process described in this report. However, this paper also provides a description of a process that could be used to specify the information flows needed and which agencies would be the desirable information sources to support the ISP objective.

This report described this process in a form that is understandable to technical and non-technical parties unfamiliar with ITS architecture application, aiding them in specifying the needs for their own urban area and ISP. At the same time the proposed process allows ample flexibility for the individual to make the necessary modifications to more accurately represent urban area characteristics, different ISP objectives and varying traveler needs.

The results of the example involving the Seattle urban area showed that many agencies could be involved in supporting the various information flows needed to meet the ISP objective. Many agencies may need to be contacted with whom working relationships must be developed. Output from the proposed process can act as a basis for developing and organizing these relationships giving both parties a starting point (information flows) on which to found future negotiations. This provides a direct link between the National ITS Architecture and its application in urban areas. Furthermore, the process allows local operational and administrative personnel to more easily understand who the information providers are without having to delve into the architecture documents themselves.

It was demonstrated, through a hypothetical situation and an actual situation, that the process would be quick, intuitive, and effective for application in the real world. The process is quick because the information needed does not go far beyond what is contained in this paper and what typical agencies currently have at their disposal; it is intuitive because it associates information providers, the primary concern, to actual agency services in the urban area; and it is effective as it relates the information needs to the agencies that could act as information providers. This provides a basis on which agency relations and cooperation can be sought; the individuals involved would know what information is needed from which agencies to increase infrequent traveler access to points of interest in an urban area using the private auto and transit transportation modes.

This process provides the groundwork for creating an ISP that could effectively determine feasible trip itineraries for a infrequent traveler. While executing this process does not guarantee successful deployment of the ISP, it is a step in the right direction.

Recommendations for Future Research

Involvement in the research discussed in this paper has led to several topics for future research. Those that are mentioned address the issues of how to work with the incoming information. The Defined ITS Architecture included over twenty information flows. Further research must be done to determine how this information can be synthesized and manipulated to be efficiently and effectively used by the traveler. Such research would allow the various components of information to be utilized in creating a feasible trip itinerary in response to a traveler query.

Information accuracy is another concern that must be addressed when developing these systems. Some process must be developed to determine the accuracy of the various data used as input to the ISP and to relate this combination of accuracies to an overall confidence level associated with the alternative itineraries. This would enable the traveler to make more informed decisions based on the risk associated with each alternative as well as the possible travel time and other important factors.

The feasibility of providing all of these information flows is also a concern where many urban areas do not possess any data to support some of them. Research should be performed to evaluate the feasibility of providing the various data flow and to investigate alternative data sets that more likely exist or perhaps are more feasible to obtain.

ACKNOWLEDGMENTS

I would like to take this opportunity to thank those that supported me in my efforts regarding this report. I would like to express my gratitude to Dr. Dudek who planned and conducted the course for which the report was written, CVEN 677 *Advanced Surface Transportation Systems*, enabling me to associate with the professional mentors. Special thanks go to Dr. Doug Robertson, my mentor, whose input was much appreciated not only in terms of this report but as guidance throughout my career. Thanks also goes to the mentors as a whole for their willingness to contribute and to Dr. Hickman who was able to discuss the topic of research with me. However, my deepest appreciation is reserved for my wife Cecily and sons Seth and Jared who never failed to provide words, and other means, of encouragement and support to the end.

REFERENCES

1. TravelTIP Traveler Information System: Task 1 - User Needs Assessment Summary Report and Recommendations. A report for Orange County Transportation Authority by Rockwell International. May, 1995.

2. Washington Metropolitan Traveler Information Service: System Requirements Definition for the Full Service Implementation. Battelle, Washington, DC. April 30, 1997.

3. ITS Architecture Implementation Strategy. Architecture Development Team. Federal Highway Administration, US Department of Transportation. Washington, D.C. June, 1996.

4. TravelTIP Traveler Information System: Task 1 - User Needs Assessment Summary Report and Recommendations. Orange County Transportation Authority, Rockwell. May 24, 1995.

5. Huchingson, Dale, et. al. Abridgement: Survey of Motorist Route-Selection Criteria. Transportation Research Record 643. Transportation Research Board. Washington DC 1977.

6. Dudek, Conrad L., et. al. Real-Time Information Needs for Urban Freeway Drivers. Report 139-4, Texas Transportation Institute, College Station, Texas. August, 1970.

7. ITS Architecture Theory of Operations. Architecture Development Team. Federal Highway Administration, US Department of Transportation. Washington, D.C. June, 1996.

8. Http://www.scubed.com/caltrans/transnet.html. June 16, 1997.

9. Http://www.goventura.org, June 17, 1997.

10. Http://www.westworld.com/~elson/larail/. June 16, 1997.

11. Http://www.georgia-traveler.com/traffic/rtmap.htm. June 16, 1997.

12. Http://www.georgia-traveler.com/rtplan/rtplan.htm. June 16, 1997.

13. Http://www.georgia-traveler.com/widearea.htm. June 16, 1997.

14. Http://www.georgia-traveler.com/MARTA/pubtrans.htm. June 16, 1997.

15. National ITS Architecture (on CD-ROM). United States Department of Transportation. June, 1996.

16. Capital Beltway ITS Showcase: Fact Sheet. Provided by Tom Hicks. June, 1997.

17. Balke, Kevin, et. al. Freeway Management Systems: A State-of-the-Practice Review. Deliverable for Contract: DTFH61-95-C-00128. Texas Transportation Institute, College Station, Texas. January, 1996.

18. Http://transit.metrokc.gov/bus

19. Http://www.ptbus.pierce.wa.us

Michael Dixon graduated from Brigham Young University with his B.S. and M.S. degrees, with an emphasis in transportation engineering. Currently Mike is pursuing his Ph.D. at Texas A&M University. His past experience in the transportation engineering profession includes a summer internship working in the Utah Department of Transportation Planning Department and a one year internship for Parsons Brinckerhoff. Mike's professional affiliations are with ITE and ITS America and he is currently serving as treasurer for the ITS Texas A&M student chapter. His areas of interest related to ITS are signal preemption for emergency vehicles, signal prioritization for public transit, and expert systems applied to incident management.

THE DEVELOPMENT OF AN INTERNET HOME PAGE TO PROVIDE INFORMATION FOR REGIONAL TRAVELERS

by

Kendall L. Fogle

Professional Mentor
Ginger Gherardi
Ventura County Transportation Commission

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

In the current information age, almost every metropolitan area in the United States maintains a home page on the World Wide Web that provides a wealth of information to the traveling public. This information includes traffic information, shopping locations, hotel and restaurant information, local attractions, transit information, and more. There is also a broad range of information on the internet that may be applied to a regional traveler information home page, that could be used to assist drivers traveling between metropolitan areas. There are very few of these home pages currently available on the internet.

The research objectives of this project were six fold. The first objective involved identifying the costs of developing and maintaining a regional traveler information home page. The next two objectives involved identifying what information travelers need and desire, and then locating where this information may be found on the internet. The results of these two objectives were then used to develop guidelines for a generic internet home page that could be used by any regional area. These guidelines not only identify what information should be presented, but the manner and format in which it should be presented. The guidelines that were developed were then used to create a generic template for a regional traveler information home page in the fifth objective. Finally, this template was used in creating a regional traveler information home page for the region along the Interstate 45 corridor between Galveston and Dallas, Texas.

TABLE OF CONTENTS

INTRODUCTION

Today, there are well over 40 million people of all ages "traveling" on the information superhighway, and the World Wide Web in particular. Projections predict that by the year 2000, there will be over 200 million users (1). There are currently more than 650,000 World Wide Web sites receiving traffic daily (2). The internet is becoming so widely used that in the near future, it is probable that internet connections will be as numerous as phone connections (3). The World Wide Web provides an opportunity for almost everyone to gain information on a wide range of topics quickly and, in most cases, accurately. With this amount of exposure and availability, the internet has the potential to be the most widely used technology for an advanced traveler information system (ATIS).

Currently, almost every metropolitan area maintains a traveler information home page on the World Wide Web. Most metropolitan areas' home pages contain information on a variety of topics of interest to travelers; this includes traffic information, shopping locations, hotel and restaurant information, local attractions, transit information, and so forth. The internet also has a large amount of regional information that can be used by persons traveling between metropolitan areas. Some examples of regional information include bus and train fare schedules and rate information, airport information, weather information, routing information, and maps. While this information is useful to the local traveler, it would be very valuable to the "out-of-town" traveler that is unfamiliar with the characteristics of the region.

There are several reasons why regional traveler information home pages are uncommon. One reason can be attributed to the fact that there is no single municipality or agency that would directly receive the benefits given by a regional traveler information system. Due to this, no one agency is willing to expend the resources necessary to develop and maintain the system. A second reason may be that there are few regional traveler information systems on the internet, and no development guidelines which can be followed by other agencies exist. These guidelines for creating an online regional traveler information system are presented in this paper.

Research Objectives

The objectives of this research project were to:

1. Identify and quantify the costs associated with developing and maintaining a regional traveler information home page.
2. Identify the information needs of persons traveling between and within metropolitan areas.
3. Identify which information needs, identified from the first research objective, can be met by using existing resources on the World Wide Web.
4. Develop information and design guidelines that can be followed when developing a regional traveler information home page.
5. Apply the results of the research to create a template that could be used by any region to develop an effective, but inexpensive traveler information home page.
6. Use the template to create a traveler information home page for the I-45 corridor that connects the metropolitan areas of Houston and Dallas.

Study Approach and Scope

To determine costs, the author surveyed five local internet marketing agencies and four local internet service providers. The survey was used to identify and quantify the cost components of developing and maintaining an internet site on the World Wide Web. The agencies were asked different questions depending on whether the agency was an internet provider, or if the agency was an internet marketing service.

The internet service providers were asked the following questions:

1. What are the cost components of having an internet site hosted?
2. How much do each of these components cost?

The internet marketing services were asked these questions:

1. How much would it cost to develop a regional traveler information home page?
2. What is this cost based on?
3. How much does it cost to have the site maintained?

The next task of the study was to identify the information needs of regional travelers. Information that could be used in the pre-trip planning stage by regional travelers was given particular attention. To obtain this information, literature searches were conducted on the Transportation Research Information Service (TRIS) database, the Texas A&M University library database, and the Texas Transportation Institute library database. This search was focused on pre-trip planning needs since the internet would most likely be used in the planning stage.

To identify what online information is available, an in-depth search was conducted on the World Wide Web. Current regional traveler information home pages, as well as sites containing information that can effectively be used on a regional traveler information system were noted. The results of this search included examples of current web sites. It was understood that specific information available for some regions may not be available on a national level.

A two-pronged approach was used to develop new guidelines to create a regional traveler information home page. Initially, guidelines presented in previous research were reviewed. Then, other guidelines were developed based on current online traveler information systems that effectively present usable information to the traveler. These guidelines are based on what information should be presented, as well as how the information should be presented. It is also important to note that these guidelines are based on using information that is already maintained on the internet. In this way the regional traveler information home page is merely a packaging tool for this information.

A world wide web page template was then created based on the information and design guidelines which were found in the research study. This template could be used to develop an inexpensive traveler information home page for any region. Finally, to test the validity of the new guidelines, they were applied to the development of a regional traveler information home page for the region along the Interstate 45 corridor between Galveston and Dallas, Texas. This home page includes all relevant information which is available for the area.

Organization of Report

This report is broken into six different sections. The costs of developing and maintaining an internet home page are discussed in the first section. These costs include the development, registration, hosting, and maintenance of the site. Each of these components are discussed in detail and cost estimates of each component are offered.

Information needs that need to be included on a regional traveler information home page are discussed in the second section. In total, six different information types are presented including: weather information, traffic information, roadway condition and construction information, maps and directional information, public transit information, and airport and flight information. After the discussion of needed information, several examples are given where this information may be found on the internet.

The third section of the report includes a discussion of design guidelines which should be followed when creating a regional traveler information home page, specifically: organization, graphics, consistency, links and feedback.

The generic template for a traveler information home page based on the information and design guidelines is presented in the fourth section. In the fifth section, the format and information content of the Interstate 45 Regional Traveler Information Home Page which was developed using the information and design guidelines presented in this paper are discussed. The location and an example of each of the information links is also presented. Conclusions that were reached from the research process are summarized in the last section.

COSTS

Before any agency makes a decision to develop and maintain an internet home page, the costs of doing so should be researched. In order to identify the cost components of developing and maintaining a home page, the author conducted a survey of five local internet marketing agencies and four internet service providers. Four primary cost components were identified. The first cost component is that of development. Development includes actually creating the home page. The second component, registration, involves having a domain name registered. The third cost component involves hosting the site. The hosting fee covers the cost to have the home page stored on an internet server that links it to the rest of the World Wide Web. The last cost component, maintenance, includes anything done to the physical appearance or content of the site after development. Each of these components are discussed in greater detail in the following sections.

Development

When an agency decides to develop a traveler information home page, the agency can choose to have the site developed professionally, by an internet marketing service, or in-house by an employee knowledgeable about the internet. The costs related to having the site professionally developed as compared to having it created in-house are vastly different. In this section the cost components and relative costs of each development type are discussed.

Professional Development

The range of costs one can expect to pay to have an internet site professionally developed is as broad as one can imagine. One internet marketing agency said that these development costs could range anywhere from $50 to $50,000,000 (4). The cost of development varies based on several factors. One factor is the actual time that the developer must spend creating the site; this cost component can range anywhere between $25 and $75 per hour (4). Another factor that plays a major part is the technology and applications that the home page uses (5). Some examples of different technologies include such things as real-time information, credit card encryption for online purchases, online databases with search functions, and interactive media (5). Graphics are another factor that significantly affects the price. If the graphics are prepared beforehand by the agency sponsoring the home page, a great deal of money can be saved (4).

To develop a regional traveler information home page that consists only of links to other information sources, an agency can expect to spend between $2000 and $3000. This price includes development of the basic graphics and buttons that must be created for the web site. The resulting site will be similar in content to the I-45 Corridor Traveler Information Home Page discussed later in this paper.

In-House Development

Another option in developing the regional traveler information home page involves using in-house employees. Almost every technical agency has someone on staff who would be more than willing to create a basic Web site that will cost almost nothing (6). The only thing other than a computer that is necessary is free internet software, such as Netscape Navigator. If graphics are desired, it may be necessary to employ the services of a graphics specialist. Many of these can be found at a reasonable price.

Registration

The second cost component of developing an internet site is registration. This component involves choosing a uniform resource location name (URL) and registering it. The URL is the internet address of the web site (e.g., www.yourname.com). Although the registration of a site is not mandatory, having an easy to remember internet address will pay dividends to the agency and the user. Registration must be done through the InterNIC registration service. The cost for registration is $100 for the first two years and $50 for each additional year. If the home page is being developed by an internet marketing agency, they will most likely handle this. On the other hand, if the transportation agency is responsible for doing this, a good start is to visit the InterNIC site at http://www.internic.net (6).

Hosting

The next cost component of developing an internet site is the hosting component. Hosting involves choosing an internet service provider that will link the site to the rest of the internet. Once again, if an internet marketing agency developed the site, they will usually take care of this component. To quantify the cost of hosting, four local internet service providers were contacted and questioned about the cost of their service. The service cost includes a setup fee and a monthly service fee. Setup fee can range between $0 and $20 depending on the service provider, while the monthly service fees range from approximately $20 to $50 per month depending on the options offered in each service package (7,8,9). The different options include such things as the amount of server memory allotted and the number of e-mail addresses assigned.

Maintenance

The last cost component related to an internet home page is that of maintenance. The cost to maintain the page is very similar to the development component. It can be done either in-house or by an internet marketing agency. If the maintenance that must be done is simplistic, it can be done in-house. The cost of maintain the site in-house is based strictly on the cost of the time of the individual doing the maintenance. Conversely, if the maintenance must be done by a professional, one can expect to spend between $25 and $75 an hour (4).

INFORMATION GUIDELINES

The key element of success for any traveler information system lies in satisfying the information needs and desires of the travelers (10). To satisfy these needs, it is necessary to first identify the users' information needs and desires, and then present the information to the traveler in a usable manner. Each of the necessary information types is presented in this section.

One of the most comprehensive studies focused on identifying ATIS user needs was conducted by Urban Engineers, Inc. The main goal of the study was to identify both pre-trip and en-route user needs for those traveling in the I-95 northeast corridor (10). The research team conducted phone surveys to identify important auto and transit user needs, and used on-site surveys to identify air and intercity rail traveler’s needs. In order to maintain the scope of this paper, the review of results are limited to those user needs that may be satisfied in the pre-trip planning stage.

A great deal of the information that should be incorporated into a regional traveler information home page can already be found on the internet. For this information, it is necessary to provide links so that the user can easily access them. Examples of this information is listed under each information category with their respective agency and internet address.

Weather Information

Weather information is a critical component of a traveler information system. With accurate weather information concerning the severity of road and travel conditions, the road user can determine whether or not to proceed with a potentially unnecessary trip (11). In the I-95 northeast corridor region, 70 percent of local automobile travelers and 80 percent of long-distance auto travelers considered weather information important. Many air and transit travelers also consider weather information very important (10). Although adverse weather conditions are more common in some areas more than others, this information should be provided on any regional traveler information home page.

There are many national and regional weather services that provide hourly online weather information including: current weather conditions, forecasts, travel information, and weather maps. With these weather information services, virtually every region in the United States, and even the world is covered. The Weather Channel Home Page even provides city road maps and airline flight delay information.

Some example weather information home pages are shown here:

- American Weather Concepts Home Page - http://www.amerwxcncpt.com/
- National Weather Service Home Page - http://www.nws.noaa.gov/
- The Weather Channel Home Page -http://www.weather.com/twc/homepage.twc

Maps and Directional Information

Drivers that are unfamiliar with an area may find maps and directional information useful. In the I-95 northeast corridor region, 70 percent of the long distance drivers considered mapping and directional information important. This information can also be valuable to local drivers who need directions to another address in their same metropolitan area. Maps and directional information should be provided on a regional traveler information home page.

There are currently several organizations that provide free online maps and turn-by-turn directions for traveling between any two cities in the United States. Given any two cities, two addresses, or even an or two e-mail address, these services can provide graphical and text directions to get the user where they want to go.

Some examples of maps and directional information home pages are shown here:

- GeoCities - http://www.vicinity.com/geocities/
- Trip Quest - http://ca-mall.com/tripques.htm
- Yahoo! Maps - http://maps.yahoo.com/yahoo/

Roadway Condition and Construction Information

With roadway condition and construction information, automobile travelers that consult the traveler information home page before making a trip can either reroute their trip to save time or reschedule the trip to avoid delays or unsafe conditions if adverse conditions exist. In the I-95 northeast corridor region, 70 percent of local travelers and more than 80 percent of long distance travelers considered roadway condition and construction information either important or very important (10). Therefore, this information should be provided on a regional traveler information home page.

Each of the 48 states in the continental U.S. currently maintain online roadway condition and construction information either through the state department of transportation or through another public agency. While some states simply provide the roadway number, relative location of construction, and the nature of the roadway condition or construction, others such as that of Ohio provide a detailed map with explanations of the roadway condition or construction project as seen in Figure 1 (15).

Road Watch America (RWA) Direct maintains a home page with links to roadway condition and construction information for each of the 48 continental United States (16). The I-95 Corridor Coalition also maintains roadway condition and construction information for the states bordering the Interstate 95 corridor from Maine to Virginia. This information is presented on a detailed map with each construction project in the area labeled with a corresponding number similar to that in Figure 1 (17).

Southeast Ohio

1997 Major Interstate Construction

SW | NW | SE | NE | Construction Home Page

construction

44. I-70 Belmont County
Upgrading 3 miles of pavement beginning 2 miles east of CR 214 to just east of Marion Street in Bridgeport. One lane each direction.
Begins: April 1997 **Completion:** June 1997

45. I-470 Belmont County
Resurfacing from I-70 to the West Virginia State line. One lane each direction.
Begins: June 1997 **Completion:** August 1997

46. I-77 Guernsey County
Traffic maintained with temporary cross-over 1 mile north of the US 22 interchange. 12' lane restriction. Expect long delays.
Begins: August 1996 **Completion:** May 1997

47. I-70 Muskingum County
Crossover lanes maintained for major rehabilitation from US 22 to SR 83. Expect delays.
Begins: April 1997 **Completion:** November 1997

48. I-77 Noble County
One lane maintained each direction from the SR 78 interchange for 5 miles south. Rebuilding southbound lanes, resurfacing northbound lanes.
Begins: April 1997 **Completion:** June 1998

Figure 1. Example of Online Construction Information.
[http://www.dot.state.oh.us/const/seohio.htm]

Roadway condition and construction information are provided for every state through this site:

- Road Watch America Direct - http://rwa.metronetworks.com/

Traffic Information

Travelers are also interested in traffic information. Seventy percent of both local and long distance auto travelers from the I-95 northeast corridor study considered traffic information as important or very important (10). In 1970, Dudek and Cummings conducted a survey to investigate driver use of real-time traffic information (12). They found that 47 percent of motorists would always use real-time traffic information to plan trips and another 38 percent would frequently use the information to plan trips. Traffic information is also of special interest to potential transit users, as it is a key factor in their decision to use either transit or automobile. For these reasons, traffic information is useful and should be provided on a regional traveler information home page.

Currently there are many cities that maintain real-time traffic information home pages. While almost all these pages contain speed information displayed on a color-coded map, some such as that of Gary-Chicago-Milwaukee Project contain information on congestion, road construction and road closures, and even travel time information (13). AccuTraffic, a private transportation information agency, also maintains traffic information home pages for 27 different metropolitan areas (14). AccuTraffic's traffic maps provide incident and congestion information on a citywide map.

Although most real-time traffic information home pages provide information on a specified metropolitan area, there are a limited number of sources, such as that of the Gary-Chicago-Milwaukee Project, that provide this information for regional areas. Whether the information provided on the traffic information page is regional or local in nature, it is helpful to the traveler and should be linked to the regional traveler information home page.

Some examples of traffic information home pages are shown here:

- Gary-Chicago-Milwaukee Project - http://www.ai.eecs.uic.edu/GCM/CongestionMap.html
- Houston Real-Time Traffic Map - http://traffic.tamu.edu/traffic.html
- Southern California Traffic Report - http://www.scubed.com/caltrans/transnet.html
- Seattle Traffic Congestion Map - http://www.wsdot.wa.gov/regions/northwest/NWFLOW/
- AccuTraffic Home Page - http://www.accutraffic.com/

Airport and Flight Information

To the air traveler, the most viable and relevant information is related to the schedules and delays of flights. More than 70 percent of the air travelers of the I-95 corridor region considered information on confirmed schedules, delays, connections, and destination information important (10). This information should be provided to the air traveler through a regional traveler information home page.

Almost all of this desired air travel information is available on the internet. Flight delays are readily available through several different locations, including the Weather Channel's Home Page (18). American Weather Concepts also maintains a flight tracking service that allows the user to track any commercial flight across the continental United States. Given the airline, flight number, and destination number, an up to the minute graphic displaying the plane's location, destination, and estimated time of arrival may be displayed (19). There are also multiple travel agencies that maintain online flight schedules that any user can use quickly and easily. Many airports also currently maintain home pages that contain a wide range of information including airport maps, parking information, airlines, terminals, and hotel and car rental information (20).

Some examples of airport and flight information home pages are shown here:

- American Weather Concepts Flyte Trax - http://www.weatherconcepts.com/FlyteTrax/
- The Weather Channel Home Page - http://www.weather.com/twc/homepage.twc
- The Directory of Transportation Resources: Airports and Airlines - http://dragon.princeton.edu/~dhb/

Transit Information

Since the transit user's ability to make timely trips depends on the transit agency, transit scheduling information is important. In particular, transit users are interested in gaining information related to the schedules, available routes, fares, delays, and estimated time of arrival for the bus or train (10). All available transit information should be provided to the user through the regional traveler information home page.

Although not all regions have a transit agency that provides service to the entire region, there are long distance bus and rail services, such as Greyhound and AmTrak, which provide service on a national basis. These agencies, as well as most metropolitan transit agencies, maintain home pages that contain a wide range of information such as schedules, fares, and routes. If a transit agency does not maintain a home page , the agency's phone number should be provided in place of a link, so that the user has the option to obtain more information.

Some examples of transit information home pages are shown here:

- AmTrak - http://www.amtrak.com/
- Greyhound Bus Lines - http://www.greyhound.com/
- Riderlink Home Page - http://transit.metrokc.gov/
- Ventura County Transportation Commission Home Page - http://www.goventura.com/
- Houston Metropolitan Transit Authority Home Page - http://www.hou-metro.harris.tx.us/

DESIGN GUIDELINES

The way that the information is presented is a very important issue that should be given special attention. If the information contained within the regional traveler information home page is not in a useable format, it is useless to the traveler. For this reason, home page design guidelines will be presented that will insure a useable site that presents information in a consistent and easy to understand manner.

Organization

The internet user needs to be able to easily navigate through the site to find what they are looking for. Consequently, it is important to provide a table of contents on the opening page with links to each subject area (21). It is also important for the user to be able to quickly and easily go back to this opening page. For this reason, it is a good idea to provide a link to the opening page on each page within the internet site. If an agency is in the process of adding new contents to the home page, it is beneficial to show "Under Construction" signs adjacent to the content title to tell the user that new information will soon be added, but is currently unavailable.

Graphics

On the internet, a picture is worth a thousand words. That is why it takes a thousand times longer to load them, or at least it seems that way (21). Although the main attraction of many home pages are the flashy graphics and the promise of multimedia, the value of the page lies in the accessability of the information that it provides. If it takes too long for these graphics to load on to the user's computer, they many times will not wait, and any information that the site provides is useless. Most internet users would rather use a simple sight that clearly presents the information that they are looking for than a site that presents flashy graphics that take too long to load (22). If it is preferred to display a significant amount of graphics, provide a text only format that presents the same information without the pictures.

Consistency

Another key to keep in mind when designing a home page is to stay consistent. Consistency should be maintained through the use a site logo, graphical elements, as well as the personality and style through which the information is presented. This quality will bring the site together and make it cohesive as a whole. Consistency also makes the maintenance of a site somewhat easier. If a site-wide theme is maintained, site-wide changes will be easy to make (21).

Feedback

Provide the user a channel of feedback. By providing an e-mail link on the home page, users can voice their concerns, opinions, and complaints directly to the agency. In this way, feedback is not only an advantage to the user, but also to the agency. In fact, this is one of the few measures of effectiveness that an agency has to rate their site. Feedback links should be provided on each page within the internet site (22).

Links

It is important that the links which are provided within the home page are meaningful. The text links within the document should flow well with the rest of the text, such that the page can be used as a stand alone document even if the links are removed. Many home pages include links by using the text "click here" instead of a word or phrase that describes the information that is being linked to. This "click here" syndrome should be avoided at all costs (21).

When creating a web site that includes multiple links that transfers the user to another home page, a forewarning that informs the user that they are leaving the traveler information home page and will have to use the "Back" button to return to that home page is helpful. This practice is currently used on the Go Ventura home page maintained by the Ventura County Transportation Commission (23).

REGIONAL TRAVELER INFORMATION HOME PAGE TEMPLATE

In order to convert the guidelines into a usable format, a regional traveler information home page template was created. The generic template, developed following the design and information guidelines discussed earlier, was created so that it may be used by any regional area. Issues concerning the information and design guidelines are discussed in the following sections.

Information Content

As seen in Figure 2, the opening page of the regional traveler information home page lists the six types of necessary traveler information including weather information, maps and directions, roadway condition and construction information, traffic information, airport and flight information, and transit information. A "Regional Cities' Home Pages" information link is also included to provide the user with additional information on the cities within the region.

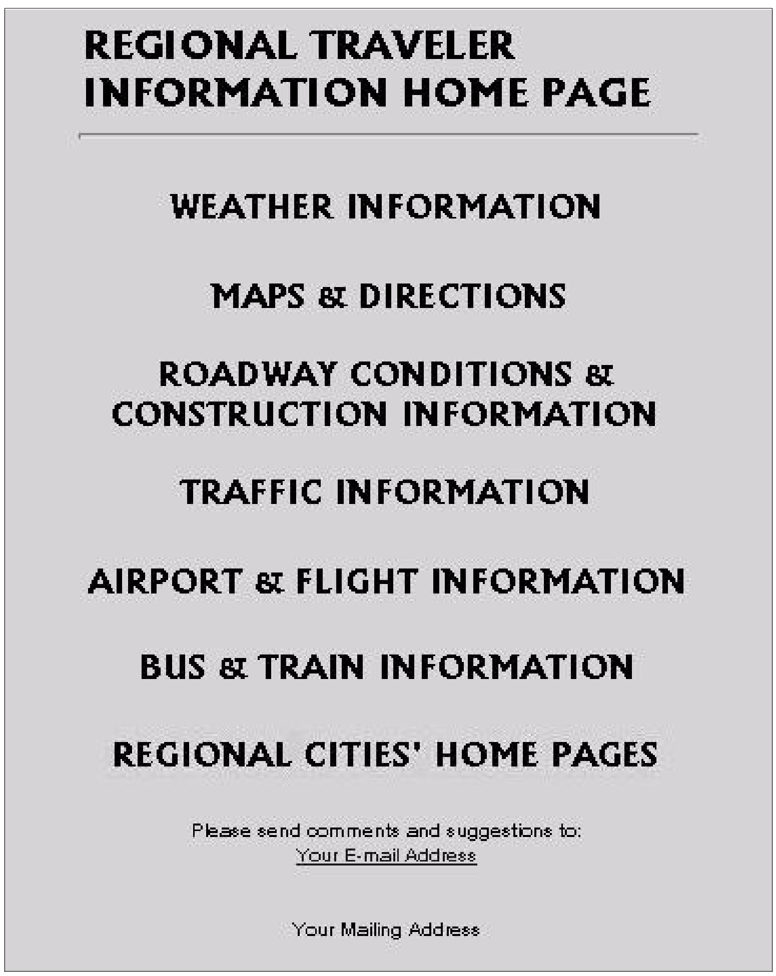


Figure 2. Opening Page of the Regional Traveler Information Home Page Template.

When converting the generic template to an actual traveler information home page, the user would specify links to each of these information types using an internet home page editor. The weather information, maps and directional information, and roadway condition and construction information links should be used to connect the user directly to the respective information sources such as the Weather Channel Home Page for weather information. The other information links including those for traffic information, airport and flight information, transit information, and regional cities' home pages must be linked to nested pages that provide the user additional choices. For example, the transit information link should be linked to a page that includes the different regional transit choices, as seen in Figure 3. Furthermore, each transit choice should be linked to the home page of the respective transit agency.

Figure 3. Transit Information Page of the Regional Traveler Information Home Page Template.

Template Design

The physical layout of the regional traveler information home page template is very simple and easy to understand. Organization was established by using a table of contents on the opening page as shown in Figure 2. The table of contents allows the user to directly link to the necessary information types. Each page contains the "Regional Traveler Information Home Page" title, the individual information links, and feedback information. Pages that are nested within a specific information area also contain the information subtitle, as well as a "Return to Start" link. An example of this information may be seen in Figure 4.

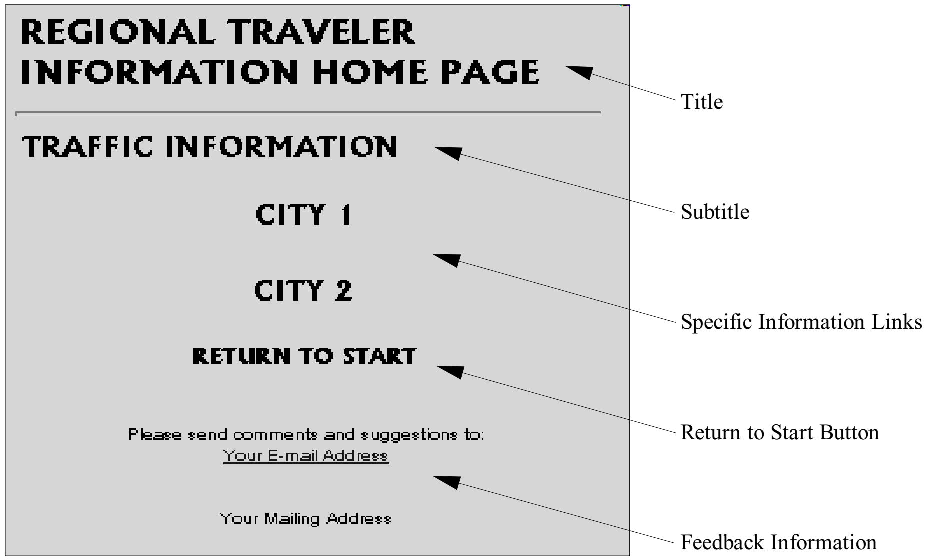


Figure 4. Information Display on Regional Traveler Information Home Page.

INTERSTATE-45 CORRIDOR TRAVELER INFORMATION HOME PAGE

To apply the template which was presented in this research report, a regional traveler information home page was developed for the region along the Interstate 45 (I-45) corridor between Galveston and Dallas, Texas. This home page is simply a packaging tool that presents the information that is already maintained on the internet into one site. A summary of the I-45 corridor characteristics and a discussion of the information content of this home page are given in the following sections.

Interstate-45 Corridor Characteristics

The I-45 corridor, as defined in this paper, connects Houston and Dallas, the two largest cities in the state of Texas and two of the ten largest cities in the United States (24). The roadway is 284 miles long with the southern end of the interstate lying in the Texas port city of Galveston, while the northern end of the corridor merges into U.S. 75 in Dallas. Of the ten worst congestion per capita cities in the nation, two of them lie on this corridor (25). The cities served by George Bush Intercontinental Airport and Dallas-Fort Worth International Airport, two of the nations twenty busiest international airports, are connected by Interstate 45.

Design of the Home Page

The I-45 Corridor Traveler Information Home Page, developed by the author, consists of six separate pages of traveler information. The opening page of the site, that may be seen in Figure A-1, consists of a table of contents of the different types of traveler information which is available, as well as a feedback e-mail link and address information in the case that the user has comments or concerns. The other five pages of the site contain specific links to information that falls under the different categories as specified in the table of contents.

Information Links

The Interstate 45 Corridor Traveler Information Home Page links to a broad range of on-line traveler information for the I-45 corridor region. Each type of information which was found important was incorporated into the home page. The following sections explain the information that was included in the page.

Weather Information

The Weather Channel Home Page was used to provide the user with weather information (18). The "weather information" link from the I-45 Corridor Traveler Information Home Page links the user directly to the Texas weather information page maintained by the Weather Channel. From this page, the user may select from any Texas city to get frequent weather updates as well as a number of informative maps and a five day forecast such as that seen in Figure 5.

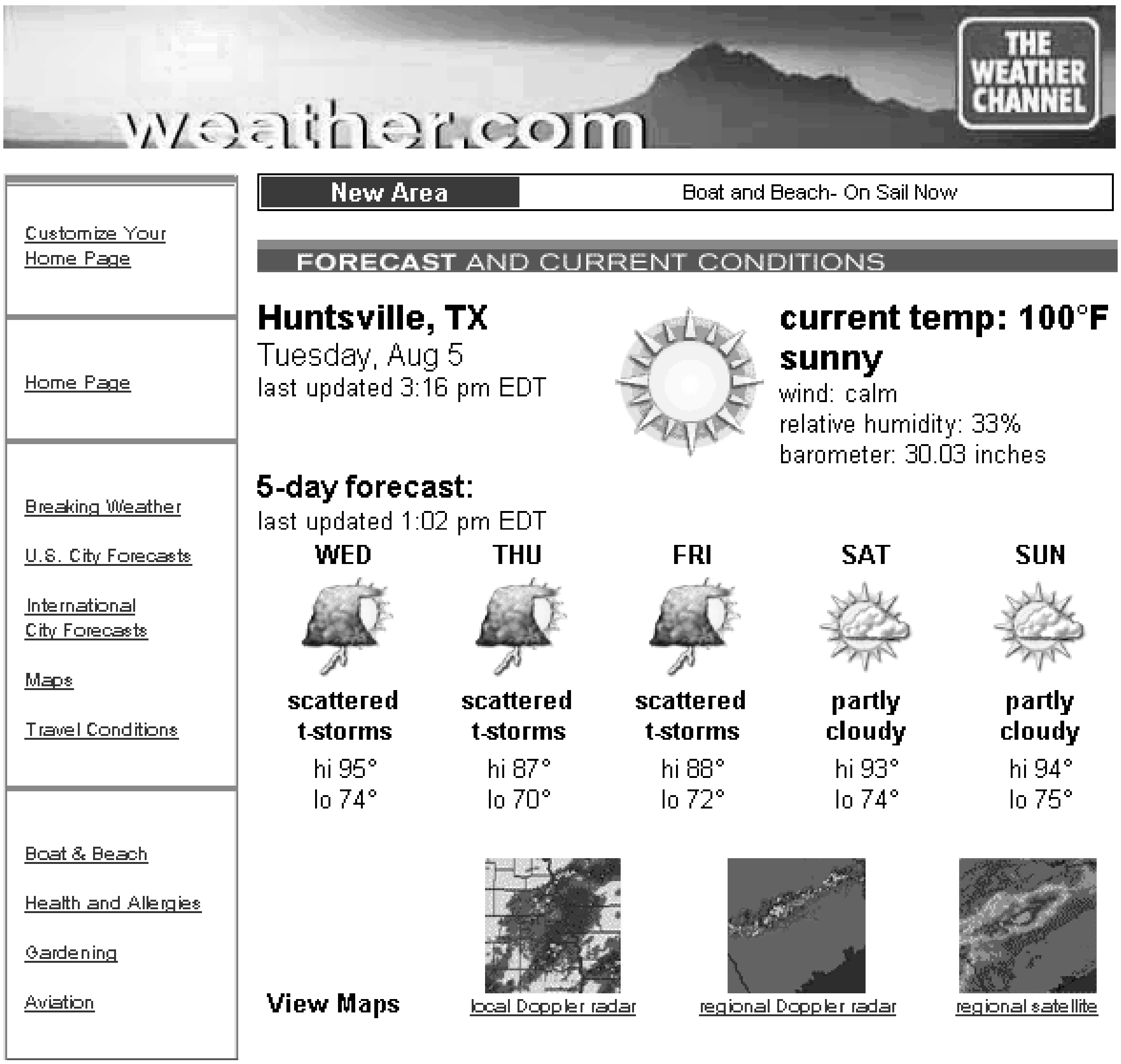


Figure 5. Example of Weather Information.
[http://www.weather.com]

Maps and Directional Information

If a user needs maps or directions, they can simply click the maps and directions button. This link will take them directly to the Yahoo! Maps page (26). On this page, the user can obtain a map of almost any city in the United States including those in the I-45 corridor region, such as that in Figure 6. This page can also supply the user with turn-by-turn driving directions and accompanying maps between any two points, given two cities or two addresses. The only constraint is that the cities must be less than 1000 miles apart.

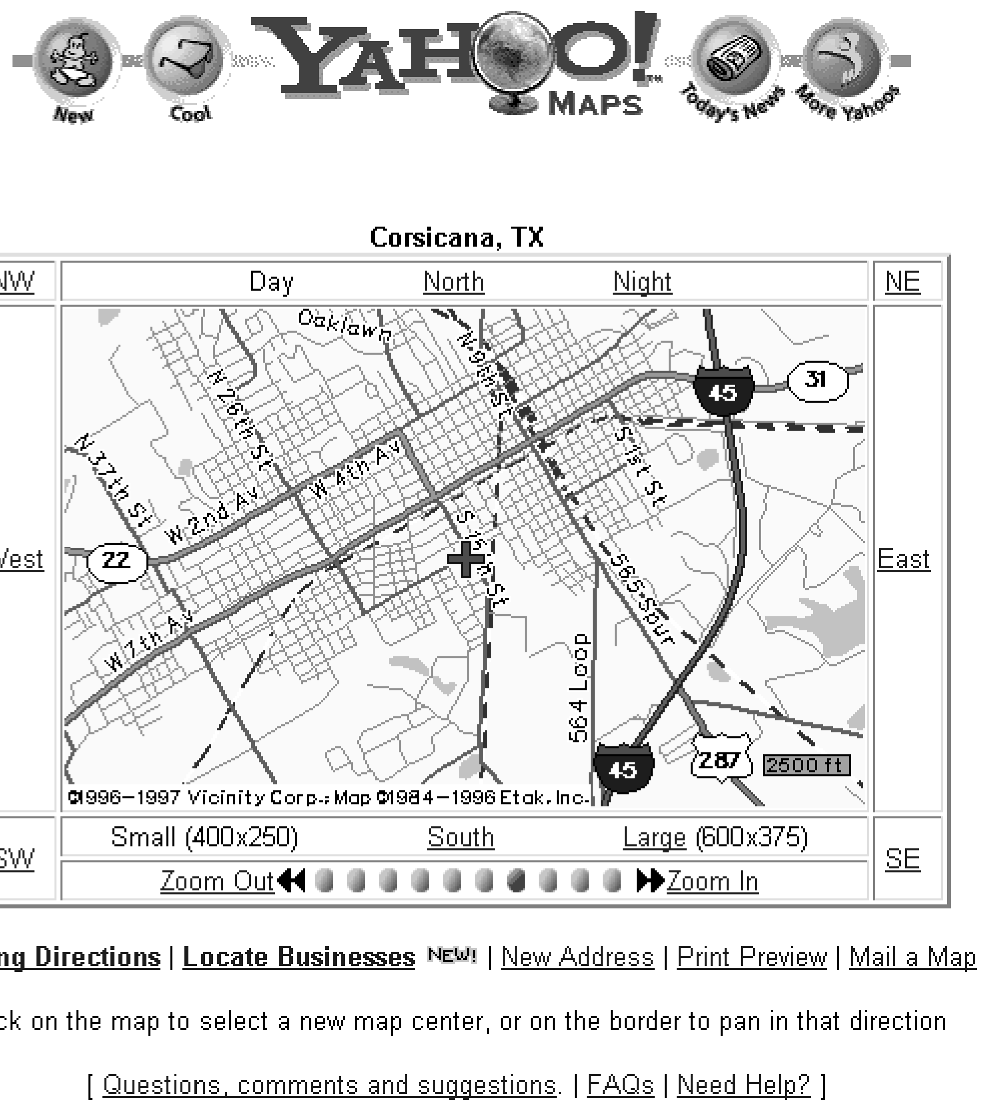


Figure 6. Example of Online Mapping Information.
[http://maps.yahoo.com/yahoo/]

Roadway Condition and Construction Information

The roadway condition and construction information for the I-45 Corridor Traveler Information Home Page was provided by the Texas Department of Transportation Home Page (27). This link provides information for all state maintained roadways by highway class. As seen in Figure 7, a wide variety of information including highway number, condition, beginning and ending points, direction, delay or detour, county, as well as other information is provided. In the summer months, most of the information that is provided is related to construction information; in winter months most of the information that is provided is related to adverse weather conditions such as snow and ice.

Texas Department of Transportation

Highway Condition Report for Interstate Highways

LAST UPDATED at Tue Aug 5 15:10:03 1997 CST

Disclaimer | **Interstate Highways** | US Highways | State Highways | Farm-To-Market | Ranch-To-Market | All Others | Today's Report | Previous Day's Report | TxDOT Districts | Weather for Selected Cities |

HWY: IH 10 **CONDITION:** CONSTRUCTION **FROM:** TURTLE BAYOU **TO:** TURTLE BAYOU **DIRECTION:** W **DELAY/DETOUR:** DELAY **COUNTY:** CHAMBERS **MAP COORD:** 22,Q **DISTRICT:** BEAUMONT **REPORT TIME:** 8:11 AM **INFO:** EXPECT DELAYS. LEFT LANE CLOSED

HWY: IH 10 E **CONDITION:** CONSTRUCTION **FROM:** US 59 **TO:** US 59 **DIRECTION:** E W **DELAY/DETOUR:** DEL DET **COUNTY:** HARRIS **MAP COORD:** 20,Q **DISTRICT:** HOUSTON **REPORT TIME:** 8:05 AM **INFO:** RAMPS TO US 59 NORTHBOUND CLOSED, DETOUR TO US 59 SOUTH TO RUNNELS U-TURN, UNTIL NOVEMBER 1997

Figure 7. Example of Roadway Condition Report from the Texas Department of Transportation. [http://www.dot.state.tx.us/high1.html]

Traffic Information

Although no traffic information is available at a regional level for the I-45 corridor region, real-time traffic information was available for the Houston and Dallas metropolitan areas. For Houston, the Houston Real-Time Traffic Map, maintained by the TransLink™ Laboratory at the Texas Transportation Institute was used. Dallas real-time traffic, as seen in Figure 8, was provided by the AccuTraffic traffic information home page (14,33). Although these sites provide traffic information in different ways, they both can be used to identify congested areas along the metropolitan surface transportation network. The "Traffic Information" page of the I-45 Corridor Traveler Information Page may be seen in Figure A-2.

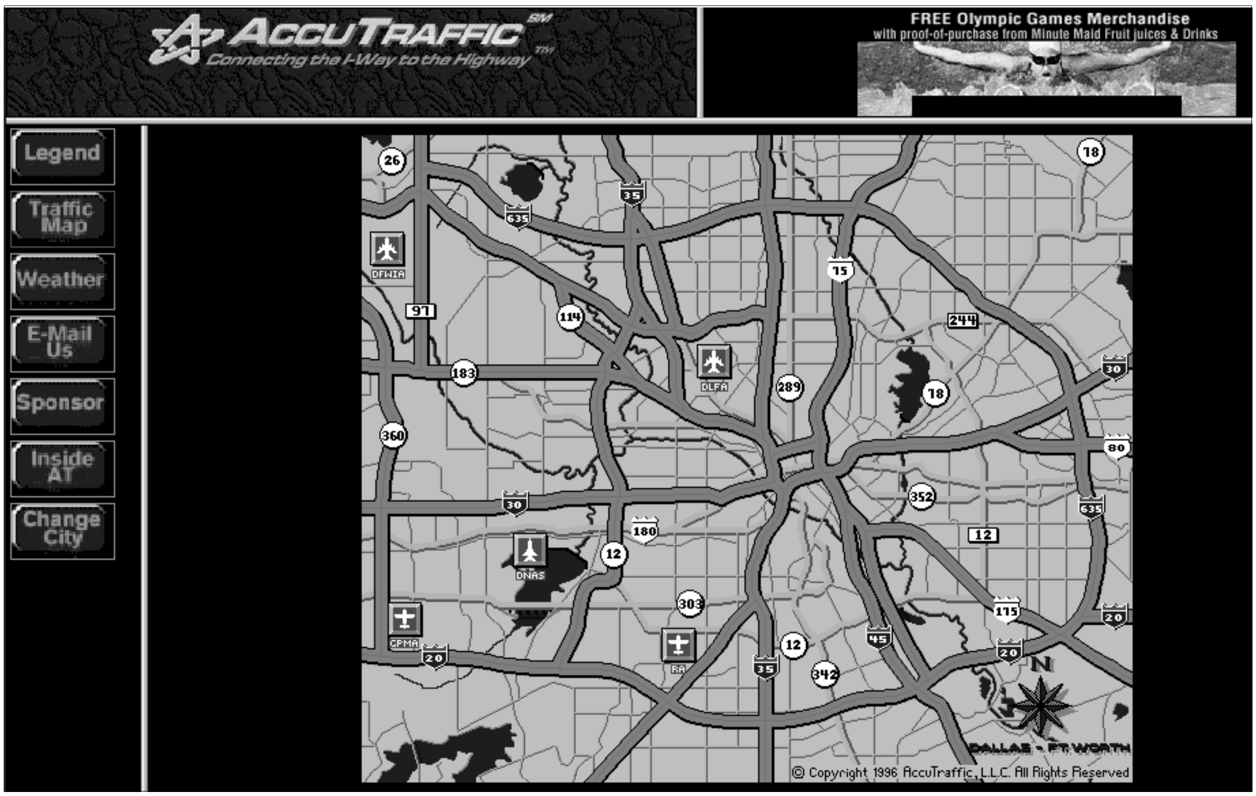


Figure 8. Example of Dallas Real-Time Traffic Map.
[http://www.accutraffic.com/accuinfo/cities/dallas.tx/home.html]

Airport and Flight Information

A broad range of airport and flight information is offered through the I-45 regional traveler information home page. With the click of a button, the user can locate information concerning flight delays, estimated time of arrival and location information on en-route flights (see figure 9), as well as information on several of the major airports of the region including Dallas-Fort Worth International Airport, George Bush Intercontinental Airport in Houston, and William P. Hobby Airport in Houston (18,19,34,35,36). The "Airport and Flight Information" and "Airport Links" pages of the I-45 Corridor Traveler Information Home Page may be seen in Figures A-4 and A-5, respectively

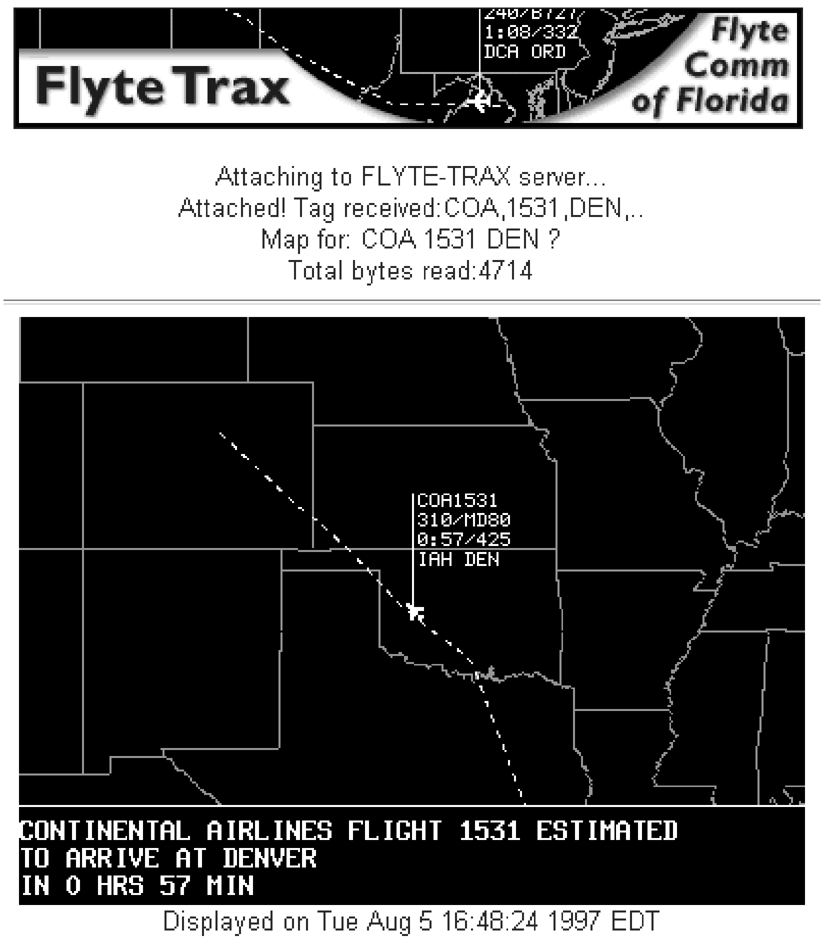


Figure 9. Sample En-Route Flight Information.
[http://www.weatherconcepts.com/FlyteTrax/]

Transit Information

The "Transit Information" page, as seen in Figure A-3, of the I-45 Corridor Traveler Information Page contains links to all of the relevant transit agencies in the I-45 corridor region. These include Dallas Area Rapid Transit for Dallas metropolitan area, the Trinity Railway Express for the area between Dallas and Irving, the Harris County Metropolitan Transit Authority for the city of Houston, as well as Greyhound bus lines, and AmTrak rail lines (28,29,30,31,32). Although Greyhound and AmTrak are not conventionally thought of as transit agencies, they do provide an alternative mode of travel between Houston and Dallas.

Each of these home page links provide vastly different information and to different degrees of detail. While Houston METRO provides a wide variety of information concerning bus schedules, route maps and fares, as seen in Figure 10, the Trinity Railway Express site offers only general information such as service times and important dates. Both the Greyhound and AmTrak home pages offer a broad range of information on fares, schedules, stops, as well as airport connections.

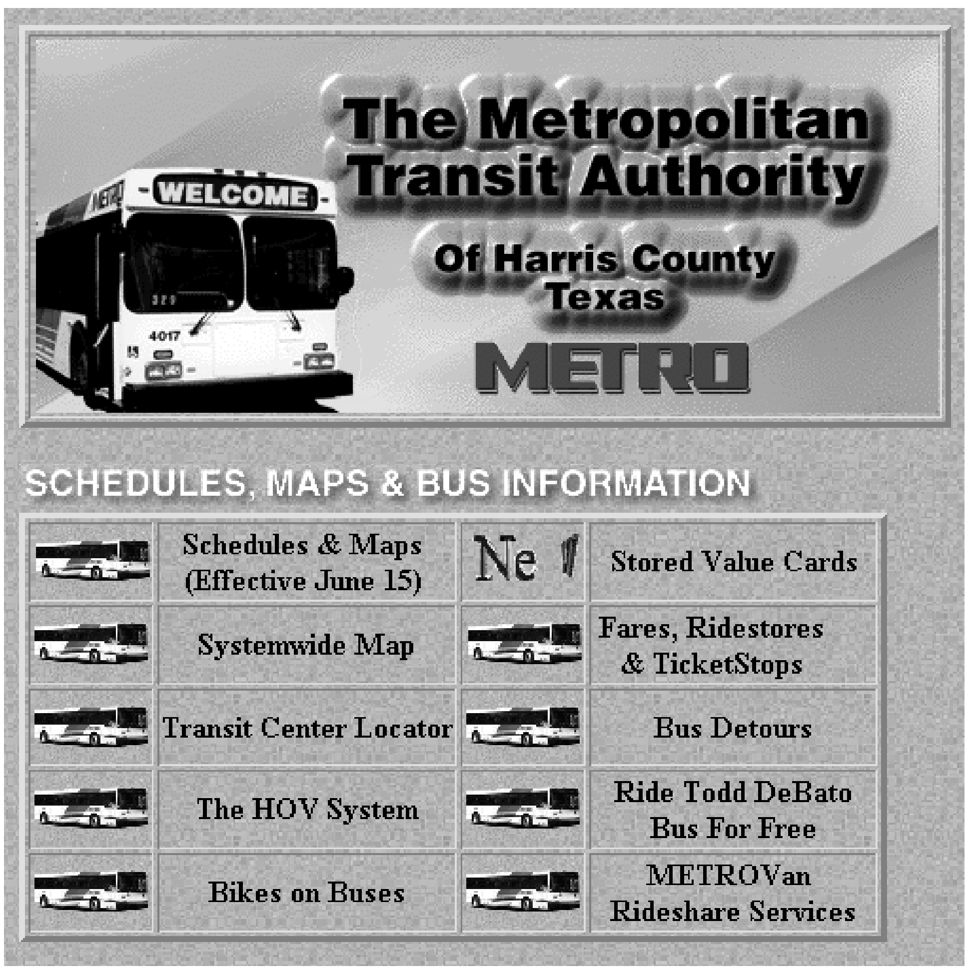


Figure 10. Example of Online Transit Information for Houston METRO.
[http://www.hou-metro.harris.tx.us/]

Regional Cities' Home Pages

The last information link on the I-45 Traveler Information Home Page is the "Regional Cities Home Pages" page, which may be seen in Figure A-3. This page contains links to the 12 cities along the I-45 corridor that currently maintain home pages. Although the information contained on the regional cities' home pages varies greatly, almost all pages contain the most basic level of traveler information including hotels, restaurants, and attractions.

CONCLUSIONS

There are six primary information needs that should be provided to the traveler through a regional traveler information home page. These needs include weather information, traffic information, roadway condition and construction information, maps and directional information, is transit information, and airport and flight information. Each of these types of information available on the internet and can be easily integrated into a regional traveler information home page.

There are several design guidelines that should be followed when developing an internet home page. Several key areas including organization, graphics, consistency, feedback, and links should be given special attention. If the guidelines which are presented are followed, the transportation agency will have a regional traveler information home page that will be helpful and easy to use.

There are four primary cost components that are encountered when developing an internet home page. These components include development, registration, hosting, and maintenance. The development component of the home page may be done by either a professional internet marketing or by an in-house employee that is knowledgeable of the internet. The costs associated with having the site professionally developed should cost between $1000 and $5000 depending on the technological content of the site. The registration component includes having the internet address registered with InterNIC, the only internet registration service. Registration will cost $100 for the first two years and $50 for each year thereafter. Hosting the site involves having the home page electronically stored on an internet server so that it will be connected to the rest of the World Wide Web. This cost ranges between $20 and $40 per month. The maintenance cost depends on the amount of time that must be spent to adequately maintain the home page as well as who does the maintenance. While maintenance done by an in-house employee will cost virtually nothing, the cost of a professional agency ranges between $25 and $75 an hour.

Although almost all necessary regional traveler information is currently maintained on the internet, there are still some “gaps” that presently remain unfilled. One such “gap” is that of traffic and incident information in rural areas. One reason why many gaps such as this exist is due to the fact that the technology is not in place to provide the necessary information to the internet. It is expected that when this technology becomes available, disseminating the information that it provides through the internet will occur soon thereafter.

This paper also presented only one of many ways that the information can be displayed to the user via the World Wide Web. There are certainly many more ways that are more efficient in providing the user the information they need. One efficient method would allow the user to input their trip origin and destination, along with the time and date of the trip. With this information, the computer would display a range of personalized traveler information including a map, weather forecasts, roadway condition and construction information, and so forth. Although the technology necessary to do this is currently available, the high cost at which it is available makes it undesirable. As the technology continues to grow, these costs should decline, and traveler information systems such as this will become a reality.

ACKNOWLEDGMENTS

This report was prepared for *Advanced Surface Transportation Systems*, a graduate level transportation engineering course at Texas A&M University. The author would like to express his sincere gratitude to Ginger Gherardi of the Ventura County Transportation Commission who served as a mentor during the development of this paper. A special thanks goes out to the other professional mentors including Marsha Anderson, Thomas Hicks, Joseph McDermott, Colin Rayman, and Douglas Robertson for their assistance and encouragement. The author also wishes to thank Dr. Conrad Dudek, the course instructor, for his direction and guidance, and to Sandra Schoeneman for her organization and dedication to the program. Finally, thanks goes out to my wife Anne for the love and support she gives me everyday.

REFERENCES

1. Let's Wep Internet Site. [http://www.letswep.com/stats.html]. June 2, 1997.

2. Web Growth Summary Internet Site. [www://www.mit.edu/people/mkgray/net/web-growth-summary.html]. June 2, 1997.

3. Szczesny, Donald. *Dissemination of Traffic Information to the Motoring Public via the Internet: A Synopsis of Current Ongoing Projects*. Institute of Transportation Engineers. 1996 Compendium of Technical Papers for the 66th ITE Annual Meeting. September 1996, pp 73-77.

4. Finklea, Ben. Of Web Wright Inc. Response to survey as administered by Kendall Fogle regarding the costs associated with developing an internet home page. July 9, 1997.

5. Employee of Global Knowledge Group. Response to survey as administered by Kendall Fogle regarding the costs associated with developing an internet home page. June 25, 1997.

6. Salwen, Peter. "Sticking with the Web". *ASCE: Civil Engineering*, June 1996, pp 37-41.

7. Bailey, Andrew. Of Alpha1. Response to survey as administered by Kendall Fogle regarding the costs associated with internet service. July 9, 1997.

8. Burleson, Jennifer. Of STARTEL Communications. Response to survey as administered by Kendall Fogle regarding the costs associated with internet service. July 9, 1997.

9. Sarver, Jennifer. Of TCA Communications. Response to survey as administered by Kendall Fogle regarding the costs associated with internet service. July 9, 1997.

10. Hobeika, Antoine, R. Sivanandan, Karen M. Jehanian, and Mary D. Ameen. Advanced Traveler Information System Users' Needs in I-95 Northeast Corridor. *Transportation Research Record 1537*, TRB, National Research Council, Washington, D.C., 1997, pp.55-62.

11. Wilson, Eugene M. "Winter Travel Motorist Information Needs". *ITE 1993 Compendium of Technical Papers*, Institute of Transportation Engineers, Washington D.C., September 1993, pp. 168-174.

12. Dudek, Conrad L. and Dannie Cummings. *Application of Commercial Radio to Freeway Communications - A Study of Driver Attitudes.* TTI Report 139-3. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, 1970.

13. Gary-Chicago-Milwaukee corridor Transportation Information Center Home Page. [http://www.ai.eecs.uic.edu/gcm/GCM.html]. August 1, 1997.

14. AccuTraffic Home Page. [www.accutraffic.com]. June 3, 1997.

15. Ohio Department of Transportation Home Page. [http://www.dot.state.oh.us/const/seohio.htm]. July 12, 1997.

16. Road Watch America Direct Home Page. [http://rwa.metronetworks.com]. June 3, 1997.

17. I-95 Corridor Coalition Traveler Information Home Page. [http://www.i95coalition.org/travel.html]. August 5, 1997.

18. The Weather Channel Home Page. [www.weather.com]. August 1, 1997.

19. American Weather Concepts Flyte Trax Home Page. [http://www.weatherconcepts.com/FlyteTrax/]. July 10, 1997.

20. Directory of Transportation Resources. [http://dragon.princeton.edu/~dhb/]. August 5, 1997.

21. Composing Good HTML. [http://www.cs.cmu.edu/~tilt/cgh/]. July 9, 1997.

22. Shull, Lee Anne. "The Use of the Internet as an Effective Tool for Disseminating Traveler Information". *Compendium: Graduate School Papers on Advanced Surface Transportation Systems.* Report SWUTC/96/72840-00003-1. Southwest Region University Transportation Research Center, Texas Transportation Institute, The Texas A&M University System, College Station, Texas. August 1996.

23. Go Ventura Home Page. [http://www.goventura.org]. June 3, 1997.

24. The Ten Largest Cities in the United States: Frequently Asked Questions. [http://sparc.hpl.lib.tx.us/hpl/tra85.html]. July 13, 1997.

25. TTI Mobility Study Executive Summary. [http://tti.tamu.edu/mobility/execsum.html]. July 13, 1997.

26. Yahoo! Maps. [http://maps.yahoo.com/yahoo/]. August 5, 1997.

27. Texas Department of Transportation Highway Condition Report for Interstate Highways. [http://www.dot.state.tx.us/high1.html]. July 12, 1997.

28. Dallas Area Rapid Transit Web Site. [http://www.dart.org/]. August 5, 1997.

29. Trinity Railway Express Home Page. [http://www.flash.net/~cymartin/opening.html]. August 5, 1997.

30. The Metropolitran Transit Authoirity of Harris County, Texas Home Page. [http://www.hou-metro.harris.tx.us/]. August 1, 1997.

31. Greyhound's Internet Station. [http://www.greyhound.com/]. August 5, 1997.

32. Amtrak Home Page. [http://www.amtrak.com/]. August 5, 1997.

33. Houston Real-Time Traffic Map. [http://traffic.tamu.edu/traffic.html]. August 5, 1997.

34. Dallas-Fort Worth International Airport Home Page. [http://www.dfwairport.com/index2.htm]. August 5, 1997.

35. George Bush Intercontinental Airport Home Page. [http://www.ci.houston.tx.us/departme/aviation/iah/]. August 5, 1997.

36. William P. Hobby Airport Home Page. [http://www.ci.houston.tx.us/departme/aviation/hou/]. August 5, 1997.

APPENDIX A

The I-45 Corridor Traveler Information Home Page

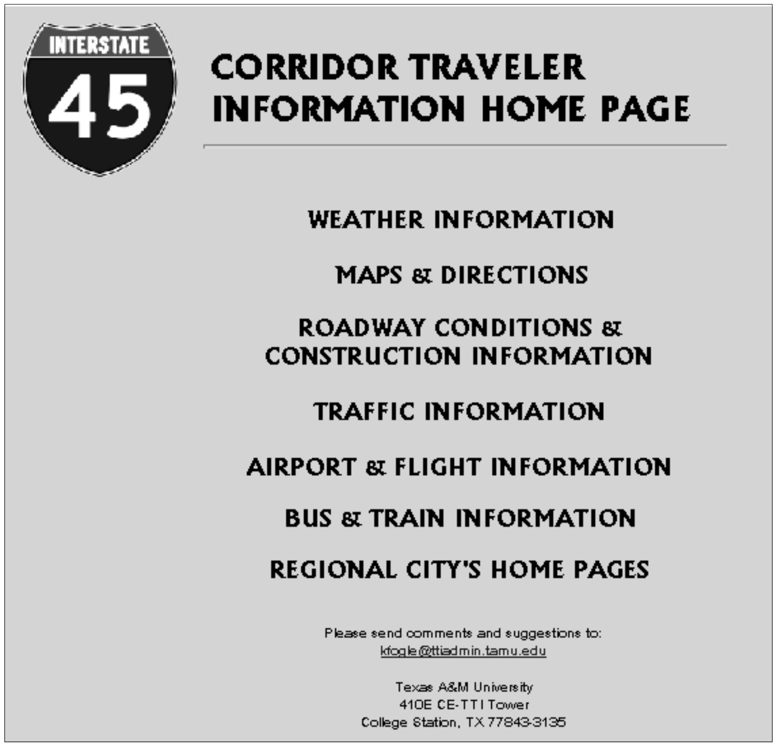


Figure A-1. Opening Page of the I-45 Corridor Traveler Information Home Page.

Figure A-2. Traffic Information Page of the I-45 Traveler Information Home Page.

Figure A-3. Airport and Flight Information Page of the I-45 Traveler Information Home Page.

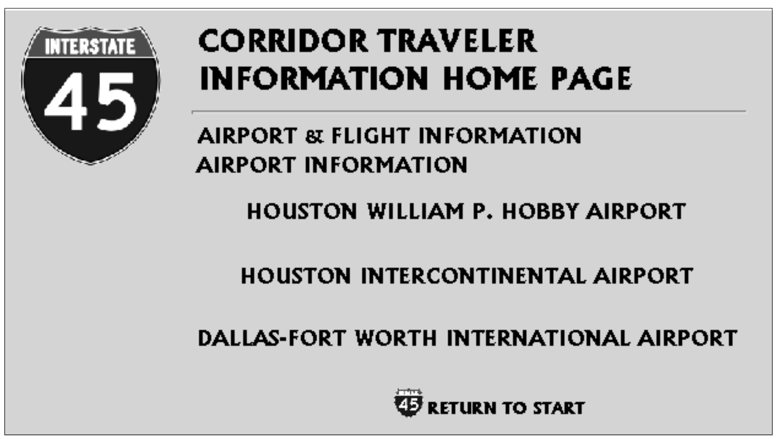


Figure A-4. Regional Airports Page of the I-45 Traveler Information Home Page.

Figure A-5. Bus & Train Information Page of the I-45 Traveler Information Home Page.

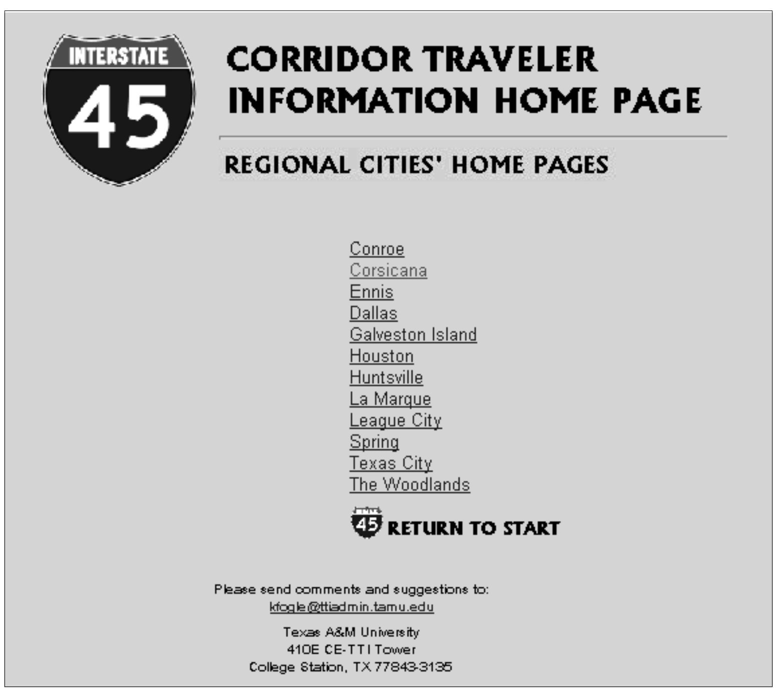


Figure A-6. Regional Cities' Page of the I-45 Traveler Information Home Page.

Kendall L. Fogle received his B.S. in Civil Engineering from Texas A&M University in May 1996, and is currently pursuing his M.S. in Civil Engineering from Texas A&M University. Kendall has been employed by the Texas Transportation Institute since 1994 and has worked as a Graduate Research Assistant since August 1996. University activities that he is involved in include: Institute of Transportation Engineers, ITS America, and the American Society of Civil Engineers. His areas of interest include: transportation planning, traffic operations, and geometric design.

KIOSK DEPLOYMENT ISSUES AND GUIDELINES FOR THE DISSEMINATION OF TRAVELER INFORMATION

by

Aaron M. Hottenstein

Professional Mentors
Marsha Anderson
Street Smarts

and

Ginger Gherardi
Ventura County Transportation Commission

Prepared for
CVEN 677
Advance Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

A growing number of public agencies in the United States are considering the use of kiosks as a tool to disseminate traveler information to tourists and commuters. The high cost of kiosks units, between $8000 and $20,000, and low use rate prompts some concern about the types of locations chosen for kiosks. The problem of determining locations where kiosks will be the most effectively used should be primary concern for public agencies.

The objectives of this research were to identify the buildings and location that are ideal for kiosks, identify barriers to the deployment of kiosks at various locations, examine experiences of public agencies that have deployed kiosks, and develop guidelines for kiosk deployment that will allow a public agency to place kiosks at ideal locations.

Six advanced traveler information kiosk projects were examined to determine the site selection processes used and kiosk use rates with each project. After examining the kiosk projects, guidelines and a site selection process was developed to aid public agencies in the determination of kiosk locations. The kiosk projects examined were:

- Travelink, sponsored by the Georgia Department of Transportation
- InfoBang$_{sm}$, a U.S. DOT and Texas Department of Transportation sponsored project
- Travlink, a Minnesota Department of Transportation Advanced Traveler information test
- SmartTraveler, a Los Angeles kiosk program used after the Northridge earthquake
- RiderLink, Seattle, Washington
- Traffic Management System of Hampton Roads, Virginia Department of Transportation

The analysis of the kiosk projects showed that kiosk use rates were low and were in the range of 20 to 50 uses a day. The use of a kiosk site selection process allows kiosk project teams the ability to justify kiosk locations. After the examination of the six kiosk projects listed above, deployment guidelines and a site selection process were developed to aid public agencies with the creation of a kiosk program. The following issues should be considered during the development of a kiosk system.

- Public-private partnerships,
- Advertising issues on public and private right-of-way,
- Kiosk design,
- Power and Communication connections, and
- Site Selection Process (Geographic Area, Pedestrian Volumes, Kiosk Accessibility, Policy and Institutional Impacts and Ease of Installation)

The deployment guidelines and the site selection process were applied to a hypothetical example to illustrate the application of each deployment guideline and the site selection process. A sample scoring methodology is also provided to illustrate a scoring system that should be used in the kiosk site selection process.

TABLE OF CONTENTS

INTRODUCTION

Kiosks comprise one component of Advanced Traveler Information Systems (ATIS) and are used in some urban areas of the United States to disseminate information to commuters and travelers. Other locations where kiosks may be used are at airports, bus terminals, train stations, parking garages, car rental agencies and rest areas (1). Typically, kiosks contain information about bus and train schedules, special events, directions to landmarks and other travel information. In order to display all of this information, several panels, or walls, may have been needed; however, with today's technology, computer touch screens provide a simple method of displaying information through the use of one single interactive display. The computerized kiosk design may consist of video monitors mounted in walls, on counter tops or as stand alone units. Computerized kiosks can provide travelers with specific travel information through the use of text, graphics and printed personalized trip instructions. Some kiosks may connect with real time traffic information sources to inform travelers of potential traffic problems (1). Not only can kiosks provide information, but they may also provide some consumer transactions, if card and bill readers are installed (2). The services that a kiosk can provide are shown in Table 1.

Table 1. Kiosk Services (2).

Kiosk Information and Services		
Real-Time Traffic Information	Mass Transit Schedules	Route Determination
Emergency Vehicle Dispatch	Mode Ticketing	Survey User Needs
Fare Calculation and Collection	Travel Reservations	Map Dispensing
Roadway Conditions	Tourist Information	Weather Information
Emergency Broadcast Information	Vehicle Registration	Advertising
Coupon Distribution	Yellow Pages Information	Banking Services

Some other forms of traveler information sources that use technology are Internet web sites, and vehicle display units. The Internet provides municipalities the opportunity to disseminate traveler information to the public. Many of these web sites may be accessed by individuals at the work place or at home and the use of kiosks allows public agencies to place traveler information at locations where individuals do not have access to computers connected to the Internet. The connection of a kiosk to the Internet would allow users to access real time traffic information (1).

Problem Statement

The location of a traveler information system is a critical component in the success of a traveler information program. Web sites that are easily accessible through the Internet are ideal for informing commuters of traffic problems on the highways. However, there are many circumstances that would prevent an individual from having access to the Internet and traveler information services. Individuals that do not have access to the Internet, or other means of real time traffic information may need a location where this information is accessible. The number of people estimated not to have access to the World Wide Web is 97 percent (3). Kiosks allow people without access to the government and the Internet an opportunity to acquire traveler information (3).

The location of kiosks is important. If people who desire traveler information cannot find the necessary information sources, then people will have to settle for traveling without any traffic information. The location of kiosks is also very important to the public agencies deploying them. If the kiosks are not used, then a large investment of capital may be lost, because individual kiosk units may cost between $8,000 and $20,000 not including the costs associated with installation, software purchases and network connections (4).

Objectives

The overall goal of this research was to identify a method for selecting kiosk locations that will generate the highest use of kiosks for the dissemination of traveler information by public agencies in metropolitan areas of the United States. The specific objectives of this research were to:

- identify the types of buildings and locations (office, shopping centers, bus/train stations, etc) that are ideal for kiosks in urban areas of the United States,
- identify barriers to kiosk deployment for public agencies,
- examine the experiences of the Georgia Department of Transportation, the Minnesota Department of Transportation and the Texas Department of Transportation,
- develop kiosk deployment guidelines for public agencies interested in disseminating traveler information, and
- apply suggested criteria to an urban area in the United States.

Scope

The scope of this research will include a review of kiosk locations in metropolitan areas of the United States. The kiosk projects that will be examined are sponsored by public agencies attempting to disseminate public transportation information and tourist information. The target kiosk users will be commuters and tourists who require transportation information (such as traffic conditions, bus schedules, among others) and traveler information (including landmark locations, special events, and others).

This research will not address issues associated with the design of the user interface of kiosks. Also due to their target audiences, private organizations that deploy kiosks for the purpose of selling a service or product will not be examined.

BACKGROUND

Kiosks allow people to access traveler information when other sources such as the Internet, telephones, radios and television are not available. Several kiosks have been deployed and the use rates of the kiosks is low. Kiosk use rates may range anywhere from 10 to 50 log-ons per day. This may be as a result of the location of the kiosks, and user awareness. The Riderlink project in Seattle, Washington indicates that approximately two to three percent of people may actually use a kiosk (5). Typically travelers tend to get most of their traveler information at home or work locations (5).

Kiosk use rates may be low due to a number of different types of factors. The presentation of traveler information may be one reason for low kiosk use. People using a kiosk must be capable of using computer touch screens and must be able to understand what commands need to be entered in order to access the desired information, or perhaps the information that is displayed may be confusing to the average traveler (5). Accessibility of the kiosk may be another factor that affects the use of kiosks. If people can not get to a kiosk, or find one, then the kiosks will not be used efficiently (6). Sometimes kiosks are not located where travelers need information or where travelers have time to use a kiosks (7).

METHOD OF STUDY

Literature and Internet Search

A search of the existing literature and Internet web sites was conducted to identify relevant research and projects related to the determination of kiosk locations. The kiosk site selection process that were identified in this paper deal with the steps and procedures used to determine the locations for kiosks and may include the factors and scoring systems used to evaluate site specific criteria. Partnerships examined in this paper deal with the relationships between public and private agencies. The barriers to kiosk deployment were the issues encountered when public agencies attempted to deploy kiosks at various locations.

Data Collection

The data collection effort consisted of the acquisition of numerous reports, papers presented at conferences, and phone interviews with individuals involved with kiosk deployment in the United States. The phone interviews were conducted to supplement the information found in the reports, gain further insight into the kiosk site location process, and identification of issues related to the deployment of kiosks. The phone interviews were conducted using a survey form (see Appendix) designed to keep a consistent method of questioning. The individuals contacted have worked directly on their respective projects at the time that the kiosks were deployed. These individuals were asked several questions to determine the site selection process methodology as well as the issues related to kiosk locations. Table 2 lists the individuals contacted and the projects represented in this research.

Table 2. Survey Contacts

Contact	Organization	Project
James Pohlman	TransCore	Traveler Information Showcase, Atlanta Georgia
Todd Long	Georgia Department of Transportation	Traveler Information Showcase, Atlanta Georgia
Michael Presley	Georgia Department of Transportation	Traveler Information Showcase, Atlanta Georgia
Marilyn K. Reemer	Minnesota Department of Transportation	TravLink
William McCasland	Texas Transportation Institute	Infobanq$_{sm}$, Houston, Texas
Dwayne Cook	Virginia Department of Transportation	Suffolk District TMS Center

Data Analysis and Application

The information presented in the “Study Results” section is examined to determine effective kiosk locations and the issues associated with various locations. The results of this analysis are found in the form of guidelines for the determination of kiosk locations. Some possible solutions to the barriers of kiosk deployment are suggested, but the solutions vary depending upon location and local legislation. A theoretical application of the proposed guidelines is presented to illustrate the proposed process.

STUDY RESULTS

The Study Results presents the examination of the kiosk deployment experiences of six different public transportation agencies. The first three of the projects are briefly described and highlight the kiosk site selection process and the kiosk use rate of some of the locations used. The last three project descriptions include an in depth analysis of the project description, information services, site location process, barriers to deployment, kiosk use and general project conclusions as well as current project status.

Riderlink, Seattle Washington

The Riderlink system implemented in Seattle Washington consisted of four kiosks, three of which were located near the employee cafeteria and one at the Metro Transit Headquarters, studies showed that people access traveler information by kiosks only a small portion (3 percent) of the time. Other locations, besides kiosks, where traveler information was accessed include the home (56 percent), work (32 percent) and school (7 percent). The kiosks located near an employee cafeteria were used an average of 10 times a month. This location for a kiosk was not ideal because the workers had set commutes and did not need alternate route or transit information, and the cafeteria may have been inconvenient for use towards the end of the day when workers are leaving the building (5). The kiosk that showed the highest use was located at the Metro Transit Headquarters and was used an average of 53 times per month (5).

Virginia Department of Transportation - Suffolk County, Virginia.

The Traffic Management System of Hampton Roads Virginia is currently in the process of negotiations with site locations and kiosk legislative issues to begin deployment of kiosks. The kiosks to be deployed in this region will provide commuters and travelers with congestion, incident and tourist information. The site selection process undertaken consisted of the examination of other kiosk projects, project team decisions and construction requirements for the kiosks, since some kiosks may be located along the beaches of Virginia. Some of the locations considered include high employment areas and tourist intensive locations. An example of a high employment center in the Hampton Roads area is a U.S. Naval Base (8).

There are several issues expected to be encountered during the deployment of the kiosks in the Hampton Roads areas. One expected issue is the possible development of sponsorship/advertising relationships. Another issue is the public-private partnership agreements required for sharing telecommunications and connecting ITS applications and databases. A third issue is site fees when deploying kiosks at mall locations. Some of the kiosks will also need to be weather resistant since some of them will be located along beaches (8).

In an effort to allow for Virginia agencies to disseminate information on kiosks, the Virginia State legislature has developed an "Information Technology Resource Management Policy Statewide Kiosk Program.(9)" Outlined in the policy are the following principles that should be followed when developing a kiosk program:

- Minimal start up cost/investment;
- Cost-neutral operating environment;
- Minimal risk of financial loss; and
- No addition to the existing State bureaucracy.

The policy also encourages the development of private-public relationships for the promotion of tourism and economic development with a possibility of providing commercial interactive services (9).

Smart Traveler Information Kiosks: Los Angeles

Originally this kiosk project consisted of 3 kiosks, but the Northridge earthquake prompted the additional deployment of 74 kiosks within the earthquake-impacted area. This kiosk system was capable of providing commuters with bus route, car pool and freeway congestion information along with other types of traveler information (10). These kiosks were deployed within a span of 3 months (May to July of 1994) with a total project cost of $2,895,735 (see Table 3) and are currently being stored in a warehouse after being in the field for 97 days (6). The sites selection process that was used for deployment contained the following criteria:

- density of foot traffic,
- site availability to the public,
- security, and
- business acceptance of the kiosk.

Table 3. Kiosk Cost Calculation for Smart Traveler Information Kiosks, in Los Angeles (6).

Kiosk Cost Calculations	
Software Purchases	$57,200
IBM Technical Assistance	$436,000
Kiosk Purchase Costs (77 Kiosks)	$1,421,547
Kiosk Site Preparation	$141,428
Phone Line Installation	$121,500
Kiosk Maintenance	$217,792
Miscellaneous	$500,268
Total Cost	$2,895,735

There was a large variety of sites chosen for the kiosks. Some were located in dense employment centers with high-rise offices, shopping malls, grocery stores, high-volume retailers, transportation centers, hospitals and public office buildings. Kiosk use was postulated to be a factor of the type of site, the level of activity in the kiosk vicinity, the quality of the area and other factors such as maintenance. For example, kiosks that were located at office buildings consistently had a lower use rate than any of the other kiosk locations. Table 4 shows the average use rates of various kiosk locations by weekday and weekends (6).

Table 4. Average Kiosk Use Per Day by Location and Time, in Los Angeles, California (6).

	Location Type				
	Shopping Center	**Grocery Store**	**Discount Store**	**Office**	**Other**
Weekend	51	23	52	5	20
Weekday	39	16	37	21	25

Reasons why the kiosk use rates at the shopping centers and stores were higher than office buildings was due to the type of activities that surrounds those locations (10). The amount of total traffic around a kiosk was dependent upon the pedestrian activity associated with a location and the number of hours of accessibility. Retail stores have longer hours of accessibility and higher amounts of pedestrian activity resulting in a higher use rate (10). While office buildings may be open during evenings and weekend, little activity occurs during these hours; therefore, a low kiosk use exists. For this kiosk program a high use rate was considered to be in the range of 39 to 49 uses per day.

A survey of people who walked near kiosks was conducted to gather information about kiosk users. A total of 1785 surveys were handed out and 325 were returned. The surveys reported that 81 percent of the respondents were aware of the kiosks and out of this group 84 percent had used them (10).

All of the kiosks contain a continuous moving light display to indicate the location of a Smart Traveler kiosk. However, there was nothing to indicate the function of the kiosks: therefore, users must be curious enough to determine the function of the kiosk before they approach them. Kiosks located in the Union Station, next to the MTA ticket office, may have indicated to pedestrians that the kiosk was available for traveler information, whereas pedestrians may not associate a kiosk located in a food court of a mall with traveler information (10).

Travelink - Atlanta, Georgia

Project Description

The Traveler Information Showcase (TIS) was a project sponsored by the ITS Joint

Programs Office in the U.S. DOT under contract to the Battelle Memorial Institute. TIS was meant to demonstrate the technology and capabilities that an Advanced Traveler Information System (ATIS) can provide to a city. Atlanta, Georgia was chosen for the site due to the 1996 Summer Olympics and the large international audience that would be present to use and experience the benefits of Intelligent Transportation Systems (ITS) (11). The TIS was able to provide traveler information through the use of personal communication devices, in-vehicle route guidance systems, cable television, interactive television and on-line services (i.e. the Internet). All of these systems were connected to one central system in order to provide various traveler information services required by users. The TIS was left in place after the Olympics as the foundation for future ITS projects in the State of Georgia (11).

In addition to the TIS, the Georgia Department of Transportation (GDOT) implemented project Travelink a kiosk system incorporated into the TIS. The kiosk system provided users with the same information as the TIS and the initial deployment consisted of 130 kiosks located in publicly accessible areas. The kiosk system was designed to disseminate traveler information and to enhance the mobility of travelers in the State of Georgia and the City of Atlanta. The kiosk system was intended to be a component of a traveler information system beyond the Summer Olympics of 1996 and is still in operation (12).

Traveler Information

Kiosks contained traveler information to aid travelers in the City of Atlanta and the State of Georgia. The kiosk system provided travelers with the following types of information (12):

- Real-time traffic information in the Atlanta region;
- Vehicle Routing;
- Metropolitan Atlanta Rapid Transit Authority (MARTA) schedules;
- Amtrak, Greyhound and Cobb County Transit information;
- Tourist Information;
- Weather;
- Airport and Airline Information; and
- Special Event notices.

Site Location Process

The site selection process began by compiling a list of potential locations based on target types described in the initial Travelink project proposal (12). A list was compiled by examining pedestrian flows at each location which considered locations at hotels, office buildings, government buildings, rest areas, malls, hospitals, visitor centers, local attractions, commuter airports, MARTA stations and Olympic sites. This list was reduced to 300 sites through a screening process performed by the project team and the following four criteria were then used to evaluate the remaining sites (12).

1. Could the site provide a benefit to visitors and the City?
2. Would the kiosk location be able to provide commuters with any necessary information?
3. Does this particular site location have a low amount of policy and institutional impacts?
4. Does this site allow for the easy installation of a kiosk?

The top 200 locations were ranked using the four criteria and the two final criteria used to screen each location were 1) no site fee and 2) site owners had to agree to pay for electricity to operate the kiosks. The 200 sites owners were contacted and 130 of them qualified and agreed to all of the previously mentioned criteria. Location types and numbers of kiosks are shown in Table five.

Table 5. Kiosk Location Types in the State of Georgia (12).

Location Type	Number of Kiosks
Tourist and Rest Areas	34
MARTA Stations	39
Office Buildings, Corporate/Institutions	25
Transportation Centers	16
Tourist Destinations/Events	9
Hotels	3
Miscellaneous	4

Barriers to Deployment

Aesthetics (the design of the kiosk) became an issue for some potential kiosk locations. The kiosks were designed to look the same in all locations. This meant that all the kiosks would have the same shape, color and name which allows all the kiosks the same amount of physical recognition at various locations. However, managers of some high-end hotels and office buildings did not want kiosks located on their property, because the site owners and managers felt that the information and services provided on the kiosks was exceptional, but the kiosk design would not fit with their image (13).

Advertising issues also played a role in the final site selection process. The advertising on the kiosks was limited to on-screen advertising. Market potential for kiosks became a deployment issue when potential advertisers wanted know what the effectiveness of kiosk advertising. The project team was unaware of the market potential for kiosk advertising, because kiosks are considered a new form of advertising medium (12).

Another issue encountered was advertising on public right-of-way. Some of the kiosk sites such as tourist and rest areas were located on public lands, because advertising on public right-of-way in Georgia is prohibited. Advertising issues associated with kiosks on public land was handled by allowing sponsors and partners to advertise their support of the kiosk program through other media not found on public property (12).

The final advertising issue that was encountered was advertising on private land. Several shopping malls were targeted as kiosk locations, but some malls refused to allow the kiosks. One management company identified the kiosks as a form of public information and feared that by allowing the kiosks onto their properties, they may be forced to allow other forms of free speech. Some privately owned kiosk locations could not allow advertising that would conflict with other major advertisers at a particular location (12).

Another issue with kiosk deployment was public acceptance of the kiosk. Some individuals questioned the value of providing a space on their property for a kiosk since they did not realize the potential the kiosk had for attracting commuters and travelers to a location. Some property owners were unwilling to pay for the power to operate the kiosk (14).

Partnerships

A public/private partnership strategy was developed in order to reduce the financial burden to the GDOT. This partnering strategy consisted of several methods for private companies to contribute to the kiosk program. Private firms could make direct financial contributions to the kiosk program, in-kind technology commitments, payment of capital and operating costs of a kiosk located within a company's building and traditional advertising methods (13).

Kiosk Use

While an evaluation of kiosk use rates is currently not available, some general findings from the experiences of individuals involved with the project were obtained. Some locations that have yielded high use rates were rest and visitor areas. Locations that have had lower rates of use were at public transportation stops, offices and Underground Atlanta, an outside pedestrian type mall (15).

Costs

No data was available for a cost analysis of Travelink.

InfoBanq$_{sm}$, Houston

Project Description

The InfoBanq$_{sm}$ project was initiated as a joint venture between the U.S. Department of Transportation, Federal Highway Administration and the Texas Department of Transportation. The program consisted of the installation of 10 computer display terminals in the Greenway Plaza, small business area in Houston, and one kiosk located at the TxDOT Public Information Office (16). InfoBanq$_{sm}$ was a two year project that began in 1990 and ended in 1992.

The timing of this project was during the reconstruction of US 59 (Southwest Freeway). Construction consisted of the widening of frontage roads, main lanes and a High Occupancy Vehicle Lane (HOV). During this reconstruction large amounts of recurring and nonrecurring congestion existed and any advanced traveler information could have helped commuters avoid congested areas (16).

Traveler Information

The objective of InfoBanq$_{sm}$ was to provide drivers with information enabling them to determine the best route for their commute trip. The primary information that was available on these kiosks was the following real-time traffic information (16).

- Construction,
- Accidents,
- Disabled Vehicles,
- Lance Closures,
- Traffic conditions, and
- Traffic Information about other access routes to the Southwest Freeway including frontage roads, ramps, and other cross streets and arterials.

Site Location Process

The Greenway Plaza was chosen due to its proximity to US 59 (Southwest Freeway) and local employment characteristics. The Greenway plaza is located inside Loop I-610 and between three other major activity centers of Houston: the Central Business District (CBD), Galleria area, and Texas Medical Center. Volumes of over 200,000 vehicles per day can be observed traveling on US 59 to these activity centers in Houston (16). See Figure 1 for the geographic location of project area.

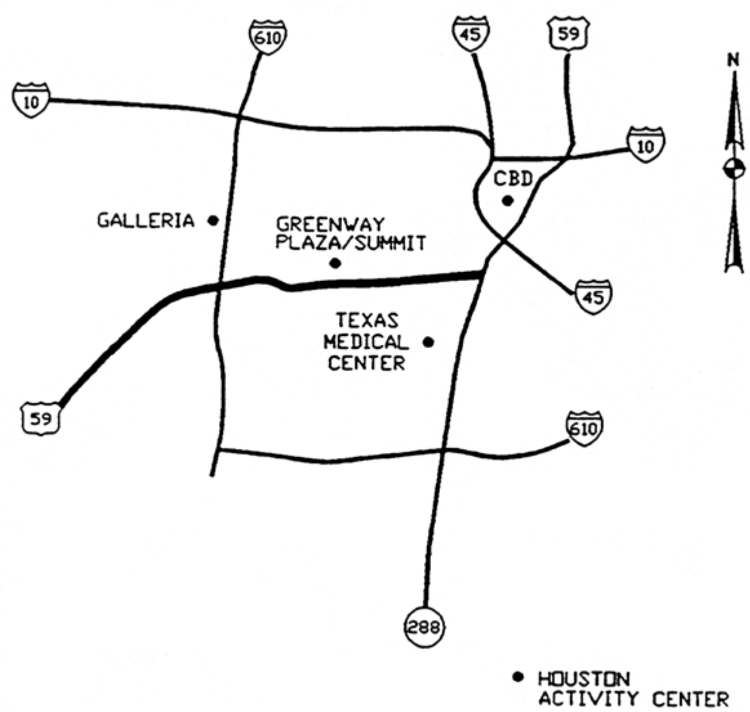


Figure 1. Infobanq$_{sm}$ Project Area. Greenway Plaza of Houston (16).

Since the goal of this project was to provide commuters with freeway traffic information in the surrounding area, it was important to locate the kiosks where commuters would find them useful. The site selection process was used to determine locations of kiosks that led from office buildings to appropriate transportation facilities (i.e.. parking lots, bus stops). A factor that determined the location of a kiosk with respect to a building was the amount of maximum pedestrian passage at one point along routes to parking garages and office buildings (17). See Figure 2 for the building locations within the Greenway Plaza and Figure 3 for the locations of kiosks along pedestrian pathways.

Barriers to Deployment

Some of the barriers to deployment of the kiosks in this setting were mostly technical issues related to the location of the kiosks. Some locations needed access to power and to telephone lines in order to be able to provide the necessary information, and some locations could not provide adequate space for a kiosk and pedestrians. Several site owners did not like the kiosk aesthetics and would not allow the kiosks on their property (17).

Kiosk Use

An evaluation of the InfoBanq$_{sm}$ identified the utilization and usefulness of the kiosks. One hundred and fifty-three surveys of tenants of the surrounding office buildings were conducted to examine the workers awareness of the kiosks and the manner in which the kiosks were discovered (for example a company newsletter explaining the purpose of the kiosks). Seventy-one percent of the individuals surveyed were aware of the kiosks and the types of information that could be found on them (16). Ninety percent of the individuals surveyed discovered the kiosks by walking by, five percent discovered the kiosks through a newsletter and the remaining five percent were shown the kiosks by a friend (16).

In conjunction with the pedestrian surveys, observations were made of the pedestrian's activities around the kiosks. Three type of pedestrian actions were observed 1) pedestrian stopped at the kiosks 2) pedestrian glanced at the kiosks while walking by and 3) pedestrian did not stop at the kiosks (16). The results of these observations showed that approximately 2.2 percent of the pedestrians stopped, another 2.2 percent glanced at the kiosks and the remaining 95.6 percent did not stop to use the kiosk (16)

Costs

The cost of the eleven InfoBanq$_{sm}$ computer display terminals was \$15,895.00 and the cost of displaying motorist information was a monthly rate of \$650.00 per terminal, resulting in a cost of \$187,498.00 over 24 months (16). Total contract costs of the InfoBanq$_{sm}$ project were \$187,498.00. A study conducted by the Texas Transportation Institute examined the cost effectiveness of the InfoBanq$_{sm}$ system and found that users would have needed to use the system approximately four times a week and would need to save 20 minutes of travel time with each use. Calculation of these values was based on the number of observed users of the system (16).

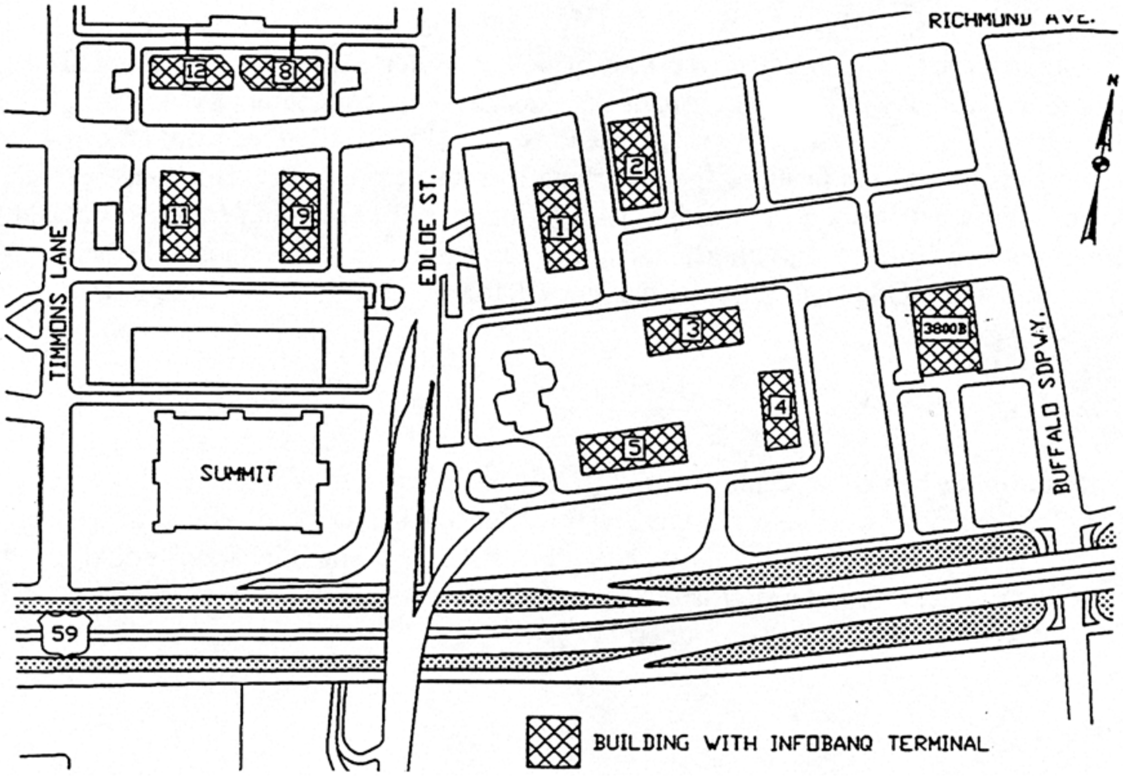


Figure 2. Building Locations in the Greenway Plaza (16).

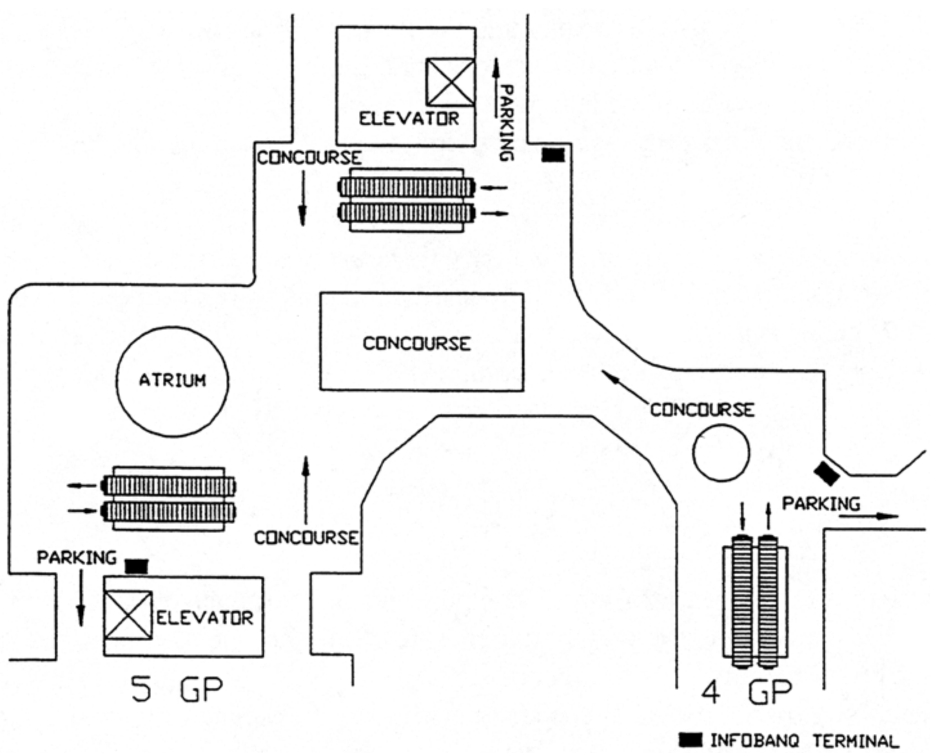


Figure 3. Kiosk Locations along Pedestrian Pathways (16).

“Project TravLink” - Minnesota

Project Description

Project Travlink was a U.S. Department of Transportation field test of an advanced public transportation system (APTS) consisting of the implementation of computer-aided dispatch and automatic vehicle location technologies (CAD/AVL) and an advanced traveler information system (7). The ATIS system consisted of videotext terminals, “smart” kiosks, electronic signs and display monitors capable of displaying real-time traffic information. Travlink was in operation from January of 1995 to December of 1995 and deployed by the Minnesota Department of Transportation’s (MnDOT) division of ITS known as Guidestar. The objective of this test was to determine if there were any positive effects when travelers were provided with quality transit information that might allow people to use other forms of transportation besides single occupant vehicles (7).

The location of this project was along the I-394 corridor, an 11-mile, six lane facility that extends from downtown Minneapolis to the western suburbs of Minnesota (see Figure 4). This corridor also has a high-occupancy vehicle (HOV) lane. There is also a series of park-and-ride lots located along I-394, near General Mills and Several transit centers providing express commuter service to downtown Minneapolis. The purpose of this facility is to maximize the number of people and minimized the number of vehicles on the roadway (7).

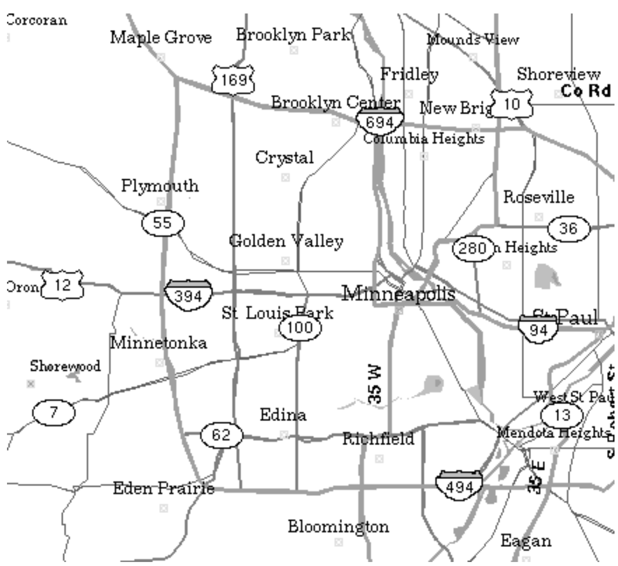


Figure 4. I-394 Corridor in Minneapolis, Minnesota (7).

Traveler Information

Information that was available at the kiosks included the following types of information about transit and traffic information:

- Routing information,
- Bus schedules, maps and fares,
- Real time bus locations,
- Park-and-Ride locations,
- I-394 commuter services,
- Special events,
- Elderly and disabled services,
- Bus service changes,
- Customer service,
- Traffic Incidents and delays,
- Roadway construction and maintenance, and
- Tourist Information.

Site Location Process

Three kiosks were deployed in downtown Minneapolis as part of the Travlink program. One kiosk was located in the lobby of the Hennepin County Government Center. Another kiosk was located in the Metropolitan Council Transit Operations (MCTO) Transit Store, and the third kiosk was located in the Commuter Connection Center, a transportation information storefront operated by the downtown business council (7).

The most important criterion used to determine the locations of the kiosks were where they could reach a large number of people who may require traveler information and aid travelers heading from downtown Minnesota to the western suburbs along I-394. After those locations were chosen the sites that were considered needed to provide a location for a kiosk with no fees, access to power and phone lines, and site owners needed to pay for the power to operate the kiosk (18).

Barriers to Deployment

One of the barriers to deployment of kiosks are the ADA (American with Disabilities Act) requirements. The project team found that the legislation related to ATIS systems was not adequate for the design of ATIS systems. For example, the project team found that the touch screen monitors in kiosks could not provide information to sight-impaired individuals, but the use of voice annunciation for the dissemination of traveler information would have been unmanageable (18).

One privately owned property was considered for a kiosk location. This location was within a mall in the Minneapolis area. However, the owners of the mall wanted to charge the MnDOT a monthly fee to provide a space for the kiosk. The project team decided not to place the kiosk at this location, due to the monthly charge for rent.

All kiosk locations that were chosen needed to have access to telephone and power lines, some sites did not have the appropriate connection and the installation of telephone and power lines was required. The cost for the installation of additional power lines and telephone lines was absorbed by the Travlink project, which allowed for the installation of the kiosks at the locations chosen. Site owners had to agree to pay for the power to run the kiosk and did not object to this fact. The Government Center needed a formalized agreement to place the kiosk on its property, therefore a formal contract was developed (19).

Partnerships

The development of a public-private partnership strategy was a critical component of the Travlink project. The development of this partnership arrangement required extensive negotiations, legal review and legislative changes because this was one of the first Operational Tests to have formal partnership agreements (19). Due to the extensive time for formation and negotiations of agreements between private and public agencies, many delay occurred during the deployment of Travlink. Partnerships required private agencies to donate and contribute various services and hardware for the completion of this project, because the donation of services and hardware did not coincide with current public and private regulations regarding the exchange of services between such agencies, because the private sector sponsored 25 percent of this project (18). Therefore, extensive negotiations and legal reviews were required to complete the project (20). The ten partners that were involved in this project were: the Federal Highway Administration (FHWA), Federal Transit Administration (FTA), MNDOT, the Metropolitan Council, 3M, Rennix, US WEST, Motorola, Etak and Transportation Management Solutions Inc (21).

The formation of public and private partnerships created an environment where the exchange of knowledge, expertise and hardware contributed to the improvement of ITS related projects. The legal issues involved with public-private partnerships deal primarily with proprietary issues, property rights, copyright, ownership, license agreements and confidentiality. During the course of this project, the State of Minnesota passed legislation that would allow MNDOT to "enter into agreements with non governmental entities for research and experimentation; for sharing facilities, equipment, staff, data, or other means of providing transportation-related services; or for cooperative programs that promote efficiencies in providing governmental services or that further development of innovation in transportation for the benefit of the citizens of Minnesota." (20).

During the development of Travlink several partnership problems arose. Several private partners experienced large changes in their corporate structure and these changes required several re-assignments of project tasks to other agencies to allow for the completion of the project. Renegotiation of specific project tasks slowed the pace at which the project was completed. The overall benefits of public-private partnership revealed the positive impacts of creative and flexible thinking, a large reserve of resources and the testing of cutting edge technology. Some of the negative impacts associated with the partnership process was the inability of the public sector to control the private vendors, small profits for the private sector, difficult team decisions and lengthy negotiations (7). Currently some Guidestar projects exist as a typical prime contractor relationship with the private agencies. This form of partnership allows for an agency to establish stronger lines of authority for project management purposes (18).

Kiosk Use

In order to determine the utilization of the kiosks, electronic records were kept on the number of log-ons and some individuals that used the kiosks were asked a few short questions. The first two months of kiosk deployment showed that a total of 250 users accessed all three kiosks in 60 days, but after two months kiosk use increased to over 1000 users a day. The Government Center kiosk had the highest usage out of the three kiosks. Figures 5,6, and 7 show the amount of annual weekday kiosk use by the time of day and Figure 8 shows the total number of log-on for each month by location. Some suggestions from the surveys indicate that the users would have liked the kiosks to be located at some downtown bus stops (7). The log-on files indicate the that highest amount of kiosk use typically occurred during the afternoon hours and the most frequently accessed screens were those that contained routing information and those that displayed incidents and delay. Other popular items that were requested was information about bus schedules and fares (21).

Costs

A detailed kiosk cost analysis could not be performed with the data sources provided.

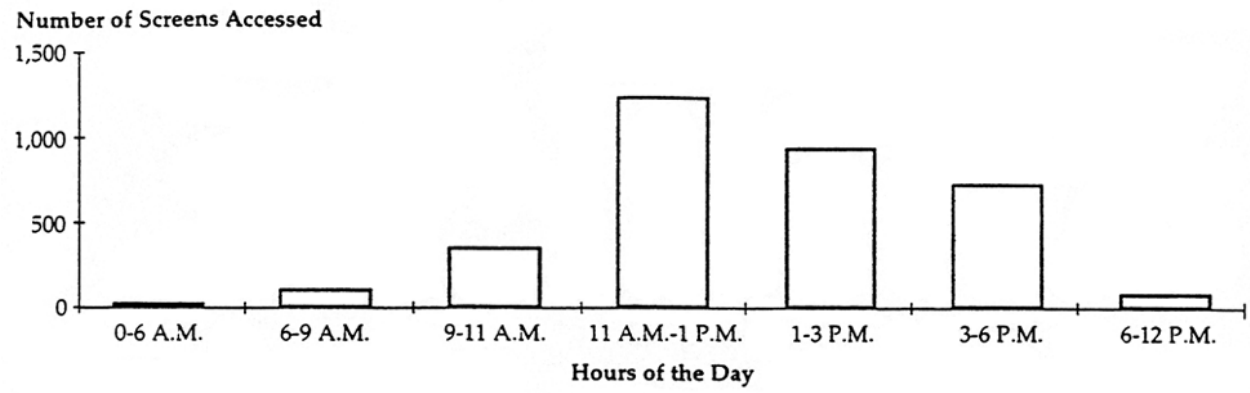


Figure 5. Annual Kiosk Use at the Commuter Connection, in Minneapolis, Minnesota (7).

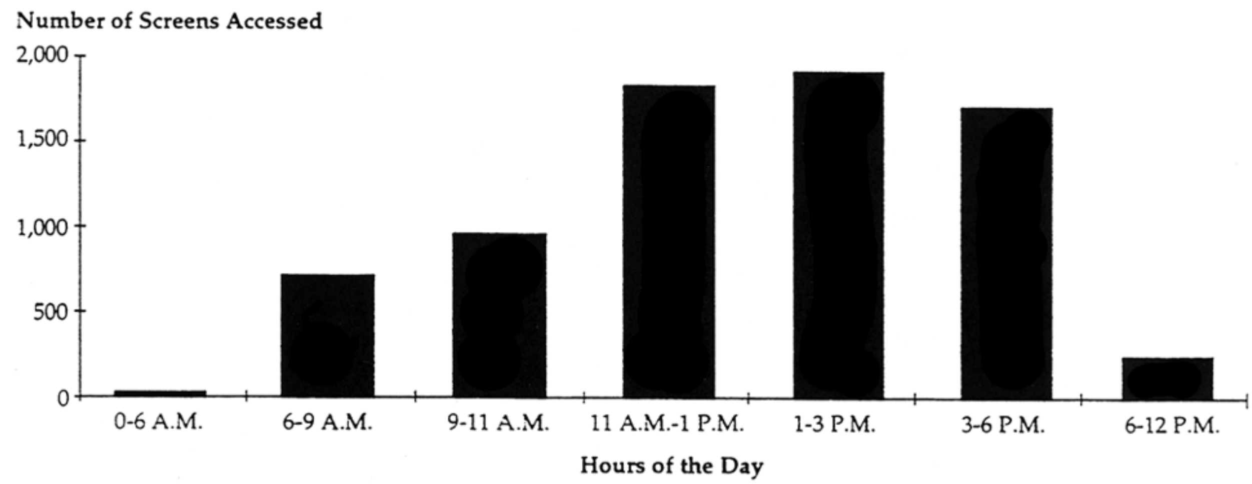


Figure 6. Annual Kiosk Use at the Government Center, in Minneapolis, Minnesota (7).

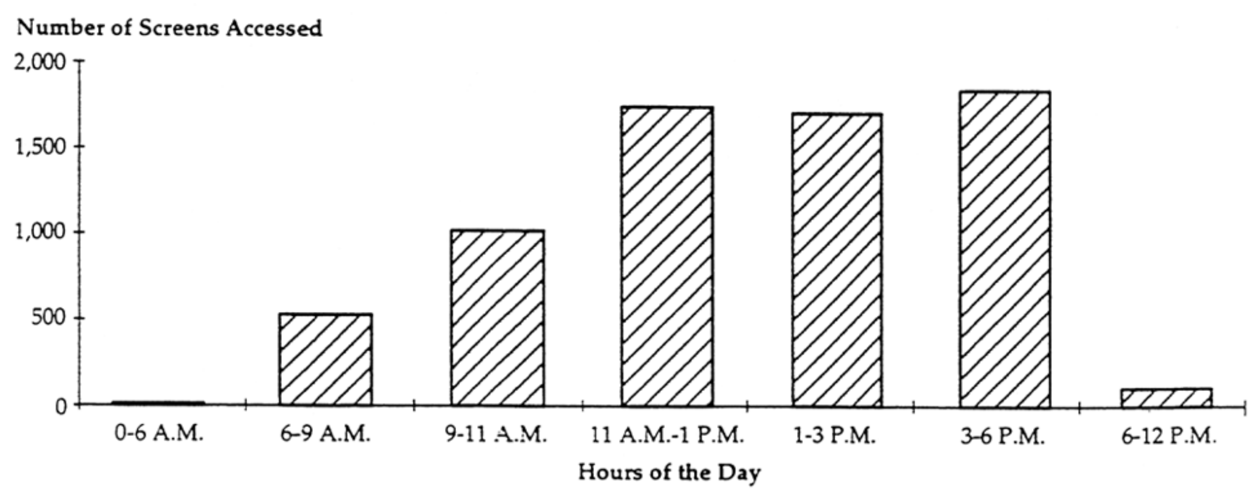


Figure 7. Annual Kiosk Use at the Transit Store, in Minneapolis Minnesota (7).

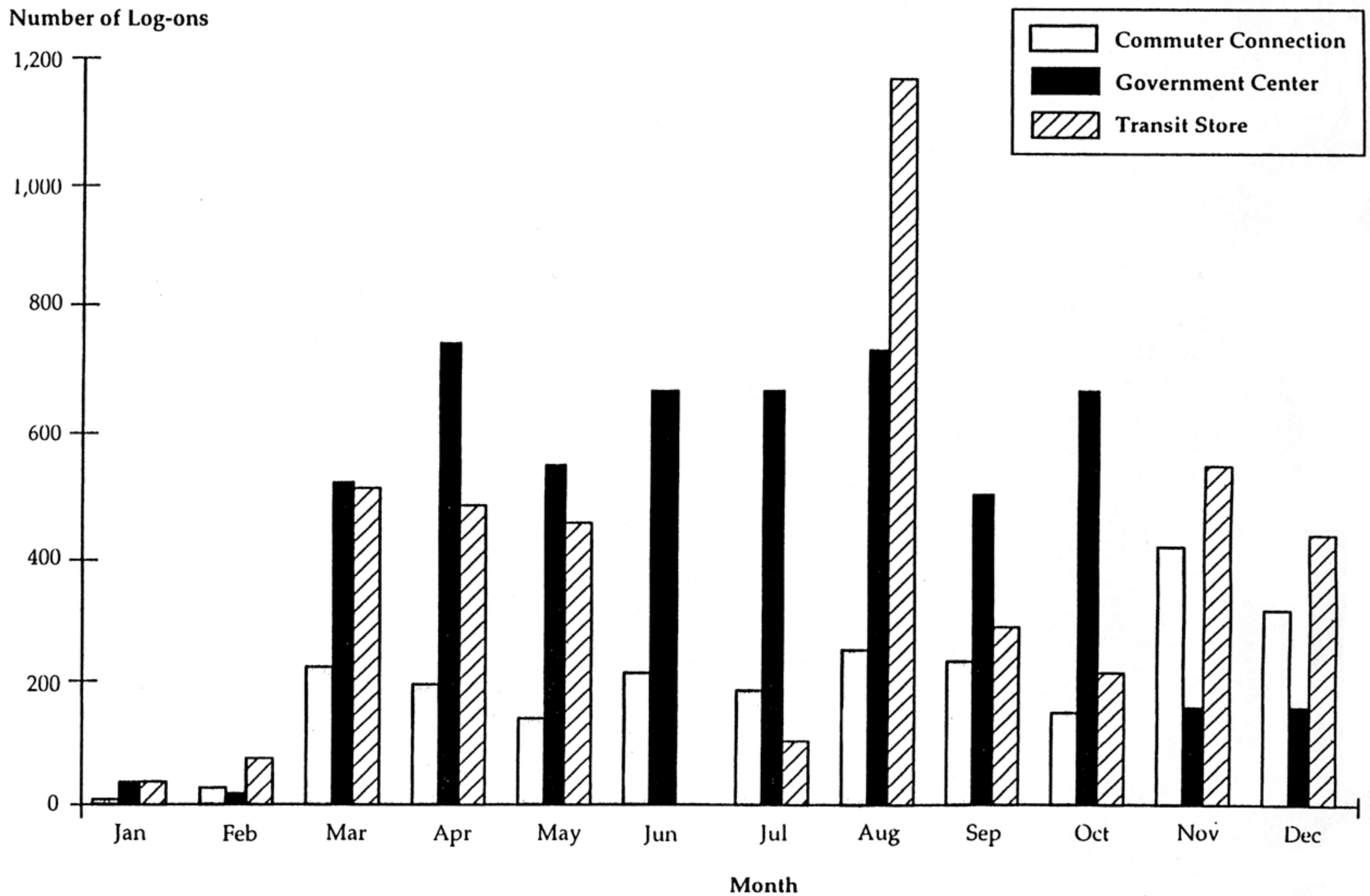


Figure 8. Total Number of Log-ons for Each Month, in Minneapolis, Minnesota (7).

SUMMARY OF FINDINGS

Site Location Selection Process

Accessibility

Most of the site selection processes identified the need for locations to be accessible to a large number of people who require traveler information. The need for a kiosk location to be accessible to a large number of people is very important for the success and utilization of kiosks. If people cannot find the kiosks then the whole purpose of the kiosk is not being served. Kiosks should be located in areas where they can be seen and not hidden by obstructions within a building (16). Some site selection processes involved sites that would be along pathways that users travel, which was one of the criteria used in the $Infobanq_{sm}$ system in Houston. The terminals were located next to elevators and escalators along the pathways that connected office buildings to parking facilities within the area. Some locations that had long hours of accessibility had higher use rates as compared to other locations.

Target Areas that Require Traveler Information

Another criterion addressed in the selection of locations for kiosks was the need to service a certain type of commuter or traveler. In the analysis of Minnesota's Travlink and Houston's $Infobanq_{sm}$ the purpose of the kiosk system was to service commuters leaving a highly populated downtown area and going to the outer parts of the city along specified corridors. Kiosk locations were chosen as a means to disseminate traveler information to a specific type of user (e.g. commuters). The identification of these business centers allowed the projects to scope a region of the city and helped to limit the number of possible locations for potential kiosk locations. The kiosks in Georgia need to fulfill the requirement of providing a benefit to the city, commuters and visitors. The targeting of a specific area or corridor narrows the focus and types of locations that need traveler information, thus helping to reduce the number of potential kiosk locations.

Installation

The final locations of some kiosks were determined by the physical installation process needed for the kiosks. If site locations had no access to power, or telecommunication lines, then other locations close by were examined for the kiosks. In some cases the deploying agency required the site owners to pay for the installation of phone lines. Often, if locations did not agree to pay for the cost of the installation of phone and telecommunications then another site was chosen. Other times the deploying agency would pay for the installation of power and telecommunication lines.

Barriers to Deployment

There were several common barriers among the projects described in the study results section. The most prevalent issue associated with kiosks involved advertising. The advertising issues created situations where a potentially good location may have been utilized, but due to the legalities of advertising on public right of way, advertising conflicts and market potential, these locations were not used. Aesthetics were another common issue that influenced the final location of a kiosk. Some groups felt that the kiosk design would not fit their image, thus possible kiosk locations were not utilized. The location of power and telecommunication lines was another issue that influence the locations of some kiosks. In some instances the site was unwilling to pay for the power needed for the kiosk, or could not provide a suitable location with power and phone lines for the kiosk. Table 6 shows the common barriers described above.

Table 6. Common Kiosk Deployment Barriers.

Barrier	Barrier Description
Advertising	No advertising allowed on public right-of-ways.
	Site locations may have clients that do not want conflicting advertisements on the kiosks.
	The lack of marketing information limits the public agency's ability to sell advertising on kiosks.
	Legislation may prohibit some forms of advertising on kiosks.
Aesthetics	Site Owners want to maintain a certain image
Power and Telecommunications	Electricity and communications lines need to be provided to operate a kiosk, solar and cellular devices increase the cost of kiosk units.
Provision of Power	Site owners must agree to pay for electricity to operate the kiosk.

Kiosk Use

The use of the kiosks was recorded for evaluation purposes. These logs were useful tools to illustrate the use rates of kiosks and to provide insight on the locations that have the potential for kiosk use. Kiosk use was recorded for the programs in Georgia and Minnesota. Data on kiosk use for Georgia has yet to be examined, but the logs from Minnesota show that a government center had higher use rates than other locations involved in the project. In Houston, the kiosk use was around 2.2 percent of individuals who were aware of the kiosks. In the Los Angeles program a high kiosk use rate was considered 39 to 49 uses per day; therefore, extremely high use rates should not be expected.

The kiosk use is a function of pedestrian traffic and the number of accessible hours. Office buildings typically have concentrated hours of activity, while stores and other locations have longer hours of activity which enables them to have a higher pedestrian rate. The office building locations usually involve fixed regular trips that do not require the use of additional traveler information (5). Another factor of kiosk use is that users need to have time available to stop and use a kiosk (15).

Kiosk Locations

Many of the kiosk programs deployed kiosks in similar types of locations. The locations that were chosen were commonly tourist areas, rest areas, public transportation stations, office buildings, transportation connections (eg. Park-and-Ride Lots), tourist destinations, special events and hotels and government centers. These locations are areas where people need traveler information and where there is a significant amount of pedestrian traffic.

KIOSK DEPLOYMENT GUIDELINES

Using the experiences of the kiosk projects reviewed in this paper, and information obtained from telephone interviews provided the author with the opportunity to develop some kiosk location and deployment guidelines. These guidelines should help a public agency to develop a kiosk location process and identify potential barriers to the deployment of kiosks.

Partnership Strategy

Partnership strategies need to be developed to allow for the best possible combination of resources and the determination of the best locations. The partnership strategy must be determined before the kiosk program begins to ensure that there is a highly efficient working relationship between private and public partners. Items to be addressed include the sharing of resources, contribution of funds for the program, project management and exchange of hardware and services required for a project. A contingency plan also should be included to allow for the loss of partners during the project.

Kiosk Deployment Issues

Advertising

Advertising on public right-of-way should be examined to determine what types of advertising are permitted. The agency should develop an advertising policy that allows contributors to the program acceptable forms of advertising, such as flashing video messages. If this step is overlooked, potential contributors to the project may be lost, due to the lack of marketing opportunity. The project team should consult with a marketing consultant to gain an understanding of the market potential for kiosks. This information is very useful for attracting sponsors to the kiosk project. The advertising on the kiosks should also be developed so that it can be changed depending upon site location. For example, malls may not want a certain type of advertising that conflicts with other advertisement within the mall.

Kiosk Design

The physical design of the kiosk should be considered very carefully. If the kiosk is designed in an attractive manner, then it will be acceptable for most locations. Marketing agencies and kiosk construction companies should be consulted to determine an optimal design. It also may be important to have one kiosk design to help potential users identify the kiosks at various locations. The construction of the cabinet should allow for protection from the things such as rain, sun glare, heat and sand and vandalism and to allow for the easy installation of additional components and maintenance operations.

Connections

The provision of power and telephone lines should be considered as part of the deployment process. The project team should decide if the project will pay for the installation of the necessary power and telecommunications. Resistance to the deployment of a kiosk is lowered if the project agrees to pay for the installation of power and telecommunications. The project team needs to determine if the site location will pay for the power, or if the project will pay for the energy consumption of the kiosks. Experiences (Atlanta, Minnesota, Los Angeles) have shown that most locations are willing to pay for electricity to operate the kiosk.

Site Agreement Contract

A formal agreement should be developed for site owners and the public agencies. This agreement used to legally define the duties of the public agency and site owner. Items included within this agreement would be advertising issues, connection requirements, power provision and maintenance. It is recommended that these negotiations are not drawn out into a lengthy process..

Site Selection Process

Because the cost of one single kiosk unit may be between $8000 to $20,000, it becomes important to determine the proper location for a kiosk so as to encourage a high use rate. If the kiosks are deployed and not used by people, then the source of funds used for the kiosks should have been allocated to another project. It is essential to determine the locations where there are the highest potential for kiosk use. The following steps may help a public agency to determine where the kiosks may be useful to travelers requiring information.

Step One

The first step of the site selection process is the determination of a geographic area or specific centers where individuals require traveler information. Some of these locations include the Central Business District of a city, tourist areas within a city, visitor centers, rest stops and shopping centers. Typically these areas are ones that have large volumes of pedestrian traffic and people who require special traveler information. This step will help to scope the area where kiosks are to be deployed.

Step Two

A listing of locations is generated to determine locations that would benefit travelers within the city or state of kiosk deployment. These locations are at points where pedestrians require information on things like bus routes, bus schedules, tourist information and traffic conditions. Using this list, pedestrian counts or estimations are performed to identify areas with high foot traffic. These pedestrian counts should be scored on a system of the agencies choosing. Pedestrian counts can be conducted using the guidelines and procedures described in the ITE Manual of Transportation Studies.

The scoring system that will be used in this example will consist of scoring a desirable site characteristic with a high score and an undesirable trait with a low score. For example, an area of high pedestrian activity is scored with a ten and an area of low pedestrian activity is scored with a two. Pedestrian activity should be measured in people per hour and ranges should be developed to determine high, medium and low ranges dependent upon the observed volumes.

Step Three

The third step is to analyze the accessibility of a kiosk location. Locations that have long hours of accessibility, or long hours where pedestrian activity occurs is scored high using the same type of scoring system as in Step Two.

Step Four

An examination of the sites chosen is performed to determine if those locations create any type of policy or institutional impacts. If a kiosk location does not create new policy or institutional impacts then this location is scored highly, using the scoring system described previously. For example, a location within a mall may want to charge a fee for the kiosk location. If the agency is unwilling or unable to pay for spaces within a mall, this site would be scored low.

Step Five

All site locations are to be examined to determine the ease of installation of a kiosk. Because the provision of power and communication lines keeps the cost of kiosk hardware low it is important that a site location have the required connections. If the location requires the installation of power lines and telecommunications it is scored low on a scale of one to ten.

Step Six

The scores from step two through five should are to be added together and ranked from the highest score to the lowest. The kiosks locations with the highest scores would be the locations that may provide the most benefit to commuters and tourists with the least amount of impacts on the project.

Step Seven

The locations that received the highest scores in the site location process are to be contacted. All installation elements required for the kiosks are to be presented to the site location owner. The site owner is made aware of the issues concerning energy, phone lines, kiosk aesthetics, maintenance, market potential and advertising issues. If the location owner agrees to provide a space for a kiosk the appropriate formal agreements are created between the public agency and the site owner.

Kiosk Evaluation

Kiosk logs that contain the amount of log-ons and the types of information requested are to be kept through out the lifetime of the kiosk program. The logs are to be examined on an appropriate time scale that is within the span of six months to one year of deployment. Afterwards the kiosk logs are to be evaluated once a year. The logs are to be used to examine which locations are being used frequently and which locations are not being used often. Kiosks could then be relocated to locations similar to high use areas. The kiosk logs may also be used to determine the types of location that would be potential sites for the expansion of the kiosk system.

HYPOTHETICAL APPLICATION

The following section is an illustration of the application of the kiosk deployment guidelines by a public agency. The fictitious city of Storyville, along with the State Department of Transportation has decided to provide Advance Traveler Information to it's citizens and tourists. This city is very large and has one central business district where many people work, shop, socialize and visit (see Figure 9). During the evening peak period extreme congestion is experienced on

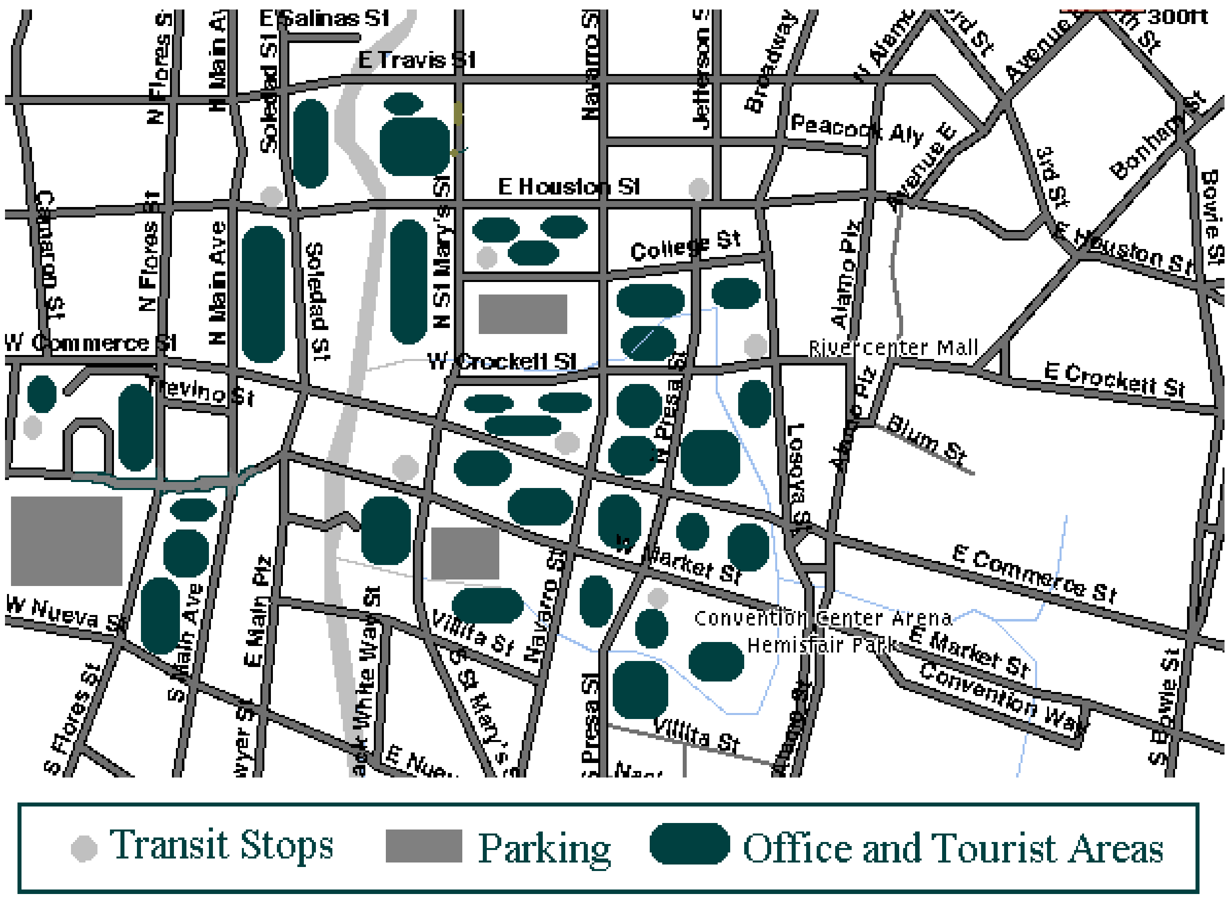


Figure 9. Storyville Central Business District.

most of the major arterials leaving the central business district. Many people have complained that the lack of information on alternative routes, and public transportation schedules and routes is limiting their travel choices. Lately there have been complaints from tourists about finding the local attractions. A kiosk system has been chosen as Phase I of Storyville's ATIS development, Project Apollo. Project Apollo currently has finances to provide 30 kiosks for the city of Storyville.

Partnership Strategy

After examining the available resources for this project the city has determined that a public-private partnership would aid in the deployment of the kiosks. This public-private partnership will allow the city to develop the best possible kiosk system. The City of Storyville and the State DOT shall enter into an agreement that right to any processes or technology developed during the deployment of the kiosk system will be shared equally by the State and City. The City will also become the recipient of all system components upon completion of the project and will be expected to maintain the system.

The Apollo project will need to enter into a partnership with a consultant company to allow for the majority of work to be performed. The consultant will help the public agency to determine kiosk locations and aid in the deployment of the kiosks. Telecommunications and kiosk manufacturers will be contacted to provide and install the necessary kiosk components.

Kiosk Deployment Issues

Advertising

The City of Storyville and Project Apollo will develop an advertising strategy that allows sponsors, contributors and partners to advertise their involvement with the kiosk project. This advertising strategy allows all parties involved to make an advertising connection with the kiosk system. Advertising on kiosks will be limited to on-screen promotions. This allows flexibility of advertising for each site location, while maintaining a single kiosk design that can be easily identified by users. The advertisements on the screens can be changed to allow for the addition or deletion of sponsors. The fictitious marketing agency of Spice Media Inc. will be contacted to develop a marketing report on kiosks. This report will be used by Project Apollo to sell advertising on the kiosks. All funds from the advertising will be used to develop and maintain the kiosk system.

Kiosk Design

Several kiosk distributors will be contacted to develop an appropriate kiosk that can be deployed at various locations. The kiosk distributors will need to submit a formal proposal describing the kiosk design, security features and cost of each kiosk. Project Apollo will review all proposals to determine the best kiosk design.

Connections

Project Apollo will pay for the costs of installing power and telecommunication lines. However, all site locations must pay for the power required to operate the kiosks. Since Project Apollo is providing the funds to install the power and communication lines, the burden on the site location is reduced to providing power.

Site Agreement Contract

All site locations shall sign a formal agreement explaining all issues related to the kiosk. The City shall be responsible for maintenance of the kiosk, while the site owner shall be responsible for power provision and reporting kiosk problems.

Site Selection Process

Step One

The site selection process begins with the determination of a specific geographic area where there is a large amount of pedestrian activity and where people may require traveler information. The choosing of this geographic area limits the number and types of locations where kiosks can be located. Storyville and the State DOT has determined that the Central Business District (CBD) of Storyville shall be the geographical area of deployment. The CBD consists of several office and tourist areas the are accessible through public transportation and several parking areas. There are currently transportation problems within this area; therefore, Project Apollo may be able to provide the commuters and tourists in this area with useful information.

Step Two

Locations where traveler information services are required by commuters and pedestrians will be chosen for pedestrian counts. These locations are where pedestrians change modes, or congregate for several minutes. If pedestrians remain in one location for any period of time, they may be inclined to examine a kiosk and discover the types of information that are available. Pedestrian counts will be conducted near transit stops, parking lots, shopping areas, office buildings and tourist areas. The areas with the largest volume of pedestrian traffic shall be examined to determine the amount of accessibility to the kiosk. These locations will be scored using a scoring system from one to ten. Storyville will use the following scoring system for pedestrian volume as shown in Table 7.

Table 7. Pedestrian Volume Scoring System.

Pedestrian Volume	Score
> 1000 pedestrians/hour	10
700 - 999 pedestrians/hour	8
400 - 699 pedestrians/hour	6
100 - 399 pedestrians/hour	4
< 100 pedestrians/hour	2

Step Three

All kiosk locations that are chosen will be examined to determine the amount of public accessibility. Locations such as shopping malls, bus stops will most likely receive high scores due to their long hours of accessibility and congregational traits of the site. A scoring system for hours of accessibility is shown in Table 8.

Table 8. Hours of Accessibility Scoring.

Hours of Accessibility	**Score**
21 - 24	10
17 - 20	8
14 - 16	6
9 - 13	4
4 - 8	2
0 - 3	0

Step Four

All location types will be examined by Project Apollo to determine if any locations will create any policy or institutional impacts beyond those associated with power and advertising. If any locations such as a the fictitious Storyville shopping mall or the Storyville Museum requires the payment of site fees, then those locations will receive a low score on the proposed scoring system Table 9 shows the scoring system for policy and institutional impacts.

Table 9. Policy and Institutional Impact Scoring.

Policy/Institutional Impact	**Score**
None	10
One	5
Two or more	1

Step Five

Agents from Project Apollo will inspect the recommended site locations to determine if the selected locations can provide the necessary power and communication services. While there may be technologies available to provide power and communications without the use of conventional power and communication lines, Project Apollo prefers to have all kiosks connected by cables to eliminate the need for additional technology. Table 10 shows the scoring system for the power and communications.

Table 10. Power and Communication Connection Scoring.

Power and Communications Availability	Score
Both Power and Communications are available.	10
Power or Communications must be installed and can be done easily.	8
Both Power or Communications can be easily installed.	6
Power or Communications cannot be easily installed or require solar and cellular technologies.	4
Both Power and Communications cannot be easily installed and require solar and cellular technologies.	2

Step Six

All of the scores from steps two through five will be added together to develop an overall site location score. To determine which sites may provide the best kiosk locations, the scores will be ranked from the highest score to the lowest.

Step Seven

The top thirty location owners will be solicited by an agent of Project Apollo. All information regarding content of the kiosk, kiosk installation, kiosk maintenance and power issues will be discussed with the site owner. If the site owner agrees to the conditions explained then a formal contract will be signed between the City and site owner. If there are any additional concerns that the site owner has, they will be handled in an appropriate manner. If any of the site locations will not accept a kiosk, then the next kiosk locations that appear on the ranked site location list will be contacted until thirty kiosk locations agree to provide space for a kiosk. After determining the kiosk locations the thirty kiosks will be deployed in Storyville's central business district.

Kiosk Evaluation

After six months the kiosk log files will be examined to determine what locations have a high use rate. This initial evaluation will be used to examine the kiosk acceptance rate. If an increasing acceptance rate is observed plans may be made to deploy more kiosks.

Another examination of the kiosk logs will occur one year after deployment of the kiosks. Kiosks that experience low use rates will be moved to other locations that were listed in the initial site selection process. The evaluation reports shall be made available to all public agencies to allow for the development of kiosk systems.

CONCLUSIONS

The results of this research illustrate the lack of a uniform kiosk site selection process. Some public agencies developed a process by which sites could be evaluated, while others used an approach that involved engineering judgement. It was evident that many of the kiosk programs attempted to identify locations where there is a need for traveler information and locations where there is a high amount of pedestrian traffic. The site selection processes used in the Smart Traveler kiosk program of Los Angeles and Travelink kiosk program in Georgia provided a basis for a location selection process. The use of a kiosk site selection process allows public agencies to make location decisions based upon a quantitative evaluation of locations. This quantitative evaluation provides public agencies the ability to chose locations based upon the needs of travelers and eliminates the guesswork from the site selection process.

In cities where a kiosk site selection process was used, the evaluation of the kiosk use will aid the further development of the kiosk site selection process. Adjustment of the site selection process can be made using kiosk use data.

The data that are available to aid agencies in the determination of kiosk locations is limited to a few evaluation reports available from different sources. The most important information that is needed from these evaluation reports is the data on kiosk use. This data would identify the types of locations that are used most frequently and can pinpoint the kiosk locations that need to be targeted. The need for a compilation of kiosk use data by location is necessary to further aid engineers in determining kiosk locations.

ACKNOWLEDGMENTS

The author would like to take this opportunity to thank Dr. Conrad L. Dudek for his organization of a course that allows students to interact and work with a diverse group of transportation professionals. Marsha Anderson and Ginger Gherardi deserve special thanks for serving as my professional mentors and for their guidance in developing this paper. Thomas Hicks, Colin Rayman, Joseph McDermott and Doug Robertson also deserve thanks for sharing their time and experiences to this program. The author would also like to thank Sandra Schoeneman for her hard work in making this program possible. The author would also like to thank Dr. Katherine Turnbull, William Eisele, Karl Passetti and Micah Hershberg for their contributions to the creation of this paper.

The author would like to thank the following people for their time and contributions to this paper:

Dwayne K. Cook of the Traffic Management System of Hampton Roads,
Michael Presley of the Georgia Department of Transportation,
Todd Long of the Georgia Department of Transportation,
James Pohlman of TransCore,
William McCasland of the Texas Transportation Institute, and
Marilyn K. Reemer of the Minnesota Department of Transportation.

REFERENCES

1. Asop, Shawn. *Transportation Management Centers: Traveler Information Dissemination Strategies.* U.S. Department of Transportation. Washington D.C. February 1996.

2. Schroeder, J.L. and Green, J. The Emergence of Smart Traveler Kiosks and the User Interface Requirements for their Successful Deployment. Moving Toward Deployment: Proceedings of the IVHS America 1994 Annual Meeting. April 1994.

3. http://www.kioskstore.com/lat.htm

4. Benson, Brien G. et al. Using Kiosks to Provide Transit and Ride-Share Information: Two Northern Virginia Test Cases. Intelligent Transportation: Serving the User Through Deployment. Proceedings of the 1995 Annual Meeting of ITS America. March 1995.

5. Burris, Mark W. et al. Kiosk Case Studies...What Works? ITS America Seventh Annual Meeting. Washington D.C. June 1997.

6. Giuliano, Genevieve. Hall, Randolph. Los Angeles Smart Traveler Field Operational Test Evaluation. California Department of Transportation. September 1995.

7. Cambridge Systematics. Travlink Operational Test Evaluation Report. Minnesota Department of Transportation Guidestar Program. August 1996.

8. Cook, Dwayne K. . Traffic Management System of Hampton Roads. Telephone interview conducted in June, 1997.

9. Commonwealth of Virginia. *Information Technology Resource Management Policy: Statewide Kiosk Program*.

10. Giuliano, Genevieve. Golob, Jacqueline. Los Angeles Smart Traveler Information Kiosks: A Preliminary Report. *Transportation Research Record 1516*. TRB National Research Council, Washington D.C., 1995.

11. Pittenger, Jerry. et al. The Atlanta Traveler Information Showcase (TIS). Intelligent Transportation: Realizing the Benefits. Proceedings of the 1996 Annual Meeting of ITS America. April 1996.

12. Pohlman, James., and Todd Long. Advanced Traveler Information Kiosk Project "TraveLink". Compendium of Technical Papers for the 66th ITE Annual Meeting. September 1996.

13. Williams, Elizabeth. and Pohlman, James. Public/Private Partnering for the Georgia DOT Advanced Traveler Information Kiosks. Intelligent Transportation: Realizing the Benefits. Proceedings for the 1996 Annual Meeting of ITS America. April 1996.

14. Pohlman, James. TransCore. Telephone interview conducted in June 1997.

15. Long, Todd. Georgia Department of Transportation. Telephone interview conducted in June of 1997.

16. Thompson, Beverly A. Evaluation of a Motorist Information System Using Computer Display Terminals. Texas Transportation Institute. College Station, Texas. August 1992.

17. McCasland, William. Texas Transportation Institute. Telephone interview conducted in June 1997.

18. Wright, J. Reemer, M. and Robinson, F. Minnesota Guidestar's "Project Travlink": Some Early Lessons. Intelligent Transportation: Serving the User Through Deployment. Proceedings of the 1995 Annual Meeting of ITS America. March 1995.

19. Reemer, Marilyn K.. Minnesota Department of Transportation. Telephone interview in June 1997.

20. Wright, James. Nookala, Martha. Minnesota Guidestar Project Travlink. Moving Towards Deployment. Proceedings of the IVHS America 1994 Annual Meeting. April 1994.

21. Wright, James. Travlink: An Intelligent Commute in Minneapolis. ITE Journal. Vol. 66 No. 6. 1996.

Aaron M. Hottenstein received his B.S. in Civil Engineering from The Pennsylvania State University in May 1996. While at Penn State, Aaron was an active member of the American Society of Civil Engineers student chapter. Aaron is currently pursuing his M.S. in Civil Engineering at Texas A&M University. Aaron has been employed by the Texas Transportation Institute since August 1996. Before that, Aaron worked for the Pennsylvania Department of Transportation as a summer engineering intern inspecting pavement conditions and construction work. Aaron is currently serving as the Treasurer for the Texas A&M Institute of Transportation Engineers Student Chapter. His areas of interest include: transportation planning, public transportation and traffic operations.

INCIDENT MANAGEMENT AND MOTORIST AID SYSTEMS IN RURAL AREAS

by

Marc W. Hustad

Professional Mentor
Joseph M. McDermott, P.E.
Illinois Department of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

Incident management and motorist aid systems are not commonly implemented in rural areas, but statistics illustrate the need for improved incident handling and emergency responses. ITS America estimates that 80 percent of the total roadway system in the United States is rural and that 58 percent of all accident fatalities occur in rural areas. Also, on average, rural emergency response times to roadway incidents are one and one-half those for urban centers. In short, the magnitude and severity of rural accidents and the larger incident response times show the need for more efficient incident handling.

The primary objective of this research was to identify practical enhancements and strategies needed for incident management and motorist aid systems to be successful in rural areas. In order to design an effective system, it is important to understand the users of the system (in this case the rural traveler) and the environment (the rural area) in which the system will be used. A literature search and review was conducted to provide an understanding of rural characteristics and current incident management and motorist aid system practices. Telephone interviews were conducted to fill in informational voids left by the literature. Communication systems and incident detection methods were analyzed to provide a better understanding of their applicability in rural areas.

Based on the lessons learned from this research, recommendations were made to aid transportation professional overcome barriers that are unique to rural areas. When implementing an incident management or motorist aid system an agency should:

- Assess Needs;
- Prioritize Needs;
- Define Team and Program Objectives;
- Provide Necessary Communication System;
- Focus Incident Management Measures on Problem Areas; and
- Evaluate.

The recommended method for implementing and continuing a successful incident management or motorist aid system in a rural area was applied to a hypothetical situation to demonstrate its usefulness.

TABLE OF CONTENTS

INTRODUCTION

Roadway incidents, such as vehicle breakdowns and accidents, occur every day. Eventually, agencies respond to clear the incident, and the roadway returns to normal conditions. The objective of an incident management system is to improve the efficiency of the existing response which reduces the duration, and thus the impact, of each incident (1). Incident management systems, or programs (IMPs), are implemented in response to increasing congestion problems and are typically limited to metropolitan areas.

While IMPs and motorist aid systems are not commonly implemented in rural areas where congestion is a lesser problem, statistics illustrate the need for improved incident handling and emergency responses to roadway incidents in rural areas. ITS America estimates that 80 percent of the total roadway system in the United States is rural and that 58 percent of all accident fatalities occur in rural areas (2). Also, on average, rural emergency response times to roadway incidents are one and one-half those for urban centers (2). In short, the magnitude and severity of rural accidents and the larger response times show the need for more efficient incident handling.

Problem Statement

The magnitude and severity of rural incidents requires the attention of the transportation community to develop more effective IMPs and motorist aid systems. However, many barriers unique to rural areas must be overcome in order to implement an effective IMP or motorist aid system in rural areas. These barriers include: organizational and institutional structures, communication infrastructure availability; low traffic volumes; infrequent cities and towns with emergency response capabilities; and vast space and distance covered by monitoring agencies. Realistically, limited funding capabilities provide the most significant barrier for rural agencies.

Rural agencies are faced with a difficult task of identifying a cost-effective plan and/or technology to facilitate better incident handling. Practical enhancements are needed for existing technologies and methods to initiate and continue a successful IMP or motorist aid system in a rural area.

Research Objectives

The primary objective of this research was to identify practical enhancements and strategies needed for IMPs in rural areas in order to facilitate better incident handling. The enhancements and strategies target, but are not limited to the following: incident detection, communication infrastructure, and emergency response. The specific research objectives were to:

- Analyze current rural IMPs and motorist aid systems;
- Identify successes and lessons learned of rural IMPs and motorist aid systems;
- Determine feasibility of further applications and consolidation of various advanced technologies in rural areas;
- Recommend strategies and enhancements for better handling of incidents in rural areas; and
- Apply the strategies and enhancements to a hypothetical rural area.

Study Approach and Scope

The research summarized in this paper reviews the unique characteristics of the "rural area," rural roadways, and rural travelers. Communication technologies and incident detection methods were analyzed to determine the applicability of, and barriers to each of the technologies and/or methods when applied in the rural area.

A literature search and review regarding current applications of rural IMPs and motorist aid systems was completed to identify technologies deployed, lessons learned, problems encountered, and methods used to overcome problems encountered. Phone interviews were used to fill in informational gaps left by the literature. Enhancements and strategies for further implementation of rural IMPs and motorist aid systems were recommended by the author and applied to a hypothetical situation to test the feasibility and thoroughness of the recommendations.

While a general overview of incident management programs is provided the reader will likely find a concentration towards incident detection and communication infrastructure issues in rural areas. However, all attempts are made to keep other components of the incident management process in proper perspective.

THE RURAL AREA

In order to design an effective system, it is important to understand the users of the system (in this case the rural traveler) and the environment (the rural area) in which the system will be used. For this reason, an understanding of the characteristics of rural areas and traveler needs should be considered in the design of an incident management system.

In an attempt to understand the meaning of "rural," Webster's Dictionary was consulted, Webster defines "rural" as (3):

ru•ral: of or relating to the country, country people or life, or agriculture.

This definition provides a broad background of rural by relating it to a common synonym, the country. Webster's definition is vague and perhaps outdated. Finally, Webster's definition does not offer any scope towards the magnitude of how much of the U.S. is rural. The Advanced Rural Transportation Systems (ARTS) defines "Rural America" as (4):

Rural America: communities or areas with less than 50,000 residents.

ARTS does not explicitly define what a "community" is, but it is thought that their definition is directly related to the statistical definition used by the Office of Management and Budget (OMB). OMB divides the U.S. into county-based Metropolitan Statistical Areas (MSAs) and non-metropolitan areas. A county is defined as a MSA if (5):

- it contains a city with a population of at least 50,000; or
- it contains an urbanized area with a population of at least 50,000 and a total metropolitan population of at least 100,000; or
- it has strong economical and social ties to a central county containing the main city or urbanized area.

Figure 1 shows the MSAs of the U.S. Defining rural areas using OMB's non-metropolitan counties seems to provide the most statistically sound definition. Figure 1 shows that non-metropolitan areas (the non-shaded areas) comprise the majority of land in the continental U.S. According to the U.S. Bureau of the Census, 81 percent of the total land area in the U.S. is non-metropolitan, or rural, while 20.3 percent (51.9 million people) of the total population in the U.S. live in non-metropolitan areas (6).

The OMB's definition for MSAs is not a perfect definition of Rural America, because an entire county may be designated as "metropolitan" if a city in that county has a population of 50,000 or more. Realistically, Rural America should include the outlying areas of these cities because these communities may be sparsely populated and located a considerable distance from the nearest city. Hence, it is noted that a greater proportion of people and land are part of Rural America than defined by the OMB. Still, the OMB's definition may be applied in order to realize the order of magnitude of rural populations and land areas.

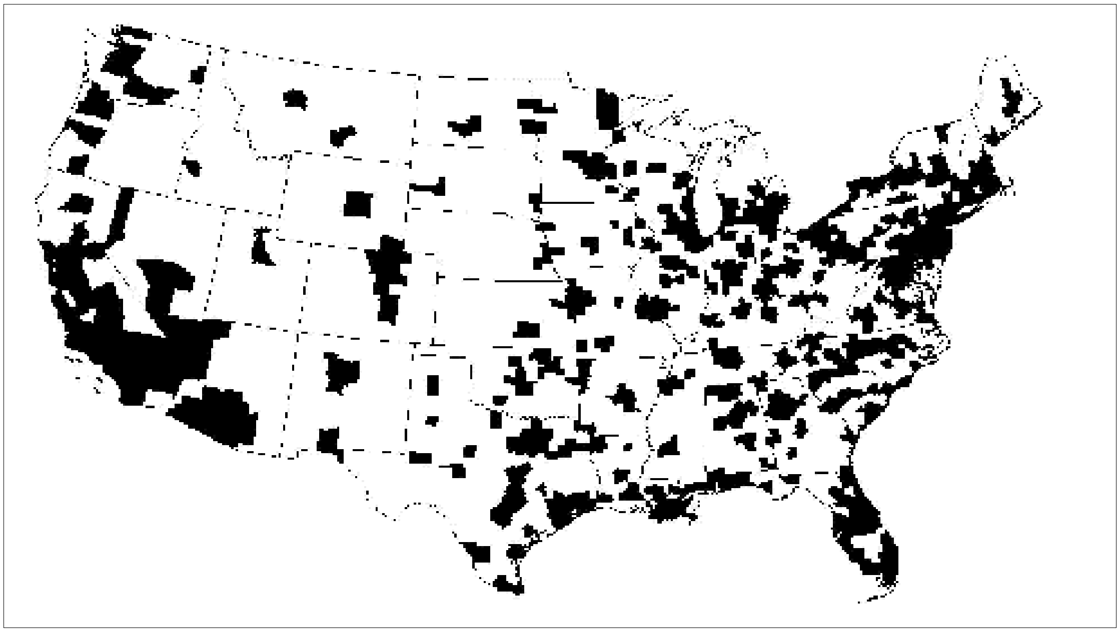


Figure 1. Metropolitan Statistical Areas in the Continental United States (7).

In addition to developing population statistics for individuals living in MSAs, the U.S. Bureau of the Census develops statistics for individuals living in a rural or urban "residence." The U.S. Bureau of the Census defines the urban and rural resident population as "*...persons living in urbanized areas and in places of 2,500 or more inhabitants outside urbanized areas...The population not classified as urban constitutes the rural population* (8)." Using the definition provided by the U.S. Bureau of the Census for "rural residence," the rural population increases from 51.9 million (defined as "nonmetropolitan" by the OMB) to 59.5 million (defined by the U.S. Bureau of the Census) (6). These statistics indicate that the "rural area" should include the outlying areas of MSAs in its definition because these communities are thought to more closely resemble rural rather than urban characteristics.

Rural Characteristics

Typical rural and urban traveler and environmental characteristics are described in Table 1. The table shows many differences exist between rural and urban areas. While Rural America comprises only 20 percent of the total population in the U.S. and 40 percent of all vehicle miles traveled, 80 percent of the national roadway system is rural (2,6). Many rural road miles are remote with smaller traffic volumes compared to those on typical urban roadways. The table also shows traffic volumes on rural roadways are typically lower because 40 percent of total vehicle-miles-traveled exist on 80 percent of the total roadway system (2). On roadways with lower traffic volumes, a stranded motorist is less likely to be assisted by a "Good Samaritan" than on roadways with higher volumes.

Table 1. Typical Rural and Urban Characteristics (2,4,9,10,11,12,13).

Characteristic	Rural	Urban
Total U.S. Land Area (1992)	80 percent	20 percent
Total U.S. Population (1992)	51.9 Million (20 percent)	203.1 Million (80 percent)
Total U.S. Roadway Miles	80 percent	20 percent
Total U.S. Vehicle-Miles-Traveled	40 percent	60 percent
Traffic Volumes	Rural traffic volumes tend to be lower. (40 percent of vehicle-miles-traveled on 80 percent of roadway miles)	
Trip Length	Rural trips tend to be longer. (Average Rural Trip Length = 150 miles	
Traveler	Unfamiliar Commercial Vehicle Tourist Farmer (Rural drivers tend to be older)	Commuter
Trip Type	Recreational/Pleasure Inter-Urban Urban-Rural	Intra-Urban
Congestion	Non-recurrent /Incidents / Recreational Construction/Maintenance	Recurrent Non-recurrent/Incidents Construction/Maintenance
Vehicle Composition	Rural areas tend to have higher percentages of older vehicles, commercial vehicles, and slow-moving farm equipment.	
Accidents	Single Vehicle (Run-offs) Vehicle-Animal 58 % of Total U.S. Fatalities	Multiple Vehicle
Average Emergency Response Times	51 minutes (1.5:1 greater emergency response times)	34 minutes
Terrain	More Rugged	Flat or Gently Rolling
Speed	Rural speed limits and operating speeds tend to be higher.	
Roadway Lighting	None	Common
Communication Infrastructure	Rare Direct Line Coverage Sporadic Wireless Coverage	Comprehensive Hard-Wire and Wireless Coverage
Transit	None (66 percent of rural communities have little or no transit service)	Taxi Para-transit Light and Heavy Rail Bus

Rural residents are more reliant on their personal vehicle because of the lack of transit service. About 66 percent of rural communities have little or no transit service (2).

Rural roadways do not exclusively serve rural residents traveling in their community. Many of the travelers in a rural area may be rural dwellers commuting to urban areas, urban dwellers traveling between urban areas, or recreational travelers traveling long distances. Rural trip lengths are usually longer than the typical urban commute and are on-average about 150 miles (2). Longer trips tend to cause driver dozing and boredom that increase the likelihood for driver errors.

In urban areas where home-to-work and work-to-home travel is typical, the commuter becomes very familiar with their surroundings and is also familiar with alternative routes. Alternative routes are available to commuters during delays on their preferred routes; however, tourists on rural roadways have little information about alternative roadways. Travelers in rural areas tend to be less familiar with their surrounding because 78 percent of all rural trips are recreational (2). A large portion of rural travelers are also commercial vehicle oriented contributing to the percentage of drivers that are unfamiliar with their surroundings. The diversity is further increased when considering the possibilities for farm equipment and the higher percentages of older drivers on rural roadways (2).

Many major metropolitan areas experience recurrent congestion; whereas, congestion is usually limited to non-recurrent events on rural roadways. Congestion is typically infrequent on most rural roadways and can be caused by construction or maintenance activities, tourist peaking, and/or an incident (9). Congestion is especially difficult to handle in rural areas because fewer alternative routes are available for a motorist to divert (11) and can hinder tourism and trade industries supporting rural areas. In short, congestion is a nuisance to otherwise enjoyable tourist trips and/or efficient goods transport, especially because motorists are unable to divert or plan better routes.

Perhaps the most alarming statistic is that 58 percent of all roadway fatalities in the U.S. occur in a rural environment (2). The high fatality rate is even more alarming considering the lower annual vehicle-miles-traveled on rural roadways. The greatest proportion of rural accidents are single vehicles running off the side of the road contrasting to urban accidents that often involve multiple vehicles (9). Another characteristic unique to rural areas is the possibility for vehicle and animal collisions (9,12). Accident detection is more difficult during single vehicle accidents because the driver may become incapacitated and unable to alert appropriate emergency response services. Also, single vehicle run-offs may be hidden from view of pass-by motorists; thus, making detection even more difficult. Rural roads generally have higher posted and operating speeds increasing the potential for more severe accidents (9).

Rural emergency response times, on-average, are one and one-half times longer than urban response times (13). According to National Highway Traffic Safety Administration, average emergency response time for rural accidents is 51 minutes, while average emergency response time for urban accidents is significantly less at 34 minutes (13).

Several factors are thought to contribute to the longer emergency response times for rural accidents. Perhaps the greatest factor is the vast area many emergency response teams must service. Large jurisdictional areas require emergency response teams to travel great distances in order to reach the incident. Also, many response teams in rural areas are volunteers who are quite capable and skilled at handling emergencies but need time to assemble personnel before responding to an incident scene.

Although most of Rural America is supported by the public switched telephone network (PSTN), some remote areas do not have wireline telephone connections (7). Almost all major urban areas have cellular coverage but much of Rural America does not (7). Many rural areas are too sparsely populated to be supported by communication networks because of the difficulty for providers to make profits in sparse populations with fewer potential subscribers. The lack of comprehensive communication infrastructure is perhaps the most debilitating factor in implementing an incident management program. The importance of infrastructure and applicability of communication technologies in rural areas is discussed later in this report.

Rural roadways are usually rugged with sharp corners and steep grades, whereas urban areas are typically centered in a flat area with gently rolling terrain (9). Severe weather can strike a rural area with little advanced warning to motorist. Roadway lighting is rarely available on rural roadways, with the exception of major intersections; whereas, lighting is typically provided on urban roadways (12). Rural transportation agencies are usually responsible for large jurisdictions with many road miles, limited manpower, and funding, which makes it difficult for the agencies to maintain acceptable road and roadside conditions.

Rural Traveler Needs

As mentioned above, it is important to understand what rural travelers need or find most useful in order to design helpful applications of advanced technologies. Results from focus group interviews, phone surveys, and mail surveys of rural travelers and transportation officials in a study for the Federal Highway Administration show that rural travelers place the highest priority on information relating to problems encountered while traveling rather than pre-trip planning or en-route travel without problems (12). Participants of the surveys indicated that the biggest en-route desire was the capability to transmit a mayday signal when faced with a problem (12). Travelers indicated that the mayday system should also (12):

- have the capability for manual and automatic activation;
- include an automatic vehicle location system; and
- have two-way communication to allow the motorist to specify the type of problem.

The second most important en-route desire for motorists is information about approaching congestion, detours, construction, or other approaching hazards (12). In summary, the results of the studies show that incident management techniques and tools would likely be well received by the motoring public and would serve a need that rural motorists desire.

Rural Communication Infrastructure

Imagine a stranded driver needing emergency assistance at a remote rural location. If the driver does not own a cellular phone or is outside cellular coverage, he or she would likely walk to the nearest residence. Due to the remoteness, the driver will likely need to walk a considerable distance to reach the nearest home (which might be in severe weather). Now, imagine the driver's reaction when he or she discovers the residence has no telephone service. Without means to communicate and notify an emergency response agency, the driver will need to rely on the possibility that another driver will pass-by the incident and have the necessary means to notify an emergency response agency. This may be unlikely because traffic volumes are typically low on many rural roads. Finally, imagine a response team arriving at the incident scene and needing additional assistance. Due to the great distance and lack of supporting infrastructure, the radio of the response team is unable to communicate to the dispatch center. This hypothetical situation may be drastic, but the underlying point is that communication infrastructure is important to provide efficient incident response.

Communication infrastructure supports voice and/or data transfer to provide information in order to help a transportation agency or dispatcher make appropriate decisions. The preferred medium to support various types of communication depends, not only on where the transmitting user is located, but also where the receiving user is located. Communication media infrastructures can be divided into two distinct categories: wireline and wireless. The technological components associated with each infrastructure are discussed to determine their applicability for rural incident management and motorist aid.

Wireline Systems

A wireline system requires a physical connection via a transmission medium. Pairs of copper wires, coaxial cable, or fiber optic cable are examples of wireline transmission media. Each transmission medium supports a limited amount of bandwidth. Of the transmission media listed, fiber optic cables support the most bandwidth followed by coaxial cable (7). Interfaces between the transmission medium and the user also restrict bandwidth capacity. Application of wireline systems are restricted by such obstacles as: extremely long distances, rugged terrain, and availability of materials because wireline systems require a physical connection between transmitting and receiving users. Wireline communication services are very expensive in certain rural areas because of the costs required to provide a transmission medium across these obstacles.

Maintenance and reliability are concerns for any communication system, but are especially important for a wireline system in order to maintain the physical connection alongside the entire distance of the transmission medium. The public switched telephone network and cable TV are basic types of wireline system in the U.S. that may offer incident management applications.

Public Switched Telephone Network - Most of Rural America has access to the public switched telephone network (PSTN), but it is not comprehensive in coverage. The PSTN is a telecommunications network providing interconnection between users via telephone lines to a central switching office. At the central switching office, a switch is used to link any user with any other user. The PSTN penetrates 91.7 percent of Rural Service Area (RSA - defined as areas outside a MSA) (7). While not comprehensive, the PSTN offers the most accessible means to communicate within an agency and between agencies. Communication may not always be possible if the telephone lines are already in use because communication on the PSTN requires a link between users. Although, the PSTN was optimized for voice communication, transmission of fax, data, and low speed video is possible using modems. Currently, data transmission rates of 28.8 kbps can be achieved using voice-band modems (7).

Cable Television - Cable television in rural areas is limited by the expense associated with providing the basic hard-wire infrastructure and the installation of the cable for distributing the television signals. These costs make it economically unfeasible to distribute comprehensively across the rural area. Many rural communities have access to cable television, but most farm houses are too sparse for cable providers to service. Many cable systems are updating their coaxial cables with a relatively new transmission medium, a hybrid fiber/coax network (7). This medium allows for two-way voice communication; however, the amount of service the cable provider can offer to clients is limited based on the amount of two-way voice communication (7). Two-way voice communication via the cable service would require special user premises equipment to interface between the radio frequency signals on the cable and standard telephone equipment (7).

The cable television industry is optimistic in providing high speed data services within its infrastructure along with personal communication services (7). Future cable services may provide infrastructure in urban areas to provide data and two-way voice communication services. Data and communication services in rural areas would be extremely limited because of the lack of infrastructure. Traveler information could be broadcast on a cable T.V. channel, but this would also be extremely limited in rural areas because of the costs of obtaining broadcasting rights to the channel. The effectiveness would also be limited because many rural residents do not have access to cable T.V. The use of cable T.V. for incident management is extremely limited in rural areas because its infrastructure is less comprehensive than the PSTN and has other costs associated with broadcasting and distributing information.

Wireless Systems

Differences between wireless communication technologies are sometimes difficult to determine because of their similarities, but wireless transmission media can be divided into terrestrial and satellite based systems. Terrestrial systems are designed to propagate transmissions along the Earth, while satellite systems propagate transmissions from Earth to an orbiting satellite and back to Earth. Some terrestrial based networks, such as cellular telephone systems, are designed primarily to provide a wireless connection to the PSTN. Others are developed as stand-alone communication networks.

Land Mobile Radio - Land mobile radio (LMR) includes radio communication between mobile users or between mobile users and a base station. LMR technology ranges from hand held, citizen band (CB) "walkie-talkies" to more elaborate trunked-radio repeater systems. Typically, LMR is used for two-way voice communication using an analog channel with about 15-30 KHZ of bandwidth (7). Some systems can be modified to transfer digital information using a modem. The Federal Communications Commission (FCC) licenses several categories of land mobile radio (7):

- Private Radio (user is licensed for a particular frequency and owns and operates exclusively within own system);
- Personal Radio (CB; user operates within 40 frequencies near 27 MHZ, owning and operating own equipment, but talking with other CB users); and
- Specialized Mobile Radio (SMR; user owns radios, but subscribes to a repeater and other services provided by a system operator).

LMR systems are the main means of mobile/personal communications in rural areas because competition for licenses is small and easily accessible. SMR systems are typically available only in urban areas (7).

Simplex radio is the most basic type of LMR operation, where a single frequency is used to listen and talk. Simplex radio requires the user to wait for the other user to stop transmitting before beginning transmission. The radio reverts back to its receiving mode when the user is not transmitting. Two frequencies, duplex radio, allow the user to transmit and receive simultaneously. Coverage areas of mobile-to-mobile communications are limited by transmitter power of the mobile radio, terrain, weather, and antenna height. The height of the mobile antenna is restricted because the mobile unit must remain near the ground for user accessibility. Coverage areas of mobile-to-base communications are limited by the antenna tower height and transmitter power at the base station. Generally, high antenna towers are expensive, but they avoid the need for powerful transmitters which are expensive and unreliable (7).

An example of a SMR system is a repeater radio which receives a signal on a F1 frequency and re-transmits the signal on a F2 frequency. Mobile users of the repeater are typically charged a fee for the use of the repeater. Subscribers to the repeater simply transmit messages on F1 frequency and listen on F2 frequency. Rural coverage via SMR is generally available and may offer the ability to change modes of communication to the PSTN. For example, a trucker may signal a repeater, the repeater then transfers the communication mode to a telephone line. The trucker can then make a long distance phone call using a credit card. The aforementioned example requires more advanced radio equipment with significantly higher user costs (7).

A choice of which mobile radio to use is determined mostly by cost, reliability, coverage area, and type of services desired. The coverage area is very dependent on the terrain of the area and the transmitter power. Many repeaters and base station antennas support limited coverage to about a 30 mile radius (7). Mobile-to-mobile communications is even more limited because of the lower antenna heights but can typically reach up to seven miles with the appropriate technology (7).

Most public safety agencies use some form of LMR when responding to highway incidents. Traditionally, each agency responding to an incident scene had its own operating system for communications. This approach required all responding agencies to carry a radio from other agencies for mutual aid communication (14). Obviously, the response to an incident can be much more efficient when all responding agencies communicate on the same system, yet are able to communicate on their own system in order to prevent burdening other agencies with unimportant information. Due to incompatibility problems and market demand, 800 MHz trunked radio systems were developed for public safety communications. The mobile hand-held 800 MHz systems allow more channel capacity as well as supporting automatic vehicle location and mobile data messaging terminals (14). Unfortunately, manufactures of the 800 MHz systems have not agreed upon common communication protocols and communication between different 800 MHz systems at an incident scene is still difficult (14).

High Frequency Radio - High frequency (HF) radio systems propagate radio waves between three and thirty (3-30) MHz along the surface of the Earth or through the sky. While HF ground waves remain near the surface of the Earth, HF sky waves are reflected from ionized layers in the upper atmosphere. The ground wave propagation can typically be used to communicate across distances of about 60 miles; the range of communication depends on terrain conditions and transmitter power. Ranges up to 100 miles can sometimes be achieved at transmission frequencies below four MHz, but as the frequency is increased, the radio waves experience increased distortion (7).

Sky wave propagation allows longer ranges for HF radio communication. The sky radio wave returns are highly variable and dependent upon frequency, time of day, season, solar activity, and geographic location. Traditionally, experienced operators were required to operate HF equipment because it was difficult to avoid poor-quality channels, identify an optimum frequency, and avoid interference with other signals. Recent technological advances in HF equipment has improved the reliability of communication and made it easier to use HF radio. HF radio transmission rates of 1200 bps are possible supporting voice, fax, and data communication (7).

HF radio has a slightly larger communication range than LMR and its equipment cost is relatively low and durable. Like LMR, HF radio communication is not possible over long distances; therefore, its application is limited to relatively short ranges.

Broadcast Radio - The most common application of broadcast radio is the use of highway advisory radio (HAR), where a specific channel is dedicated to broadcast information about special events, parking, traffic conditions, weather, and/or congestion locations. Broadcast radio coverage is limited to the area in which the radio wave propagates along the terrain and requires the motorist to tune their radio to the proper station in order to receive the transmission. Typically, HAR consists of low power AM broadcast transmitters alongside major roadways at selected locations to provide maximum coverage. Some transportation agencies mount HAR transmitters on equipment, such as service trucks used at incident scenes (7,15).

Broadcast Radio Subcarrier - A conventional FM or AM broadcast does not require the entire channel bandwidth; therefore, digital audio and data services can be added to the broadcast. The additional services are available to users with a receiver capable of accessing the digital data. Two methods are being explored in order to provide these additional services. The first method, FM High-Speed Subcarrier (FM HSS), incorporates digital data into the conventional FM broadcast by adding the digital data signal to the existing radio signal before FM modulation. The second, digital audio broadcast (DAB), is a fully digital transmission that is transmitted in addition to the conventional FM. This separate signal is added to the conventional FM signal after the FM modulation, as shown in Figure 2 (7).

Conventional subcarrier systems provide approximately a few hundred bps of data to the receiver. Prototypes have been developed for a new high-speed data service that can be incorporated into the FM signal. Current prototypes of FM HSS systems provide data rates up to 8,000 bps; while others are planned to provide data rates of up to 56,000 bps (7,15).

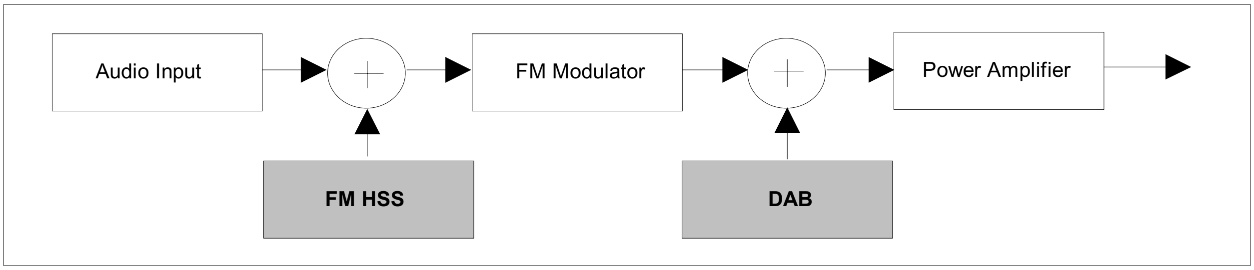


Figure 2. Insertion Of FM HSS And DAB Into A Conventional FM Broadcast (7).

The FM broadcaster typically charges fees to the company that installs and administers the FM subcarrier system. Accessibility in rural areas to broadcast radio varies depending on the proximity of the user to the broadcaster. Typically, the coverage range of a broadcast radio channel is a 30-50 mile radius depending on interference and terrain. The primary communication path is via ground wave propagation, but some sky wave propagation is possible during certain times of the day. AM subcarrier systems provide the potential for data transfer at a lower transfer rate (100 to 200 bps) then FM radio but offers a larger coverage area (7,15).

A potential application of subcarrier systems is to provide traffic information to mobile vehicles that include: mapping services, traffic information, advisory messages, and weather messages. This application is limited to the range in which the radio broadcast can propagate across the terrain. To accommodate motorists traveling in and out of coverage areas of a single channel, it would be necessary to subscribe to several subcarrier systems on different channels.

Cellular Telephone - No communication technology has seen more development and growth over the past decade than the cellular communications industry. However, cellular coverage is not completely comprehensive of the entire U.S. It has been estimated that 96 percent of the total population in the U.S. has cellular coverage but only 60 percent of the total U.S. is geographically covered (7). The percent of land covered by cellular telephone systems in the U.S. is significantly affected by the portion of Alaska that is not covered (7). Cellular coverage is prevalent along interstates and in urban centers, but it remains in very limited use in many rural areas in the western U.S. (7).

Traditionally, mobile telephones use a high-power transmitter with a tall antenna to cover a large area. Cellular technology changed this method and added smaller cells with smaller areas of coverage and low-power transmitters. Using smaller cell areas allows the same frequencies to be used in different cell areas that would be unavailable in a large encompassing cell area (7). However, cell-splitting is inefficient because of the costs associated with more base stations and increased networking. Figure 4 shows the cellular system architecture.

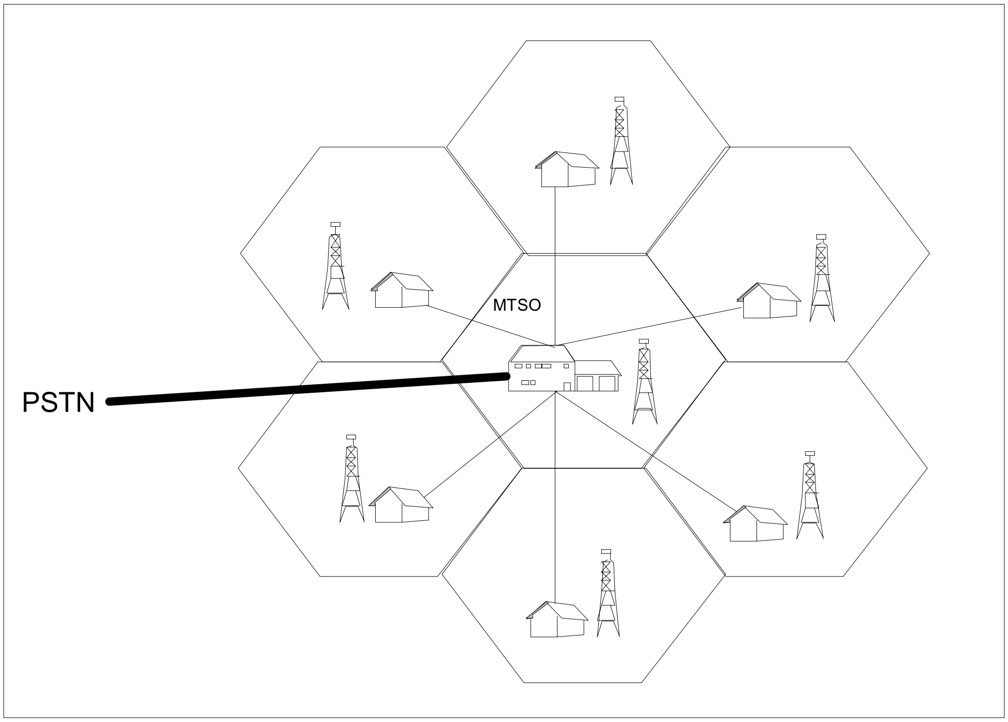


Figure 4. Cellular System Architecture (7).

Cell sites consist of an antenna usually mounted on a tower or tall building together with a building to house equipment. The antennas pick up, intensify, and repeat telephone signals to a mobile telephone switching office (MTSO), which transfers the signal to the PSTN. The coverage area of a cell is generally thought of as hexagonal, although, normally the cells are many shapes and sizes. Cell radii vary from one to forty miles, with five to ten miles being typical. In rural areas, the cell sizes are typically bigger than in urban areas and are generally 35 miles in radius (7).

The mobility of the cellular telephone user necessitates the system to "handoff" to other cells to retain an appropriate signal strength. Handoffs are accomplished by occasionally polling signal strength. When signal strength drops below a certain level, the switch scans adjacent cell sites for the greatest signal strength and performs the switch (7).

Motorists with cellular telephones are an effective tool for detecting incidents on roadways. However, cellular telephone use for detecting incidents is dependent on the coverage area of the cell, motorists carrying cellular telephones in their vehicle, and motorists using their telephones when encountering an incident.

Cellular telephone systems provide analog voice communication. Cellular Digital Packet Data (CDPD) uses idle times between voice transmission to transmit data across the analog cellular network but requires cellular modems (12,16). The most obvious use of cellular telephones is the capability to call 911 service (public safety answering points (PSAPs)), to report a roadway incident. Some metropolitan communities have special cellular call-in programs to improve the efficiency using cellular emergency calls to detect and verify incident (17). The applicability of cellular call-in programs for incident detection and verification in rural areas is discussed later in this report.

Personal Communications Services - Personal communications services (PCS) allows transmission of digital voice and messaging services along a network system similar to cellular. Slight differences do exist between PCS and cellular systems. PCS systems use only digital transmissions and use higher frequencies than cellular. The use of digital network technology converts the original analog voice to a compressed binary type transmission. A receiver converts the digital signal back to analog voice (7,15,16).

The PCS mobile network architecture is similar to cellular in that frequencies can be reused by using smaller cell coverage areas. In rural areas, cell sizes are very large to generate the maximum coverage because the subscriber density is low. In urban areas, the cells are smaller to increase the availability of radio channels for individual cells because the subscriber density is higher. (7)

PCS coverage is almost complete in many urban areas and extends in areas surrounding urban centers, especially along interstates and major arterials (15). However, PCSs are not as comprehensive as analog cellular (16). Like cellular, the most obvious use of PCS technology is to call 911 to report a roadway incident. Unlike cellular systems, PCSs use digital transmission which allows direct transfer of data through its networks (16).

Satellite Systems - The Global Positioning System (GPS) satellites are the most famous of the communication satellites. The GPS system consists of 24 low-earth orbit satellites and a ground control system that was originally developed by the Department of Defense (DOD) to provide worldwide positioning (16). The DOD decided to add a civilian component that is free of direct user charges. Two dimensional positioning is possible when in communication with three satellites. Three dimensional positioning is possible when in communication with four or more satellites (7). A horizontal accuracy of 100 meters can be expected using the civilian component of the GPS when in communication with four or more satellites (16).

Satellite systems have advantages over other wireless systems because coverage is worldwide. Rural communication to satellite systems are generally less obstructed than in urban areas where man-made obstructions can block satellite signals. Examples of GPS applications for incident management purposes include GPS receivers in vehicles to determine position location. However, the GPS receiver only provides the position location to the mobile user. Another means of communication must be used to transmit the position location information to another party (16).

Unlike wireline and other wireless systems, satellite system costs to the user are not directly related to user density. Hence, satellite system applications in rural areas appears to be very feasible given the lack of user density in most rural areas. In addition to the GPS, many satellite systems are being ventured to provide two-way data and voice communication. Satellite systems offering wide-spread two-way voice and data communication are still under development.

Table 2 summarizes the communication infrastructures available in rural areas. The table shows the applicability of and the barriers to using each communication technology in rural areas.

Table 2. Applicability of and Barriers to Detection/ Verification Communication in Rural Areas.

Communication	Applicability	Barriers
Wireline Systems		
Public Switched Telephone Network	• Interagency and intra-agency correspondence. • Correspondence from rural household to appropriate authorities.	• Limited number of lines may cause unavailability during heavy use.
Cable Television	• Broadcasting information messages regarding incidents. • Data transmission using subcarrier systems .	• Infrastructure costs for laying cables in rural areas for relatively few subscribers.
Wireless Systems		
Land Mobile Radio	• Mobile-to-mobile and mobile-to-base voice correspondence. • Ranges under 30 miles.	• Coverage limitations of radio transmission. • Incompatibility between different LMR systems due to lack of communication protocols.
High Frequency Radio	• Mobile data transfer. • Mobile-to-mobile and mobile-to-base voice correspondence. • Ranges under 100 miles.	• Complicated procedures require experienced users to avoid transmission problems. • Coverage limitations of radio transmission.
Broadcast Radio	• Highway Advisory Radio broadcasting informational messages.	• Coverage limitations of radio transmission. • Acquiring licenses to broadcast.
Broadcast Radio Subcarrier Systems	• Data transmission.	• Coverage limitations of radio transmission. • Acquiring channel bandwidth.
Cellular Telephones	• Cellular call-in programs. • Mobile data transmission. • Mobil-to-mobile and mobile-to-base correspondence.	• Cost of infrastructure to support cell sites. • Special modems required to transfer data. • Coverage and frequency limitations of cell site.
Personal Communication Services	• High-rate mobile data transmission. • Mobile-to-mobile and mobile-to-base correspondence.	• Cost of infrastructure to support cell sites. • Coverage and frequency limitations of cell site.
Satellite Systems	• Remote data transmission. • Remote voice correspondence.	• Cost of infrastructure and maintenance of satellites. • Cost of user interfaces.

INCIDENTS AND INCIDENT MANAGEMENT

As mentioned previously, characteristics of urban and rural environments, travelers, and roadways vary; however, the incident management technologies and methods used in urban areas may have practical application in rural areas. A summary of incidents and incident management methods is discussed in this section to explore the potential for applying these methods in rural areas as well as the barriers associated with implementing each method.

An incident is any non-recurrent event which causes reduction of roadway capacity or abnormal increase in demand (18). Incidents may be divided into two categories: predictable and non-predictable (18). Table 3 provides a summary of typical incidents and the categories of each. Predictable, or planned events are still considered incidents since they occur irregularly and are often unexpected to the general motoring public (18).

Table 3. Incident Categories (18).

PREDICTABLE	**UNPREDICTABLE**
Maintenance	Accidents
Construction	Stalled Vehicle
Special Events (concerts, ball games, fairs, parades, Olympics)	Adverse Weather (fog, ice, snow, or rain)
	Bridge or Roadway Failure
	Spilled Load

The frequency of incident types varies between urban and rural areas. While many urban accidents involve multiple vehicles, most rural accidents are single vehicles that run off the roadway (9). Vehicle stalls are likely to occur in both the rural and urban area, but drivers may be stranded a significantly greater distance from a service station in rural areas. With lower traffic volumes, the driver is less likely to receive help from a "Good Samaritan" passing by the breakdown.

Other types of incidents, such as hazardous material spills, rock slides, or roadway failures may limit the use of the roadway to many motorists and are difficult to detect in rural areas because communication infrastructures and surveillance technologies are not available.

Incident management is the coordinated preplanned use of human, mechanical, institutional, and technological resources to reduce the duration and impacts of incidents. In other words, the major goal of the incident management system is to reduce the impacts of incidents to traffic. Incidents can not only lead to excessive congestion and delays but also to secondary accidents. IMPs attempt to reduce the impacts of these delays and secondary accidents by clearing the incidents as rapidly as possible while providing information to motorists. A benefit of IMPs is that the tasks involved in the process of clearing an incident occur more efficiently and require less time. This in turn can restore the roadway to normal conditions faster and reduce the impact of the incident. (1,18)

Evaluations of IMPs usually focus on the ability of the program to restore normal conditions to freeways, and reduce congestion and motorist delays associated with urban incidents. Other measurable benefits of IMPs include quicker response of emergency personnel and quicker removal of the incident from the roadway. Typically, evaluations of an IMP consider cost-to-benefit ratios. One method used to evaluate an IMP is to convert the delay savings provided to the motoring public to a monetary value and compare it to the cost of the expenses required to run the program (18,19,20). In rural areas where congestion and motorist delay savings are less likely to be significant, the evaluation would be better suited to consider improvements related to emergency response time. Therefore, the cost-to-benefit ratio of rural systems would be based on emergency response time savings-to-cost rather than delay savings-to-cost.

Different incident management techniques are used in urban areas; however, their use in rural roadways has been limited. Limited applications of IMPs in rural areas may be because: 1) it is not cost-effective to monitor rural roadways in the same manner as urban roadways; 2) the frequency of non-recurrent and recurrent congestion on rural roadways is lower; or 3) rural communities and travelers have not clamored in support of such measures.

Several agencies have taken the initial steps to develop a program that could handle incidents more effectively in rural areas. The unique characteristics of the rural environment and travelers require innovative approaches to implement IMPs. For example, some metropolitan communities have implemented service patrols to assist stranded motorists, whereas it would not be practical or cost-effective to roam rural roadways with the same frequency.

Detection and Verification

Detection is the determination that an incident of some nature has occurred. This information needs to reach a location where response can be initiated (18). Verification is the determination of the precise location and nature of the incident as well as the display, recording, and communication of this information to appropriate agencies (18).

Detection is difficult to accomplish in the incident management process in rural areas because many accidents are single vehicle and communication and surveillance technologies are not readily available to detect and/or verify an incident.

Several techniques are potential candidates for detecting and verifying rural incidents. Many of these techniques can be used individually or in coordination with other techniques in order to increase effectiveness. Public agencies and private companies have implemented different approaches to improve incident detection. Public agencies implement infrastructure to support incident management systems on selected main roadways to benefit the motoring public. Private companies implement technologies to support emergency services for selected motorists on all roadways. The differences in the public and private approaches present a dilemma. Is it best to implement systems on selected main roadways to benefit the motoring public or is it best to implement systems to benefit individual subscribers of the system on all roadways? Incident detection techniques are discussed in the following section to highlight the differences in approach.

Mayday Systems

Mayday systems generally consist of two basic in-vehicle components: a GPS locating device and a cellular telephone. A mayday system allows the motorist to notify an emergency dispatch center when an emergency occurs. Some mayday systems require the motorist to manually activate the system, while other systems include sensors that automatically detect an emergency (21,22,23). With the former system, the motorist presses a button which automatically activates the cellular telephone to dial a predetermined emergency service center. The cellular telephone transmits the GPS coordinates of the vehicle to an emergency service center. With the latter system, the cellular telephone automatically dials the emergency dispatch center when sensors detect an emergency, such as an air bag deployment. In either case, an operator at the center can call back the user and if no one responds, can dispatch emergency services to the motorist's location (21,22,23). Two approaches can be taken to dispatching emergency services: 1) the operator, who is part of the highway patrol, can notify the nearest highway patrolmen of the incident; or 2) an operator, who is part of a subscriber service, can notify the nearest PSAP of the incident.

Some mayday system providers charge a monthly fee in addition to the normal monthly cellular telephone charges (24). Initial set-up costs of mayday systems range between \$500 and \$2,000 (25,26). Advantages of detecting incidents with a mayday system are: motorists are able to remain in their vehicle and avoid roaming the roadway; detection is nearly instantaneous; the location of the incident is known; and the motorist can communicate other information about the incident to expedite an appropriate response. Mayday systems, however, are limited by their relatively high costs and restricted to areas with cellular systems. Some mayday packages include features such as remote car unlock, stolen vehicle tracking, and traveler information in addition to their emergency services (21,22).

Cellular Telephone Call-in Programs

Cellular telephone call-in programs have been successful as an incident detection tool in urban areas and are often the first method through which an incident is detected. For example, after initiating a cellular call-in program, the estimated time from incident occurrence to response arrival decreased from 15.7 to 13.4 minutes for major incidents in the six county region near Chicago, Illinois (17). Other urban areas have reported similar successes for both major and minor incidents using cellular call-in programs (17). In order to expedite responses to roadway incidents, some cellular 911 calls are directly routed to a highway patrol agency on the assumption that most cellular emergency calls require a response by a highway patrolman. Routing cellular calls directly to the likely responding agency eliminates the need for a call taker at a PSAP to gather sufficient information about the incident, then decide what actions to take and which response agencies to notify.

Cellular call-in programs are restricted to areas with available cellular coverage. The location of the source of a cellular call cannot yet be feasibly pinpointed because of technological limitations and cellular carrier policy (17). Currently, the cellular caller reporting the incident is relied on to pinpoint the incident location. Operators can ask the cellular caller about landmarks, route number, mile post marker, and other features surrounding the caller to pinpoint the location of the cellular caller. Duplicate callers reporting the same incident serve as verification of the incident and also help pinpoint the incident location. The FCC adopted a plan that requires location referencing for wireless 911 calls. Phase one of the plan requires wireless providers to locate the cell site or base station on 911 calls by April 1, 1998. Phase two requires wireless provider to locate the caller within 125 meters by 2001 (27). Testing and development of systems to fulfill both phases of the FCC plan are underway. Location technology costs per cell site are estimated at $50,000 and issues regarding cost recovery measures for wireless providers to implement location technology are yet to be determined (27).

In rural areas, where traffic volumes are lower, the detection and verification process relying on cellular callers would take more time because it is less likely a cellular user would pass-by the incident scene. Figure 5 shows the average minutes to receive the first call in detecting an incident based on the number of vehicles per hour on the roadway and different rates of cellular ownership. This figure is based on 10 percent of cellular owners reporting incidents.

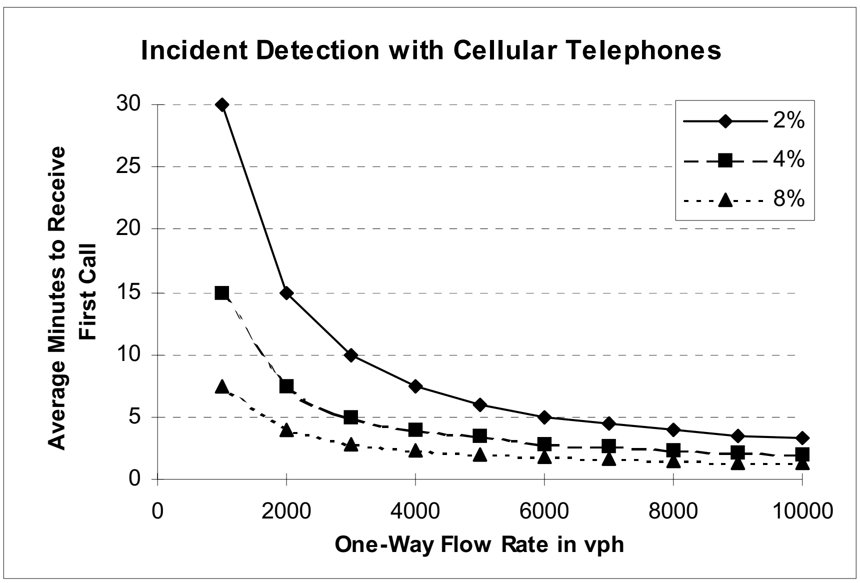


Figure 5. Cellular Phone Use for Incident Detection (17).

Although cellular use has increased exponentially in the past decade, much of the cellular growth has been centered in urban areas (7,17). As of December 1994, there were 24.5 million cellular subscribers, but only 2.5 million were from Rural Statistical Areas (RSAs) (7). Market analysts estimate that 10.8 percent of the total population in MSAs are cellular subscribers, while only 4.5 percent of the total population in RSAs are cellular subscribers (12). Cellular has experienced exponential growth in the past decade, but a recent market study projects that cellular market penetration will likely plateau at 30 percent of the population unless major reductions are initiated in cellular charges (25,28). Some cellular providers have started to sell low-cost cellular telephones specifically designed for emergencies.

Motorist Aid Call Boxes

Motorist aid call boxes consist of a box with push-buttons or toggles, that when pressed, signal the monitoring agency that an incident has occurred. Motorists can choose from several buttons in the call box depending on the type of service needed at the incident scene. Motorist aid telephones are a variation of the call box except they are capable of two-way voice communication. Two-way communication allows the motorist to describe the type of incident and possibly the severity which assists an agency to respond more appropriately and faster (20).

Call box systems using wireline media are usually limited to bridges and tunnels and require significant installation costs but generally have low operating costs. Cellular systems are either analog-voice or data-signal and require little infrastructure besides the call box itself. Large operating costs to cover cellular phone bills area disadvantage to cellular call box systems (20). Generally, power is supplied from a solar-panel system with a self-contained battery. Other call box systems use AC power which requires more infrastructure (20).

Call box systems were first implemented in the 1960s and were the first major motorist aid system (20,29). Currently, the effectiveness of call box systems are challenged by other detection/verification tools, such as cellular telephones (911 calls), closed-circuit television, and service patrols. However, call box systems remain in significant use by motorists in California, which has one of the highest concentration of cellular phones (25). The continued use of call boxes show that call box systems provide a needed service. The service may be especially helpful where aforementioned detection alternatives are not provided.

Call boxes are usually implemented on major roadways offering accessibility to all motorists in the event of an emergency or vehicle breakdown. Effectiveness of call box systems is debated because considerable delay may result between when an incident occurs and when agencies are notified. Much time may elapse because the motorist must first decide to use the system, then locate and walk to the nearest call box, and finally make the appropriate request for assistance (20). Call boxes are typically spaced farther apart on roadways with lower traffic volumes, so motorists on rural roadways with lower traffic volumes may need to walk a considerably longer distance than in urban areas to reach the nearest call box.

While call box systems are successful in California, some agencies have removed their call boxes because detection of incidents is more effective using other methods, especially cellular telephone call-in programs. Some states do not use call boxes because they prefer motorists to remain in their vehicle rather than walk alongside the roadway to reach the call box.

Closed Circuit Television (CCTV)

CCTV systems allow agencies to reduce response time because of their capability of assessing video images of the incident scene. While detection of incidents is possible using video images, images are mainly used to verify incidents because of the labor intensive work required to watch video images. For this reason, CCTV systems are usually used in coordination with other detection technologies, and their sole use for detecting incidents is not recommended (20). CCTV is generally used in major metropolitan areas to help agencies assess incident characteristics which allows them to dispatch the appropriate response.

A disadvantage of CCTV systems are the high capital cost of the communication infrastructure to support the transmission of the video image back to the control center as well as operating and installing the components of the system. Hard-wired coaxial cable systems were traditionally used to relay the video image, but coaxial systems required the signal to be amplified every mile or so in order to maintain a quality image. Newer fiber optic cable systems allow the video image to be transmitted directly to the control center. Installing hard-wire communication medium to support CCTV limits its application in rural areas to small areas with high frequency of incidents.

Electronic Surveillance

The most common type of electronic detector is the inductive loop. Inductive loops detect vehicles as they pass over them by monitoring the change in the magnetic frequency. Agencies can monitor loops to estimate vehicle speed, lane occupancy, and volume. Other electronic surveillance devices in the developmental stage include the magnetometer, magnetic non-directional, magnetic directional, pressure plate, microwave radar, ultrasonic, and video imaging (14).

Incident detection algorithms have been developed in attempts to alert agencies when incidents occur. Algorithms are mathematically or comparatively based to detect incidents when specific thresholds are crossed. Once a threshold is crossed an alarm alerts the agency of an incident. Measures of effectiveness of incident detection algorithms are detection rate, detection time, and false alarm rate. Ideally, algorithms would like to alert agencies of incidents quickly, have a high detection rate, and low false alarm rate. A review of incident detection algorithms revealed that it is unrealistic to expect any algorithm to alarm an agency of an incident the moment it occurs, and at the same time, produce little or no false alarms (30). Figure 6 shows the tradeoffs between the measures of effectiveness of an incident detection algorithm. (30)

Electronic surveillance systems are primarily used to monitor congestion locations and incidents not covered by the other portions of the overall incident management program (30). When an algorithm triggers an alarm, the operator monitors the detector station that triggered the alarm to assess the situation (congestion may or may not be caused by incidents). In addition to the ineffectiveness for detecting incidents, electronic surveillance systems are costly to install, operate, and maintain (20).

Calibration of algorithms is a time consuming process that must be performed on a station-by-station basis to ensure adequate algorithm performance. Many traffic operations centers throughout the U.S. have abandoned incident detection algorithms because of the unreliability and frequency of false alarms (30).

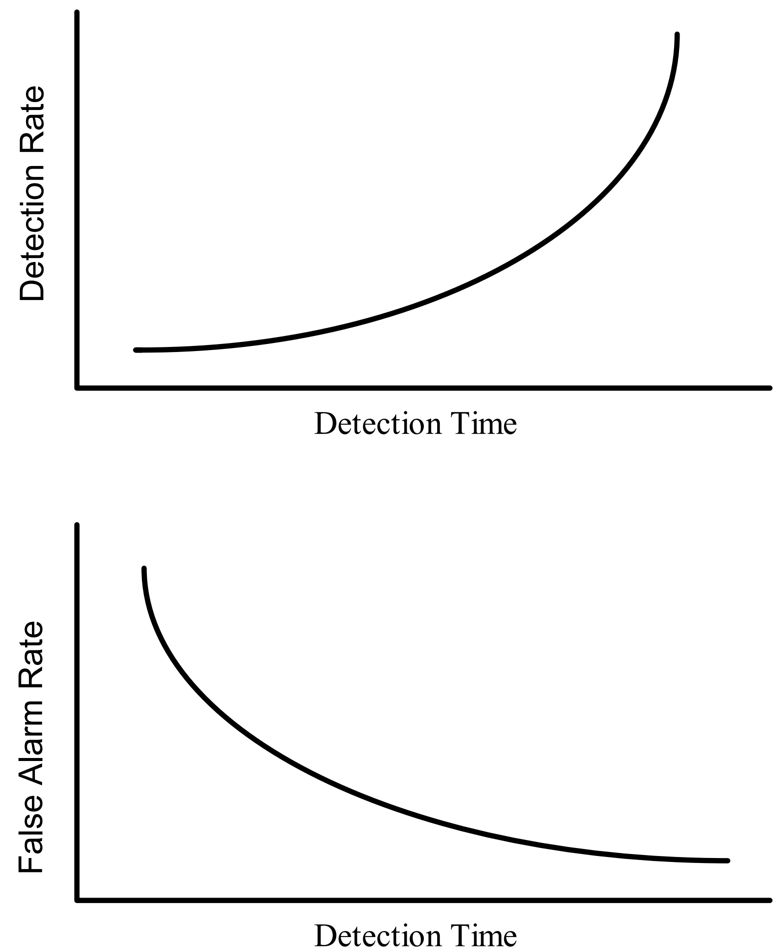


Figure 6. Relationship Between Detection Rate, False Alarm Rate, and Detection Time (30).

Rural incident detection using electronic surveillance is not recommended. Electronic surveillance incident detection methods require time consuming calibration, much oversight, and large maintenance and installation costs making it impractical for detecting incidents in rural areas. Ineffectiveness of detection algorithms to distinguish between congestion and congestion caused by incidents requires an agency to verify if an incident has occurred using other surveillance methods, such as CCTV; however, other surveillance methods may not be available in rural areas.

Service Patrols

Service patrols (or motorist assistance patrols) circulate roadway systems locating, detecting, and assisting stranded motorists. Most service patrols are able to remove minor incidents from the roadway, but they can also be used as a means to detect and report incidents. The ability of service patrols to provide accurate information improves a dispatcher's ability to initiate the appropriate response. Service patrols also assist managing traffic at incident scenes and perform other functions if needed.

Incident detection rates from service patrols are directly related to the headways of the service patrol. For example, a service patrol may pass any given point on the freeway at least once per hour. The headways of the patrol are related to the number of possible patrol vehicles the agency can afford to deploy at one time and the number of roadway miles in the coverage area. Service stops, such as assisting breakdowns or clearing accidents, can disrupt the headways of the circulating service patrol.

An advantage of service patrols is that they provide diverse services in the incident management process, but their primary benefit is that the time to begin clearing an incident is greatly reduced. Once a service patrol arrives at an incident scene, clearance can begin immediately. A major disadvantage with service patrols is the cost associated with maintaining a vehicle fleet and the labor intensive work required when staffing a service patrol (20). Like CCTV systems, rural applications of service patrol units would likely be limited to small areas with a known high frequency of incidents. Monitoring large rural areas comprehensively with service patrols is impractical because of the labor intensive work required to roam roadways.

Law Enforcement Patrols

As has been discussed, many techniques and technologies have been used in the attempt to detect incidents quicker and with more reliability. Perhaps the oldest technique is the use of law enforcement patrols that circulate the freeways and other roadways to detect incidents. A technique to reduce the time to detect incidents is to increase the frequency of law enforcement patrols circulating past a given point along the freeway.

The main advantage of using law enforcement patrols is similar to the service patrols in that they are flexible in handling an incident. Law enforcement officials can also determine what type of response to initiate by assessing the incident before communicating to the response agency; thereby, saving overall response time. A disadvantage of law enforcement patrols is that headways can be disrupted if they stop to assist a breakdown or incident. Non-uniform headways may lead to sporadic reports and delays in detecting incidents (18).

Automatic Vehicle Identification Systems

This type of detector system automatically identifies specific vehicles at predetermined points on the highway. Three elements are required in an Automatic Vehicle Identification (AVI) system (14):

- Vehicle-mounted electronic transponders or tags;
- Roadside reader units, and associated antenna; and
- A computer system for data processing and storage.

Roadside reader units are spaced along a roadway and transmit back to a central computer when vehicles equipped with AVI tags pass the reader. The central computer system can determine average segment speeds of vehicles based on known distances between successive reader stations and the time intervals between readings of the vehicles' transponder (14). Incident detection algorithms for AVI systems have been explored mainly through simulation but effectiveness of AVI systems for incident detection is yet to be determined. Many AVI systems are used for electronic toll collection and congestion management; hence, the use of AVI systems for incident detection would typically be a secondary use of the AVI data. Incident detection in rural areas using AVI systems should be limited to existing or planned electronic toll collecting facilities because of the cost of installing and maintaining such a system (31).

Citizens' Band (CB) Radio Monitoring

The use of CB radios have decreased since the late 1970s; however, the CB radio remains a staple in the communication between truckers on the roadway. Truckers monitoring roadways provide surveillance and the ability to communicate that an incident has occurred. Trucker and motorist surveillance may be especially important in rural areas where other means of communicating to an appropriate authority is not readily available. CB radio frequencies can be monitored by truckers, CB clubs, and other volunteers that can report observed incidents to appropriate agencies. Dedicated CB frequencies for the use of incident correspondence and detection can provide a means for better incident detection, but it requires motorist awareness. CB radio monitoring is dependent on motorists to use the system for its intended purpose and may require advertisement on traffic signs to remind motorists. Monitoring of CB radio communication as a sole means of detecting incidents is not recommended because of the suspect reliability. Its use is helpful as an initial detection and verification tool but requires other techniques to account for its unreliability. (20)

Stationary Observers

In some cases, stationary observers have been positioned in areas with a high frequency of incidents. Observers could be located in tall buildings that overlook the freeway where the incidents tend to occur. The observer can scan significant amounts of roadway and report incidents as they occur to the appropriate response agencies (20). Stationary observers for incident detection is limited to urban centers with tall buildings and frequent incidents. A disadvantage to using stationary observers is the significant labor required to continually scan the roadway. This application is extremely limited because tall buildings are few in rural areas and the labor required is significant. Table 4 summarizes the applicability and barriers to incident detection and verification techniques.

Table 4. Applicability of and Barriers to Detection/Verification Techniques in Rural Areas.

Technique	Applicability	Barrier to Implementation
Mayday Systems	• Areas with cellular coverage.	• Substantial technology costs, subscriber fees, and installation fees. • Minimal testing and evaluation of large-scale systems. • Subscriber services may not apply to help other vehicles in need.
Cellular Telephone Call-in Programs	• Areas with cellular coverage. • Roadways with relatively high traffic volumes.	• Limited number of users. • Reliability of caller to identify incident location (anonymity of cellular user).
Motorist Aid Call Boxes	• Rural areas with cellular coverage. • Main arteries of the rural roadway system.	• Requires motorist to locate and walk to nearest call box.
Closed Circuit Television	• Finite rural areas with history of high incident frequency. • Primary application is to verify or assess incident rather than detect incidents.	• Extensive infrastructure to support relaying images to TOC. • Labor intensive to monitor video images - limited to verifying and assessing incidents.
Electronic Surveillance	• Main arteries of the rural roadway system. • Mainly used to monitor congestion which may or may not be caused by incidents.	• Difficult calibration of algorithms to provide acceptable tradeoffs between detection rate, speed, and false alarm rate. • Extensive infrastructure to support system.
Service Patrols	• Finite rural areas with history of high incident frequency.	• Labor intensive to monitor and roam roadways. • Service stops cause headways to become non-uniform.
Law Enforcement Patrols	• Can be applied in all rural areas because of existing law enforcement circulation.	• Other responsibilities limit amount of surveillance devoted to highway related incidents.
Automatic Vehicle Identification (AVI) Systems	• Rural facilities with existing AVI monitoring or toll collection (detection is secondary use of AVI).	• Extensive infrastructure to support system.
Citizens' Band (CB) Radio Monitoring	• Rural roadways with high truck traffic.	• Limited number of users. • Lack of driver awareness

Response and Removal

Response is the activation, coordination, and management of the appropriate personnel, equipment, communication links, and motorist information media as soon as there is reasonable certainty that an incident is present (18). Removal is the clearance of wreckage, debris, spilled materials, etc. from the roadway along with restoring the roadway capacity to its pre-incident conditions (18).

Reiss and Dunn express the importance of inter-agency communication for effective response to incidents (18). The communication links should be reliable and should be capable of functioning in wide range of emergency conditions (18). The advantages and disadvantages of potential communication links in rural areas are described in the previous section.

Traffic operations centers can serve as a focal point for managing incidents and information on a regional basis. Department of Transportation facilities or other public agencies, such as the police dispatch center, can serve as the central point depending on available room (18).

Infrequent emergency facilities in rural areas contribute to longer response times. Bad weather in many rural areas can also delay the response, especially in severe locations such as mountain passes where it may be impassable for an emergency response team. Many rural accidents have been aided by the use of flight for life helicopters, but even these are susceptible and limited during severe weather.

Most roadway incidents are vehicle breakdowns which are often confined to the roadways shoulder. Minor incidents, such as vehicle breakdowns, need to be addressed because they are potentially major incidents. Private wrecker services may be called to remove the incident under the guidance of the police agency. Informal and formal arrangements can be used to ensure prompt and adequate response. Examples of arrangements include rotational lists and franchise agreements (1). In rural areas, the number of alternative private wrecker services may be very limited. Unavailable wrecker services may cause the incident to remain on the roadway until a wrecker service has the available means to respond and remove the vehicle off the roadway.

Service patrols also serve as a response mechanism in addition to its detection/verification capabilities. Service patrols can provide motorist assistance in the case of a minor breakdown and assist in removal, traffic management, communication coordination, and equipment assistance during major incidents (18). Intensive labor and vehicle requirements limit service patrol use in rural areas to small patrol areas with a history of frequent incidents.

Motorist Information and Traffic Management

Motorist information is the activation of various means of communicating incident site traffic conditions to motorists (18). Variable message signs are an effective means to distribute information to the motorists at the roadside. Portable signs can be driven prior to the incident site to warn oncoming drivers of the circumstances in the roadway ahead. Also, HAR can provide drivers, who tune to the proper radio station, with information along the freeway. Some agencies use truck mounted HAR which broadcast information to motorists. Other means of disseminating information includes commercial radio, CB radios, cable T.V., cellular telephone, pagers, in-vehicle devices, or the Internet. Success of information disseminating devices in rural areas is dependent on the ability to support the communication infrastructure for each of the devices.

Traffic management is the application of traffic control measures in the area of the incident site including: lane closures and openings, establishing and operating alternate routes, diversions, parking of emergency vehicles and ensuring safety of incident victims, motorists and emergency personnel (18).

The traffic management process in rural areas is more difficult than urban areas because many miles of roadway may need to be blocked or warnings must appear many miles in advance so motorists are properly informed and may divert to alternate routes. Rural areas generally have less options for alternate routes because of the larger space between major routes.

Incident Prevention

Incident prevention is the activation of various means to sustain driver alertness or warn drivers of incident potential; thereby, decreasing the likelihood of an incident. Incident prevention methods can involve advanced applications of technologies, such as crash warning systems. More practical methods involve rest areas and off-highway restaurants to help relieve traveler fatigue. Rural facilities need better enticement to attract drivers for rest and relaxation rather than the prevalent stop-and-go process.

SELECTED APPLICATIONS

Selected motorist aid systems and incident management programs in rural areas are discussed in this section. Project descriptions of each application were found in literature, and phone interviews were conducted with professionals involved in each of the projects to fill in informational voids.

OnStar, General Motors Corporation

Project Description

OnStar, a division of General Motors, was first available on the 1997 front-wheel drive Cadillacs, except the Catera model (which will be available in 1998). The Seville, DeVille, and Eldorado models from 1996 can be retrofit to accommodate the OnStar Option. OnStar, an in-vehicle communications system, features a GPS receiver and a cellular telephone in addition to other service options including: a theft detection notification, stolen vehicle tracking, roadside assistance, remote door unlock, route support, and informational services (21,32).

In an emergency, the driver can press an emergency service button on the cellular telephone. The GPS receiver communicates with satellites to triangulate the position of the vehicle. The cellular telephone then dials a pre-determined number of the customer service center (the OnStar Center) and transmits the GPS coordinates. The OnStar Center will call back the driver to learn about the driver's situation. If needed, the OnStar Center will call the regional PSAP corresponding to the GPS coordinates (33). The OnStar Center is also capable of transferring the driver to an emergency service operator which allows direct communication between the driver and PSAP operator (32).

Perhaps the most advantageous attribute of the OnStar system is its ability to send an emergency signal when an air bag deploys. In the air bag deployment scenario, the cellular phone sends an emergency signal to the OnStar Center (also containing the location of the vehicle). An advisor at the Center will then attempt to communicate with the occupants of the vehicle. If the occupants do not respond, the advisor will determine the exact location of the vehicle and notify the nearest PSAP (32, 33).

As mentioned, other services are included in the OnStar package. Drivers needing directions, the nearest gas station, or nearest hotel can call the OnStar Center to receive directions. The driver can record these directions (up to two minutes) and replay them, but the system does not have step-by-step navigational capabilities (32).

Institutional and Funding Arrangements

General Motors Corporation is the vehicle distributor and charges $895 plus installation for the OnStar system. The subscriber pays a monthly service fee of $22.50 for the system and chooses a cellular provider (21,33). As of July 31, 1997, 15,000 OnStar systems were purchased (33).

Hughes Network Systems produces the cellular telephone. The cellular phone is a digital/analog unit and its appearance is similar to a standard car phone. The duality of the phone means that it can transmit using traditional analog technology and automatically switch to digital operation when the subscriber enters a digital service area (34). The phone has dedicated emergency service and customer assistance buttons and can be used "hands-free." The cellular telephone is also capable of voice-activation, allowing the user to dial while focusing on the roadway (34). The communication platform can automatically transmit data by the driver's discretion, such as vehicle ID, event codes, diagnostics information, and telephony via the cellular telephone (34).

The OnStar Center provides 24-hour emergency, roadside and informational services to the subscriber of the OnStar system. EDS (Electronic Data Systems) provides the customer service and emergency answering services which is based in Farmington, Michigan (21,32).

Conclusions

The major advantage of the OnStar system is that it provides emergency communication from the security of the driver's vehicle to summon an emergency response. The capability of the system to call back the driver to assess the situation decreases the response time of the emergency service to an incident because details may be known of the driver's location and situation. Drivers are no longer relied on to provide information on the location of the incident because coordinates from the GPS were transmitted to the customer center. Another advantage to the OnStar system is that air bag sensors are able to activate an emergency signal to the OnStar Center.

The use of the OnStar system, however, is restricted to areas covered by cellular sites. Another disadvantage of this system is the relatively high cost to the user. Subscribers of this system will have to be capable of funding the system cost ($895), installation fee (unknown), monthly service fee ($22.50), and monthly cellular phone charges (related to cellular provider fees, roaming charges, and number of uses). Lastly, the customer service advisors, in Farmington, Michigan are not likely to be very familiar with local terminology of roadway or landmarks, rather they refer to roadways in proper number terms (26).

The OnStar system is limited to GM Cadillac car-buyers but GM plans to expand the OnStar package to other models in 1998 (33). The success of the system is reliant on a strong cellular signal to transmit the position of the incident. Accurate information databases are also needed to identify the GPS coordinates with an identifiable route location. This will allow the OnStar advisor to relay the motorist's location to a PSAP. Informational databases must also include assigned territories of PSAPs to relate the position of the incident with the nearest PSAP. Finally, informational filtering may unknowingly occur because incident information is relayed from the motorist, to the OnStar Center operator, to the PSAP operator, to the response agency dispatcher, and finally to the actual responder. Errors, although accidental, may occur in relaying incident information.

RESCU, Ford Motor Company

Project Description

RESCU (Remote Emergency Satellite Cellular Unit), like OnStar, provides subscribers with the ability to summon emergency help by pressing buttons in their vehicle. The RESCU package was first available on the 1996 Lincoln Continental and is currently available on new models of the Continental. In-vehicle components of the RESCU package are the GPS receiver and the cellular telephone. The RESCU package also includes four Michelin "run-flat" tires and a JBL Audio System (22).

The RESCU system architecture is similar to the OnStar system. In an emergency, the driver presses a button which activates the cellular telephone to dial the Lincoln Security Response Center. The cellular telephone transmits the coordinates obtained from the vehicle's GPS system to the Center (35). After the position data is sent, the driver is automatically connected to an operator. The operator asks the driver of the specific details of the situation. After assessing the situation the operator can notify the regional PSAP corresponding to the location of the motorist.

Each RESCU system has a personal password. If the emergency button is pressed and the driver informs the operator that the call was a false alarm, the operator will ask for a password. If an incorrect password is given, the operator automatically notifies the PSAP nearest the vehicle (22).

Other services of the RESCU package include a set of four Michelin tires that can drive about 50 miles at 55 mph and zero pressure. The JBL Audio System with Digital Signal Processing is used for dialogue between the operator and the motorist (22).

Unlike OnStar, RESCU does not currently offer anti-theft or automatic emergency services if an air bag is deployed. Other components, such as the automatic door unlock, vehicle locating service, and directional services are not part of the RESCU package. Ford is considering the addition of these components, especially the air bag sensor in future models (22).

Institutional and Funding Arrangements

Ford Motor Company is the vehicle distributor and charges $1,995 for the RESCU package but does not charge a monthly service fee (22). Lincoln Continental expected between 10 and 30 percent of vehicle buyers to purchase the RESCU package. As of May 31, 1996 16 percent of Lincoln buyers had optioned for the service (22). Motorola produces the cellular telephone.

The Lincoln Security Response Center is based in Dallas, Texas and provides 24-hour emergency service. Westinghouse Security Systems operates the Lincoln Security Center and consults Etak, Inc. for digital map databases (22). RESCU subscribers are entitled to unlimited responses during the vehicle's four-year warranty period (22).

Conclusions

The RESCU package is very similar to OnStar; therefore, RESCU has many of the same advantages and disadvantages as OnStar. Only differences between RESCU and OnStar are described in this section.

Subscribers of the RESCU package pay an initial $1,995 fee but are not subject to monthly service fees. Ford plans to expand RESCU to other makes of its production line depending on the success of this system. In 1998, RESCU will be offered only on the Lincoln Continental (36). About 16 percent of Lincoln car-buyers subscribe to RESCU (26). The main disadvantage of RESCU compared to OnStar is its inability to transmit an emergency signal automatically if the air bag is deployed, but Ford is considering adding this feature in future models.

While both the OnStar and RESCU packages offer subscriber services, it is specifically designed to offer service to only the motorist with the system. However, "Good Samaritan" signals and cellular telephone calls are possible if another vehicle needs emergency service.

The OnStar and RESCU packages receive no public funding to support their efforts. GM has admitted that it is unlikely to turn profits in its OnStar division for a few years (24). It is likely that the mayday packages will gain additional public acceptance over time. The purchase of more systems will increase the economies of scale making the technological equipment less costly. However, larger amounts of subscriber to either of the RESCU or OnStar systems will necessitate service operator expansion to adequately provide emergency and customer assistance.

The Colorado Mayday System, ENTERPRISE

Project Description

The Colorado Mayday System is an ITS field operational test, initiated in 1993, evaluating the use of a Mayday system to provide assistance to travelers. Phase I of the operation test consisted of conceptualizing and designing the mayday system. Phase II equipped 50 vehicles with the mayday system. The mayday operational test evaluated global positioning system (GPS) location technology, cellular phone data transmission, and two-way communications covering an area about 12,000 square miles in central Colorado (23).

The in-vehicle unit consists of a button box to provide the user a means to activate the system, a cellular data modem, and a cellular telephone. In the event of an emergency the user simply pushes the button to activate the system. A light emitting diode flashes to ensure the motorist that the system is responding. Once the system is activated, vehicle position is determined by TIDGET, a GPS receiver. TIDGET takes a snapshot of raw data from the GPS satellites within communication range of the vehicle. The receiver does not process the data at the vehicle, instead TIDGET converts the GPS satellite signals into digital data. The cellular data modem sends the data to the Colorado State Patrol (CSP) where a workstation processes the message and determines the location of the vehicle.

The workstation can present the dispatcher details on the location of the vehicle, the user, vehicle identification, and type of assistance requested. Once the data transmission is completed, the system converts into voice mode to allow the operator to communicate with the motorist. The Mayday system architecture is shown in Figure 7 (23).

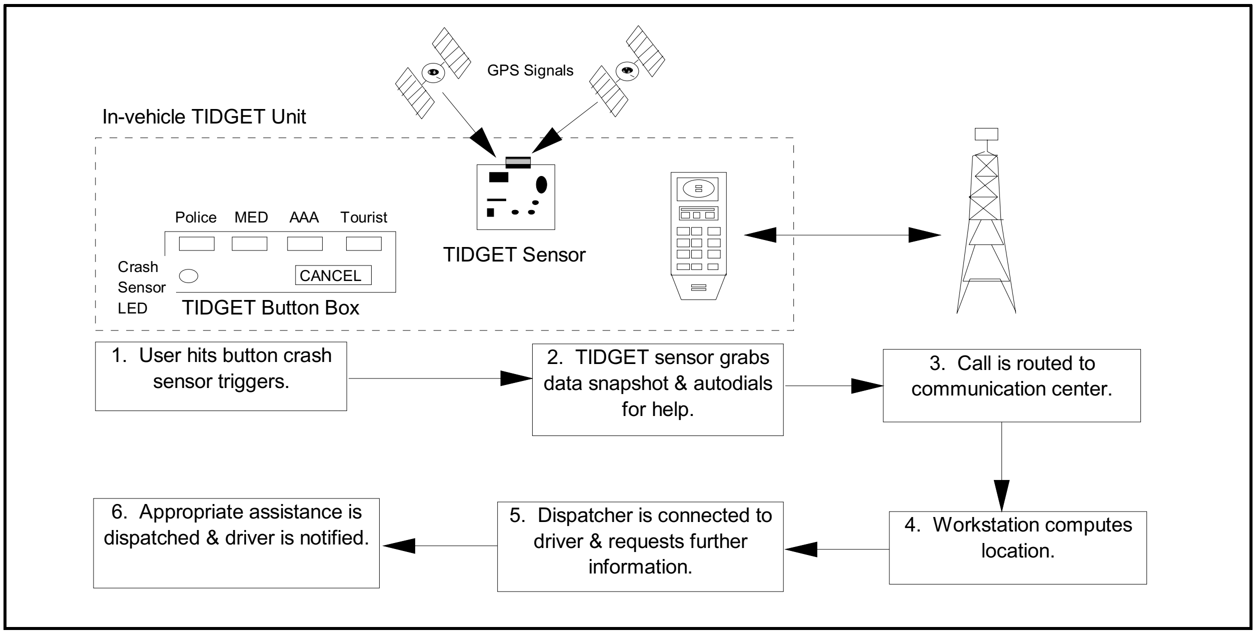


Figure 7. Mayday System Architecture (37).

Preliminary evaluations of the communications system reveal a system limitation, in that the reliability of the data code is based significantly upon the availability of a strong cellular signal. Of the 444 calls communicated, 388 (87 percent) calls communicated a valid position (23).

Institutional and Funding Arrangements

Unlike OnStar and RESCU, the Colorado Mayday Project is a federally funded operational test. ENTERPRISE initiated and heads the project. Other partners include the CSP, NAVSYS Corporation; AT&T Wireless; Commnet Cellular; and US West Cellular. The project is sponsored by a $2,400,000 federal grant, with $800,000 from private industry and other public matching requirements (23). The CSP is the primary response provider of the project.

Conclusions

While GPS receivers of the OnStar and RESCU systems convert GPS data to coordinates, the TIDGET device takes only a snapshot of GPS satellite signal data and transmits to the CSP. A workstation at the CSP processes the data to determine the location of the vehicle. The TIDGET GPS receiver costs considerably less (about one-third) than other GPS receivers because it does not determine the location of the vehicle but rather gathers only the raw GPS data.

Accuracy of mayday signals were directly dependent on cellular signal strength. Some communication transmissions are susceptible to weak signals or errors; therefore, the position of the vehicle could be invalid or not discernable. When cellular signal strengths are strong the vehicle's position is likely to be determined. Mass implementation of a mayday system in any state would likely cause a significant increase for labor requirements to dispatch and receive all mayday signals.

An advantage of the three mayday systems reviewed is that they are applicable in all areas with cellular coverage. The vehicle location capability can assist both urban and rural response agencies pinpoint locations of incidents and thus improve response times.

Call Box Program, California

Project Description

Call boxes have been used since Los Angeles County installed 30 phones on the Harbor Freeway in central Los Angeles in 1962. Currently, over 15,000 call boxes are in operation throughout California. Most are in use around densely populated regions, but a significant number of call boxes are in use in rural areas of California. In all, call boxes in California line more than 6,300 miles of highway in 26 counties. Call boxes are operational on Interstate highways, limited access state routes, rural non-limited access three- and four-lane state routes and rural two-lane state routes (29).

The call box system architecture is shown in Figure 8. The call boxes themselves are solar-powered with a rechargeable battery. A signal is sent from the call box to the nearest cellular site once the user lifts the receiver, the cell site relays the signal to a mobile switching office. Hard-wire telephone lines carry the signal from the mobile switching office to the central switching center where the cellular radio signals are converted into telephone signals and sent into the standard telephone network. The signals are then routed to the California Highway Patrol Dispatch Center through the public switched telephone network. At the Center, a computer sorts and routes incoming calls according to their priority status. Another computer records and stores information about the call including location, access route to call box site, and emergency services available in the area. The dispatch center then contacts the appropriate agency to respond to the incident (29).

Calls from call boxes are answered as priority-three by the California Highway Patrol (CHP). Mobile cellular calls (priority-one) and other law enforcement agencies (priority-two) are answered before call box calls because of the higher priority (29). Once the dispatcher answers the call box call, voice communication is possible between the user and the dispatcher to ascertain more information about the situation at the incident scene (29).

Although California provides call box spacing guidelines, an understanding that non-uniform spacing of call boxes may be appropriate in rural areas because of roadside configuration or other constraints. CalSAFE (California Service Authority for Freeways and Expressways) underscores its philosophy, "*... rural sites are selected to provide the best possible coverage under existing constraints. In the rural environment, other communications facilities are generally limited or not available, therefore even a non-standard-spaced system provides a benefit to the motorist*" (29).

Unlike urban call box spacing guidelines, which attempt to limit motorist vulnerability to heavy traffic flows, rural design guidelines attempt to provide a means to communicate where alternative communication facilities are not available. CalSAFE reports that on-average, rural call boxes receive three or four calls per month, per box, while urban call boxes are used slightly more with an average of 6 to 10 calls per month, per box (29).

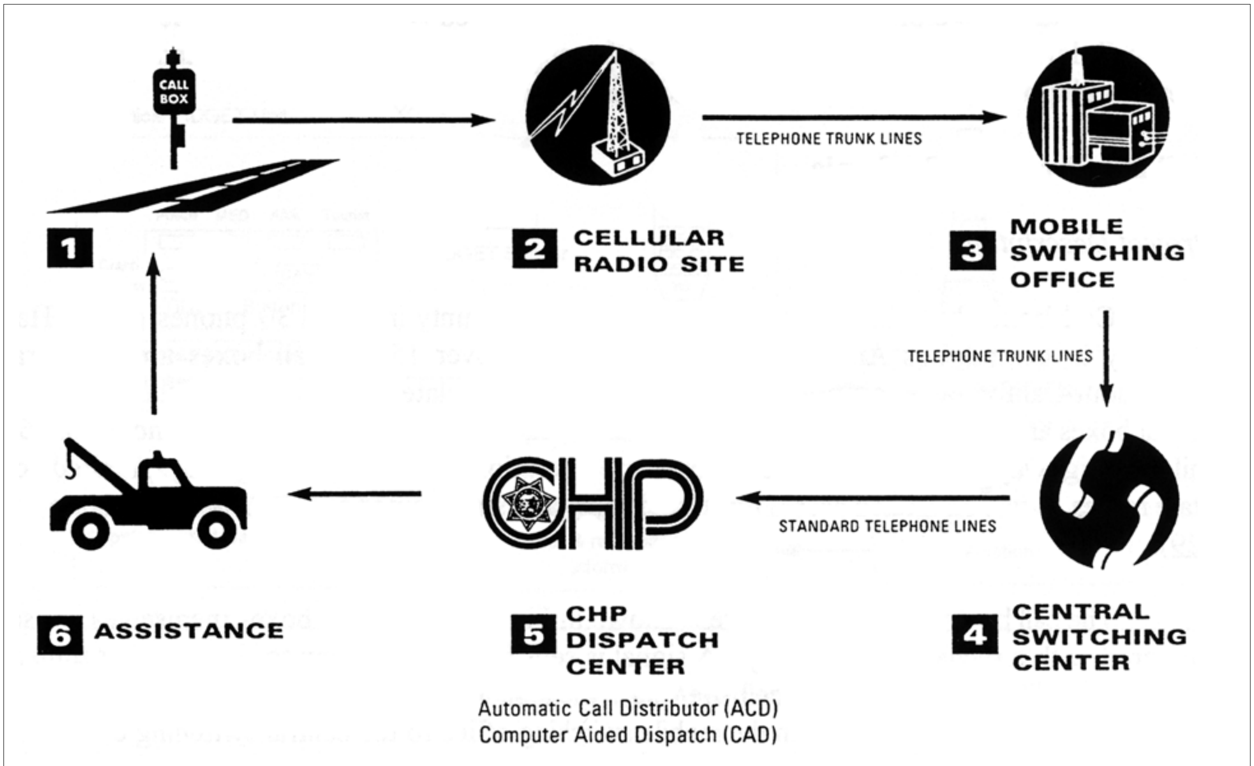


Figure 8. Call Box System Architecture (29).

Institutional and Funding Arrangements

Legislation passed in 1985 enables counties in California to form SAFE programs (Service Authority for Freeways and Expressways), once formed, SAFEs are usually governed by elected officials. A county-wide SAFE program may assess a $1 per vehicle annual registration fee to fund a call box program (29). These funds can also be used to finance other motorist-aid improvements.

Stakeholders in California's call box program are as follows (29):

- SAFEs - county-wide separate legal entities that are generally administered either by a county department of public works, council of government, or a metropolitan planning organization. These entities own and operate the call box system.
- California Highway Patrol (CHP) - The CHP answers all call box calls and dispatches

appropriate service to the motorists. SAFE agencies contract with CHP for answering calls, dispatching, and equipment agreements.

- California Department of Transportation (CALTRANS) - Provides installation guidance, permits, plan reviews, site selection support, and construction inspection.
- California Department of Motor Vehicles (DMV) - Assesses vehicle registration fees of $1 per vehicle, per year.
- California Safe Committee (CALSAFE) - Provides individual SAFE entities with a forum to share information and resources to further the success of the call box program.

Conclusions

Call boxes in rural areas provide a communications link where other alternatives are not available. Rural call boxes are used less frequently by motorists than urban ones, a result from lower traffic volumes using the rural roadways. Call boxes are able to provide the dispatcher with the exact location of the call box; thereby, improving the response times to the incident by assuming the incident is in close proximity to the call box.

With call boxes, motorists are able to describe incident characteristics which allows CHP officers to attend to other responsibilities because they may not be required at minor vehicle breakdowns if a private tow truck service has already been summoned to the incident scene. When CHP officers are not required at minor vehicle breakdowns, they can attend to other responsibilities. Many CHP man-hours are saved in this scenario because ninety percent of call box calls are for minor vehicle breakdowns, while only 10 percent require immediate and emergency response assistance at the incident scene.

The success the call box program in California has exceeded other successes in the U.S. Many agencies are discovering other incident detection measures, such as cellular call-in programs detect incidents quicker than call box programs. The call box program in California has maintained a uniform level of call box calls even during the rising use of cellular telephones. Several legislative acts have spurred California's call box success. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 encouraged the growth of call boxes as a development of ITS. Also, California legislation provided the necessary means for individual counties to form SAFEs and to collect a $1 fee for vehicle registration to fund the county program. California's cellular coverage is not comprehensive; therefore, call boxes are limited to areas that are covered by cell sites. California's long-standing use of call boxes has led to high motorist awareness of call box availability to inform the CHP of vehicle breakdowns and incidents.

Interstate 70 Rural Corridor - Eastern Colorado

Project Description

The I-70 corridor study was initiated to assist motorists having problems in the mountainous regions between Denver and Glenwood Springs and other primary state highways and U.S. routes adjacent and intersecting I-70. Interstate-70 is the heaviest traveled rural corridor in Colorado and is the setting for many trips to nearby ski resorts and other recreational areas. Two tunnels are located along the corridor and are the sites of regional traffic management centers (TMCs). The

TMC serve as statewide communication hubs for the Colorado DOT. Early deployment programs include: five variable message signs; six HAR stations; improvements to the communications system; detection devices and CCTV cameras at selected critical locations; courtesy patrols at selected critical locations; incident investigation sites; and call boxes at interchanges where there is currently no way to call for emergency help (38,39,40).

CCTV cameras were placed at the tunnel locations to monitor traffic conditions and are supported by a fiber optic communications system to relay video images to the TMC. Fiber optic communication systems are limited to the area surrounding the tunnels and the operation centers which are staffed 24-hours a day. A courtesy patrol was initiated to assist many vehicles that overheat along a short stretch of I-70 that is extremely mountainous and steep. The courtesy patrol is a single unit system that operates 24-hours a day (38).

Colorado is supported by a state-wide microwave communication system. Communications between DOT and other public agencies are supported by the microwave system (38).

Institutional and Funding Arrangements

The Colorado Department of Transportation is the sole developer of the I-70 Rural Corridor Project matching 10 percent to the federally funded 90 percent. Stakeholder meetings were held to identify needs of the corridor. A short of stakeholders follows: Colorado DOT (three regional DOT offices); Colorado State Patrol; local governments; corridor transit companies; ski and recreational organizations; local chamber of commerce; local residents; and the traveling public (40). The Colorado DOT divided the corridor into 25 specific areas to identify unique needs in each area (40).

Conclusions

Of the selected applications in this section, the I-70 Rural Corridor project is truly the only incident management program. In developing an incident management program across the entire I-70 corridor, the Colorado DOT has focused on "hot spots" with recurring incidents. However, the Colorado DOT has also implemented or plans to implement corridor-wide measures to improve incident response and efficiency in handling incidents. For example, it has been proposed to implement a corridor-wide call box program. Call boxes would be spaced closer together in problem areas, but the call box programs intended use is to establish two way communication with motorists where other communication alternatives are not available.

As discussed above, a diverse set of individual methods to improve incident management has been initiated in the I-70 rural corridor. Deployment of these activities has recently began and benefits associated with these methods have yet to be determined.

LESSONS LEARNED

Discussion in this section focuses on lessons learned and findings from reviewing literature and interviewing professionals regarding rural incident management and motorist aid systems.

The lessons learned from this research were:

- Although detection and verification technologies are best used together to offset deficiencies of each other, some means for detecting and verifying incidents in rural areas should be provided where there are no other means for detection or communication. The philosophy of providing at least some means of communication is especially crucial for: 1) problem areas with a history of frequent incidents; 2) high volume rural roadways; and 3) roadways with a high percentage of unfamiliar travelers.
- Current practices of transportation agencies suggest that call boxes are the method of choice to provide detection capabilities in rural areas where other methods are not available.
- State-of-the-practice techniques for evaluating incident detection methods and IMPs are better suited for urban areas. Usually, evaluations of detection methods or IMPs are based on delay savings to motorists (i.e. lessening impacts of incidents on a roadway reduces congestion caused by incidents and delay savings are provided to motorists). Overall, rural roadways typically have lower volumes, and it is unlikely to evaluate the true performance of an incident detection method or IMP by measuring delay savings provided to motorists. A recommended method to evaluate an incident detection method or IMP is to measure the improvement in emergency response times. Improving emergency response times will decrease the likelihood of a critical or fatal outcome.
- Limitations of state-of-the-art methods for detecting incidents make it difficult for an agency to monitor all rural roadways all the time. Rather than monitoring roadways, incident detection may be more efficient by monitoring by monitoring motorists.
- Congestion and bottlenecks are typically non-recurrent on rural roadways making rural incidents more random than urban roadways; therefore, rural incidents are more difficult to predict than urban incidents. The unpredictability of most rural incidents causes rural agencies to focus on problem areas. Problem areas are likely to be determined by using historical accident data or logging motorist complaints.
- Incident detection methods that are labor intensive (e.g. service patrols) and/or infrastructure intensive (e.g. wireline communication systems - CCTV) should target significant problems in rural areas to avoid expensive operating costs for little benefit.
- Mayday systems are yet to be tested with a large number of vehicles deployed. The selected applications of this report demonstrated mayday system deployment on only a small number of vehicles. Large deployment of mayday systems would likely uncover many additional issues. Although growth of the economies of scale would reduce technological costs of mayday systems, service costs would increase. Until service issues are resolved, it is unlikely for mayday systems to be federally mandated. Federal mandate of mayday systems may also uncover additional issues such as: motorist equity; public/private arrangements; service arrangements; cellular coverage limitations; and cost recovery issues.

- Current applications of mayday systems do not test the true commercial market. The mayday systems highlighted in the previous section include additional features which add cost to the overall package. An increase in consumer interest is likely if additional components are removed from the packages to reduce the relatively high cost.
- Although only deployed on a small number of vehicles, mayday systems offer the most efficient and secure means for motorists to notify an appropriate agency of an incident. The motorist is able to remain in the vehicle and is not relied on to describe the incident location. Until advances in cellular technology are made to reduce the cost of pinpointing cellular caller location, GPS location devices are needed to determine vehicle location.

BARRIERS TO IMPLEMENTATION

A discussion of the major barriers to implementing incident management measures in rural areas is discussed in this section. Barriers associated with institutional arrangements, communication systems, rural environment, and funding are discussed.

Organizational / Institutional Structure

Organizational and institutional problems are not unique to rural areas; they are also common in urban areas. Widespread applications of advanced technologies in rural areas will likely include public/public and public/private relationships.

Each of the selected applications highlighted in this research report overcame organizational barriers to implement successful programs. Overcoming a lack of agreement between agencies and partners is unique in every situation because each agency has a unique set of policies and agendas. Some organization structures require informal agreements, written contracts, or even formal legislation in order to form an understanding between parties. Stakeholder meetings during the development of the system to air agencies policy and agenda will bring all interested parties closer to understanding each other and overcoming organizational or institutional problems.

Communication Infrastructure

Many communication technologies currently exist and continue to develop. Continued development of technologies will likely serve rural areas more comprehensively in the future. Currently, communication infrastructure is sporadic in rural areas simply because it is not cost effective to implement certain communication technologies where the number of potential users is relatively small. Other communication trends are noted:

- Communication systems requiring wireline connections will remain extremely limited in rural areas because the significant costs associated with installing and maintaining the communication infrastructure usually does not offset subscriber service fees.
- Some wireless communication methods such as LMR, HF radio, and broadcast radio, are very affordable but have coverage limitations (i.e. radio waves can only propagate so far). Coverage limitations are the main barrier to these wireless communication methods to provide comprehensive coverage in rural areas.
- Other wireless communication technologies such as cellular, PCS, and satellite communications are limited by infrastructure and user interface costs. As these technologies advance and their economies of scale grow, costs should lower making use of these communication technologies more widespread in rural areas.
- Satellite communications are easier to use in rural areas than urban areas because communication does not require terrestrial infrastructure. Currently, user interfaces and communication permission fees to satellite providers bar widespread use of satellite communications in rural areas.

Distance / Space / Remoteness

Long distances make implementation of incident management or motorist aid systems more difficult. Response times to incidents are longer in rural areas when compared to urban areas because response teams usually have to travel greater distances to arrive at an incident scene. Large distances between rural residences, service stations, and emergency response teams may make motorists walk farther to find communication means.

Lower residential density does not allow for profitable communication implementation by the private communication industry because the potential for paying subscribers is low. Fierce competition in the communication industry requires companies to maximize profitability. Profitability is not as likely in rural areas because the potential for paying customers is lower.

Limited Funding Capacities

In many cases, implementing the best idea or technology is not feasible because of cost-ineffectiveness. Cost issues are especially magnified in rural areas where traffic volumes are lower and incidents are less frequent.

OVERCOMING BARRIERS TO IMPLEMENTATION

Outlined in this section are ways to overcome the barriers associated with implementing a rural incident management or motorist aid system. The benefit of outlining a method to overcome barriers is that it helps public officials, such as county, regional, state, or federal transportation and governmental officials develop an understanding of the procedures necessary to implement a successful incident management or motorist aid system. The method outlined below focuses on important issues rural agencies need to address when developing rural incident management or motorist aid systems.

Step 1: Assess Needs

Determining a need for an incident management or motorist aid system is accomplished by identifying problems. Possible problems include: high frequency of critical and non-critical incidents; occasional congestion caused by incidents; motorist perception of frequent incidents; and unavailable service options for stranded motorists. It should also be determined if an IMP has the potential to mitigate the problems identified.

Step 2: Prioritize Needs

Unvariably, prioritizing needs are politically motivated or involve personal bias. However, objective analysis of needs should be conducted to prioritize rural areas with the greatest need. Suggested priorities of an agency may include: safety of motorists; serving trade industry; serving recreational and tourism activity; serving mobility; or serving remote areas with unavailable communication.

Step 3: Define Team and Program Goals

In order to achieve a successful program, the goals and objectives must be clearly defined. The goals of the program will undoubtably reflect individual goals of stakeholders; therefore, all stakeholders should be identified so that goals of the program reflect the best interest of those agencies affected. Once goals are defined other tasks involved in the program are based on the process to achieve the stated goals and objectives. It is important to form well balanced goals and objectives that reflect interests of individual stakeholders as well as overall system goals that meld with the surrounding transportation system. A policy should be implemented to encourage communication and information exchange between stakeholders to help all stakeholders identify commonalities and differences that exist. Objectives of the system will reflect, not only the characteristics of the stakeholders, but also the characteristics of the transportation system and surrounding community. Possible goals can resemble those stated for the I-70 West Corridor in Colorado (40):

- Improve safety;
- Reduce congestion;
  - Decrease disruptions due to weather/road conditions;
  - Encourage alternative mode usage;

- Disseminate traveler information;
    - Traveler peace of mind;
    - Good driver decision;
- Overcome institutional barriers; and
- Build a constituency.

Step 4: Determine Necessary Communication System

As discussed previously, a communication system is the back-bone of an incident management or motorist aid system. The selection of alternative communication systems depends on the needs of the users and the coverage of the IMP. The applicability of communication systems in rural areas were provided in Table 2. Communication systems should provide comprehensive coverage throughout the coverage area of the IMP. Agencies should also be able to communicate with other agencies efficiently. In some cases, a facility may be needed to serve as a central point for all communications. A central point for communication may improve the efficiency of disseminating important information to all stakeholders.

Step 5: Focus Incident Management Measures on Problem Areas

Incident management measures should focus on the problems identified in Step 1, "Assess Needs." It is likely that the program will not have funding to provide labor or infrastructure intensive incident detection methods comprehensively; but rather, would focus on problem areas within the system. Focusing on areas with the greatest problems offers a better chance for success which could then offer future expansion to include other areas within the system.

Step 6: Evaluate the System

Evaluation of the program should be continuous and focus on the ability to provide better service to motorists in need of emergency assistance. Successes should be documented to provide ideas for similar success. Failures should also be documented and analyzed to eliminate the potential for repeating a similar failure.

APPLYING RESEARCH FINDINGS

The following is a discussion of the research findings applied to a hypothetical situation. The hypothetical situation presented below utilizes:

- The applicability of communication systems outlined in Table 2 of this report;
- The applicability of incident detection and verification methods outlined in Table 4 of this report;
- Lessons learned from reviewing state-of-the-art systems which are discussed in the "Lessons Learned" section of this report; and
- The method outlined in the previous section, "Overcoming Barriers."

The author does not intend to endorse any of the communication or detection methods used in this hypothetical situation. The intent of the discussion in this section is to provide advice for transportation professionals when making difficult decisions associated with developing an IMP in a rural area.

Step 1: Assess Needs

By analyzing state-wide incident data and logs of motorist complaints, the Anystate Department of Transportation (AnyDOT) has determined that three rural regions consistently report higher incident frequency and motorist complaints than similar rural areas. Preliminary analysis shows that all three regions would benefit by implementing an incident management or motorist aid system. The AnyDOT will have to choose a single region due to funding constraints.

Step 2: Prioritize Needs

In order to choose the region with the most critical need, AnyDOT has created a table to directly compare attributes of each region. The comparison of region attributes is shown in Table 5. Attributes selected for comparison were listed in order of importance and were selected based on the overall objective of AnyDOT which is to provide the best service to the motoring public in Anystate.

Although it appears that Region A has the greatest need for an IMP, AnyDOT knows that the ranking of most attributes for each site was subjective. The subjectiveness of the attribute ranking also makes the selection of the site with the highest priority debatable. AnyDOT selects Region A as the area with the most and potential for success. In this case, the selection of Region A was made easier because of political and public concern due to a recent fatality and hazardous material spill. The selection of the highest priority site was a difficult decision and officials for Region B and Region C were disappointed. However, AnyDOT does plan to implement an IMP at Region B and Region C in future years based on the performance of an IMP in Region A.

Table 5. Relative Comparison of Regional Attributes (Hypothetical Example).

Attribute	Region A	Region B	Region C
Motorist Safety	Low	Medium	Medium
Incident Frequency	High	High	High
Tourism Activity	High	Medium	Low
Commercial Activity	High	Low	High
Mobility Needs	Medium	Low	High
Motorist Complaints	High	Medium	Low
Traffic Volumes	High	Low	Medium
Congestion	Medium	Low	High
Relative Priority	*High*	*Low*	*Medium*

A map of Region A is shown in Figure 9. Several main features of Region A are noted. The Interstate 1 corridor is about 300 miles from Big City A to Bigger City B. Interstate 1 connects Big City A and Bigger City B which are the biggest cities in Anystate. Interstate 1 supports the large amount of commercial trade between Big City A and Bigger City B. Interstate 1 between Big City A and Bigger City B is mainly rural with the exception of Little Town. Two major routes intersect Interstate 1: U.S. Highway 76 and State Highway 51. Many tourists and recreational travelers are attracted to Region A, especially to areas near Tourist Trap and Lake Fish.

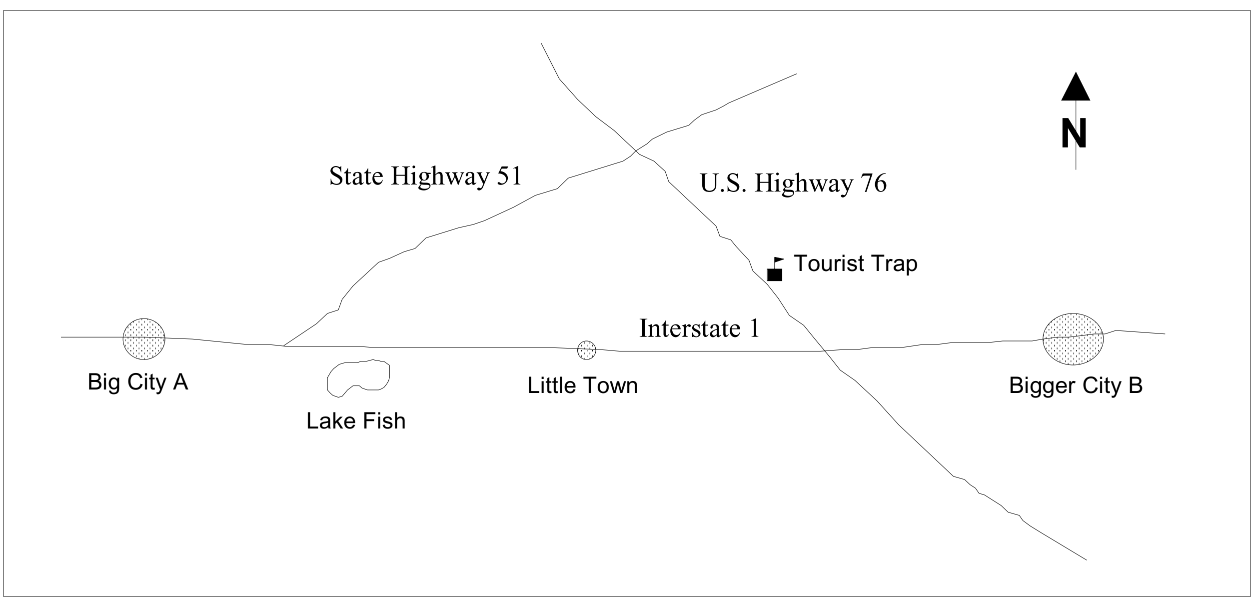


Figure 9. Site Map of Region A, Anystate (Hypothetical Example).

Step 3: Define Team and Program Objectives

AnyDOT decided that the main objective of the IMP is to provide quicker and more efficient incident responses to motorists needing service in Region A. In order to identify problems areas and other objectives for the IMP, the AnyDOT invited officials from Region A to participate in a stakeholders meeting. At the stakeholders meeting, each of the individual stakeholders were asked to voice their concerns and identify specific problems within Region A. The AnyDOT invited officials from the following agencies:

- The Anystate Highway Patrol;
- County governments in Region A;
- Local governments in Region A (including Big City A, Bigger City B, and Little Town);
- Lake Fish;
- Tourist Trap;
- Chambers of Commerce in Region A (including Big City A, Bigger City B, and Little Town);
- Emergency service providers in Region A (from Big City A, Bigger City B, and Little Town);
- Towing service providers in Region A (from Big City A, Bigger City B, and Little Town);
- Motoring public of Region A

After the stakeholders meeting, the AnyDOT developed a final list of program objectives to reflect concerns voiced during the stakeholders meeting:

- Provide quicker and more efficient incident responses to motorists needing medical and service assistance;
- Improve safety for motorists traveling in Region A;

Perhaps more importantly, several specific problems were identified within Region A. The AnyDOT decided that early actions of the IMP should focus on the problems raised during the stakeholders meeting:

- There are too many vehicle breakdowns near Lake Fish causing secondary accidents;
- It currently takes too long for incident response around Tourist Trap;
- The remoteness (no service stations and few residences) of the area around the U.S. Highway 76 intersection with State Highway 51 makes notifying the Anystate Highway Patrol and emergency service providers difficult;
- Major incidents along Interstate 1 cause traffic back-ups making motorists frustrated; and
- The only towing service provider in Little Town is sometimes unable to respond immediately causing vehicle breakdowns to remain on roadways for extended periods of time.

Step 4: Provide Necessary Communication System

The stakeholders agreed to upgrade their communication systems to make communication at an incident scene more efficient. The stakeholders choice of communication was the 800 MHz specialized mobile radio. The upgrade in communications will allow all agencies to correspond with each other at incident scenes and also provides complete coverage in Region A (radio repeaters are located throughout the Region allowing communication from a mobile unit back to base units from anywhere in the region). Originally, it was proposed that all stakeholders upgrade to cellular communication. Big City A, Bigger City B, Interstate 1, and U.S. 76 have cellular coverage, but much of State Highway 51 is not covered by cellular. Cellular was ruled out because it did not provide comprehensive coverage.

Step 5: Focus Incident Management Measures on Problem Areas

The incident detection measures implemented by AnyDOT focused on the problems raised during the stakeholders meeting.

Problem: There are too many vehicle breakdowns near Lake Fish causing secondary accidents.

- The AnyDOT implemented a service patrol on Interstate 1 between its intersection with State Highway 51 and Lake Fish. The service patrol consists of a two unit crew and will operate only during daylight hours. Incident logs show that most incidents occur during daylight hours. The AnyDOT will provide the labor and vehicles to support the service patrol. The service patrol is able to handle most vehicle breakdowns without assistance from the Anystate Highway Patrol.

Problem: It currently takes too long for incident response around Tourist Trap.

- Call boxes were installed along Interstate 1 and U.S. Highway 76. Call boxes were spaced every mile along these roadways except near Tourist Trap where call boxes were spaced every one-half mile. Call box communication is two-way and utilizes cellular technology to transmit signals back to the regional PSAP. Motorists using call boxes will be able to communicate characteristics of the incident scene and allow the operator to dispatch a better response.
- Emergency service providers in Little Town moved their facility closer to major highway access; thereby, providing quicker response to rural highway incidents.

Problem: The remoteness (no service stations and few residences) of the area around the U.S. Highway 76 intersection with State Highway 51 makes notifying the Anystate Highway Patrol and emergency service providers difficult.

- Call boxes are spaced every one-half mile near the U.S. Highway 76 intersection with State Highway 51. Call boxes will provide a means to detect incidents where other means are not available.

Problem: Major incidents along Interstate 1 cause traffic back-ups making motorists frustrated.

- Highway advisory radio transmitters and variable message signs were implemented on Interstate 1 in advance of its interchanges with State Highway 51 and U.S. Highway 76. Information provided by HAR and VMSs will allow motorists to divert to an alternative route during a major incident.

Problem: The only towing service provider in Little Town is sometimes unable to respond immediately causing vehicle breakdowns to remain on roadways for extended periods of time.

- Towing agreements were made with towing providers in Little Town, Big City A, and Bigger City B. The agreements stipulate that towing providers must be able to remove a vehicle within six hours of being notified by the Anystate Highway Patrol or have its turn in rotation skipped.

Step 6: Evaluate

An evaluation of the system shows that incident response times have dropped for many incidents. The AnyDOT analyzed the response times of incidents in Region A to compare "before" (response times before IMP) and "after" (response times after IMP) the IMP.

Table 6. Average Estimated Time Elapsed between Incident Occurrence and Response.

Roadway	**Before (minutes)**	**After (minutes)**
Interstate 1	16.5	15.0
U.S. Highway 76	22.5	21.0
State Highway 51	32.0	31.5
Area	**Before (minutes)**	**After (minutes)**
Lake Fish	22.0	15.0
Tourist Trap	28.0	20.0
Intersection of U.S. Highway 76 and State Highway 51	45.5	35.5

The analysis in Table 6 shows that response times were significantly reduced in areas where the IMP focused. The roadways in Region A showed slight improvements in response times, but were the improvements were not as significant as those at the problem areas (i.e. Lake Fish, Tourist Trap, and Intersection of U.S. Highway 76 and State Highway 51).

Summary

The hypothetical example presented in this section demonstrated some of the difficult decisions an agency must make to implement a successful rural IMP. The method outlined in this report provides a logical step-by-step process to aid agencies make good decisions.

Although only minor improvements were realized across the region, major improvements for incident response times were noticed. Realistically, agencies are faced with far more complex issues than were presented in this hypothetical example. The main objective of this hypothetical example was to show the importance of focusing attention towards problem areas rather than attempting to improve an entire region.

CONCLUSIONS

The unique characteristics of rural areas affect the applicability of incident management and motorist aid systems. The main barriers that affect implementation of these systems are: institutional or organizational problems; unavailable communication; large distances; and limited funding. Agencies that focus incident management measures on problem areas, rather than attempt to provide universal coverage, are likely to be more successful in improving the efficiency of an incident management or motorist aid system and overcoming these barriers. The method presented in this paper has demonstrated the ability to overcome barriers and provide improvements to the motoring public. Although the method was presented hypothetically to a somewhat simple situation, the basic principles underlying the method should help transportation agencies develop and sustain incident management and motorist aid systems in rural areas.

ACKNOWLEDGMENTS

This paper was prepared for *Advanced Surface Transportation Systems*, a graduate course in Civil Engineering at Texas A&M University. I would like to express my gratitude to Dr. Conrad Dudek, the course instructor. Dr. Dudek's dedication to this course provided a challenging and rewarding experience. I would like to especially thank Mr. Joseph M. McDermott, my professional mentor, for his assistance, guidance, and insight in preparing this report. Special thanks also go to: Marsha D. Anderson, Ginger Gherardi, Thomas Hicks, Colin Rayman, and H. Douglass Robertson, the professional mentors, for their expertise and guidance. The opportunity to interact with Dr. Dudek and the professional mentors was both challenging and enlightening. Ms. Sandra Schoeneman deserves special recognition for assisting Dr. Dudek put together both the symposiums and this compendium. Sincere thanks are given to Cindy Broesch for reviewing my paper, but especially for her unselfish sacrifices which have allowed me to pursue my academic goals.

Finally, thanks go to the following professionals who provided me direction and information that contributed to this paper:

- Steven J. Cyra, HNTB Corporation
- Gerald Ullman, Texas Transportation Institute
- Joni L. Brookes, Colorado Department of Transportation
- Ed Chrumka, General Motors Corporation
- Wendi Parson, Ford Motor Company

REFERENCES

1. Judycki, D. C., and J. R. Robinson. Managing Traffic during Nonrecurring Congestion, *ITE Journal*, Volume 62, Number 3, March 1992.

2. *Advanced Rural Transportation Systems Rural Research Agenda*. Draft, Advanced Rural Transportation Systems Committee, ITS America, Internet Web Site, http://www.itsa.org/members/comm/art2.html.

3. *Webster's Ninth New Collegiate Dictionary*. Merriam-Webster Inc., Publishers, Springfield, 1988.

4. *Advanced Rural Transportation Systems (Rural ITS) Strategic Plan*. U.S. Department of Transportation, Washington, D.C., December 1996.

5. *Metropolitan Statistical Areas (as defined by the Office of Management and Budget in 1983), Supplementary Report*. U.S. Bureau of the Census, U.S. Department of Commerce, Washington, D.C., December 1984.

6. *Statistical Abstract of the United States: 1994*. U.S. Bureau of the Census, U.S. Department of Commerce, Washington, D.C., 1995.

7. *Survey of Rural Information Infrastructure Technologies*. National Telecommunications and Information Administrations Special Publication 95-33, U.S. Department of Commerce, Washington, D.C., September 1995.

8. *Rural and Farm Population by Current (1980) and Previous (1970) Farm Definitions, for States and Counties: 1980*. U.S. Bureau of the Census, U.S. Department of Commerce, Washington, D.C., April 1985.

9. *Rural Applications of Advanced Traveler Information Systems (ATIS), State of the Art Technology Report*. JHK & Associates, Prepared for the Federal Highway Administration, Norcross, January 1994.

10. Wallace, C. E., and A. K. Kilpatrick. IVHS Applications for Rural Highways and Small Towns. In *The Proceedings of the 1993 Annual Meeting of IVHS America*, IVHS America, Washington, D. C., April 1993.

11. Zarean, M., R. Sivanandan, and D. Warren. Rural ATIS: Assessment of User Needs and Technologies. In *The Proceedings of the 1994 Annual Meeting of IVHS America*, IVHS America, Washington, D.C., April 1994.

12. Sivanandan, R., M. Sobolewski, J. Kiljan, and D. Warren. An Assessment of Rural Traveler Needs for ITS Applications. In *The Proceedings of the 1995 Annual Meeting of ITS America*, ITS America, Washington, D.C., March 1995.

13. *Fatal Accident Reporting System - A review of Fatal Crashes in the United States*. National Highway Traffic Safety Administration, Washington, D.C., 1990.

14. Cullison, J. T., and M. A. Ogden. *Freeway Incident Management Handbook Update.* Working Draft, Texas Transportation Institute, Houston, January 1997.

15. Arnold, J. A. Rural versus Urban: A Communication Infrastructure Perspective. In *The Proceedings of the 1996 Annual Meeting of ITS America*, ITS America, Washington, D.C., April 1996.

16. James, R. D., and A. Hannan. Summary of Position Location Technologies for Mayday and Other ITS Applications. In *The Proceedings of the 1997 Annual Meeting of ITS America*, ITS America, Washington D.C., June 1997.

17. Christenson, R. C. Evaluation of Cellular Call-In Programs for Incident Detection and Verification. In *Graduate Student Papers on Advanced Surface Transportation Systems*, Southwest Region University Transportation Center, College Station, August 1995.

18. Reiss, R. A., and W. M. Dunn, Jr. *Freeway Incident Management Handbook*. Report No. FHWA-SA-91-056, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., July 1991.

19. Urbanek, G. L., and J. M. Bruggemean. *Alternative Surveillance Concepts and Methods for Freeway Incident Management - Volume 3: Computational Example for Selecting Low-Cost Alternatives*. Report No. FHWA-RD-77-60, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., March 1978.

20. Balke, K. N., and G. L. Ullman. *Method for Selecting Among Alternative Incident Detection Strategies*. Research Report 1232-12, Texas Transportation Institute, College Station, August 1992.

21. *OnStar*. General Motors Corporation, Internet Web Site, http://www.dimmitt.com/onstar.html.

22. *RESCU Package*. 1997 Lincoln Continental, Ford Motor Company, Internet Web Site, http://www.lincolnvehicles.com/Continental/rescu.html.

23. Deeter, D., N. Lacey, and L. Smith. Exploring the Potential Benefits of a Mayday System: Phase One Results. In *The Proceedings of the 1996 Annual Meeting of ITS America*, ITS America, Washington, D.C., April 1996.

24. Samuel, P. ITS Gets Personal with GM's OnStar. *ITS International*, Issue Number 7, November 1996.

25. *Texas Motorist Aid System Implementation Plan*. Report to the Advisory Commission on State Emergency Communications, Draft, Comarco Wireless Technologies, Irvine, March 1997.

26. Mateja, J. RESCU (Ford) vs. OnStar (GM): How Safety Systems Compare. *Chicago Tribune*, Automotive News, Chicago, May 1996.

27. Author Unknown. Cellular Industry Tests Effectiveness and Cost of Location Technology. *Inside ITS*, Volume 7, Number 12, June 1997.

28. Nee, J., J. Carson, and B. Legg. *An Evaluation of Motorist Aid Call Boxes in Washington*. Washington State Transportation Center, Seattle, June 1996.

29. *State of the Call Box Program, A Report on the First 10 Years of California's Service Authority for Freeways and Expressways (SAFE) Program*. California Service Authority for Freeways and Expressways Committee (CalSAFE), Sacramento, May 1996.

30. Balke, K. N. *An Evaluation of Existing Incident Detection Algorithms*. Report No. FHWA/TX-93/1232-20, Texas Transportation Institute, College Station, November 1993.

31. Kelly, A. B. The Use of Electronic Toll and Traffic Management Systems for Freeway Incident Detection. In *Compendium: Graduate Student Papers on Advanced Surface Transportation Systems*, Southwest Region University Transportation Center, College Station, August 1996.

32. *Cadillac Journey of Innovation - New in 1997, OnStar*. General Motors Corporation, Cadillac, Internet Web Site, http://www.cadillac.com/cgi-bin/nonprod.pl?innovate/newin97+onstar.

33. Chrumka, Ed. Telephone interview, General Motors Corporation, Troy, August 1997.

34. *New Cellular Platform Featured in GM's OnStar*. Press Release, Hughes Network Systems, Internet Web Site, http://www.hns.com/News/Archive/onstarpr.htm.

35. *Lincoln RESU: Personal Security at the Touch of a Button*. Press Release, Ford Motor Company, Public Affairs, Dearborn, Undated.

36. Parson, Wendi. Telephone interview, Ford Motor Company, Dearborn, July 1997.

37. Cameron, M., A. Brown, J. Siviter, and J. Kiljan. A Mayday System for Rural Highway Travel. In *The Proceedings of the 1995 Annual Meeting of ITS America*, ITS America, Washington, D.C., March 1995.

38. Brookes, Joni. Telephone interview, Colorado Department of Transportation, Lakewood, July 1997.

39. *Early Action Projects Executive Summary*. I-70 Rural IVHS, Corridor Planning and Feasibility Analysis, by De Leuw, Cather & Company for the Colorado Department of Transportation, Denver, October 1995.

40. Corridor Master Plan. I-70 Rural IVHS, Corridor Planning and Feasibility Analysis, by De Leuw, Cather & Company for the Colorado Department of Transportation, Denver, April 1996.

Marc W. Hustad received his B.S. degree in Civil Engineering from University of Wisconsin-Milwaukee in December 1995. As an undergraduate, Marc was employed by HNTB, Corporation for three terms. During the summer of 1995, Marc participated in the Undergraduate Transportation Engineering Fellows Program at Texas A&M University. Mr. Hustad continued to work at HNTB as a transportation engineer between January to August 1996. Marc is currently pursuing his M.S. degree in Civil Engineering at Texas A&M University and is employed by the Texas Transportation Institute. University activities include active participation in the Texas A&M Institute of Transportation Engineering Student Chapter. Marc's professional interests include: traffic operations; geometric design; human factors; and traffic impact analysis.

AN INVESTIGATION OF TRAFFIC SIGNAL PREEMPTION AT RAILROAD-HIGHWAY GRADE CROSSINGS

by

Marc S. Jacobson

Professional Mentor
Joseph M. McDermott, P. E.
Illinois Department of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph. D., P. E.

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

August 1997

SUMMARY

Collisions at railroad-highway grade crossings are often deadly due to the large difference in both size and speed of the vehicles involved. While train-vehicle accident rates have been on the decline, the potential for accidents at railroad crossings has been increasing as a result of higher train and automobile volumes. Thus, new methods to enhance the safety of railroad-highway grade crossings are constantly being sought.

Traffic signals that are located near railroad-highway grade crossings are designed to permit vehicles that may be stopped on the tracks to move to safety when a train approaches the crossing. In most cases, the warning time that is provided to the traffic signal system is as little as 20 seconds before the train arrives at the crossing. Often this short duration of this warning time can cause crossings to operate in a more unsafe and inefficient manner. This report provides a detailed investigation of current methods of traffic signal preemption and the problems that are encountered. Those technologies that have been applied in the area of light-rail transit signal priority that have the potential to be adapted to increasing the available warning time are identified. This report concludes by providing a new strategy to improve the safety and efficiency of signal preemption at railroad-highway grade crossings.

The issues surrounding signal preemption were obtained through a review of the available literature on the topic. Representatives from both highway agencies and railroad agencies were interviewed via telephone to assess the current signal preemption practices that are used. In addition, manufacturers of detection technologies that are currently used for transit priority systems were interviewed to determine which systems could best be adapted to the railroad-highway grade crossing environment.

The examination of the literature and the results of the telephone interviews indicated that a detection device that utilizes a GPS receiver and a two-way radio could best be adapted to provide increased warning time to the traffic signal controllers that a train was approaching the crossing. With the additional warning time that would be provided using the new technology, the traffic signal controller could use the Transitional Preemption Strategy that was developed in this research to help improve the safety and operational efficiency of the crossing environment.

TABLE OF CONTENTS

INTRODUCTION

Where the paths of any two vehicles meet, it is desired to minimize the number of collisions occurring when one vehicle fails to yield to the other. At railroad-highway grade crossings, the results of such a collision is often deadly due to the large difference in both size and speed of the vehicles involved. While accident rates have been on the decline, the potential for accidents at grade crossings has been increasing as a result of higher train and automobile volumes. Thus, new methods to enhance the safety of railroad-highway grade crossings are constantly being sought.

Signalized highway intersections located near railroad-highway grade crossings create a potential safety problem. When adequate storage space is not available, the queue of vehicles waiting at the traffic signal may extend over the railroad tracks. One study that examined accidents at railroad-highway grade crossings with active warning devices (such as lights and gates), revealed that at least 20 percent of the accidents involved motorists that were stopped on the tracks (1). Highway intersections located within 23 m (75 ft) were found to contribute to these accidents. Since trains approaching a crossing would most likely be unable to stop in time to avoid colliding with a vehicle stopped on the crossing, it is necessary to clear vehicles from the tracks before the train arrives. For this reason, traffic signals located near railroad-highway grade crossings are interconnected with the active warning devices and are programmed to preempt their regular timing sequence and present a green signal to motorists on the intersection approach that crosses the tracks to allow them to move out of danger as a train approaches (2).

If the preemption of the traffic signals should malfunction in anyway, a disaster could result if a vehicle fails to move off of the tracks before the train arrives. Such a tragedy occurred in the community of Fox River Grove, Illinois, on the morning of October 25, 1995 (3). The green signal to clear vehicles from the tracks was not displayed in sufficient time for the arrival of an express commuter train. As a result, a school bus that had stopped at the signal with its back end over the tracks was struck by the fast moving train. Seven high school students were killed in the collision.

As the accident at Fox River Grove indicated, the current systems that are in place to "alert" the traffic signal controller to the presence of an approaching train may not always provide adequate time to preempt the existing timing and clear the tracks while maintaining a reasonable safety buffer before the arrival of a train. Even when enough time is provided to clear motorists from the tracks, the abrupt interruption of the traffic signal's normal sequence can lead to motorist confusion and inefficient operation on the street that does not cross the tracks and increase the danger to pedestrians. Train warning systems that are used today are mainly based on logic and technology that was developed more than one hundred years ago (4). Thus, newer methods of alerting the traffic controller at an earlier time are desired to improve crossing safety and efficiency. Some intelligent transportation system technologies that have been used for other purposes, such as light-rail transit signal priority, may help in the search for a solution to this problem.

Many of the problems associated with interconnected railroad and highway traffic signals arise from poor communication channels between the two industries involved in operating the crossing. For this reason, efforts to improve the safety and efficiency of these interconnected crossings have been very slow to get started. The sluggishness of research efforts in this area is reflected by the small amount of literature that was found pertaining specifically to the preemption of traffic signals at railroad-highway grade crossings. Thus, one goal of this paper is to present in one location a discussion of many of the issues that must be considered by both the highway and railroad industries when tackling the problems with interconnected traffic signals.

Objectives

The objectives of this study were as follows:

1. Identify the issues surrounding the preemption of traffic signals at railroad-highway grade crossings.
2. Identify any systems in place that provide increased preemption notification to the traffic signals and the implications of earlier preemption.
3. Identify those technologies and strategies that are being applied to light-rail transit and bus preemption that could potentially improve safety at railroad-highway grade crossings.
4. Develop a strategy that uses an adapted technology to improve the safety and operational efficiency of the crossing and provide a theoretical case study to compare the warning time and clearance capabilities of the existing preemption system with the proposed system.

Scope

This paper presents a detailed discussion of the issues that warrant and govern the use of signal preemption at railroad-highway grade crossings. The feasibility of other priority and preemption systems that have been used for other transportation purposes, such as transit priority, were investigated. These investigations were limited to that basic case of an isolated, single-track crossing that carries freight trains. An example crossing is presented to compare the existing preemption system to that proposed by this research.

Study Approach

The work plan consisted of the tasks necessary for completing the objectives of this research. These tasks and descriptions are provided below:

Literature Review

A literature review was conducted to identify the current state-of-the-practice for traffic signal preemption at railroad-highway grade crossings. Those unique issues that pertain to controlling this multi modal intersection are presented. The review also investigated technologies that are currently being used in other areas of the transportation system that have the potential to increase safety at the railroad-highway grade crossing. Several transportation journal publications, technical reports, and conference proceedings were utilized in this literature review.

Surveys of Transportation Personnel

Transportation professionals were surveyed on local practices at signalized railroad-highway grade crossings and were asked to identify any new technologies that are being investigated to increase crossing safety. These surveys targeted a diverse group of people with knowledge and experience with traffic signal preemption and were designed to provide the information that was not found in the literature that was reviewed. Those persons that were contacted can be classified into the following categories:

- Department of Transportation professionals involved with highway design, traffic signal design, and preemption operations;
- Railroad professionals with knowledge of train detection and active warning devices; and,
- Signal preemption system manufacturers.

Report Organization

This report is divided into nine sections. This section contains the objectives and study approach of the report. A discussion of train detection and active warning devices used at many railroad-highway grade crossings is presented in the next section. Section 3 is an investigation of the current preemption practices used for traffic signals near railroad crossings.

The fourth section of the report contains a discussion of several of the problems and issues associated with current preemption issues. The review of the literature is concluded in the fifth chapter which discusses various LRT signal priority detection systems that are available.

The results of the telephone interviews are presented in Section 6. Section 7 consists of a discussion of those technologies that have been presented which are most suitable to be adapted for use at railroad-highway grade crossings. Section 8 included a strategy to improve the preemption of traffic signals at railroad-highway grade crossings. This strategy was developed after reviewing the results of the literature study and the telephone interviews. The paper concludes with some recommendations for implementing the information in this report.

TRAIN DETECTION AND ACTIVE WARNING DEVICES

The first step in initiating preemption at a railroad-highway grade crossing is to detect an approaching train. The direction of the train, the speed of the train, and the train's estimated arrival time at the crossing are all desirable parameters to be detected. Once a train is detected on the approach to a crossing, a signal is sent to the traffic signal controller to initiate the preemption sequence. At the same time, the warning devices at the crossing are activated to alert motorists to the presence of the on-coming train. This section consists of a description of the commonly used train detection systems and warning devices found at railroad-highway grade crossings.

Train Detectors

The basic train detection systems that are currently in place use technology that was initially developed over 100 years ago (4). A relay contact, or switch, is maintained in the "off" position within the warning device controller by providing a steady voltage across the track rails. The voltage that is supplied is either direct current (DC), for conventional systems, or alternating current (AC), for motion-detection systems. As a train passes on the rails upstream of the crossing, its steel wheels cause a change in the voltage and the switch releases to the "on" position which activates the warning device and, in the case of preemption, alerts the traffic signal controller (2).

In both conventional systems and motion-detection systems a backup power supply is present to monitor the warning devices in the case of a power failure. If any type of power interruption were to occur, the voltage across the rails would drop and the warning system would be activated. Hence, the detectors operate in a fail-safe mode meaning that the warning devices would activate and remain on in case of a system failure. The differences between the two types of detection systems are presented in the following paragraphs.

Conventional Systems

Conventional train detection systems divide the track into three zones in the vicinity of the crossing. These three circuits, an approach zone on either side of the crossing with an island zone in the middle of the crossing, have insulated joints between them to create an isolated circuit in each zone. The separate zones are used to allow the circuitry to determine the direction of the train and to activate and deactivate the warning devices (2). The approach zones on either side of the crossing must be of sufficient length so that the highest speed train that uses the crossing would activate the warning devices at least 20 seconds before arriving at the crossing. This can lead to approach circuits that are over 915 m (3000 ft) long (5). The major disadvantage of this type of system is that the warning time that is provided varies with the speed of the train. Thus slower trains will arrive at the crossing much later after the warning devices have been activated than faster trains causing some motorists to lose respect for the warning device (2).

Motion-Detection Systems

The motion-detection systems use an alternating current voltage across the two running rails and do not require the insulated joints that are needed in the conventional systems. The impedance (or resistance) of the track circuit is measured after the front axle wheels of the train have shunted the circuit. This impedance value is then used determine the train's position relative to the crossing and its approach speed. Basic motion-detection systems activate the warning devices as soon as a train traveling at sufficient speed is detected. So called "constant warning time" systems use the train's position and the assumption that the train's speed will remain constant to predict the arrival time of the train at the crossing. This estimated arrival time is used to activate the warning devices at a "constant" set time before the arrival of a train, regardless of the speed of the train (2). In many cases the warning time setting is programmed for the 20 second minimum required by the MUTCD.

Active Warning Devices

In order for the preemption of traffic signals at railroad crossings to currently take place, the detection equipment that is installed with active warning devices needs to be provided so that trains can be detected. The two most common types of active warning devices are alternating flashing lights and automatic gates with flashing lights. Since this research is mainly focused on the operation of highway traffic signals near railroad crossings and not the active warning devices at the crossings, only a brief discussion of these devices is presented.

The red alternating flashing lights that are used today were first used in 1920. They replaced and are supposed to duplicate the "wig wag," which imitated a watchman waving a lantern at the crossing (5). Unlike other traffic control devices, the normal state of these lights is to be blank or display no indication. The lamps that are used in the devices are relatively low wattage so they can be battery powered in case of a power failure.

At many crossings, automatic gates supplement the flashing lights to prevent access across the tracks when a train is present or nearing a crossing. As with the train detection systems, these systems are designed to be "fail-safe." This means that if power should be lost to the system, the electric locks that hold the gates up would release and the gates would drop under the force of gravity (5). At most crossings these gates are provided only on the near side of the highway approach to the crossing. This arrangement does not prevent vehicles from driving around the lowered gates to gain access across the tracks. Since crossing in this manner is very dangerous and may lead to a train-vehicle collision, a four-quadrant gate system has been developed to minimize the ability to drive around the gates. This system uses gates on both the near and far sides of the crossing. The gate on the far side has a lowering delay to prevent vehicles from being trapped on the tracks between the lowered gates.

PREEMPTION OF TRAFFIC SIGNALS

Before designing a preemption plan for a signalized intersection, it is necessary to first determine if preemption is required at the particular intersection. If preemption is necessary, a well planned preemption sequence must be designed so that the traffic signal can clear the tracks in the shortest amount of time. The preemption capabilities of the traffic signal controller used in the field is important consideration in the preemption of traffic signals at railroad-highway grade crossings. All of these items, along with some other important issues that must be considered, is presented in this section.

When is Preemption Required?

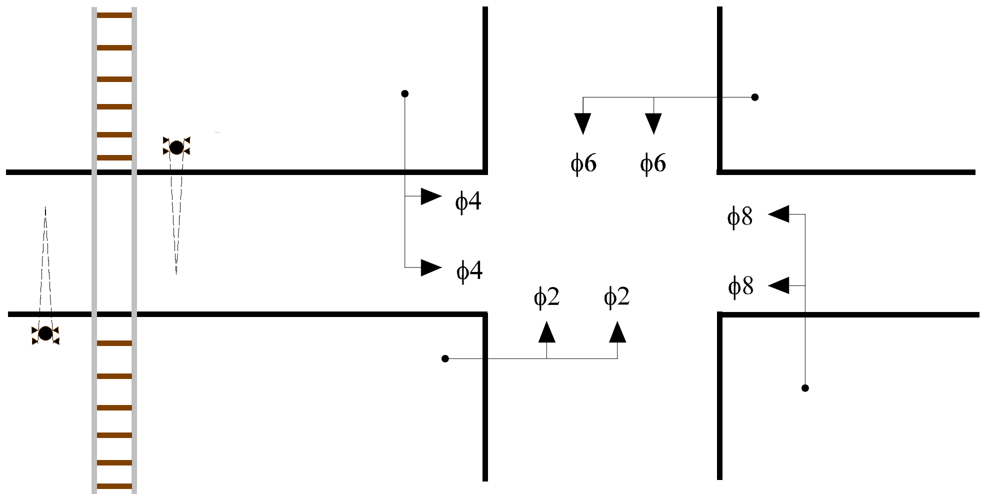
Any time an approach to a signalized intersection crosses a railroad track, it is necessary to analyze the signalized intersection to determine if preemption is required at the intersection. The *Manual of Uniform Traffic Control Devices* suggests that highway traffic signals and the railroad warning devices be interconnected when the signalized intersection is located within 60 m (200 ft) of a railroad-highway grade crossing (6). However, the traffic volumes and geometry of the intersection may cause vehicles to queue over the railroad crossing even if this crossing is located more than 60 m (200 ft) from the intersection.

In order to help determine if preemption is required, Marshall and Berg (6) have developed a computational process to determine the expected maximum queue length for the intersection approach that extends over the tracks. The process uses a Poisson distributed arrival rate based on traffic volume, cycle length, and performance level, to determine the maximum queue length. If the maximum queue length calculated exceeds the available storage length between the tracks and the stop bar at the intersection, preemption must be used. Thus, preemption may be required at intersections that are more than 60 m (200 ft) from the crossing.

Preemption of traffic signals may also be required if a downstream railroad-highway grade crossing causes vehicles blocked by a train to queue into the upstream highway intersection (2). In this situation, it is necessary to preempt the operation of the upstream signal to maintain an adequate level-of-service for those vehicles that are not attempting to travel down the route that is blocked by the train.

Preemption Sequence

There are two basic components to the preemption sequence used at signalized intersections near railroad-highway grade crossings. The first component involves providing a green signal to those vehicles that may be stopped across the tracks so that they can move out of danger. Once the tracks have been cleared, the next preemption component either prevents the signal controller from displaying green indications to those movements that conflict with the train or sets the controller to flash red for all phases. Any non-conflicting movements may be provided with green indications while the train is approaching or occupying the crossing (7).



LEGEND

Signal Face

Railroad Warning Device

Signal Preemption Sequence

When the preemption sequence is initiated, the right-of-way transfer interval begins, as shown

Signal Phase	Right-of-Way Change Intervals				Clear Track Intervals		Preemption Hold Interval	Exit Phase to Normal Operation
	ϕ 2 and ϕ 6		ϕ 4 and ϕ 8					
	Train	CL	Train	CL	Green	Clear		
ϕ 2	G	Y	R	R	R	R	G	
ϕ 6	G	Y	R	R	R	R	G	
ϕ 4	R	R	G	Y	R	R	R	
ϕ 8	R	R	G	G	G	Y	R	

Notes: 'Train' indicates phase status when train is detected.
'CL' is the clearance interval before the track clearance phase begins.
G, Y, and R indicate GREEN, YELLOW, and RED ball signal displays, respectively.

Figure 1. Basic railroad-highway grade crossing layout with nearby signalized intersection.
The basic preemption sequence is shown for the two-phase signal that is depicted. (Adapted from 2).

in Figure 1 for a two-phase signal. During this interval, every phase that is currently green, except for phases used to clear the tracks, should be terminated in the shortest possible time with a proper change interval (2). In order to shorten the time required to transfer the right-of-way, the following approved options are available to the traffic engineer:

1. Any pedestrian clearance intervals (flashing "DON'T WALK") in effect at the time of preemption may be shortened and;

2. If the track clearing phase is yellow when preemption is initiated the phase may go straight back to green without displaying a red indication.

The total time required to clear all phases conflicting with phase for vehicles over the tracks is evaluated for every possible phase combination that could be active at the time the preemption call is received. The preemption sequence must be designed to accommodate the longest right-of-way transfer interval found in these evaluations.

Once the conflicting phases have been terminated, the phase used to clear the tracks should display a green indication, if it is not currently green. The length of this clearance interval is determined by the geometry of the crossing and the traffic characteristics (6). This time interval includes the time required for the last vehicle not on the tracks to move forward and the time needed for vehicles stopped on the tracks to move to safe position.

Thus the minimum warning time required to initiate preemption is the sum of the maximum right-of-way transfer time, the required clearance interval time, and any needed safety buffer time. Without the safety buffer, the calculations assume that the last vehicle stopped on the tracks would clear out of danger just as the train arrives. Marshall and Berg have recommended (6) that this safety buffer be between four and eight seconds, although longer times may be required in certain circumstances. The Institute of Transportation Engineers (2) states that if the calculated minimum warning time exceeds the warning time provided by the railroad train detection equipment, advance preemption should be considered. Advance preemption involves initiating the preemption sequence before the railroad warning devices activate.

Preemption Capabilities of Signal Controllers

When designing a preemption plan for an intersection, it is important to understand the capabilities of the traffic signal controller when a preemption call is received. Some controllers, such as those that strictly follow the NEMA TS-1 standard, do not include preemption capabilities built directly into the controller. In these instances, an external preemption device is used to control the intersection when a train is detected. Other controllers have the ability to handle multiple preemption inputs. If a controller of this type is used, it is necessary to set the input for the railroad preemption at a higher priority than other forms of preemption, such as emergency vehicle preemption or transit vehicle preemption/priority (2).

Upon receiving the call from the train detection equipment, most controllers will immediately enter into preemption. However, some controllers will allow a delay to be specified before preemption is initiated (7). If this delay were to be unknowingly set, a potential for disaster would result. Some controllers will allow minimum green times and pedestrian WALK intervals to be shortened for conflicting phases when the preemption signal is received; however, on many controllers these intervals can not be shortened and will be retained in their entirety even after preemption is initiated.

After the track clearance interval has completed, the preemption sequence next proceeds to the hold interval. During this interval some controllers will allow cycling between all of the different phases that do not conflict with the passage of the train. The remaining controllers will remain in a single, specified phase while the train is passing. Many controllers also allow a minimum duration for the hold period to be set. This setting would avoid the display of unusually short green indications if a train should enter and then quickly leave the detection circuit.

Important Issues to Consider

On the surface, the issue of traffic signal preemption seems relatively simple: a train is detected, the currently active phases (except the track clearance phase) are terminated, and the tracks are allowed to clear. However, a basic railroad-highway grade crossing near a signalized intersection, such as the one shown in Figure 1, can become complicated very quickly. The design of the preemption sequence at each intersection is unique and is determined by the geometry of both the highway and the railroad near the crossing.

One of the most important issues to consider is the fact that the preemption routine must be designed to be initiated at any point during the normal timing plan of the signalized intersection and must always safely accommodate the longest expected right-of-way clearance interval. As the number of phases increases at the signalized intersection, the number of possible preemption entry points that must be checked increases dramatically. For simultaneous preemption, when the preemption is initiated at the same time as the active warning device, the difference in time required to clear the tracks will influence the available buffer time between the time the last queued vehicle is cleared and the time the train arrives at the crossing. If the signal is already in the phase for track clearance, a very large buffer time will exist at the conclusion of the track clearance interval since no phases have to be cleared before the tracks are cleared. On the other hand, if the preemption is initiated immediately after the start of a conflicting phase, the extra clearance times will reduce the buffer time.

Next, the case where there are two tracks at the crossing is considered. In this case, the immediate impact of the preemption plan is that the time required to clear the tracks is increased since the "danger area" is expanded by the width of the extra tracks. Moreover, the addition of the second track makes it possible that a second preempt call will be received from a train traveling in one direction immediately after exiting from a first preemption call caused by a train going in the opposite direction. If adequate warning is not available, this situation would lead to a series of very short green indications because the controller will exit from and then reenter preempted operation.

To this point the discussion has focused on a railroad that is parallel with one of the highways of the nearby signalized intersection such that only one approach to this intersection crosses the tracks. Often times, however, the railroad is located at such an angle that it crosses two or more approaches. As the example in Figure 2 shows, this configuration requires that not one, but two approaches receive the green signal to clear vehicles from the tracks. This signal can only be provided to one movement at a time, however, since they are conflicting movements in the intersection area. Moreover, the critical approach, the approach that must be cleared first, can depend on the travel direction of the train. For example, if the train were coming from the north, A Street should be cleared first; trains from the south, on the other hand, would require the clearing of B Street first. However, while most controllers are capable of clearing two separate approaches when preempted, many cannot alter the order in which the approaches are cleared (7). Once again this means that the worst case would have to control the design and a much longer warning time will be required which could result in gate violations.

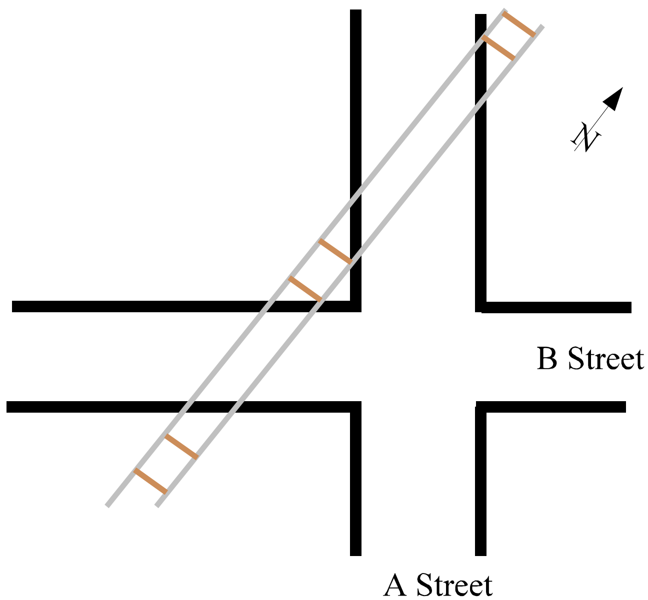


Figure 2. A signalized intersection that requires two track clearance phases due to the crossing geometry.

In summary, the following items must be considered when designing the preemption system and calculating the required warning time (2):

- Long required clearance times,
- Intersection and crossing geometry,
- Vehicle characteristics (such as acceleration rates),
- Approach speed of trains; and,
- Warning time variability due to the train detection equipment.

The last two items deserve special attention and will be discussed in the next section of this report.

PROBLEMS WITH CURRENT PREEMPTION METHODS

As the previous section indicated, there are several factors that can influence the preemption routine that is used at a signalized intersection located near a railroad-highway grade crossing. In most of the cases that were presented, the solution to the problem is an increase in the available warning time that is provided as a train nears the crossing. The guidelines that currently specify the required minimum warning time is presented in this section. The constant warning time train detector devices are also discussed with an emphasis on the effect of changes in train speed on the operation of these devices. The effects of the current preemption methods on the approaches that conflict with the approach that extends across the tracks are also addressed.

Warning Time Guidelines

All actively controlled railroad-highway grade crossings must provide the minimum warning time to motorists as specified by the *Manual on Uniform Traffic Control Devices* (MUTCD) and the American Association of Railroads. The MUTCD states that the active warning devices (and thus, signal preemption) must be activated a minimum of 20 seconds before the arrival of the train at the crossing. This minimum is applied to all crossings without regard to vehicle characteristics, train speed, number of tracks, or existence of an interconnected traffic signal.

As mentioned previously, the MUTCD also specifies that traffic signals at intersections within 60 m (200 ft) of a railroad-highway grade crossing should be interconnected with the railroad warning equipment. However, if the method presented by Marshall and Berg (6) is used to calculate the warning time required to clear a 60 m (200 ft) queue, the warning time is found to be 25.6 seconds. This calculation has assumed a recommended eight second safety buffer, single-unit truck design vehicle, and a saturation flow rate of 1500 vph. The results of this calculation would indicate that a conflict exist between the spacing and warning time guidelines presented in the MUTCD since crossings that are withing both guidelines could still result in inefficient warning times.

The *Signal Manual* published by the American Association of Railroads (AAR) also specifies that the warning time provided should not be less than 20 seconds (9). However, in addition to this minimum warning time, three other time intervals are suggested to increase the warning time. The first interval is the clearance time which specifies that an additional one second be added to the warning time for each 3 meters (10 feet) that the required clearance distance exceeds 11 meters (35 feet). An adjustment time can then be added to provide additional time for equipment response, such as the lowering of gates at the crossing. Finally, a safety buffer may be provided to increase the amount of time between the activation of the warning devices and the passage of the train.

While the AAR guidelines offer some improvements over those specified by the MUTCD, they still do not specifically address the additional time that may be needed by an interconnected signal that may be required. This necessary additional time results from the long clearance intervals or multiple clearance phase requirements discussed in the previous section. Thus, it is clear that neither of these minimum guidelines may result in adequate warning time to initiate preemption and clear vehicles from the tracks (2).

Constant Warning Time Devices

As mentioned previously, two basic types of train detection systems are commonly used. The conventional system uses detection circuits that activate the warning devices as soon as a train enters the circuit. With this system, the devices will be active longer before the arrival of a slower train since that train will occupy the track circuit longer. A fast train on the other hand, will occupy travel through the detection circuit at a faster rate and thus arrive in a shorter time after the warning devices have activated. Thus the length of the detection circuit is such that the minimum (or set) warning time is provided when the fastest expected train nears the crossing. All other trains will provide warning times that are longer than this set warning time.

The lack of consistency in warning times that results from the conventional system has been shown to contribute to some undesirable driver behavior (10). As a driver becomes accustomed to the warning devices being active long before the arrival of the (slow) train, he is more likely to drive around the lowered gates or past the flashing lights to avoid extra delay to his trip. However, since a faster train will produce a shorter warning time, the impatient driver may find himself stuck on the tracks as the train arrives. The desire to prevent accidents caused by disregard for the variable warning times led to the development of the motion-detection systems.

As stated previously, the motion-detection systems that wait to activate the warning devices based on the train's predicted arrival time at the crossing are called "constant warning time" systems. As their name implies, these systems are designed to provide more consistent warning times no matter how fast the train is approaching the crossing. A study by Richards et. al. found that the use of constant warning devices reduced the mean warning time from 75 seconds to 42 seconds (11). The study also found that the constant warning time devices helped to reduce the number of vehicles that were crossing within 20 seconds of the trains arrival at the crossing, indicating an increase respect for the consistent operation of the warning device.

The results from the Richards study would indicate that constant warning devices could be used at crossings to increase the safety. However, one problem with so-called constant warning time devices is that they are not constant and have the potential to produce warning times that are actually less than their design time or even the specified minimum. This occurs when a train accelerates after entering a detection circuit because the detection equipment will base the predicted arrival time at the crossing on the train's speed as it entered the circuit. The accelerating train would arrive at the crossing before it was predicted, hence the warning time provided would be less than that which was set (2). This problem would not occur with the conventional system so long as the train did not accelerate above the design speed for the circuit.

In summary, it is clear that their are advantages to using constant warning time systems at railroad-highway grade crossing to provide more consistent warning times. However, since certain train speeds and track conditions may cause these systems to produce warning times that are shorter than expected, they can create problems with traffic signal preemption plans that require almost all of the available warning time for clearance intervals. For this reason, a balance is needed between warning times for consistent warning device operation and those required by traffic signal preemption.

Effects on Other Highway Approaches

While the preemption sequence is designed to clear queued vehicles off the tracks as quickly as possible, it does not make any attempt to perform this function in the most efficient manner for the intersection as a whole. The vehicular and pedestrian phases that conflict with the track clearing phase suffer as a result of the current method of abruptly preempting the intersection. Several of the problems experienced by these conflicting phases can be summarized as follows:

- Since the preemption sequence may shorten (or eliminate) pedestrian clearance intervals in the effort to clear the tracks as quickly as possible (2), pedestrians that are in the middle of crossing the intersection may find themselves in the path of the clearing vehicles. This violates the expectancy of the pedestrians since they are used to having an adequate amount of time to cross the street if they begin their crossing maneuver on the "WALK" indication.
- Interconnected signals that are part of a coordinated system can disrupt the coordination between the signals. This could result in platoons of vehicles having to needlessly stop while the track clearance phase is serviced even if there are no vehicles stopped on the tracks. It may take as many as five cycles after the train has passed before the intersection can once again be properly coordinated with the other intersections. Of course, by the time the signal is re-coordinated, another train may be arriving at the crossing.
- Even if the intersection is not coordinated, the sudden onset of preemption can result is very short green displays for the conflicting phases. These short greens can lead to poor operation along the affected street and may cause rear-end collisions since drivers are not expecting signals to turn red right after they have first turned green.

LRT SIGNAL PRIORITY SYSTEMS

While the literature suggests that not much attention has been focused on the operation of interconnected signals at railroad-highway grade crossings, several efforts have been made to improve the coordination of highway traffic signals with public transit. These efforts, known as transit signal priority routines, adjust the traffic signal timing f possible so that the transit vehicle, either bus or light rail, will receive a green signal as they approach the intersection. These priority systems may allow the transit vehicles to maintain their schedules in the attempt to attract more users. Since light-rail transit (LRT) vehicles more closely parallel the environment that is encountered at railroad-highway grade crossings, the following discussion focuses on systems designed to give priority to this type of transit vehicle.

This section presents some of the differences between LRT Signal Priority systems and signal preemption systems at railroad-highway grade crossings. Several detection systems that are currently being used or are available for light-rail transit are also presented.

Differences Between LRT Priority and Signal Preemption

Before discussing the various systems that are available for LRT Signal Priority, it is important to note the differences between these systems and those required for the preemption of traffic signals at railroad-highway grade crossings. The first difference is the objectives of each system. While transit priority systems are designed to provided green indications to the transit vehicle (and any non-conflicting vehicular movements) as it approaches the crossing, preemption systems are designed to provide a green signal to the traffic stream that crosses the track (12).

Second, the priority phasing routines will only be enacted if they will not detrimentally effect the overall efficiency of the intersection. If the transit vehicle is not going to receive the priority, the LRT driver is alerted and the vehicle is brought to a stop at the crossing. Also, LRT vehicles that are running ahead of schedule may choose not to activate the priority system at the intersection so they do not arrive early to the next stop. Preemption systems on the other hand must activate when any train arrives and must assume that none of the trains would be able to stop in time to avoid colliding with a vehicle that is stopped on the tracks.

For these reasons it is clear that the algorithms that are used to provide LRT Priority at intersections could not directly be applied at railroad-highway grade crossings for the purposes of initiating preemption. However, with slight modifications, many of the available detection systems could be used to provide increased warning time and eliminate many of the problems associated with preemption that were presented in the previous section.

Sonic Detectors

Several of the transit priority systems that are available use a sonic waveform detector to alert the traffic signal controller to the transit vehicle's presence. These systems were first developed to identify the siren from an emergency vehicle to provide that vehicle with a green signal as it approached the intersection (13). These systems are modified for LRT vehicles so that a silent emitter is installed in each vehicle to emit sonic waves that can be detected by the receiver located at the intersection. Once a vehicle is detected, a "preemption" signal is sent to the traffic signal controller to provide the vehicle with a green signal. The emitters can be disabled by the driver of the vehicle if priority is not needed or desired at an intersection.

Since LRT vehicles, as well as trains, can approach an intersection from either direction and in several environmental conditions it is important that these vehicles can be appropriately detected. The manufacturers of these sonic detection systems claim that these systems can properly identify the approach direction of the vehicle (14). The systems also claim to be unaffected by wind, fog, rain, snow, lightning, or other adverse weather. Since the sonic waves can travel around objects that are in their path, the sonic detection systems are not affected by "line of sight" interruption between the transit vehicle and the intersection receiver.

There are also some systems that are under development that use the train whistle as the method of activation. Train operators are required to sound the train's whistle as they approach a crossing. As the whistle is blown, it creates a discernable sound wave pattern that can be detected by a track-side device (15). These receivers can be placed farther away from the crossing to increase the warning time that is provided. However, the maximum warning time that can be provided is dictated by how close to the crossing the train whistle is blown. These devices are currently being marketed for railroad grade crossings that are not near any electrical power source to provide some warning to motorists of an oncoming train.

AVI / RF Devices

Automatic Vehicle Identification (AVI) technology has been used successfully in several applications including electronic toll collection. These systems utilize a transmitter device or identification tag in the vehicle that contains identifying information about that vehicle (16). A radio frequency (RF) antenna is used to send a signal to the on-board equipment that it should transmit it's identifying information. A roadside reader is then used to detect the information that is being transmitted by the vehicle. This information is then sent to an interface module which determines if a priority signal should be sent to the traffic signal controller and, if so, the appropriate signal is sent.

GPS / Two-Way Radio

Some of the most sophisticated detection systems available utilize satellites orbiting the earth to help to detect the approaching vehicles. A global positioning system (GPS) unit is installed on each transit vehicle. This device is used to determine the vehicle's position on the tracks, direction of travel, and vehicle speed at any point along the approach to the crossing (17). A two-way radio is used to communicate with the GPS unit on the vehicle and transmit differential corrections to the vehicle. The differential corrections are used to account for any errors that the military has embedded in the code transmitted by the satellites (18).

Since the system will always "know" the location of the vehicle along with the vehicle's speed, it is possible for the system to estimate the train's arrival time at the crossing. This can provide up to two or three minutes in advanced warning to the traffic signal controller to prepare for the preemption of the traffic signal. Also, since the arrival prediction changes each second based on the newly calculated train speed, train acceleration or deceleration on the approach to a crossing are taken into account and the warning time provided will not decrease (18).

Loop Detectors

Conventional inductive loop detectors that have been used to detect vehicles approaching signalized intersections have also been applied to LRT Priority systems. Several tests have revealed that burying these detectors under the track ballast have led to a decrease in the effectiveness of the detector. For this reason, a loop detector that can be mounted directly on the tracks was developed (19). Systems of three to four detectors are often used to detect an approaching train an activate the priority system at the intersection. While these detectors do offer an alternative over the conventional track circuitry, they have many of the same limitations.

TELEPHONE INTERVIEW RESULTS

In order to gain a better understanding of practices around the country with regards to preemption of traffic signals near railroad-highway grade crossings, telephone interviews were conducted with transportation professionals. Three types of agencies were contacted: highway officials in charge of the traffic signal systems, railroad personnel responsible for the railroad circuitry, and developers of new technologies being applied in the field of LRT Signal Priority with the potential to be applied for signal preemption.

A summary of the questions that were asked during each interview along with a summary of the responses are presented in the following discussion. The number of questions asked during each interview was kept to a minimum so as not to take up too much time of the professionals. However, the questions were phrased in such a manner to encourage each respondent to elaborate on certain answers or provide additional information more pertinent to his or her particular area. These additional responses are also summarized below.

Interviews with Highway Officials

Department of Transportation or local government officials were contacted to gain further insight into the perspective of the operators of the traffic signals. Those contacted were members of the Technical Working Group on Rail-Highway Intersections that was formed by the U. S. Secretary of Transportation. The following two agencies were contacted:

- City of College Station Public Works Department
- South Carolina Department of Transportation

Six questions were asked of those contacted at these agencies. Table 1 lists these questions and summarizes their responses. In addition to responding to the questions that were asked, those interviewed provided some additional comments.

In one situation all of the signals that were interconnected to the railroad warning devices were also part of a coordinated system designed to provide progression to vehicles along the street parallel to the tracks. The respondent in charge of these signals indicated the progression timings are disrupted with each passage of a train and up to five cycles are required before progression is reestablished.

The other agency that was interviewed was concerned that by providing separate train detection devices for the traffic signals, all of the liability for that aspect of crossing safety would be placed in the agency in charge of the traffic signals. Under existing detection methods, the liability is shared between the highway authority and the railroad agency.

Table 1. Interview Responses from Highway Officials (20, 21).

Question	Summary of Responses
1. How many interconnected signals are in your jurisdiction?	The number of interconnected signals varied from 4 to 85.
2. On average, how much warning time is currently provided to the traffic signal controller before the train arrives at the crossing?	The warning times reported varied from 25 to 45 seconds.
3. Does the warning time that is provided always allow adequate time to clear the tracks with an appropriate safety buffer before the train arrives?	One respondent indicated enough warning time was provided while the other indicated that adequate warning time was not always provided.
4. Are constant warning time devices used at some of the interconnected crossings?	Both agencies indicated constant warning time devices were used.
5. Have there been times where these constant warning time devices did not provide the minimum time that they were designed to provide?	Neither agency has studied to see if the warning times varied below the minimum.
6. How difficult is it to have the warning time increased if the preemption sequence requires a longer time for safety reasons?	One agency indicated that it can take up to six months to have let the contract and move the track circuitry in order to change the times.
7. Have you studied other methods besides using the standard train detection equipment to provide increase warning time to the traffic signal controller?	One agency has experimented with video detection techniques and the other is planning to study various detection technologies in the coming year.

Interviews with Railroad Personnel

Two agencies affiliated with the railroad industry were also contacted to obtain their perspective on the issue of preemption of interconnected traffic signals. The railroad agencies that were contacted were:

- Association of American Railroads
- Illinois Central Railroad

The personnel contacted at these agencies were asked four questions. These questions and answers are summarized in Table 2. In addition to responding to the questions that were asked, the respondents provided some additional comments.

Again liability was a chief concern of those railroad agencies that were interviewed. One of the respondents pointed out that off-track detection methods are not currently approved by the Federal Railroad Administration. For this reason, several railroad companies are not bothering to study other detection technologies. However, this respondent also indicated that since these devices could improve safety at the crossing, the industry should encourage the research and development of such technologies.

Table 2. Interview Responses from the Railroad Industry (22, 23).

Questions	Summary of Responses
1. On average, how much warning time is currently provided to the traffic signal controller before the train arrives?	Both agencies said that an average warning time is hard to calculate due to the large number of crossings. However, both pointed out that the warning time is never less than 20 seconds.
2. Does the warning time that is provided always allow adequate time to clear the tracks with an appropriate safety buffer?	Both agencies said adequate time was always provided.
3. What is required to increase the warning time that is provided to the traffic signal system?	In some cases the warning time may be increased by turning a dial on the detection equipment. However, where the track circuit is not long enough to provide the required warning time, the circuit has to be replaced at a cost between $500 and $100,000 depending on how far the circuit must be extended. This cost is often paid by the Departments of Transportation.
4. Have you studied other methods besides using the standard train detection equipment to provide increase warning time to the traffic signal controller?	One agency reported that research into using the train's horn for detection is under way. Also the use of electromagnetic fields and global positioning systems are being investigated.

Interviews with Manufacturers of Detection Technology

Four companies that manufacturer train detection devices were contacted. Most of the devices are still under development and are marketed to transit agencies to be used to provide LRT transit priority at signalized intersections. The agencies that were contacted were:

- Emergency Preemption Systems
- Midwest Traffic Products, Inc.
- Smart Stops Unlimited Corp.
- Sonic Systems Corp.

Each respondent was asked a total of three questions. These questions and a summary of the responses are shown in Table 3.

Table 3. Interview Responses from Technology Manufacturers (24, 25, 26, 27).

Questions	Summary of Responses
1. Has this device ever been used to provide advance warning of a train's arrival at a railroad-highway grade crossing?	Two of the devices have been tested at crossings. The other two devices are still being adapted for use in the rail environment. These devices were initially designed for use on busses and emergency vehicles.
2. For those devices that have been implemented in the field, are there any specific problems that were encountered during development that needed to be corrected?	One manufacturer is working on improving the isolation of radio-waves that are emitted by the train from other devices that may falsely activate the system. Another manufacturer noted that one problem was trying to get railroad authorities to implement the systems in the field due to liability concerns.
3. For those devices not yet implemented, what modifications are required to adapt the device to the rail environment?	Some devices must be adapted to distinguish the front of the train from the rear of the train in order to accurately predict arrival times. This is primarily due to the fact that locomotives can be pushing or pulling a train.

ADAPTABLE TECHNOLOGIES

The key component to increasing the warning time available to the traffic signal controller during a preemption event is the ability to estimate the arrival time of a train. The previous two sections presented some of the technologies that are being used to facilitate light-rail transit signal priority. This section investigates which of these technologies hold the most promise for being adapted to the task of providing improved preemption at railroad-highway grade crossings.

GPS / Two-Way Radio

The detection system that uses the global positioning satellite along with two-way radio communications for differential corrections has a lot of potential for being adapted to provide increased preemption warning time. This system can accurately track the train's position to within 5 m (16 ft) and update the estimated crossing arrival time as often as every second (17). Systems of this type are under development by both Midwest Traffic Products (17) and Harmon Industries (18). The latter system is currently being tested in Michigan to provide more consistent warning times to railroad warning devices for high speed trains.

With its accurate positioning and arrival time estimation capabilities, this system offers a few advantages over the current track circuitry. First, this system can update its estimated time of arrival for a train that has decelerated or accelerated as it approaches the crossing. Second, the range of the GPS transceivers and two-way radios is much larger than what most current track circuits can provide without reconstruction. Finally, the data that are provided by these units can be used in other transportation applications such as alerting emergency vehicles or busses to the presence of a train and providing information to an Advanced Traffic Management Center.

The major drawback of this type of detection system is that GPS units and two-way radios would have to be installed in every locomotive that could use a crossing. Since it is possible that many different engines will travel down a single railroad line on any given day, the amount of equipment that would have to be purchased could grow quite large. However, with more railroad agencies moving to centralized, computer control, the need to install such equipment may exist anyway.

Track Circuitry Improvements

Another method that could be used to increase the warning time provided to initiate preemption is to extend the existing track circuits to provide warning farther from the crossing. The existing detection equipment would have to be modified so that the signal that is sent to the traffic controller occurs separately and before the signal is sent to the railroad warning devices. This will allow the traffic signal controller to be more prepared for the preemption routine when the train has arrived, but will discourage disrespect of the railroad warning devices by keeping waiting times minimal.

By keeping the detection equipment on the tracks, there is no need to install any additional equipment on the trains that use the crossing. This will allow trains of any railroad agency to use the crossing and activate the traffic signal preemption. Also, the failsafe properties of these systems have been repeatedly tested and may ease some of the liability concerns of railroad and highway agencies.

A disadvantage of extending the track circuitry is that the current train arrival estimates produced by these systems do not account for acceleration, deceleration, or in many cases, stops within the detection circuit. The algorithms and equipment used to estimate the train's time of arrival need to be improved so that these estimates can be more reliable. Also the large extension distances that may be required and the spacing between crossings can make extending the detection circuit very expensive and complicated.

Disadvantages of Other Technologies

Each of the other technologies that were investigated in this paper had some qualities that made them undesirable for adaption to traffic signal preemption at railroad-highway grade crossings. It should be noted that these systems do not advertise that they should be used to provide increased warning time for traffic signal preemption. Thus, transportation officials should not reject these products for their advertised intended use.

The major disadvantage of the "train horn" system is that trains will sound their horns only within a limited distance of a crossing. While the horn detectors can be placed further upstream of a crossing, the actual warning time provided is determined by the farthest upstream location at which the horn is sounded. This limited distance would not provide enough increased warning time to the traffic controller.

The AVI transponder systems that were discussed are useful for identifying vehicles and providing general location information along the track. However, since information is gathered only at receiver locations, only an average speed can be determined. Thus, accelerating and decelerating trains may not be accurately accounted for in the predicted train arrival.

TRANSITIONAL PREEMPTION STRATEGY

The discussion to this point has shown that existing preemption methods are not the safest and most efficient means to clear the tracks and prevent movement across the tracks while a train is approaching. Technologies are currently available that can be adapted to provide additional warning time to the traffic signal controller so that the preemption sequence can be initiated before the railroad warning devices are activated. The Transitional Preemption Strategy utilizes the additional warning time to improve the safety and efficiency of signal preemption at a single-track crossing on one approach to a four-leg intersection.

Preemption Strategy

The strategy that is presented below is designed to be used at a railroad crossing and an isolated signalized intersection like the one shown in Figure 3. For the purposes of developing this strategy, it is assumed that the rail line is used solely by freight trains with a top speed through the area of 65 km/h (40 mph).

Much of the logic for the Transitional Preemption Strategy does not currently exist in many controllers. For this reason, new controllers (such as the customizable 2070 type) or new software for existing controllers will have to be purchased and installed at the intersection. This device will be used to store the following information:

- *Minimum required clearance time for all phases that conflict with the track clearance phase.* The minimum clearance time for a phase is defined as:

  MINCLR = (PEDCLR) + (YELLOW)

  where: MINCLR = minimum clearance time for a phase
  PEDCLR = required pedestrian clearance time
  YELLOW = change interval and any all-red interval

  For example, a pedestrian clearance time of 10 seconds with a 5 second clearance and change interval would result in a minimum required clearance time of 15 seconds.

- *The length of the track clearance phase* (TRKCLR). The length of the queue clearance interval is calculated by accounting for the geometry of the crossing, the available storage space between the tracks and the signalized intersection, and the start-up characteristics of the design vehicle (2). Equations, such as those presented by Marshall (6) may be used for this calculation.

- *The time before the train's arrival to begin the track clearance phase* (CLRSTART). The clearance phase will begin a minimum of five seconds before the warning devices are activated and should end five seconds before the arrival of the train.

- *Minimum desirable green time for all phases that conflict with the track clearance phase* (DESGRN). These minimum green times will prevent an unexpected very short green interval from being displayed and also allow for part of a progression band to be maintained in a coordinated system.

From the above variable definitions, the minimum desirable length of a phase can be defined. The minimum desirable length of a phase is the sum of the minimum required clearance time and the minimum desirable green time for a phase. The minimum desirable length attempts to prevent the abandonment of pedestrians and the displaying of very short green indications.

In order to provide as smooth a transition as possible into preemption, the advance detection equipment that is used should notify the signal controller of the train's estimated arrival time before the train is within two cycle lengths of the crossing. For the example freight train, a 60 second cycle length would require that the train be detected 1.4 km (0.9 mi) from the crossing. A 120 second cycle length would require detection 2.5 km (1.6 mi) from the crossing.

Once the train is detected, the controller would enter into "transitional preemption mode." The following logic then used to determine whether the current phase should be shortened, extended, or allowed to last its set duration:

1. The projected time that the current phase would end if allowed to continue for its programmed duration is determined. This projected time is then used to determine how much time will be available between the projected end of the current phase and the time that the track clearance phase is set to begin.
2. If there is enough time between the projected end of the current phase and the beginning of the track clearance phase to service the next phase in the signal sequence for at least its minimum desirable length, the current phase is allowed to run for its full programmed duration.
3. If there will not be enough time to completely service the next phase for at least its minimum desirable length, the current phase will be shortened until enough time is provided for the next phase to be serviced for its minimum desirable length before the time to start the track clearance phase
4. If, however, the shortening the current phase will not provide enough time to service the next phase for its minimum desirable length without making the current phase shorter than its minimum desirable length, the current phase would be held in green until the track clearance phase is set to begin.

The above steps will be performed every time the train's predicted arrival time at the crossing is updated by the detection equipment and each time the a new signal phase becomes active. The one exception to the above sequence of events occurs if the phase immediately following the current phase in the sequence is the phase used to clear the tracks. When this occurs, the logic will look ahead to the next two phases that follow the current phase to determine if they both can be serviced for their minimum desirable time. This prevents very long track clearance greens that would clear the tracks and remove the queue too soon before the train arrives at the crossing.

The logic for the system is presented graphically in the flowchart shown in Figure 3. If for any reason the track clearance phase would not have been initiated by the time the warning devices are activated, the existing interconnection with the train detection equipment would force "normal preemption" at that time. Thus, the existing detection equipment and warning devices at the crossing would not be changed and would continue to serve as a "fail-safe" backup for the transitional preemption strategy.

This strategy will create a smoother transition into preemption than that which is provided by the normal shorter warning times. The desirable minimum greens are all provided to avoid confusing the motorists and to possibly maintain some system progression. Also, since the minimum clearance times are always provided, pedestrian safety is considered. When this strategy is followed, the green signal indication for the track clearance phase should always be displayed at the same time before the train arrives at the crossing, regardless of train speed or the other factors.

By providing the green signal before the warning devices even activate, the preemption strategy guarantees that the maximum buffer time will be provided before the arrival of the train and after the warning devices have activated. The more consistent operation of the traffic signal would hopefully encourage further compliance with the railroad warning devices and increase the safety of the crossing.

Illustrative Example

In order to demonstrate the advantages of the transitional preemption strategy that was presented above, the example crossing shown in Figure 4 will be considered.

As Figure 4 indicates, the example intersection operates on a 100 second cycle length with available time split 60/40 between Main St. and Preempt Lane. Therefore the example freight train would have to be detected 2.2 km (1.4 mi) upstream of the crossing using the GPS/Two-Way Radio equipment. The time lines in Figure 5 indicate the signal displays for the various approaches.

The time line in Figure 5a indicates the sequence of events that would be expected to occur if a normal preemption sequence was used. In this case preemption is initiated at the same time that the warning devices are activated. In this example it is assumed that the warning devices will first activate 20 seconds before the arrival of the train.

The sequence of events that would occur under the transitional preemption strategy presented in this report is shown in Figure 5b. Again, the railroad warning devices are activated only 20 seconds before the arrival of the train. However, in this case the signal controller is first warned about the pending arrival of the train 200 seconds (or two cycle lengths) before its estimated arrival at the crossing.

For this example it is assumed that when the train is 200 seconds from the crossing, the main street green ($\phi 2 + \phi 6$) has been active for 25 seconds. This time is arbitrary since the train may first be detected during any part of the cycle.

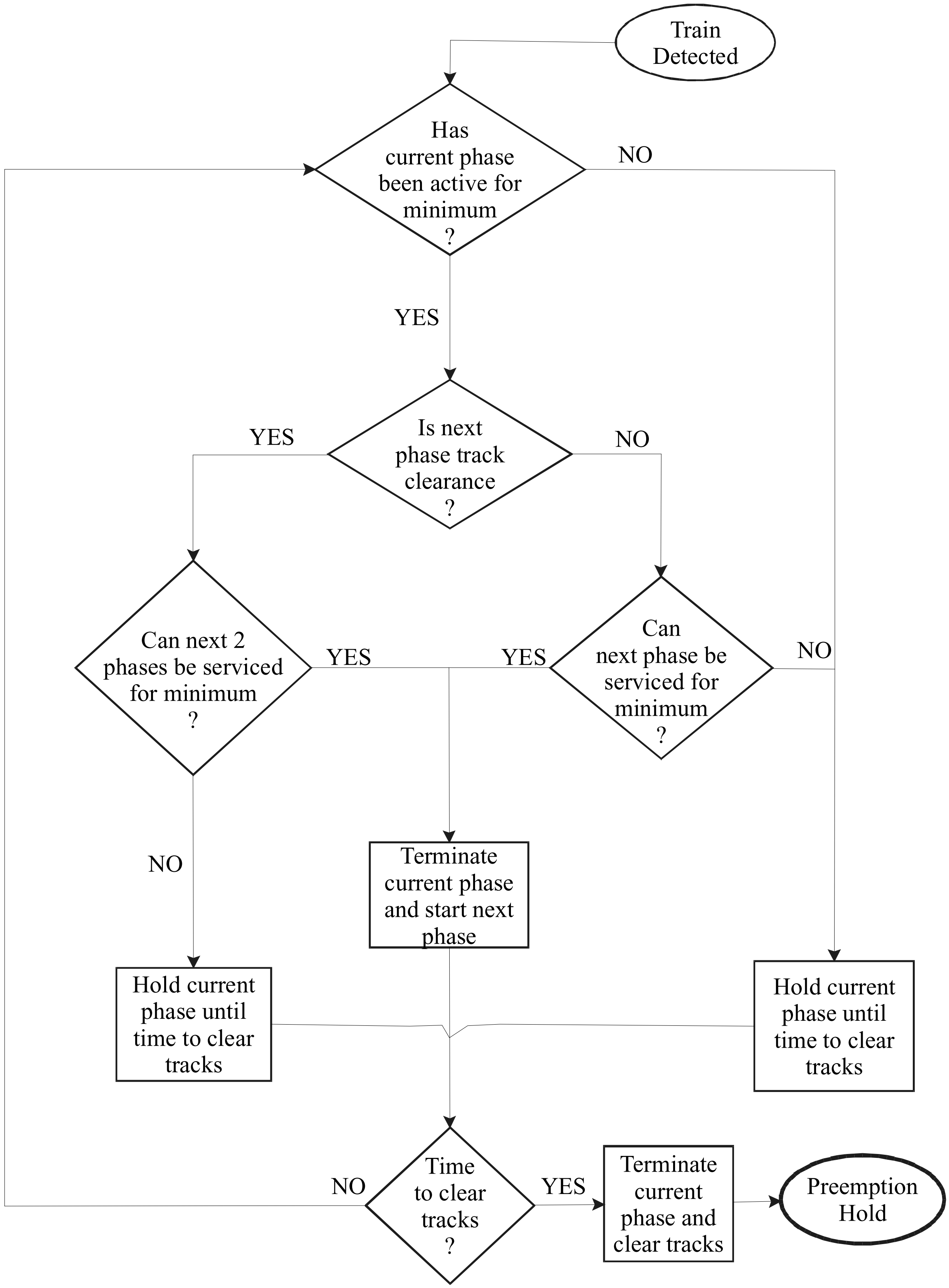
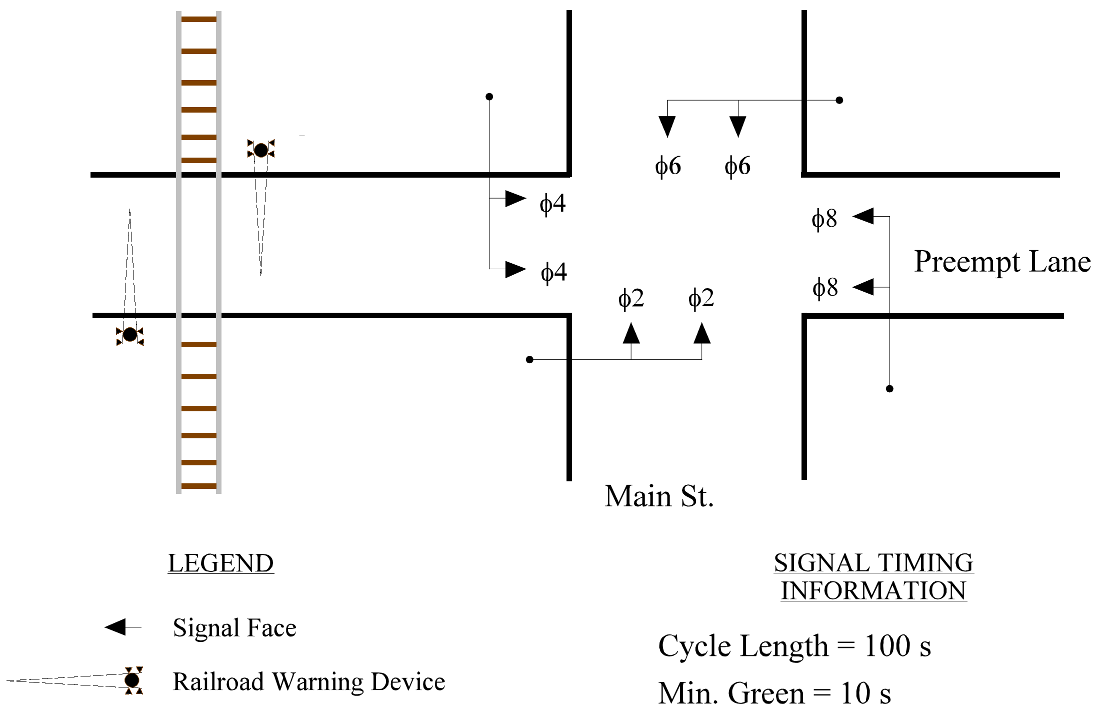


Figure 3. The logic used in the Transitional Preemption Strategy to determine if the current phase should be terminated or held.



SIGNAL TIMING INFORMATION

Cycle Length = 100 s
Min. Green = 10 s
Pedestrian Clearance = 15 s
Min. Desired Time = 25 s
Track Clearance Green = 10 s

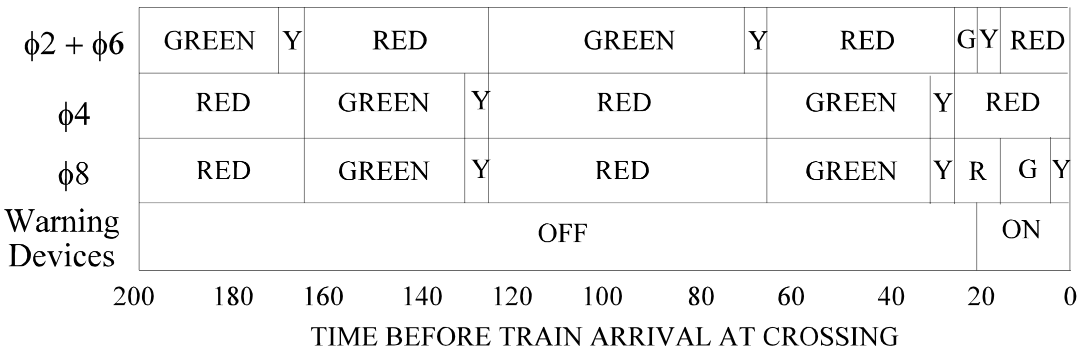
ϕ 2 + ϕ 6
- Green = 55 s
- Yellow = 4 s
- Red Clearance = 1 s

ϕ 4 + ϕ 8
- Green = 35 s
- Yellow = 4 s
- Red Clearance = 1 s

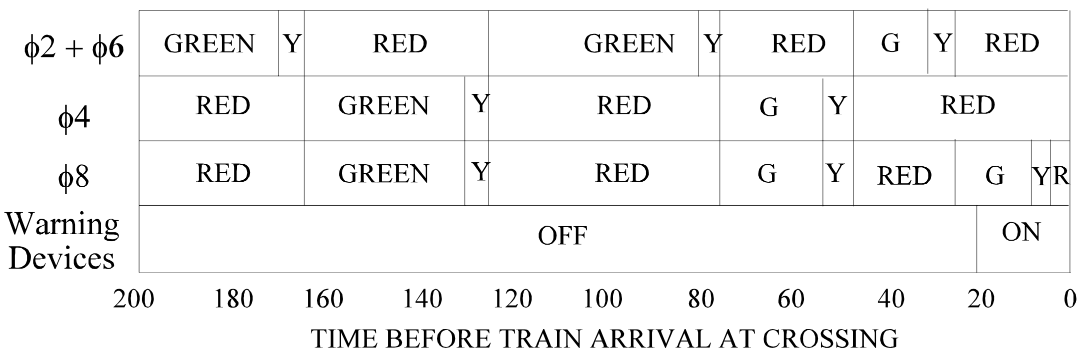
Figure 4. Crossing layout and traffic signal timings for the illustrative example to demonstrate the transitional preemption strategy.

As the two time lines indicate, the difference between the preemption treatments does not become evident until 75 seconds before the train has arrived at the crossing. While the normal preemption sequence allows the main street green to last its entire 55 seconds, the transitional preemption strategy terminates this phase after only 45 seconds of green. The reason for this early termination is that the next phase in the sequence is for the approach across the tracks and terminating the current phase ten seconds early allows both the track clearance phase and the following phase to be active for their minimum desirable times. Note that no phase in the transitional preemption sequence is terminated before its minimum desirable time.

The advantage that is gained by using the transitional preemption strategy in this example is the elimination of the very short green that is displayed to the main street in the normal sequence just before the warning devices are activated. This short green is unexpected by motorists and may lead to rear-end crashes. The short length also does not allow for proper pedestrian clearance which can also be very dangerous.



(a) Normal Preemption Sequence



(b) Transitional Preemption Sequence

Figure 5. The phasing sequence under (a) normal preemption and (b) transitional preemption.

Additional buffer time is also provided before the trains arrival using the transitional preemption strategy. The track clearance phase is able to run in its entirety and clear the tracks well before the arrival of the train. The display of the yellow signal nine seconds before the train's arrival and the red signal five seconds before the train's arrival will discourage motorists from racing around the railroad warning devices in front of the train in the attempt to make the green signal.

The normal preemption sequence also provides the track clearance green for the required amount of time. However, the yellow signal is not displayed until four seconds before the arrival of the train and the red signal comes on just as the train enters the crossing. These signal displays may cause some motorists to race around the warning devices and increase the chances of a collision.

RECOMMENDATIONS

The railroad-highway grade crossing is an area in transportation engineering that deserves extra attention. The guidelines and standards that exist to govern the operation of traffic signals near these crossings have only been slightly changed over nearly 20 years. Yet, even with the instituted changes, many crossings operate each day in inefficient and potentially unsafe manner.

The strategy presented in this paper offers one method to help improve the efficiency and safety of those railroad-highway grade crossings that are located near signalized intersections. It is recommended that areas with very high traffic volumes or very little storage space between the highway intersection and the railroad tracks employ a strategy similar to that which was set fourth in the proceeding discussion. Also, as train operations are updated to be linked with a traffic or rail management center, the effort should be made to install the transitional preemption system concurrently.

The strategy presented in this report was based on a simple single-track, crossing geometry with relatively slow moving freight trains. As was pointed out earlier in the paper, several other issues can quickly complicate this simple scenario. For this reason, both the rail and highway authorities are encouraged to investigate other methods of transitional preemption for different crossing layouts such as multiple track configurations or crossings that effect more than one leg of the signalized intersection.

While the liability concerns expressed by both sides are real, the consequences of a one second less of warning time are also real. For this reason, it is recommended that the quest to improve the safety of railroad-highway grade crossings and preempted traffic signals be a top priority of the transportation profession.

ACKNOWLEDGMENTS

This report was prepared for the graduate summer course CVEN 677 *Advanced Surface Transportation Systems* at Texas A&M University. The author would like to thank Dr. Conrad Dudek, the instructor for the course, for organizing this excellent summer program and providing an excellent opportunity to share ideas and work with a great group of very skilled transportation professionals. In addition I would like to express my sincere gratitude to Mr. Joseph McDermott for his time, assistance, and inspiration. A special thank you is also extended to all of the other mentors that participated in the program for all of the thought provoking questions and comments that they asked and all of the advice that they gave.

In addition, thanks goes out to the following individuals who kindly gave some of their time to provide assistance with this research:

Mr. Rick Bartoskowitz - Texas Transportation Institute
Mr. William Browder - Association of American Railroads
Dr. Dan Fambro - Texas A&M University
Mr. John Ferrari - Smart Stops Unlimited Corp.
Mr. Andy Jones - Midwest Traffic Products, Inc.
Mr. Mike Krasny - Sonic Systems Corporation
Mr. Kevin Newell - Emergency Preemption Systems, Inc.
Mr. Lee Robinson - City of College Station Department of Public Works
Ms. Carol Young - South Carolina Department of Transportation
Mr. Tom Zeinz - Illinois Central Railroad

Finally, my sincerest gratitude goes out to my parents, Arthur and Karen, and my fiancee Elizabeth who are my greatest supporters and have graciously listened to more about traffic signal preemption than they ever wanted to hear.

REFERENCES

1. Halkins, J. A. and Blanchard, L. Accident Causation Analysis at Railroad Crossings Protected by Gates. *Transportation Research Record 1114*, TRB, National Research Council, Washington, D.C., 1987, pp. 123-130.

2. Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices: ITE Recommended Practice. Final Committee Report. Institute of Transportation Engineers, Washington, D.C., February 1997.

3. Accidents that Should Not Happen: Executive Summary. Institute of Transportation Engineers. March 1996. [http://www.ite.org/blribrep.htm]

4. Bowman, B.L. The Effectiveness of Railroad Constant Warning Time Systems. *Transportation Research Record 1114,* TRB, National Research Council, Washington, D.C., 1987, pp. 111-122.

5. Moe, J. Train Activated Rail-Highway Protection. *Proceedings of the 1972 National Conference on Railroad-Highway Grade Crossing Safety*, National Safety Council, U. S. Department of Transportation, Washington, D.C., 1972, pp. 13-16.

6. Marshall, P.S. and Berg, W.D. Design Guidelines for Preemption at Signalized Intersections. *ITE Journal*, Vol. 67, February 1997, pp. 20-25.

7. Marshall, P.S. and Berg, W.D. Evaluation of Railroad Preemption Capabilities of Traffic Signal Controllers. *Transportation Research Record 1254*, TRB, National Research Council, Washington, D.C. 1990, pp. 44-49.

8. *Manual on Uniform Traffic Control Devices.* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1988.

9. *Signal Manual.* Communication and Signal Division, Association of American Railroads, Washington, D.C., 1995.

10. Richards, S.H. and Heathington, K. W. Assessment of Warning Time Needs at Railroad-Highway Grade Crossings with Active Traffic Control. *Transportation Research Record 1254*, TRB, National Research Council, Washington, D.C. 1990, pp. 72-84.

11. Richards, S.H. and Heathington, K. W. and Fambro, D. B. Evaluation of Constant Warning Times Using Train Predictors at a Grade Crossing with Flashing Light Signals. *Transportation Research Record 1254*, TRB, National Research Council, Washington, D.C. 1990, pp. 60-71.

12. Noyce, D. A. Barriers to Implementation of Signal Priority Systems for Transit Operations: Lessons Learned from Advanced Traffic Management Systems. *Compendium of Graduate Student Papers: Advanced Surface Transportation Systems*, Southwest Region University Transportation Center, Texas Transportation Institute, The Texas A&M University System, College Station, TX, August 1996.

13. Sonic Systems Traffic Preemption and Priority Systems. Sonic Systems Homepage. As of June 12, 1997. [http://www.sonic-systems.com]

14. Emergency Preemption Systems Homepage. As of June 12, 1997. [http://www.preemption.com]

15. The EPS RWD-IV Active Warning Device. Emergency Preemption Systems Homepage. As of June 12, 1997. [http:/www.preemption.com/rwdintro.htm]

16. Mowatt, M. G. Transit Signal Priority: A Regional Implementation. *ITE 1995 Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, D.C., pp. 85-91.

17. MTP Priority One GPS Traffic Preemption System. Midwest Traffic Products Homepage. As of June 12, 1997. [http://mtp-gps.com]

18. Incremental Train Control System. *Traffic Engineering Council Update.* ITE Traffic Engineering Council Committee 96-04, Institute of Transportation Engineers, Washington, D.C., Spring/Summer 1997, pp. 6-8.

19. Lancaster, T. R. Light Rail Transit Preemption of Actuated Signals. *ITE 1989 Compendium of Technical Papers,* Institute of Transportation Engineers, Washington, D.C., pp. 335-337.

20. Telephone Interview with Mr. Lee Robinson, Public Works Department, City of College Station, Texas, June 1997.

21. Telephone Interview with Ms. V. Carol Young, Lower State Engineer, South Carolina Department of Transportation, SC DOT, June 1997.

22. Telephone Interview with Mr. William Browder, Director of Operations, Association of American Railroads, June 1997.

23. Telephone Interview with Mr. Tom Zeinz, Illinois Central Railroad, June 1997.

24. Telephone Interview with Mr. Kevin Newell, Emergency Preemption Systems, Inc., July 1997.

25. Telephone Interview with Mr. Andy Jones, Midwest Traffic Products, Inc., July 1997.

26. Telephone Interview with Mr. John Ferrari, Smart Stops Unlimited, Corp., July 1997.

27. Telephone Interview with Mr. Mike Krasny, Sonic Systems Corp., July 1997.

Marc S. Jacobson received his B.S. in Civil Engineering from Texas A & M University in December 1996. Marc is currently pursuing his M.S. in Civil Engineering at Texas A&M University. Marc has been employed by the Systems Applications Program of the Texas Transportation Institute since May 1995. University activities he is involved in included: Institute of Transportation Engineers, Texas A&M Student Chapter and ITS America, and the Texas A & M Chapter of the American Society of Civil Engineers. His areas of interest include: transportation operations, traffic signals, and Intelligent Transportation Systems applications. His expected graduation date is December 1997.

USE OF AUTOMATED ENFORCEMENT FOR RED LIGHT VIOLATIONS

by

Karl A. Passetti

Professional Mentors
Joseph M. McDermott, P.E.
Illinois Department of Transportation

and

Thomas Hicks, P.E.
Maryland Department of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

Traditional police methods cannot safely and efficiently address the increasing frequency of drivers violating (running) red lights. The use of automated enforcement systems offers the potential to decrease the number of red light violations and improve the safety of intersections. Despite the potential benefits of automated enforcement for red light violations, few jurisdictions in the United States have implemented such programs. Included in this report is an evaluation of the operating conditions where automated enforcement was effective, a study of the legal, legislative, and social issues needed to implement a program, a review of the current technology being used for automated enforcement, and a review of previous and current automated enforcement of red light applications in the United States and abroad. A strategy to create and implement an automated enforcement program for red light violations was established. The implementation strategy was then demonstrated using a hypothetical application.

A state-of-the-art literature review was conducted to establish background information on the use of automated enforcement for red light violations. In order to provide more recent and site specific data that are not available in the literature, a diverse group of professionals were interviewed and a survey was conducted. The professionals contacted were automated enforcement program representatives, law enforcement officials, manufacturers of automated enforcement technology and systems, and research engineers and scientists. The interviews and survey were completed through a combination of telephone conversations and fax transmissions.

The results of the survey and the information presented in the literature were incorporated into this report and were used to develop the following strategy for implementing an automated enforcement program for red light violations:

- Demonstrate a need for the program;
- Establish institutional arrangements;
- Review applications in the United States and abroad;
- Create a public education and awareness campaign;
- Establish legislation to allow for the use of automated enforcement technology and processes;
- Advertise a Request For Proposal (RFP);
- Undertake a demonstration project;
- Evaluate the demonstration project;
- Implement selected vendor system; and
- Expand the program.

Based on the results of this study, the use of automated enforcement systems provided police departments and jurisdictions with the ability to consistently enforce red light violations without placing the total responsibility on police departments. By following the strategies presented in this report, agencies will be able to implement an automated enforcement program that may improve the safety of intersections. The automated enforcement program will also be acceptable to law enforcement agencies, highway and traffic engineers, supporting governments, and the general public.

TABLE OF CONTENTS

INTRODUCTION

The use of automated enforcement is providing governments and police departments with an alternative to address the increasing problem of red light violations. Although each state specifies its own traffic laws, a red light violation is commonly defined as when the front wheels of a vehicle enter the defining boundary of an intersection (usually the stop bar or crosswalk) after the traffic signal changes to the red phase and the vehicle proceeds through the intersection while the signal is red. The common phrase used to describe when vehicles proceed through an intersection after the traffic signal turns red is running a red light.

Drivers who "run" red lights pose a danger to both other drivers using the facility and to themselves. Traditional means of using police personnel to enforce red light violations have several problems. Often, police departments have very limited resources and personnel. Decisions usually are made to allocate resources to other areas of need before supporting increased traffic enforcement.

Enforcing a red light violation places police officers in a very difficult situation. If a red light violation takes place while an officer is present at a traffic signal and the officer does not pursue the violator, the officer will be viewed as indifferent and the message that red light violations are not serious offenses will be portrayed to the public. Pursuing red light violators can also be dangerous to police officers, motorists, pedestrians, and bicyclists.

In order to enforce a red light violation, police personnel often have to go through the red light in pursuit creating a dangerous situation. The high speed necessary to 'catch' a violator and the limited space in urban areas to 'pull a vehicle over' also increase the chance for accidents to occur. Should a driver fail to obey a police officer and a high speed pursuit occur, public injuries and substantial property damage can also occur.

Automated enforcement has been used in several countries to reduce the number of red light violations. In the Netherlands and Australia, it has been reported that automated enforcement technology can reduce red light violations by 35 to 60 percent and reduce right-angle accidents by 32 percent (1). Reductions such as those previously stated have prompted the Federal Highway Administration (FHWA) to support additional applications of automated enforcement technology for red light violations.

Recently, several cities in the United States have begun using automated enforcement in an attempt to reduce red light violations. Preliminary data show that the cities of San Francisco, California, New York City, New York, and Howard County, Maryland experienced between a 20 to 30 percent reduction in red light violations after automated enforcement and/or warning programs were initiated (2). The cities incorporated different ways to finance the programs, enacted different legislation, and had different opinions on whether or not citations should be sent or warning notices issued.

Problem Statement

The use of automated enforcement for red light violations in the United States has been very limited. Several different programs with varying degrees of success have been used in the past. Because of the potential to decrease the number of red light violations and improve the safety of intersections, a need exists to evaluate the operating conditions where automated enforcement is effective, the legislation needed to implement a program, the public involvement necessary to gain acceptance of the program, and the technology that can be used for such a program.

Objectives

The objectives of this research were as follows:

1. Identify the extent of the problem of red light violations.
2. Evaluate legal, legislative, and social issues associated with automated enforcement of red light violations.
3. Review the current technology being used for automated enforcement and identify its strengths and weaknesses.
4. Review previous and current applications in the United States and abroad using automated enforcement for red light violations.
5. Formulate a strategy for the implementation of an automated enforcement program for red light violations.
6. Demonstrate the implementation strategy using a hypothetical application.

Method of Study

Literature Review

A state-of-the-art literature review was conducted to establish background information on the use of automated enforcement for red light violations. Included in this literature review were reports documenting the creation of automated enforcement programs in the United States and abroad, literature describing the barriers faced in implementation, and reports on the operational effectiveness of automated enforcement programs for red light violations. Information related to the current technology being used for automated enforcement systems for red light violations was also reviewed.

Data Collection

Surveys, telephone interviews, and a review of information provided by professionals were used to collect data concerning automated enforcement programs for red light violations. A group of professionals which included law enforcement officials, city and county representatives, traffic engineers and engineering consultants, technology representatives, and researchers with knowledge about the creation, organization, technology, and operations of automated enforcement programs was targeted to provide more recent and site specific data that is not available in the literature. The professionals targeted for this study were classified into one of the following four categories:

1. Automated enforcement program representatives;
2. Law enforcement officials;
3. Manufacturers of automated enforcement technology and systems; and
4. Research engineers and scientists.

Table 1 lists the organizations and individuals contacted for this study.

Table 1. Individuals and Organizations Contacted For This Study.

Automated Enforcement Program Representatives	Law Enforcement Officials	Technology Manufacturers	Research Engineer/Scientists
Rudy Popolizio, Chief of Red Light Camera Program for New York City, NY	Chief George M. Ferris, Fort Meade Police Department, FL	AUTOPATROL™	Richard A. Retting, Insurance Institute for Highway Safety
C. Edward Walter, Chief, Traffic Engineering Division of Public Works of Howard County, MD	Sgt. Glenn A. Hansen, Supervisor, Research and Planning Section, Howard County, MD	CONTROL TECHNOLOGIES	Mila Plosky, FHWA
Tarek Tarawneh, Head of Red Light Camera Program for Lincoln, NE	Officer Anthony Taylor, Bryan/College Station Police Department	EASTMAN KODAK COMPANY	Richard A. Raub, Northwestern University Traffic Institute
Chief George M. Ferris, Fort Meade Police Department, FL	Chief John Wintersteen, Paradise Valley Police Department, AZ	U.S. PUBLIC TECHNOLOGIES INC.	Harold Lunenfeld, FHWA
Susan Law, Associate Project Manager, Nelson Nygaard Consulting, San Francisco, CA		TRAFFIPAX Traffic Surveillance Systems	
Tom Fletcher, Manager of Traffic Management, Ontario, Canada		Truvelo Manufacturers	
		Cohu, Inc., Electronics Division represented by Ruyle & Associates and Pete Schumacher	

Organization of Report

The report is divided into nine sections. Section 1 consists of the introduction to the report. Background information on the extent of the problem of red light violations is provided in Section 2. Legal, legislative, and social issues associated with automated enforcement are evaluated in

Section 3. The current technology that is being used for automated enforcement is reviewed in Section 4 . The study design used to complete this paper and the questions asked in the interview process are provided in Section 5. A detailed discussion describing current applications of automated enforcement for red light violations in the United States and abroad is presented in Section 6. Implementation strategies for a program using automated enforcement of red light violations are formulated in Section 7. The strategies formulated in Section 7 are applied through the use of a hypothetical application in Section 8. Conclusions and recommendations based on the previous sections are provided in Section 9.

BACKGROUND

Motorists driving through an intersection after the traffic signal has turned red are a dangerous problem that is increasing in most states. Several studies conducted by Richard Retting of the Insurance Institute for Highway Safety (IIHS) have defined the magnitude and seriousness of the problem. IIHS defines a violation when a motorist deliberately enters an intersection after the signal light has turned red as a red light run (3). Retting, citing United States Department of Transportation statistics from 1993, 1994, and 1995, stated that more than one million motor vehicle collisions resulting in over one-half million injuries and several thousand fatalities occur at traffic signals. Statistics, also from the United States Department of Transportation, showed that the number of fatal crashes occurring at traffic signals had increased by 15 percent between 1992 and 1995 (4).

A different study also conducted by the Insurance Institute for Highway Safety showed that 22 percent of all crashes in urban areas were the result of drivers running traffic control devices (traffic signals, stop signs, and yield signs). Of those crashes, 24 percent involved running red lights. The same study also showed that a higher percentage of occupants were injured in red light running crashes (45 percent) as compared to injuries resulting from the running of other traffic control devices (30 percent) (5). The economic impact of crashes resulting from red light violations in terms of medical costs, time off work, insurance hikes, and property damage is estimated at $7 billion each year (6).

An example of the problem of red light violations can be seen in the state of Maryland. Currently, running a red light is a cited cause in four percent of all accidents. During the 12-year period between 1983 and 1994, failure to stop for a red light has been the primary cause of approximately 47,000 traffic crashes resulting in more than 250 fatalities. A review of accident records has also shown that the percentage of accidents in which running a red light was listed as the primary cause of the accident has increased steadily since 1983 (7).

Due to the frequency of red light violations and the severity of the incidents that have resulted from them, the Insurance Institute for Highway Safety conducted a study to determine the characteristics of drivers who run red lights (8). In the study it was found that red light violators as a group have significantly more tickets for moving violations, generally poorer driving records, are younger, and are less likely to use safety belts than law abiding drivers. From this study, it was concluded that red light violators are a "higher risk group that merits enforcement resources not only because of the violation itself and its danger, but because of their higher risk characteristics in general" (8).

The process of identifying a driver running a red light and enforcing the violation is time consuming using traditional police methods. Although enforcing red light violations is a high priority for many police departments, the actual enforcement of the violation is difficult for several reasons. In order for single officer on patrol to stop an individual observed running a red light, the officer has to have a direct view of the traffic signal so that the decision can be quickly made if the suspected vehicle ran the red light or actually was in the intersection before the light turned red.

In some states, such as Florida, the courts require that the officer issuing the citation must see the same face of the traffic light as the violator (9). Such laws have implications that severely limit the ability of a police department to enforce red light violations. In Polk County, Florida, only seven percent of all traffic citations written in the past six months were for red light violations.

By requiring officers to have the same view of the traffic signal as the violator, officers who observe violations from cross streets or the opposing direction of traffic cannot enforce the violation. If an officer does observe a violation while viewing the same face of the traffic signal, that officer will have to follow the violator through the flow of cross traffic that has the green signal, creating a very dangerous situation for both the officer and the crossing vehicles. These factors make it nearly impossible for an officer on patrol to enforce red light violations and force officers to position themselves in a stationary spot to view violations. Most police departments do not have the manpower or resources to allow officers to enforce violations for a long period of time.

To counter the difficulties many areas are having with enforcing red light violations and the danger posed to officers who do enforce red light violations, some areas are using a team approach. The team approach involves having at least three officers present at an intersection together. One officer is positioned upstream of the traffic signal in an unmarked vehicle to observe violations and two officers are positioned downstream of the intersection to pull-over the violators when radioed by the upstream officer. Although the team enforcement method is safer for officers and is successful in citing red light violators, the cost to have many officers at one location is difficult to justify.

In Howard County, Maryland, team enforcement was used during the three peak traffic periods of the day. One operation consisting of a two-hour session done three times a day for three consecutive days was estimated to cost about $1,500. For the seven jurisdictions participating in the program to each enforce five sites, three times a day for three consecutive days, the estimated cost of the program was approximately $52,000 (10). More information about Howard County's team enforcement program can be found in Section 6, Applications of Automated Enforcement Programs.

The amount of time an officer spends preparing and attending court for violations that are challenged depends on several factors. To prepare for court, an officer typically reviews the field notes recorded at the time of the violation. The amount of time an officer will spend in court is determined by the court docket. If the case is slotted for an early time, the officer will be able to quickly complete the case, but if the slot is later in the day, the officer may be required to wait as long as five hours before the case is heard. In Maryland and Florida, officers receive a minimum of two hours of pay to compensate for court appearances.

When violations are challenged in court, the judgement of the police officer will usually be upheld. In Polk County, Florida, only 1.3 percent of violations are dismissed or found not guilty (9). Reasons that may be grounds for a violation being dismissed or a driver being found not guilty include an officer not showing up for the trial, lawyers being able to establish that the officer did not actually see the signal turn red when the violator proceeded through the intersection, and an officer preparing poor field notes.

LEGAL AND SOCIAL ISSUES

An understanding of the legal and social issues associated with the use of automated enforcement is necessary in order for an effective program to be designed and implemented. A review of relevant United States court decisions concerning constitutional issues, privacy rights, and admissibility requirements for automated enforcement is included in this section. Legislation passed in various states and countries was also reviewed to determine what legislation is needed and most compatible with automated enforcement of red light violations. Also included in this section is an examination of public opinions concerning the use of automated enforcement.

Constitutional and Privacy Issues

There is currently no court case which has specifically defined an individual's right to privacy under the First Amendment with respect to operating a vehicle. Although the Supreme Court has protected an individual's right to privacy in matters relating to marriage, family, and sex (California v. Belous, 80 Ca. Rptr. 354, 458 P.2d 194 [1969]; Griswold v. Connecticut, 381 U.S. 479 [1965]), the act of driving would not appear to be protected (11). Because driving is considered a privilege that is not guaranteed to everyone and because of the fact that driving takes place in view of the public, it is not logical to believe that an individual's right to privacy while operating a vehicle would be protected by the Constitution.

Several other Supreme Court decisions have led to the belief that the use of automated enforcement technology does not violate an individual's right to privacy. Because a vehicle travels public roadways and the vehicle and its occupants are in the public view, the Court decided in Cardwell v. Lewis, 417 U.S. 583, 590 (1974) that a vehicle has little ability to escape public scrutiny (12). In the United States v. Knotts, 460 U.S. (1983), the Court ruled that the defendant had no reasonable expectation of privacy in using public streets and that surveillance by police using a radio transmitter, or beeper, in the vehicle was equivalent to following the vehicle on the public streets (12). In New York v. Class, 475 U.S. 106, 106 S.Ct. 960, 38 CrL 3128 (1986), the Court ruled that a police officer's search for a VIN (vehicle identification number) did not violate an individuals right to privacy because the VIN was considered important in maintaining pervasive government automobile regulations (11).

The decisions previously described are based on the standard established by the Supreme Court that Fourth Amendment protection is based upon whether or not a person has a reasonable expectation of privacy. Because drivers are in the open view of the public when operating vehicles, the expectation of privacy has no basis. Therefore, the use of automated enforcement devices does not appear to violate any constitutional rights (11).

Admissibility Issues

The use of photographs taken by automated enforcement equipment is allowed by the Courts as evidence if a "strong showing" is made establishing the photograph's competency and authenticity (11). The elements of authenticity required by the courts are identification of the defendant as the same person shown in the photograph (if the violation is classified as a moving violation), clear identification of a vehicle's license plate, and verification that the equipment used to take the photograph was properly functioning. Additional information also sought by courts is the training of individuals using the system and expert testimony concerning the scientific reliability of the system.

In 1958, the Supreme Court in People v. Pett 178 N.Y.S.2d (1958) decided that the use of a photographic radar device called Foto-Patrol which recorded a vehicle's speed and photographed the vehicle's license plate was not a violation of an individual's constitutional rights (11). The Court stated that: "We have passed the horse and buggy days and are living in a new era. The question is, did the defendant do it and was there sufficient proof offered to find the defendant guilty beyond a reasonable doubt." After hearing testimony by police officers and viewing tests of the system, the Court found the system was scientifically reliable and allowed the evidence to be admitted.

In the case of using automated enforcement for red light violations, the police must establish that the photograph taken, the position of the vehicle in the intersection while the traffic signal was red, and the time shown were provided by an instrument which has been proven to accurately identify, photo, and synchronize these events. If the violation is going to be treated as a moving violation with points being assessed to the driver's license, the identity of the driver must also be clearly shown.

Enabling Legislation

In order for a program using automated enforcement of red light violations to be successful, legislation should be present that clearly defines the criminal or civil liabilities of the operator or owner of vehicles photographed that are in violation of the law. The major decision that must be made when enacting enabling legislation is whether positive identification of the driver must be made to enforce a violation or if the registered owner of the vehicle can be held responsible for the violation. The remainder of this discussion focuses on the general laws that need to be passed for both of these options. Specific examples of legislation passed in conjunction with automated enforcement applications for red light violations is given in Section 6, Applications of Automated Enforcement Programs.

The legislation needed to accompany any automated enforcement program of red light violations must first authorize enforcement agencies to cite red light violators by mail and not require an officer to be attending the equipment at all times. Most agencies currently require that moving violations be issued by a police officer and be signed by both the enforcing officer and the law violator. By not requiring an officer to be attending the equipment at all times, savings in manpower hours can be realized.

In order for a red light violation to be classified as a moving violation in most states, the driver of the vehicle must be able to be identified. A moving violation in most states is considered to be a criminal act by the court and require a verdict of either guilty or not guilty (13). In addition to being subjected to a monetary fine, a person found guilty of a moving violation would be assessed points against his/her driver's license and be subject to increases in automobile insurance.

The process of driver identification through the use of automated enforcement technology involves the use of frontal photography. As stated previously, the use of frontal photography as evidence in a court case requires a "strong showing" identifying the defendant as the same person shown in the photograph. The use of frontal photography often results in public concerns over privacy violations and the perceived threat that drivers may be photographed in potentially embarrassing situations (11). Frontal photography of a vehicle also raises the issue of how to address the identification of other occupants in the vehicle.

To avoid the need of identifying the driver through the use of frontal photography, many countries and states enact enabling legislation that would place responsibility for a red light violation detected using automated enforcement on the owner of the vehicle. The most common form of such a civil vicarious liability statute for traffic offenses is a parking violation. The violation would be classified as a non-moving violation and most often require a decision of liable or not liable (11). By classifying a red light violation as a non-moving violation, a fine would be charged to the owner of the vehicle, but no points would be assigned to an individual's driving license.

Opposition to legislation placing responsibility for violations detected using automated enforcement often cite the scenario where individuals will be unfairly charged for a penalty they did not commit. The Insurance Institute for Highway Safety (IIHS) conducted research into this area using a sample of tickets issued for red light violations during a 20-day period in Arlington, Virginia (4). The study found that 72 percent of the tickets matched the name on the registration identifying the owner of the vehicle. From this study, IIHS concluded that drivers who violate red lights are either the registered owner of the vehicle or reside in the same household as the registered owner.

By having legislation that makes the registered owner of the vehicle responsible for red light violations detected through the use of automated enforcement, the need for frontal photography and driver identification is not required. The owner of the vehicle is instead identified by matching the photograph of the vehicle's license plate with registration records. Concerns about the privacy of individuals in the vehicle, the extra cost associated with frontal photography (picture development, additional equipment), and the difficult process of identifying a person who is not the registered owner of a vehicle caught violating a red light are eliminated.

Many other issues also exist when examining the requirements for enacting legislation that allows for the use of automated enforcement technology and processes. Such issues include the adjudication process, non-payment sanctions, and provisions to allow the registered owner of the vehicle to identify the individual who violated the red light . Although these issues are important, a detailed discussion is beyond the scope of this research.

The National Cooperative Highway Research Program (NCHRP) published a paper discussing the legal issues associated with automated enforcement technology in December of 1996 (14). The report provides a detailed analysis of the precedence that has been set by the Courts concerning the use of automated enforcement technology. Also included in the report is a comparative analysis of the photographic traffic enforcement laws in the United States.

The NCHRP paper can serve as a valuable reference when deciding the context of the legislation that will need to be enacted for the use of automated enforcement technology for red light violations. A research guide is included in the paper to assist individuals in gathering information about State policies that will need to be addressed in the proposed legislation. A model law is also provided as an example that can be used when drafting the proposed legislation.

Public Education and Awareness

In response to the increasing trend of red light violations, the severe accidents associated with red light running, and the high economic impact of such violations, the Federal Highway Administration (FHWA) developed the Red Light Running Campaign Strategic Planning Guide℠[1] (6). The guide provides a comprehensive description of the programs that can be implemented by a community to increase the public's knowledge and awareness of red light violations. The organization of the guide allows users to follow the guide in a step-by-step manner, use it as a reference to improve specific aspects of a program, or to use the guide as a basis to formulate ideas on how to create a public education/awareness program.

The guide is divided into 11 major subject areas: Campaign Overview, Campaign Funding, Organizing Your Staff, Pre-Campaign Assessment, Law Enforcement Participation, Campaign Materials, Media and Public Relations Techniques, Campaign Kickoff, Events and Activities, Post-Campaign Evaluation, and Addenda. Included in the guide are master dubs of video and audio public service announcements (PSAs) and camera-ready art. The strategies presented in the guide were field tested in Charleston, South Carolina and are presently being used in many areas of the United States.

The Red Light Running Campaign Strategic Planning Guide℠ does not provide a great amount of information on using automated enforcement technology. The guide suggests using automated enforcement systems after the conclusion of the public education/awareness program at specific hazardous intersections (6). Because the guide is organized in a manner that is divided by specific subject area, many of the topics can be incorporated into a program to educate the public about the use of automated enforcement technology. Sections such as Campaign Funding, Pre-Campaign Assessment, and Campaign Kickoff all contain information that can be directly incorporated into a program using automated enforcement technology.

An example of a public education campaign being performed in association with an automated enforcement program can be seen in Paradise Valley, Arizona (15). Paradise Valley gained experience using automated enforcement technology by being the first area in the United States to operate a continuous photo-radar program. On August 27, 1996, Paradise Valley expanded its automated enforcement program to include enforcement of red light violations.

In initiating the automated enforcement of red light violations program, Paradise Valley also started a public education and awareness program. The program consisted of a wide variety of techniques used to inform people about the use of automated enforcement technology. Figure 1 shows a handout distributed in Paradise Valley describing the automated enforcement program (15). The handout was given to every school child in town, distributed at city meetings (e.g. City Council and Zoning Board meetings), and mailed with warning notices sent during the first three months of system operation. Other methods that were used to inform the public about the program included

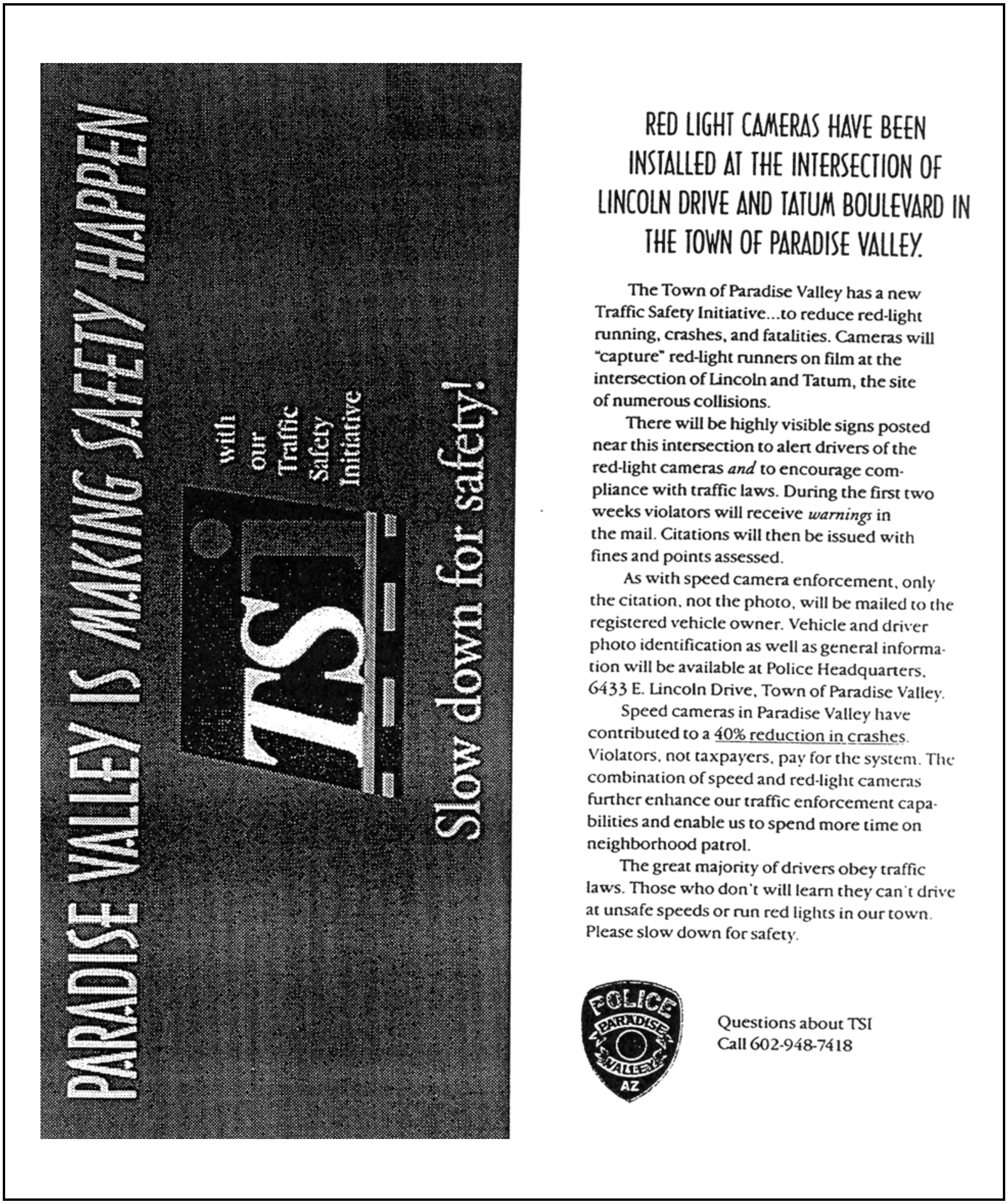
---

[1]For information about the Red Light Running Campaign Strategic Planning Guide℠, contact Mila Plosky, FHWA Headquarters, 400 Seventh Street, S.W., Washington, D.C. 20590.

having a bumper sticker about the program placed on all city vehicles and showing short advertisements at local movie theaters that donated advertisement time.

The intersections where the automated enforcement system operated were made to look different in an attempt to make the public aware of the program. Red reflective strips were placed at the defining boundaries of the intersection at all approaches. Signs informing the public that automated enforcement technology was being used also were placed before each approach to the intersection.

The news media also played a major role in making the public more aware of the automated enforcement program. Members of the police department frequently appeared on radio call-in talk shows and traffic information channels to answer questions about the program. Information packets for the media containing example photographs taken by the system and operational facts were also distributed. By informing the media about the construction, testing, and operations of the system, Paradise Valley was able to keep the topic of automated enforcement in the news and gain public support for the program.


PARADISE VALLEY IS MAKING SAFETY HAPPEN

TSI

with our Traffic Safety Initiative

Slow down for safety!

RED LIGHT CAMERAS HAVE BEEN INSTALLED AT THE INTERSECTION OF LINCOLN DRIVE AND TATUM BOULEVARD IN THE TOWN OF PARADISE VALLEY.

The Town of Paradise Valley has a new Traffic Safety Initiative...to reduce red-light running, crashes, and fatalities. Cameras will "capture" red-light runners on film at the intersection of Lincoln and Tatum, the site of numerous collisions.

There will be highly visible signs posted near this intersection to alert drivers of the red-light cameras *and* to encourage compliance with traffic laws. During the first two weeks violators will receive *warnings* in the mail. Citations will then be issued with fines and points assessed.

As with speed camera enforcement, only the citation, not the photo, will be mailed to the registered vehicle owner. Vehicle and driver photo identification as well as general information will be available at Police Headquarters, 6433 E. Lincoln Drive, Town of Paradise Valley.

Speed cameras in Paradise Valley have contributed to a 40% reduction in crashes. Violators, not taxpayers, pay for the system. The combination of speed and red-light cameras further enhance our traffic enforcement capabilities and enable us to spend more time on neighborhood patrol.

The great majority of drivers obey traffic laws. Those who don't will learn they can't drive at unsafe speeds or run red lights in our town. Please slow down for safety.

POLICE PARADISE VALLEY AZ

Questions about TSI
Call 602-948-7418

Figure 1. Front and Back of Handout Distributed by Paradise Valley Police Department (15).

Public Opinion

Public opinion surveys concerning the use of automated enforcement for red light violations show that the public supports such programs. Sixty-six percent of 1,006 people surveyed across the United States by the Insurance Institute for Highway Safety said they were in favor of using automated enforcement for red light violations as opposed to 28 percent who indicated opposition (16). In a different survey of 500 people in Northern Virginia also conducted by the Insurance Institute for Highway Safety, 47 percent of the people surveyed believed running red lights is a big problem, 30 percent rated it medium, and 21 percent believed running red lights was not a problem. Sixty-three percent of the people in that same survey favored the use of automated enforcement to address the problem of red light violations (16).

The use of automated enforcement for red light violations is also being supported in areas where other uses of automated enforcement is being opposed. The Auto Club of Southern California has supported programs using cameras to photograph red light violators, but has opposed the use of photo radar for speed enforcement (17). In a study conducted in British Columbia concerning an automated enforcement of red light violations program in operation from 1988 to 1990, the profile of drivers who think such programs were unfair was determined. The typical person who opposes automated enforcement programs for red light violations is a young to middle age male, drives more than 10,000 km/year (6,210 mi/year), and has two or more convictions in the last three years (1).

TECHNOLOGY

Automated enforcement systems designed to detect red light violations must have the capability to detect and record violations under varying field conditions and also produce clear images that are easily retrieved and stored. Gary Erickson of Eastman Kodak Company, a manufacturer of automated enforcement technology, cites the following 10 requirements that automated enforcement systems should include (18):

- The ability to capture, transmit, process, store and recover captured images so that data may be managed in an efficient manner;
- Sufficient resolution to satisfy court standards for the image-reading of vehicle license plates, clear detail of the vehicle, and identification of the vehicle operator (if necessary);
- The capability to prevent the spreading of overexposed portions of an image (anti-blooming) that may result from vehicle headlights or sunlight from highly reflective surfaces;
- Adequate differentiation of light to dark areas within an image to provide necessary details (also referred to as contrast latitude);
- The ability to provide blur-free images of moving vehicles;
- The ability to detect at varying levels of light;
- Image enhancement circuitry to eliminate major sensor defects such as bright or dark columns which detract from the visible presentation of an image;
- Continuous read-out of images to support monitoring along with single frame capture capability for recognizing several successive vehicles committing a violation;
- The ability to be moved to different locations or to be mounted into a permanent position; and
- Components that are environmentally friendly.

Currently, three types of cameras are available for use with automated enforcement of red light violation systems. Thirty-five millimeter cameras have been used by most systems to photograph violators. Video cameras have been used to collect data concerning red light violations, but are rarely used for automated enforcement purposes. Digital imaging cameras are currently being introduced for use with automated enforcement systems and show great promise for their applicability to automated enforcement of red light violations.

Each approach to an intersection that is using automated enforcement will usually be equipped with one camera to record red light violations. If a need exists to photograph both the front and rear of a violating vehicle, a two-camera system must be used. An example of the need of a two-camera system would be an area where passenger cars only have a rear license plate and semi-trucks only have a front license plate. The higher cost of two-camera systems has limited the implementation of such applications.

Many different accessories are available with the three camera types used for automated enforcement systems. A variety of camera flash units used to provide special illumination needs and night-time photography and camera filters used to improve the quality of photographs may be incorporated into an automated enforcement system. The addition of flash units and camera filters is based on site specific requirements, such as the angle the sun hits the intersection and the reflectivity of vehicle license plates, and the financial limitations of the automated enforcement program.

The remainder of this section provides a general description of the three types of cameras and necessary equipment used for the automated enforcement of red light violations. A listing of companies that produce red light violation equipment is included in the Appendix of this report. Description of specific systems and problems encountered at specific locations is provided in Section 6, Applications of Automated Enforcement Programs.

35-mm Cameras

Thirty-five millimeter cameras are the most common cameras used for automated enforcement of red light violation systems. Most automated enforcement systems equipped with 35-mm cameras produce black and white photographs, but some systems may produce color photographs. Although black and white photographs are less expensive than color photographs, it is often difficult to tell which light is illuminated on the traffic signal. In Maryland, color photography is used to eliminate any doubt as to whether the traffic signal is actually red and the use of color photography has been found to be very acceptable by the courts.

The camera system is typically connected to both the traffic signal system controller and to loops or piezoe sensors (19). The traffic loops or piezoe sensors are placed in the pavement to detect on coming vehicles and determine vehicle speeds. Cameras are located in a special unit to protect them from the elements and vandalism and placed atop poles. Poles may be either hinged or contain specially designed "elevator" systems to allow access to the cameras. Figure 2 shows a schematic diagram of a red light automated enforcement configuration used in New York City (20).

In Figure 2, only the first three travel lanes next to the red light camera are equipped with loop detectors. Although vendors of automated enforcement technology will often claim that a single camera can enforce four through travel lanes, experience in New York and other areas has shown that reliable, accurate enforcement can only be performed on the first three travel lanes next to the red light camera. The loop detectors shown are also used only for the automated enforcement system. By having the loop detectors used only for the automated enforcement system, interference and conflicts with other detectors used for the traffic control system can be avoided.

When the traffic signal switches to the red phase, the camera used by the automated enforcement system becomes active (ready to take photographs). Vehicles traveling over the detectors while the camera is active signal the system to photograph the vehicle. A small period of time, referred to as a grace period, and a preset speed necessary to activate the system are usually allowed in order to differentiate between vehicles attempting to stop or turn right on red and vehicles that clearly are running the red light (19). A common grace period is 3/10 of a second and a minimum speed necessary to activate the system ranges from 15 to 20 miles per hour.

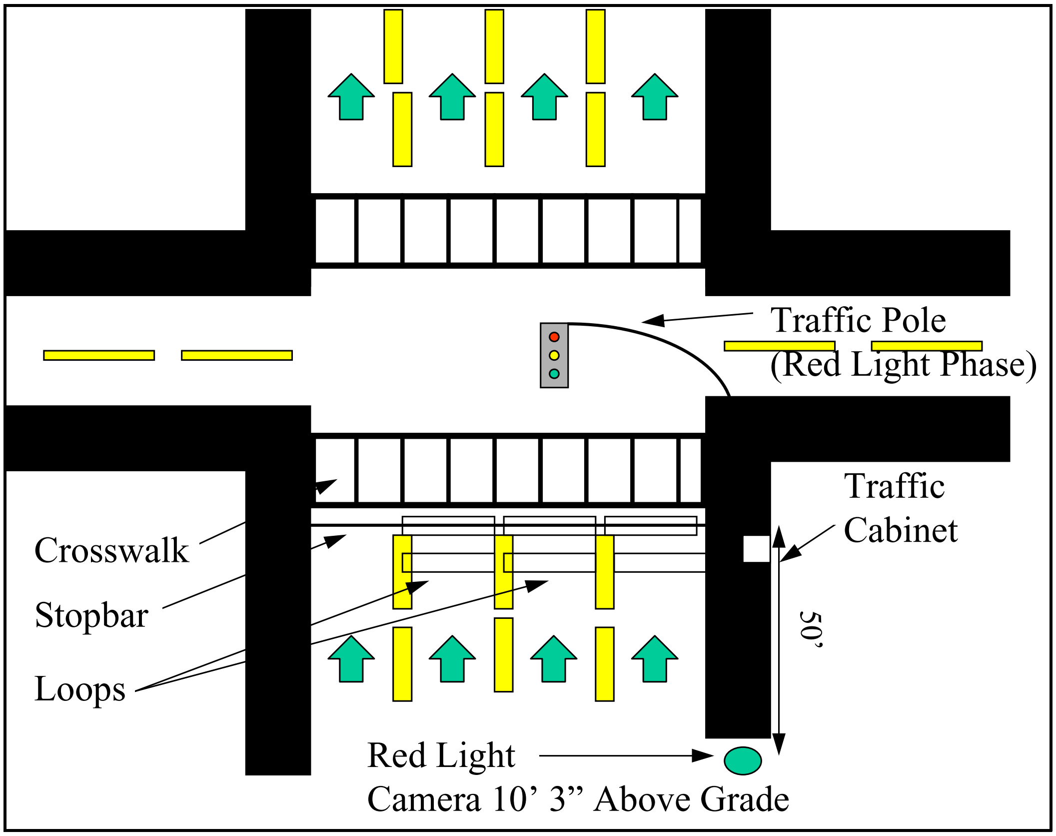


Figure 2. Automated Enforcement Configuration Used in New York City (20).

When the system is activated by a vehicle running a red light, at least two pictures are taken by the camera (21). The first picture shows that the front of the vehicle is not in the intersection when the traffic signal is red. This picture must show the pavement marking defining the intersection (usually the stop bar or the crosswalk), the traffic signal displaying a red light, and the vehicle in question . The second picture then shows the vehicle in the intersection a short time later (0.5 to 1.5 seconds). If driver identification is necessary, a third picture of the driver may be taken. From the pictures taken, the license plate will be magnified to allow for identification of the vehicle.

Two pictures taken by the automated enforcement system in Howard County, Maryland are shown in Figure 3 and Figure 4. The pictures shown were originally in color, but were changed to black and white for reproduction in this report. The magnification of the vehicle's license plate is not shown and all vehicle license plates are blurred for legal reasons. The position of the vehicle behind the stop bar while the traffic signal is red is shown in Figure 3. The first line of the "stamp" placed on the photograph (13^{36}, 02-01-97) is the time (military format) and date that the photograph was taken. The second line shows the length of the preceding yellow phase ($1Y4^{0}$) which was four seconds and the amount of seconds the traffic signal had been red ($R02^{1}$) which was 2.1 seconds. The photograph number (009) and a code for the intersection (0751) are listed on the third line.

Figure 4 is the second picture taken by the automated enforcement system showing the vehicle in the intersection while the traffic signal is red. The first line of the "stamp" placed on the photograph again shows the time in military format and the date the photograph was taken (13^{36}, 02-

01-97). The second line again shows the length of the preceding yellow phase ($1Y4^{0}$) which was four seconds and the amount of seconds that the traffic signal has been read ($R02^{7}$), 2.7 seconds. The photograph number (009) is again listed for matching purposes and the vehicle speed (V=53) in miles per hour is shown on the third line. By viewing the photographs shown in Figure 3 and Figure 4, it can be proven that the vehicle entered the intersection 2.1 seconds after the traffic signal turned red and proceeded through the intersection.

The placement of traffic loops or piezoe sensors is very important in determining the accuracy and success of the overall automated enforcement system. Because traffic loops and piezoe sensors have to be placed in the pavement, careful consideration of loop and sensor placement should take place. Extra costs and driver inconvenience associated with the need to adjust sensor locations can cause a program to be canceled before it gets a chance to become functional.

The ability of a system to photograph only red light violators is important in limiting the costs associated with each picture and the amount of resources needed to reduce the data collected by the cameras. The placement of traffic loops or piezoe sensors will often determine how many pictures will be taken by the system and the capability of the system to differentiate between vehicles accelerating to run the traffic signal and vehicles attempting to stop or turn right. In Pasadena, California several problems were experienced with a red light violation automated enforcement system. Ninety-five percent of the photographs taken by the system were of non-violating vehicles (22). The high rate of photographs was attributed to the improper placement of the loops which caused left turning vehicles "trapped" in the intersection making turns after the onset of a red signal and vehicles that would creep forward passed the stop bar to be photographed.

New York City had a similar problem at the beginning of its automated enforcement of red light violation program (21). Original design plans required only one loop per lane of moving traffic to be placed in a location to detect a vehicle before it entered the intersection. The placement of only one loop at the crosswalk required the use of speed/distance calculations to determine where the vehicle may have been "X" amount of time before the photograph was taken (21). The use of any calculation that did not provide absolute information was feared to be susceptible to court challenges.

During a mini-demonstration program using the single-loop configuration, the system photographed too many vehicles that were not committing a red light violation. A second loop was installed which allowed the criteria of a minimum speed to be added to the system before the camera took a picture. The reasoning in adding a minimum speed criteria was that by calculating the vehicle's speed, the system can determine if it is possible for the vehicle to stop before entering the intersection. The two loop system was successful in detecting red light violations and nearly eliminated the photographing of vehicles not committing violations.

Figure 3. First Picture Taken By Automated Enforcement System
(Courtesy of Howard County Police Department).

Figure 4 . Second Picture Taken By Automated Enforcement System
(Courtesy of Howard County Police Department).

A study completed in 1995 by Blackburn for the National Cooperative Highway Research Program identified six major manufacturers of red light violation detection systems (11). Fitzpatrick also listed the same six major manufacturers in research conducted at the Texas Transportation Institute in 1991 (22). Table 2 provides a listing of the red light violation enforcement systems identified in the research described above and the companies that manufacture them.

Table 2. Red light Violation Enforcement Systems Identified in Previous Research.

Company {Country} (Source)	Device	Sensor Type	Camera	Comments
Eltraff S.r.l. {Italy} (11,22)	Velomatic 103A	Inductive loops or coaxial cables.	Fujica FTIF	Attachments are used to convert Velomatic Speed Meter for use with red light violations.
[1]U.S. Public Technologies {United States} (23)	AutoPatrol RLL-200	Inductive loops or piezoelectric sensors.	TC-1000 Trafficam	Unit may be installed as a single unit, or in conjunction with a second camera to photograph both the front and rear violating vehicles. Cameras can be exchanged with other automated enforcement applications (rail crossings, speed enforcement) that use the same manufacturer.
Traffipax-Vertrieb {West Germany} (24)	Traffiphot III	Inductive loops.	Traffiphot III	System has the capability to take either rear or frontal photographs. System was field tested in New York City.
Trans-Atlantic Equipment {South Africa} (11,22)	Trafficam	Roadway rubber tube sensors.	N.S.	Rubber tube sensors have approximately the same thickness as a pencil.
Truvelo Manufacturers {West Germany} (25)	Truvelo Combi	Inductive loops or piezoelectric sensors.	Robot Motorrecorder 36DCE	System has the capability to take either rear or frontal photographs. Company has been producing automated enforcement technology for 15 years.
Zellweger Uster AG {Switzerland} (11,22)	Multafot	Inductive loops.	Jacknau	System can be installed to take either rear or frontal photographs. The system was field tested in New York City and Pasadena, California.

[1]U.S. Public Technologies is the United States representative of the Dutch company Gatsometer B.V.

The use of 35-mm camera units also have the advantage of being portable. Although each intersection has to be equipped with the necessary sensors and connections to the traffic signal field box, several housing units for the camera can be placed at intersections without a camera actually being in the unit. By having many housing units placed at different intersections, more areas per camera can be covered and drivers will not know which unit has a camera and which unit does not.

The Metropolitan Police in the United Kingdom apply the principle of rotation to its automated enforcement programs (26). The criteria for judging automated enforcement programs successful is a reduction in accident figures. To satisfy that criteria, 35-mm cameras are rotated with approximately one out of every eight of the 380 housings actually having a camera in it.

Video Cameras

Current technology would allow video cameras to be used as part of an automated enforcement program. When used with applications such as license plate recognition (LPR) to perform automatic vehicle identification (AVI), a central processing unit, and a storage subsystem to record information such as the date, time and location, video cameras will provide documentation in a very similar manner to 35-mm cameras. Video technology has not been used as frequently as 35-mm cameras for automated enforcement of red light violation programs because legislation and court precedence in many states does not support the use of video recordings as evidence (27).

The use of video cameras is very practical for jurisdictions that currently have laws forbidding the use of automated enforcement of red light violations and for areas seeking to establish a need for improved enforcement of red light violations. Intersections can be equipped with traffic surveillance video cameras that record the intersection when the signal changes to red. Recordings of an intersection by video cameras may be in either color or black and white, depending on how specific the data requirements are and the available funding for the project (black and white video cameras are less expensive than color video cameras). By recording intersections and viewing a large number of violations, evidence can be presented to officials about the severity of the red light running problem and a need for the implementation of programs addressing red light running can be established. The relatively inexpensive cost of traffic surveillance video cameras and the ability to move cameras to different locations with little cost will also give jurisdictions with a limited budget a means to begin a red light enforcement program that can be expanded to include automated enforcement using other types of cameras in the future.

Digital Cameras

Manufacturers of digital cameras are predicting new capabilities for automated enforcement of red light violation systems (26). Because the use of digital cameras is very new to the area of automated enforcement of red light violations, little information is available about field tests or implementations of digital camera applications. Although places such as Nebraska and Maryland are conducting or plan to conduct research using digital cameras, at the time this paper was written, results were not available (19,27).

Due to the lack of digital camera applications at the present time, information from manufacturers of digital cameras will be used to discuss their capabilities and potential (26,28). Digital cameras have the capability to produce higher resolution, more sharply detailed images of vehicles, and are equipped to prevent reflections or headlights from smearing the image. Photographs produced by digital cameras may be in color or black and white.

Along with producing better vehicle images, the major expected benefit of digital cameras is in improving the processing and distribution of notices of violation (tickets). Digital cameras have the capability to be linked using dedicated lines or existing phone lines to a computer located in a central facility. Once the images have been transferred from the digital cameras to the central facility, pattern and optical character algorithms can be used to determine the owner of the vehicle by cross-referencing the license number with records of vehicle registration databases (28). Once license plate numbers are successfully matched with registered vehicle owners, tickets can be automatically processed and mailed to violators.

The automation of image retrieval, violator identification, and ticket processing streamlines the traditional practice of having to have personnel to remove the film from the cameras, develop the film, run license plate matching algorithms, and prepare and mail tickets. The automation of the processing system that the use of digital cameras permits allows for a savings in the number of personnel needed and also eliminates potential errors made by humans when evaluating and handling the pictures manually. Because the pictures produced by digital cameras are created in a format that can be viewed on a computer screen, the need to have personnel to scan traditional photographs into a computer format is also eliminated. This allows more clear images to be produced and reduces the amount of time necessary to prepare images to be shown on monitors in the court room.

The configuration of digital camera applications will be very similar to the one described for applications using 35-mm cameras. As with 35-mm cameras, digital cameras will be placed in protective housings atop poles. Sensors will be placed in the pavement in the same manner as for 35-mm applications, with two sets of sensors per lane to detect vehicle presence and speeds. The cameras will be wired to the signal controller and the loop sensors so when the signal turns red, the system becomes active. When a vehicle traveling over the allowed range of 15 to 20 miles per hour crosses the sensors, two pictures will be taken. Again, the first picture will be before the entrance to the intersection, usually the cross-walk or the stop bar, and the second picture will be a preset time later, usually 0.5 to 0.9 second later, with the vehicle in the intersection.

Ticket Processing

Computer software packages have been developed or are being developed to assist in the processing and creation of notices of violation (tickets). CITEWARE is a Windows™ based program created by U.S. Public Technologies (USPT) that is designed to be a cost-effective way to process the photographs taken by automated enforcement cameras (23). After the film from the cameras is developed, it is scanned into the program. Once the film is scanned into the program, an operator enters the enlarged picture of the vehicle's license plate and a match of the registration is made using motor vehicle records or other databases. CITEWARE prints the ticket and records the violation so that it can easily be accessed if it is challenged in Court.

CITEWARE also has the ability to generate a statistical analysis of the automated enforcement program. This feature is very useful in measuring the effectiveness of the program and providing interested people (government officials, news media) with detailed information about the program.

STUDY DESIGN

In order to provide current information and fill voids that were present in the existing literature, a survey of state and local jurisdictions with experience using automated enforcement systems in the United States was conducted. The survey was completed through a combination of telephone conversations and fax transmissions. Five of the six areas contacted completed the survey. Survey questions sent to individuals associated with automated enforcement programs for red light violations included the following questions:

1. What type of automated enforcement technology is your organization using and who was the manufacturer of the equipment? How long has the system been in operation?
2. Have there been any operational problems associated with the location of the system, the effects of glare at certain hours of the day, inclement weather, the type of camera being used, the visibility of the camera at intersections, or other factors? If so, please describe.
3. What was the cost of the system? Was the system purchased, leased, or given to the agency in exchange for a percentage of the fines collected?
4. How does your agency process citations? Does your agency use computer software packages (i.e. CITEWARE) for the purpose of license plate identification? Did additional staffing take place as the result of automated enforcement?
5. How much enforcement is done using automated enforcement in relation to how much is done using traditional enforcement methods? (e.g., 30% automated enforcement vs 70% with police officers; 6 automated locations vs 200 enforcement officers)
6. Has a reduction in red light violations occurred since the initiation of the automated enforcement program? (e.g. 30% reduction)
7. Were there any political or social issues that arose due to the use of automated enforcement? Was any legislation required to initiate or operate the red light automated enforcement technology? Was any legislation changed in regard to how red light violations were classified (e.g. civil infraction, misdemeanor offense, vicarious liability provisions)? If so, please describe the required legislation and the process to have the legislation enacted.
8. Were any attempts made to educate or inform the court system about the effects of red light violations on accidents or the public benefits of an automated enforcement program? If so, please describe.
9. Were any attempts made to educate or inform the public about the effects of red light violations on accidents or the public benefits of an automated enforcement program? Are advanced notice signs required at intersections using automated enforcement? If so, please describe.

Little information is available describing the methods used by police officers to enforce red light violations and the emphasis that is placed on red light violations. To gain an understanding of the issue of red light violations from a law enforcement perspective, a small survey of police officers was performed. From the five police departments that were contacted, three completed the survey. The survey was completed through a combination of personal interviews, telephone conversations, and fax transmissions. Survey questions sent to police departments included the following questions:

1. What emphasis, high or low, do you place on enforcing failure to stop at red signals (exclude right-turns on red) and why?

2. What percent of citations issued during the past 6 months were for driving through a red traffic signal? Please distinguish between violations of right-turns on red and other violations.
3. Are officers specifically assigned the task of enforcing traffic signal compliance? If yes, what prompts the assignment: complaints, patterns of high crashes, or special grants?
4. How many officers are normally assigned to enforce red light violations?
5. How many minutes, on the average, does an officer spend enforcing a red light violation from the time of detection, until the officer is finished handling the violator?
6. How many minutes, on the average, are spent by an officer preparing for and attending court for a simple traffic law violation, such as a violation of a red traffic signal?
7. What percent of citations for disobeying a red signal are challenged in court? What percent of these violations are dismissed or found not guilty by the court? What is the most common reason for violations being dismissed or an individual being found not guilty?

Contacting individuals knowledgeable about the use of automated enforcement technology for red light violations also resulted in the accumulation of materials relevant to the subject area such as journal references, newspaper articles, and actual photographs from automated enforcement systems. Information was also collected using the following methods:

- Meetings with members of the Institute of Transportation Engineers (ITE) technical committee on automated enforcement;
- A computerized literature search by the Transportation Research Information Service (TRIS);
- A search of the world-wide-web; and
- Telephone conversations with automated enforcement technology vendors.

The results of the surveys, conversations with individuals knowledgeable about automated enforcement, and the information obtained were incorporated into this report and were used to develop the strategies for implementing an automated enforcement program for red light violations and developing the hypothetical case study used to apply the implementation strategies.

APPLICATIONS OF AUTOMATED ENFORCEMENT PROGRAMS

This section reviews applications of automated enforcement of red light violation systems. The section begins with a review of applications from the United States located in New York City, New York, Polk County, Florida, Howard County, Maryland, San Francisco, California, and Lincoln, Nebraska. The review of applications focuses on public relations and involvement, the type of legislation proposed or enacted to accompany deployment, the technology being used, operational issues that arose from the use of the technology, and the results of the automated enforcement program.

Applications abroad from Ontario, Canada, and Victoria, Australia are also reviewed in this section. Although information for these applications is not as detailed as for the applications in the United States, the information that is provided is very valuable in presenting details and issues that should be addressed when creating and implementing a program for the automated enforcement of red light violations. This section combines information derived from the literature review and telephone interviews and surveys completed by individuals from both the transportation profession and law enforcement profession knowledgeable in the area of automated enforcement for red light violations.

New York City, New York

New York City has the oldest and currently the largest automated enforcement of red light violation program in the United States. The program began operation in 1993 and is installed at 18 intersections. The Chief of the Red Light Camera Program for New York City, Rudolph E. Popolizio, has also published several articles detailing many aspects of the system. The New York City Department of Transportation (DOT) began researching red light camera technology in the early 1980s in an attempt to become educated about the programs being used in Europe and Australia (21).

The primary guideline in establishing an automated enforcement system for red light violations was that the system had to operate in a stand-alone mode that did not interfere with any existing vehicle summonsing or tracking procedure (21). This guideline was viewed as essential because of the need to track each notice of liability and the revenue that was produced. By making the system self-sufficient and trackable, officials reasoned that the number of administrative errors would be reduced and the revenue from the system could be carefully reviewed and recorded.

The contract for the automated enforcement program between New York City and Electronic Data Systems (EDS), the technology vendor, stated that the program would operate "at no cost to the City". The contract was based on the premise that the revenue gained from the payment of violations would offset the costs paid by the city for the system. A contract of $8,440,000 was agreed upon with the City adding a cost of $5,460,000 for operations bringing the total cost for the three and a half year contract to $13,900,000.

Public Involvement

No efforts were made to educate or inform the public about the effects of red light violations on accidents. The use of automated enforcement for red light violations was also not publicized and advanced notice signs at intersections using automated enforcement technology are not required.

Legislation Enacted

Before the Request For Proposal (RFP) could be advertised, a state law had to be enacted allowing for the use of automated enforcement technology for red light violations. When considering whether to use frontal photography to identify drivers or to use rear view photos, the issue of driver privacy lead to the decision to pursue only rear photography (21). The use of rear photography meant that the violation would be classified in the same manner as a parking ticket. By classifying the violation as a non-moving violation, the enacted legislation had to place responsibility for the violation on the registered owner of the vehicle.

The law passed by the State of New York allowed any city with a population of over one million people to implement and operate a demonstration project limited to 50 intersections using automated enforcement technology for traffic control violations (29). The law contained the provision that the owner of the vehicle would be held responsible for violations recorded by automated enforcement systems, but that the violation would not be a conviction against the owner and would not become part of the owner's operating record. Provisions allowing for notices of liability to be mailed, the owner of the vehicle to be assessed a monetary fine, and the owner of the vehicle to contest the violation were also contained in the law.

A "Sunset Provision" that places a time limit on the program is also written into the legislation. This provision states that the legislation will expire on a specified date unless it is extended by state legislation. The first date for expiration was December of 1996. The legislation has been extended and the expiration date currently stands at December of 1999.

Technology

The company that manufactured the technology used in New York City was Traffipax-Vertrieb from Germany. The camera used for the system was the Robot 35-mm camera. As described previously in Section 4, Technology, and shown in Figure 2, two loops per lane were placed in the pavement, a three tenths of a second (0.3 sec) buffer was allowed, and the minimum speed criterion of 15 miles per hour for vehicles to be photographed was included in the system.

Although cameras have shown some wear, the replacement of gears, bushing rings, and flash units on all the cameras have solved this problem (21). No effects from climate were found on the cameras from winter operation. Modifications to the software used to process violations and track notices of violation have also been made when necessary without disrupting the operating system.

Data Processing

In order to process the information obtained from the automated enforcement system, people were hired to form a photograph viewing staff and additional employees were hired to the adjudicating staff. The photograph viewing staff is responsible for viewing the photographs taken by the system, determining if the photographs are of the quality needed, and preparing notices of violation to be sent. The adjudicating staff is needed to give the public the opportunity to appeal the violations. Because of budget constraints, only one help center, located in Manhattan, is open exclusively for the automated enforcement program. When the program expands, it is expected that more centers will be opened throughout the city.

Operational Problems

The presence of parking lanes affected the ability of cameras to provide a clear picture of intersections (21). Double parked trucks also blocked the view cameras had of intersections. To combat the problem of the intersections being blocked, the cameras were placed on large "mast arm installations" that were sixteen feet high and extended out about eight feet from the curb. This was in contrast to the standard camera set-up that was ten feet in the air and two feet from the curb.

Glare produced from the flash of the cameras has also presented some problems with photograph clarity. To combat this problem, different flash intensities and configurations are being researched. Short term glare problems from rain at night are also a problem.

Program Results

Violations at intersections using automated enforcement technology have decreased by 20 percent since the program was initiated. Statistics about the program show that 65 percent of the violators pay the fine in response to the first notice of violation that is sent. The revenue that was collected during the three year period, $18.5 million, was also greater than the $15.5 million total cost of the project over the three year contractual period.

The success of the program has lead to the extension of the legislation enabling the use of automated enforcement for red light violations. New York City also plans to expand its program by 12 cameras in the near future.

Polk County, Florida

Polk County, Florida began using automated enforcement technology for red light violations in September of 1994 as part of a Federal Highway Administration (FHWA) demonstration project. Systems were placed in Fort Meade, Haines City, and Lakeland. The demonstration was conducted in different environments that included a multi-lane divided highway with heavy concentrations of through traffic, a heavily traveled downtown corridor, a medium size city, and a small rural community. The cameras for the system were leased or placed on loan from the FHWA (9).

Public Involvement

As part of the automated enforcement campaign, a public education program was initiated. The program was funded by the FHWA and followed the suggestions given in the Red Light Running Program Strategic Planning Guide (6). The goal of the program was to reinforce the problems and dangers associated with red light running. Advanced warning signs were placed prior to intersections where automated enforcement cameras were being used.

Legislation Enacted

Florida does not currently have a law which permits the issuance of citations for automated enforcement of red light violations. Legislation has been introduced for five successive sessions of the legislature and has not been successfully enacted. Warning letters are mailed to drivers who are caught running red lights by automated enforcement systems.

Technology

Three vendors originally participated in the demonstration project started in 1994. American Traffic Systems of Scottsdale, Arizona, U.S. Public Technologies of San Diego, California, and Truvelo of South Africa were all assigned location in the participating cities. Currently, only the Truvelo system is still in place. Cameras photograph vehicles from the front and rear and record the time, date, speed, lane location, time since the light was red, and photo identification number (30).

Data Processing

Data processing was completed by members of the County's automated enforcement program. Information to identify violators is obtained by manually matching photographs of license plates with records from the state department of motor vehicles. Additional staffing took place on a temporary basis to assist in processing information and preparing and mailing warning notices. Volunteers were also utilized to assist in data processing.

Operational Problems

Overall, the cameras have performed in a satisfactory manner (9). Because Florida has a high volume of tourist and winter resident population, many different license plate colors and configurations from different states are present. The presence of so many different types of license plates has made it difficult to set the filters to handle the different reflectivity and configuration characteristics. Although the presence of many different types of out-of-state license plates has made the process of vehicle identification difficult, violations are sent to vehicle owners that are able to be matched with registration records. Florida has also experienced some problems with large trucks in the lane closest to the camera blocking the camera's ability to clearly photograph the intersection.

Program Results

Statistics are not currently available concerning if a reduction in red light violations has taken place since the initiation of the automated enforcement program. Because legislation has yet to be passed allowing for the issuance of monetary fines, only warning notices can be mailed to violators. The project has served to heighten awareness among the motoring public about the problems associated with red light running and the increased risk of apprehension at the four intersections (9).

Howard County, Maryland

The State of Maryland has identified vehicles running red lights as a serious problem that must be addressed. The percentage of accidents in which running a red light was listed as the primary cause has increased steadily since 1983 (7). Running a red light is the reported cause of between 3,500 and 4,500 traffic accidents annually, with 20 to 30 of those crashes resulting in at least one fatality (7). In Howard County, Maryland, the Police Department receives the most frequent complaints about traffic violations with citizen concerns about vehicles running red lights being one of the top two reoccurring themes (31).

As discussed in Section 2, Background, the Maryland State Highway Administration joined with State and local law enforcement agencies to address the dangerous increasing trend in red light violations by using the team enforcement method (7). Although the team enforcement concept was successful, it was also very expensive. A recent cost analysis conducted by the Police Department showed that the team enforcement approach resulted in a personnel cost of $25.40 for every red light violation citation issued (31). Experience has also shown that only frequently repeated enforcement efforts have a positive impact on reducing the number of observed violations.

Due to the high cost of the team method and the need for frequent enforcement of intersections, Howard County began exploring other means of enforcement. Through funding granted by the Federal Highway Administration, Howard County field tested two cameras from March of 1996 to March of 1997. Because Howard County wanted to know the true capabilities of the system and the maintenance and manpower associated with operating an automated enforcement system, the decision was made to rent the cameras and equipment only and not to contract out the duties of film loading, unloading, and developing and the issuing of warning notices.

Public Involvement

A significant public awareness and education program was conducted as part of the effort to make drivers aware of the danger posed to both other drivers and to the driver who runs the red light. The television ads and the radio announcements were created by a professional ad firm. To get the message out to many people, the ads were run during major events. An example of this effort was the fact that television ads were run during the National Football League conference championship games. Volvo also participated in the public education/awareness effort by running short announcements about the dangers of red light running at the conclusion of each of its commercials.

The possibility of using automated enforcement technology to enforce red light violations has also been covered by the media and advertised during the camera test period. Signs were posted on roadways that contained cameras, but the exact location of the intersections was not publicized. Many editorials have been sent to newspapers showing strong support for the use of cameras to combat the problem. During the test period, warning notices were sent to vehicle owners informing them that they had committed a violation and showing the photographs taken by the cameras. The warning notices also contained a phone number to address concerns or questions about the program and during the test period reaction to the system was very positive.

The goal of the public education/awareness programs was to change peoples' opinions about the enforcement of red light violations. In a questionnaire issued in 1996, Howard County residents were asked the question: "Out of 100 drivers who run a red light in Howard County, how many do you think will actually be stopped or ticketed by the police?" The majority of the people responded with an answer of two or less people would receive a citation for the violation (31).

Legislation Enacted

An attempt was first made in Maryland to pass a statewide law without a Sunset provision that allowed for the mailing of violations to drivers. Although the bill passed through the House Committee, it failed in a general House vote. A similar bill also failed in Committee of the Maryland Senate. According to a Howard County official, the reason that the bills failed is because the effort to pass the bills was not unified and counties were not aware that the bills were being considered (19).

House Bill 391 allows for the use of automated enforcement technology for red light violations effective October 1, 1997. The Bill states that "the owner of a motor vehicle is subject to a civil penalty if the motor vehicle is recorded by a traffic control signal monitoring system" (32). A traffic signal monitoring system is defined as "a device with one or more motor vehicle sensors working in conjunction with a traffic signal to produce recorded images of motor vehicles entering an intersection against a red signal indication". House Bill 391 also allows for citations to be mailed to offenders and does not contain a Sunset provision. The Bill establishes that the registered owner of the vehicle will be held responsible for the violation and that rear photography of the license plate will be used. Also defined is that the civil penalty may not exceed $100 and that citations must be mailed within two weeks of the alleged violation (32).

Technology

The technology being used is manufactured by Gatsometer B.V. and the specific camera being used is a Robot Industrial High Speed Camera with a 100 foot film pack. U.S. Public Technologies is the representative for Gatsometer B.V. in the United States. The sensor configuration and location is very similar to the configuration used in New York City where two loops per lane were placed in the pavement, a three tenths of a second (0.3 sec) buffer was allowed, and the minimum speed criterion of 20 miles per hour for vehicles to be photographed was included in the system.

Data Processing

The Police Department had the responsibility of operating the cameras, processing the film, and preparing notices of violation. It was possible to assign the Police Department with those tasks because of the small nature of the demonstration project (only two locations). Even with the small nature of the project, data quickly accumulated and the need for a formal processing technique became evident. Research is being conducted by the Police Department to determine how to best process violations for future programs. It is believed that portions of the data processing task will be contracted out, but that the Police Department will still have a role in determining what constitutes a violation.

Operational Problems

The major problem with the use of the automated enforcement system involved glare from the highly reflective Maryland license plates affecting the quality of the photographs taken from the camera. Glare presented the most significant problems in the winter time with lower angles of the sun hitting the plates and at night. Glare also affected many of the photographs because of the equipment being used in Howard County to identify vehicle license plates. In Howard County, the license plates were being magnified for clarity, whereas the technology exists to use equipment that can change the contrast of the photograph to make the license plate more clear.

Servicing the cameras also presented a significant problem for the program. Being responsible for the operation and maintenance of the cameras and for the loading, unloading, and processing of the camera film was very manpower intensive. Many work hours were also spent matching violations and preparing and mailing notices of violation.

Program Results

Although only warnings were issued in the notice of violations that were mailed to drivers who ran red lights, a significant decrease in the number of violations at intersections equipped with automated enforcement technology resulted. Before the public was made aware of the automated enforcement technology and its purpose, the system was used to gather information about the number of violations occurring at the study intersections. Analysis of the data collected at the study intersections showed that the number of violations remained relatively constant from Monday through Friday with one intersection experiencing approximately 90 violations a day and the other intersection experiencing approximately 24 violations a day. The combination of mailing warning notices to violators and the public education and awareness campaign resulted in a reduction in the number of violations from 90 to 60 per day and from 24 to 18 violations per day. Overall, a 23 percent reduction in the number of violations took place (33).

The positive results of the demonstration program and the passing of legislation allowing for the issuing of notices of violation that fine the owner of vehicles that are photographed running red lights has led Howard County to plan on expanding its automated enforcement program. An unsolicited proposal by the Federal Highway Administration has also been answered by Howard County to test the capabilities and limitations of digital cameras for use with other automated enforcement technology.

In planning for the future installation of automated enforcement technology, Howard County is taking steps to ensure that the resources it dedicates to the program will be used in the most efficient manner. Intersections that are candidates for the use of automated enforcement technology to record red light violations include intersections with a high accident rate, locations where public complaints are high, and intersections where highly publicized accidents have occurred. Traffic engineers determine if engineering factors (poor signal timing, bad intersection geometry, limited sight distance) are the cause of high accident rates or if the accident history is the result of red light violations.

San Francisco, California

The city of San Francisco, California estimates that red light violations cause approximately 1,000 reported accidents annually which account for nine percent of all reported accidents and 17 percent of all reported accidents where an injury occurs (34). A conservative estimated cost to the city for the accidents that result from red light violations is $21 million. In enforcing red light violations, the San Francisco Police Department issues over 15,000 citations annually.

In 1996, San Francisco initiated a pilot study to determine the feasibility of using automated enforcement technology to combat the problem of red light violations. Three vendors were invited to compare and contrast the different types of technology and methods used for processing tickets and tracking violations. One vendor quickly declined to proceed, and the two vendors that participated in the program were EDS and US Public Technologies. Currently, US Public Technologies is the only vendor participating in the project.

Public Involvement

In addition to addressing the frequency and costs of the red light running problem in San Francisco, the use of automated enforcement technology to enforce violations resulted from public outcry over a particular incident. The incident involved a vehicle that ran a red light and smashed into a group of people waiting at a bus stop. Several fatalities resulted from the incident and intense pressure was placed upon politicians to address the problem of red light violations.

The high profile accident resulted in subsequent incidents involving red light violations to be magnified. A large scale public education campaign was begun to inform drivers about the dangers of running red lights. The education campaign included billboards, radio announcements, and the creation of slogans such as “RED Means STOP” to draw public attention to the issue.

The initiation of the automated enforcement program received mostly positive coverage from the newspapers and local television news stations. To test the system and make drivers aware of the program, warning notices showing drivers committing a violation were mailed. Street signs placed in advance of intersections are also required to let the public know that automated enforcement technology is being used at that specific intersection. Figure 5 shows a warning sign placed before intersections (35).

Legislation Enacted

The State Legislature amended the California Vehicle Code in 1996 (SB833) to permit the use of “automated enforcement” for red light violations (34). In amending the California Vehicle Code, the attitude of the State Legislature was that red light violations are a very serious problem and have to be addressed as such. The seriousness of the problem and the political atmosphere resulting from recent fatalities caused the Legislature to decide that red light violations had to be judged as moving violations so that fines could be issued and points could be added to a driver’s record.

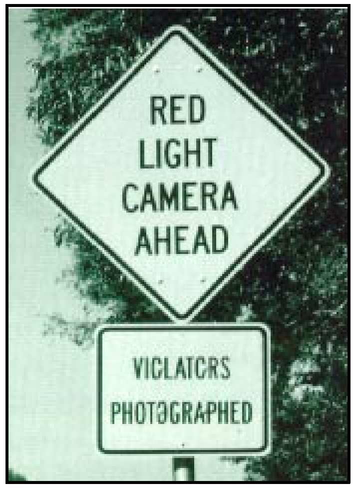


Figure 5. Warning Sign (36).

The decision to enforce red light violations as a moving violation required that the driver of the vehicle be positively identified. To identify drivers using automated enforcement, frontal photography had to be used. Once a driver is positively identified, the Police Department signs the violation and it is mailed to the violator. The violation has to be mailed 15 days from the date of the violation. If a driver does not respond to the violation, the Department of Motor Vehicles is contacted and instructed to withhold the issuance or renewal of the driver's license.

The original amendment to the California Vehicle Code in 1996 (SB833) allotted \$17.50 from the fine of \$104.00 to the vendor as compensation for the cost of the cameras, film and citation processing, statistical and data analyses, and follow-up court liaison and support (36). In order to expand the current automated enforcement program of four locations, legislation is currently before the State Senate to increase the fine to \$271.00 for the violation of a red light. Assembly Bill 1191, commonly referred to as the Shelley Bill, has been approved by the State Assembly and its enactment is viewed as essential for funding future automated enforcement efforts.

Passage of the Shelley Bill will allow for the revenue received from the automated enforcement program to be distributed in a more balanced manner between the State, County, and City. Specifically, \$80 per violation will be set aside for the purpose of furthering the automated enforcement program which will be expanded by approximately 25 intersections (34). It is also believed that the increase in the fine and the publicity generated by the increase will serve as a further deterrent to running red lights. A previous measure in San Francisco of raising the fine imposed on motorists parking at bus stops to \$250 was very successful in reducing violations (37).

Technology

As stated previously, two vendors, Electronic Data Systems (EDS) and U.S. Public Technologies, Inc., initially provided the technology for the project. Currently, only U.S. Public Technologies is involved with the project. The technology being used is manufactured by Gatsometer B.V. and the specific camera being used is a Robot Industrial High Speed Camera. The sensor configuration and location is very similar to the configuration used in New York City where two loops per lane were placed in the pavement, a three tenths of a second (0.3 sec) buffer was allowed, and the minimum speed criterion of 15 miles per hour for vehicles to be photographed was included in the system.

Data Processing

The legislative requirement that vehicle drivers must be positively identified using frontal photography in order for a violation to be sent makes the task of data processing very important and very labor intensive. In order to identify drivers, photographs of the driver and the vehicle license plate must be matched against Division of Motor Vehicle (DMV) records. In San Francisco, the vendor, U.S. Public Technologies, is responsible for determining, matching, and printing out violations. To assist in this process, U.S. Public Technologies developed the software package CITEWARE that allows for a more efficient issuing of citations.

The small number of cameras installed for the demonstration project has not resulted in staff increases. Should the Shelley Bill become law, additional staffing of the department of traffic, municipal court, and police department will be necessary to handle the large number of violations that will be recorded as a result of program expansion.

Operational Problems

Several factors have limited the effectiveness of the photographs taken by the automated enforcement cameras. Statistics show that about 20 percent of the photographed violations cannot be matched with vehicle records because the vehicles do not have front license plates (38). Although San Francisco law requires vehicles to have a front license plate, the law is rarely enforced. An additional 10 to 15 percent of the photographed violations are also not matched because the photographs are affected by glare.

The requirement of frontal photography for driver identification also poses several problems. The use of sun visors and the location of rear-view mirrors in vehicles can prevent the identification of drivers. Gender differentiation has also been very difficult in identifying drivers. Other problems associated with the automated enforcement program include:

- Low quality photographs resulting from the very reflective California license plates;
- Difficulty identifying the driver using night time photography; and
- The inability of the system to operate in the fog (especially near the ocean).

Program Results

The number of vehicles photographed running red lights at intersections using automated enforcement technology has dropped by over 40 percent since police started issuing citations in October of 1996 (34). The 40 percent decrease in violations was calculated using data collected by the automated enforcement system (38). A ratio of the number of vehicles photographed running the red light to the number of vehicles proceeding through the monitored approach (obtained from vehicles passing over loops) is taken for each intersection included in the program and averaged together at the end of each month. At the end of a six month period (in this case from November of 1996 until the end of April 1997) , the averaged ratio of violators to through vehicles for the first month (November) is compared to the averaged ratio for the sixth month (April) to determine the percent reduction of red light violations.

Approximately 30 percent of all violations that are photographed by the automated enforcement system are matched with a driver and result in the issuing of a citation. Of the citations that are issued, 42 percent of the people elect to pay the fine, 30 percent opt to attend traffic school (still have to pay the fine, no points assessed to drivers license), 18 percent are dismissed from court (mostly by claiming they are not the person in the photograph), five percent try to dispute the violation but are found guilty, and five percent of the people cited do not respond (38).

The reduction in vehicles running red lights at intersections with automated enforcement systems has lead officials to submit a request for proposal (RFP) to expand the program by at least 20 intersections by early 1998. The passage of the Shelly Bill will allow San Francisco to continue to operate and expand its automated enforcement program. In an attempt to expand the enforcement capabilities of the program, legislation placing responsibility for red light violations on the owner of the vehicle when the driver cannot be identified is being considered. The violation for drivers that can be identified would remain a moving violation with points being assessed to the driver's license, while the violation when drivers of the vehicle cannot be identified would result in the owner of the vehicle receiving a nonmoving violation that does not assess points to the driver's license.

Lincoln, Nebraska

The automated enforcement system in Lincoln, Nebraska was operational from January of 1997 to April of 1997. The purpose of the system was to collect data only and funding to purchase the system came from the State Department of Roads and the Mid-America Transportation Center at the University of Nebraska. Although the system was intended to only collect data, the high visibility of the cameras resulted in the public being unsure of their purpose. Many people thought that the cameras were being used to identify and ticket violators (39).

Public Involvement

Officials in Lincoln had become increasingly concerned over the number of red light violations that were occurring in the city. To make the public more aware of the severity of the problem and the danger that running red lights presented, a public awareness campaign was initiated. The campaign consisted of public service announcements on television and on the radio and the use of billboards. The intention of the program was to educate the public about red light violations, not to inform them about the use of automated enforcement technology.

Legislation Enacted

Legislation allowing for the use of automated enforcement technology for the purpose of enforcing traffic violations is currently pending in the Nebraska Unicameral (LB 881 - Nebraska Rules of the Road). Under the legislation, the registered owner of the vehicle is held responsible for violations detected from automated enforcement technologies. The original legislation contained a provision allowing the registered owner of the vehicle who claimed that he/she was not driving the vehicle to file an affidavit which identified the driver of the vehicle. By filing the affidavit, prosecution of the registered owner was prohibited. This provision was removed by the adoption of an amendment (40).

Technology

The technology used consisted of purchased video cameras that were configured and installed by the research staff. The video cameras are manufactured by Cohu, Inc. and were purchased from Ruyle and Associates. For this system, no loop detectors or sensors were placed in the pavement. Instead, the video cameras were mounted on the street light poles to capture an overhead view of the traffic lanes as was recommended by previous studies using similar technology (39).

The goal of using the video cameras was to measure the elapsed time when vehicles entered the intersection after the onset of the yellow/red phase and to measure the average speeds at which those same vehicles went through the intersection (39). In order to avoid using two cameras per approach and still be aware of when the signal had changed from yellow to red, the recording unit was located in the signal control cabinet and connected to both the camera and a DC driven logic board that was also located in the signal control cabinet. Each time the signal changed, a sound signal was emitted (a different pitch was emitted for each signal termination) and recorded by the video recorder through the sound input port. A time/date generator was also connected to the video recording unit to stamp the time and date at the bottom of the video display. Figure 6 shows a diagram of the system used.

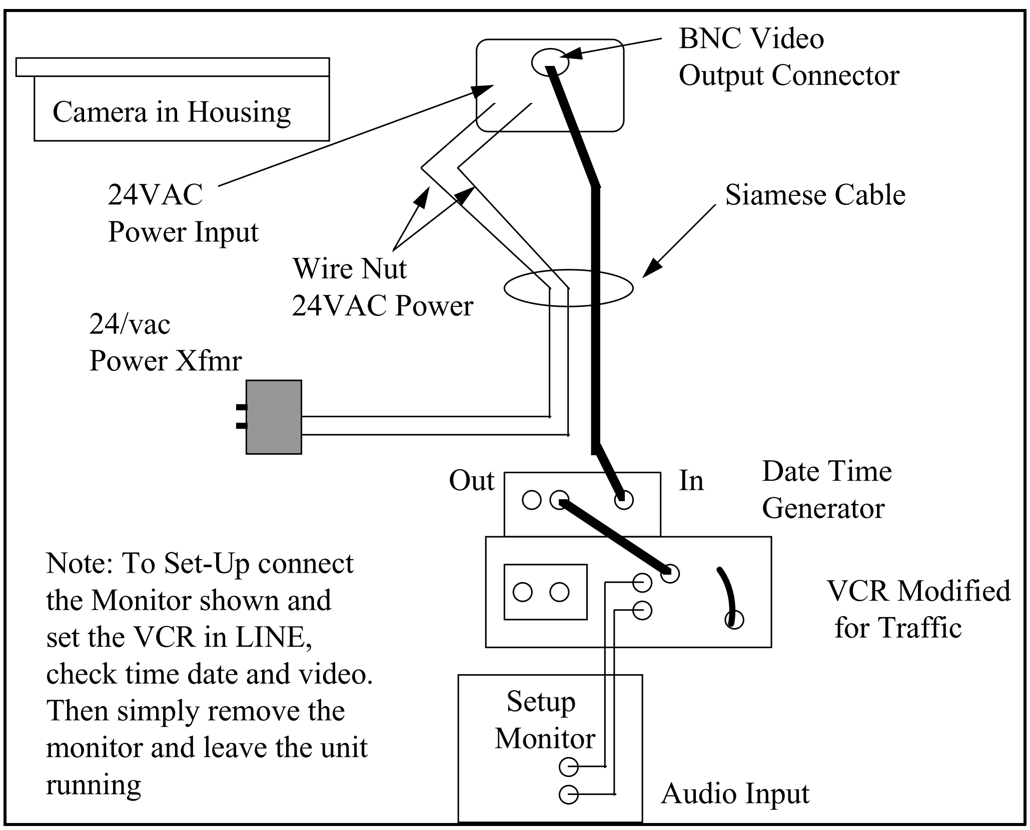


Figure 6. Video Equipment Configuration Used in Nebraska (39).

Data Processing

Data was collected at each of the six study sites during the morning peak period (7:00 am to 9:00 am), the off-peak period (11:00 am to 1:00 pm), and the afternoon peak period (4:00 pm to 6:00 pm). Because of the number of cameras purchased, data was collected for three intersections at a time. At the beginning of each study period, a member of the research team had to activate the system, insert a blank video tape, and turn the recording unit on, and at the end of each session the video tape had to be retrieved and the system was shut off. In order to extract the desired information from the video tapes, an observer had to carefully view the tapes and record several observations.

Operational Problems

Several problems occurred with both the installation and operation of the video camera system. Because the system was installed in January, problems were encountered getting the necessary wires through conduits that were blocked by ice and a concern over the ability of the recording equipment to operate in low temperatures also existed. To ensure that the video recording system would not have to operate in low temperatures, a 300 watt light was added to the field cabinet to produce heat.

Glare problems that did not allow references points to be visible on the tape were also experienced by the system. Glare was especially a problem when recording east-west approaches. Problems with other weather related elements were not documented because the cameras were only operated during dry pavement conditions.

Program Results

Although preliminary results of the study have shown a significant decrease in the number of red light violations (as compared to manual counts performed before the installation of the camera) at intersections where the cameras are present, final conclusions about the study have not been made. The preliminary results of the study have gained the attention of police departments in the area. With the pending passage of legislation enabling automated enforcement for red light violations, police departments are currently researching the possibilities of investing in an automated enforcement system that can issue violations. Research on the use of digital cameras for several applications is also being conducted.

Ontario, Canada

Political Issues

Ontario, Canada began using automated enforcement technology for speed limit violations in 1994 (41). The Highway Traffic Act, which allowed for the use of automated enforcement technology to enforce traffic violations, contained provisions that stated that the government had to approve of the areas where automated enforcement could be used. The use of automated enforcement technology for speed limit violations was not popular with the public and received mixed reviews in the media.

Due to the unpopularity of the use of automated enforcement technology for speed limit violations, a group opposing the acting government in the upcoming political election included the position that automated enforcement programs would be stopped if they won the election. When the group won election in 1995, they quickly revoked the power of the Highway Traffic Act by not approving of any areas for the use of automated enforcement. This action eliminated the possibility of using automated enforcement technology for red light violations.

Victoria, Australia

Australia has used automated enforcement technology for red light violations since 1979 (1). In Victoria, automated enforcement systems were installed to reduce the number of collisions occurring as a result of motorists running red lights (42). The program began with a six month demonstration period in 1981 and was implemented in August 1983 when the Road Traffic Authority purchased ten cameras to be used for an automated enforcement program. Currently, the automated enforcement program for red light violations incorporates 35 cameras that are rotated through 132 sites throughout the Melbourne metropolitan area.

Technology

The technology being used in Victoria is manufactured by Gatsometer B.V. and the specific system is the Type 36 MSG (42). The sensor configuration of the system uses vehicle detection induction loops that are set in the pavement. The loops are placed as close as possible to the stop line, usually between the stop line and the first pedestrian crossing line.

The system becomes active when a vehicle crosses a loop 0.9 seconds after the traffic signal has changed to red. When a violation is detected, two photographs are taken one second apart. The first photograph is taken of the rear of the vehicle as it crosses the sensor and the second photograph shows if the vehicle stopped or if it continued through the intersection.

Data Processing

After unloading the film from the camera, a police officer seals it in a secure bar coded canister and takes it to the Traffic Camera Office (T.C.O.). The T.C.O. forwards the sealed canisters to a photographic laboratory for the photographs to be developed and printed and then reviews the photographs to ensure that no interference with the pictures took place. Details from the photograph that are stamped by the automated enforcement system are then entered into a computer and the photographs are reviewed by a Verification Officer.

If the decision is made that a violation has occurred, the information is retrieved from the database of the Roads Corporation Victoria. When information from the photographs is matched with registration information, a Traffic Infringement Notice (T.I.N.) is processed. T.I.N.s are processed using the Traffic Infringement Management System (T.I.M.S.©).

Program Results

An independent evaluation of the automated enforcement program was performed in 1988 by David Souths in order to judge the effectiveness of the program (42). The report stated that the use of automated enforcement technology resulted in over a 30 percent reduction in right angle accidents. A 10.4 percent reduction in the number of casualties resulting from accidents was also reported.

A different evaluation of the program reported that red light cameras reduced the incidents of red light violations by 35 to 60 percent (1). The same report also stated that right-angle accidents were reduced by 32 percent, right-angle turning accidents decreased by 25 percent, rear-end accidents decreased by 30.8 percent, and an increase in rear-end turning accidents of 28.2 percent occurred.

Summary of Applications

Based on the findings of this research, the use of automated enforcement technology for red light violations was effective in reducing the number of red light violations that occur at intersections. Although each application reviewed for this study is unique in its operating conditions, all of the applications that maintained statistics about the effectiveness of the program reported a decrease in the number of red light violations occurring at intersections equipped with automated enforcement technology. Table 3 provides a description of the applications reviewed for this research.

Table 3. Description of Automated Enforcement Applications.

Location	Number of Locations	Year Installed	Legislation Present	Type of Photography/ Individual Responsible	Reduction in Violations
New York City, NY	18	1993	New York State Law Section 111-a	Rear photography/ Owner responsible	20%
Polk County, FL[1]	4	1994	None	Front & rear photography/ Owner responsible	N/A
Howard County, MD	2	1996	House Bill 391	Rear photography/ Owner responsible	23%
San Francisco, CA	4	1996	State Bill 833; Shelley Bill Pending	Frontal photography/ Driver responsible[2]	40%
Lincoln, NE[3]	3	1997	Legislative Bill 881 Pending	N/A	N/A
Victoria, Australia	132[4]	1983	Road Safety Strategy	Rear photography/ Owner responsible	30%

[1]Only warning notices issued, statistics about program not available.
[2]Driver must be positively identified from photograph to be held responsible.
[3]System used only to collect data.
[4]Thirty-five cameras rotated through 132 sites.

The following conclusions can also be made from the applications reviewed for this research:

- The implementation and continued operation of automated enforcement programs for red light violations in Victoria, Australia (since 1983) and New York City, NY (since 1993) has proven that the overall benefits of an automated enforcement program are acceptable to local governments, law enforcement agencies, and contracted vendors who support the costs of implementing, operating, and maintaining such programs.
- The programs in Polk County, FL and Ontario, Canada are examples of the importance of legislation allowing for the use of automated enforcement technology and processes. Because legislation has failed to be passed in Polk County, the system is limited to issuing warning notices. After the authority of the legislation passed in Ontario was revoked, the use of automated enforcement systems was prohibited.
- The program in Lincoln, NE shows how the use of video cameras recording a high number of red light violations can lead police to consider the use of automated enforcement systems.
- More recent programs such as Howard County and San Francisco also show that the use of automated enforcement for red light violations is becoming a publicly accepted method to address the problem of red light violations at intersections.

IMPLEMENTATION STRATEGIES

Strategies developed to assist jurisdictions in the creation and implementation of programs for the automated enforcement of red light violations are presented in this section. In order for an automated enforcement of red light violations program to be successful, many political, economic, and social issues must be addressed. A listing of the strategies for the creation and implementation of programs for the automated enforcement of red light violations is provided in Table 4 and is followed by a description of each strategy.

Table 4. Strategies for Implementing an Automated Enforcement Program.

Step	Strategy
1	Demonstrate a need for the program.
2	Establish institutional arrangements.
3	Review applications in the United States and abroad.
4	Create a public education and awareness campaign.
5	Establish legislation to allow for the use of automated enforcement technology and processes.
6	Advertise a Request For Proposal (RFP).
7	Undertake a demonstration project.
8	Evaluate the demonstration project.
9	Implement selected vendor system.
10	Expand the program.

1. **Demonstrate a need for the program.** Due to the limited budgets of most police departments and transportation agencies and the high costs associated with traditional enforcement methods, the use of automated enforcement technology is providing governments and police departments with an alternative to address the increasing problem of red light violations. In demonstrating the need for an automated enforcement program of red light violations, many methods can be used. Several studies completed by Richard Retting at the Insurance Institute for Highway Safety provide statistics that document the problem on a national level. These reports also provide information on the characteristics of red light violators, summaries of methods to address red light violations, and public opinions concerning red light runners and the use of automated enforcement technology (4,5,8).

Information from local police departments and transportation agencies concerning the severity of the problem of red light violations and the history of different enforcement methods attempted is necessary to bring the issue of red light violations “close to home”. Statistics such as the percent of all accidents where running a red light is the cited reason, the number of accidents and fatalities caused by red light runners, and the trends in the number of red light violations that have occurred over a long period (10 to 15 years) of time often define the problem in terms the public can understand. Having police departments describe the various enforcement methods used (assigning officers to intersections, team enforcement) and the limitations and high cost of such programs will further show that traditional enforcement methods are not the most efficient solution and new programs should be tried.

Sometimes the need for an automated enforcement program is demonstrated by a highly publicized accident or incident. Events resulting from a red light runner causing the death of pedestrians or fatal vehicle collisions often receive substantial coverage in the media. Publicity from such events often results in public outcry demanding action from the government.

2. **Establish institutional arrangements.** In order for an automated enforcement program of red light violations to become a valid alternative for a jurisdiction, strong partnerships between the police department, political leaders, citizen safety organizations, and transportation officials must exist. The responsibilities of each agency should be understood and program leaders should be identified. A strong partnership will result in resources being used more efficiently through a combination of engineering, education, and enforcement (3E) principals. An example of the benefits resulting from institutional arrangements will be better site selection (using a combination of police knowledge and traffic engineering principles) and the ability to share knowledge and capital. Strong institutional arrangements will also be essential in the passage of enabling legislation.

3. **Review applications in the United States and abroad.** Knowledge gained through the study of applications of automated enforcement technology for red light violations used in the United States and abroad will provide a basis to determine the feasibility of using such systems in a given area. Conducting a literature review will provide an understanding of how the technology works and give statistics about the effectiveness of various programs and methods. To gain a true understanding of the limitations of the technology and the barriers that were faced in implementing and operating an automated enforcement program, individuals who participated in such programs should be consulted.

   A review of the state laws enacted to allow the use of automated enforcement technology and processes should also be performed to gain an understanding of the legal requirements of automated enforcement programs. As discussed previously, the paper entitled Photographic Traffic Law Enforcement, published by the National Cooperative Highway Research Program (NCHRP), contains an analysis of the precedence that has been set by the Courts concerning the use of automated enforcement technology, a comparative analysis of the photographic traffic enforcement laws in the United States, and an example model law that can be used when drafting proposed legislation.

4. **Create a public education and awareness campaign.** Making the public and government aware of the danger of red light violations is very important in both helping to reduce the number of violations that occur and gaining support for the use of automated enforcement technology. An effective program will serve the purpose of publicizing the importance of the issue and emphasizing the need for action to be taken. The Federal Highway Administration recently has published the Red Light Running Campaign Strategic Planning Guide which provides recommendations and materials to plan and implement a public education and awareness campaign (6).

5. **Establish legislation to allow for the use of automated enforcement technology and processes.** One of the most important aspects of an automated enforcement program is the legislation that is passed allowing for its use. The legislation determines if automated enforcement will be allowed in a given area, specifies if the violation will be a moving violation requiring driver identification or if the violation will be treated in a manner similar to a parking ticket in which the owner is held responsible, establishes the adjudication/appeals procedure, and defines the processing procedure. Legislation can also address how revenue from tickets issued will be distributed between the State, County, and jurisdiction operating the program.

   The most important decision to be made when presenting the need for legislation is whether violations detected using automated enforcement technology will be treated as moving violations or if the owner of the vehicle will be held responsible for the violation. As explained previously, if the violation is going to be treated as a moving violation, positive identification of the driver is required and the penalty will usually consist of a fine and points assigned to the driver's license. If the registered owner of the vehicle is going to be held responsible, driver identification is not required.

   Although the penalty imposed is greater when the violation is classified as a moving violation, the process of driver identification requires frontal photography and is very labor intensive. Frontal photography also has a lower percentage of violations to which citations are sent. The use of rear photography where the license plate of the vehicle is used to be matched with motor vehicle records usually does not allow for points to be added to the driver's license. Rear photography also does not raise as many questions about privacy, does not face the public opposition, and is not confronted with many of the operational problems associated with driver identification. As stated previously, the high cost associated with the need for a two-camera setup severely limits the use of both frontal and rear photography.

   When the bill is being introduced into committee and the classification of the violation is being determined, the police department and transportation groups should make every effort to educate the legislatures about the problem and inform the public about the purpose of the bill. By working with the legislature, drawing media attention to the issue, and getting the public to become involved, the bill has a greater chance of being passed.

6. **Advertise a Request For Proposal (RFP).** The RFP for an automated enforcement program is very important in stating the provisions that are expected from the program and establishing the relationship that will exist between the vendor of the automated enforcement system and the jurisdiction. If possible, the RFP process should follow a procedure that allows for the selection of the system that is believed to offer the best match for the jurisdiction, not necessarily the system that is submitted by the lowest bidder. Potential bidders would submit both a technical proposal and a cost proposal and would be judged on predefined criteria. Possible criteria could include:

   - Experience and qualifications of the proposer;
   - Type of camera being used in the system;
   - Process and equipment used to load and unload, develop, and view film;
   - System used to identify, construct and mail, and track violations; and
   - Maintenance and support capabilities for the system.

7. **Undertake a demonstration project.** The initiation of a demonstration project is a good mechanism to determine if an automated enforcement system will be applicable to a given area. By showing that automated enforcement systems work, future projects will receive more support. Demonstration projects may also receive special grants from the FHWA and other transportation agencies to assist with financing the project.

   In conducting the demonstration project, goals and criteria should be established before the program begins so participating vendors can be fairly evaluated. The demonstration project should operate for a period of time long enough to allow for a variety of weather patterns and other events to take place so that the performance of the system can be judged under many conditions.

   Site selection for the demonstration project should be based on recommendations made by both enforcement agencies and traffic engineers. The enforcement agency should create a list of high accident intersections and intersections where citizen complaints are high. After creating the list of potential sites, a traffic engineer should evaluate the sites to ensure that the red light violations and accidents are not a result of engineering deficiencies such as poor signal timing or limited sight distance. Proper site selection for an automated enforcement program is essential because the public will quickly lose respect for and demand the termination of a program that enforces violations at intersections where poor engineering is the reason for drivers violating red lights.

   Consideration should also be given to whether the contracting agency will want to be responsible for the maintenance of the system and the processing and issuing of violations or if the agency will contract these duties out. Should an agency desire to operate the system "in-house", the demonstration project should be designed to leave all responsibility to the agency so that a thorough understanding of the responsibilities associated with running the system can be obtained.

8. **Evaluate the demonstration project.** By thoroughly evaluating the demonstration project, many decisions about the use of an automated enforcement system for the detection of red light

violations can be made. Based on the criteria and goals established in Strategy 7, choices can be made regarding if the use of automated enforcement technology should be further pursued and, if so, which vendor should be selected for the project. A cost to benefit analysis should also be conducted as part of the evaluation. The analysis should calculate how much each violation produced by the automated enforcement system costs the operating agency and be compared to the use of methods such as team enforcement.

The evaluation of the demonstration project and the cost to benefit analysis will serve as the basis to gain both public and governmental support for the implementation of an automated enforcement program. When presenting the evaluation of the demonstration project and the results of the cost to benefit analysis to the public and local governments, it should be emphasized that automated enforcement programs provide the advantages of constant enforcement, shows the public that steps are being taken to address the problem of red light violations, and that the program enforces a much larger number of red light violations than traditional methods.

9. **Implement selected vendor system.** The implementation of the automated enforcement program by the vendor selected in Strategy 8 should be done soon after the expiration of a successful demonstration project. Implementation should be done soon after the expiration of the demonstration project because that is the time when public and political support will be highest. By showing people and legislators that programs using automated enforcement for red light violations can be successful in their community, support for implementation will be strong.

   In implementing the selected automated enforcement program, detailed statistics and information about the system should be maintained. Such information will allow legislators and the public to see the effectiveness of the program and will provide a basis for future program expansion.

10. **Expand the program.** After the selected vendor system has been operational for a given period of time and is working to the satisfaction of both the city and the public, the expansion of the program should be considered. Additional intersections should be added to the program based on the list developed in Strategy 7. Again, the potential intersections should be reviewed by a traffic engineer to ensure that poor engineering is not the cause of the violations.

    The expansion of the program should be done at large intervals, for example the addition of five or ten intersections to the program, so that the event will be publicized by the media. When expanding a program, provisions in the enabling legislation should be rechecked. Caution should also be taken so that all parts of the program stay in balance. If more intersections are added to the program, maintenance and violation processing will increase as will the need for more people and locations to hear appeals. The size of an automated enforcement program should be based on the success of the demonstration project, available funding and the contract with the vendor, and the public acceptance of the program.

HYPOTHETICAL APPLICATION

The hypothetical application will be set in the fictional city of Anywhere. Anywhere has a population of over four-hundred thousand people and is rapidly expanding due to economic prosperity. As with most cities, the police department is under a strict budget that leaves limited resources for traffic law enforcement. Due to the rapid rise in population of Anywhere and the increase in the number of vehicles using the City's infrastructure, the main roadways experience heavy traffic throughout the day. The presence of traffic signals on many of these roadways further limits the ability of vehicles to travel quickly through Anywhere.

Over the past five years, the police department has noticed a disturbing increase in the number of accidents where failure to obey a traffic signal is listed as the primary cause of the accident. Recent public complaints about an increase in red light violations has also gained the attention of the police department. To combat the problem, a program using team enforcement concepts was initiated. Although the program heightened the publics' awareness about the dangers of red light violations and was successful in catching many red light violators, the high cost of the program did not allow it to operate with the frequency necessary to change the attitudes of most drivers. To further combat the problem, the city of Anywhere is interested in the use of automated enforcement technology.

The following section contains a description of the use of automated enforcement technology for red light violations by the city of Anywhere. The purpose of this section will be to apply the implementation strategies presented in this report. Each of the ten strategies listed in Table 4 will be addressed individually in the application.

1. Demonstrate a need for the program.

As stated previously, the police department of Anywhere has noticed an increase in the number of accidents where failure to obey a traffic signal is listed as the primary cause and has received frequent public complaints about red light violations occurring at several major intersections throughout the City. Due to the limited personnel and resources available to the police department, the use of traditional enforcement methods are not able to provide the frequent enforcement necessary to lower the number of violations taking place. After reviewing accident records for the past 10 years, it was found that an increase in the number of red light violations per registered vehicle has occurred every year and that red light violations have been cited in an increasing number of accidents over the period.

To analyze the problem of red light violations on a national level, several reports from the Insurance Institute for Highway Safety were reviewed. By reviewing the reports, an understanding about the severity of the problem was gained as was a description of the typical red light violator. The reports also identified the use of automated enforcement as a publicly accepted method to combat red light violations.

2. *Establish institutional arrangements.*

After gathering and organizing the information described in Strategy 1, the police department presented the need for the use of automated enforcement technology to several institutions with the purpose of establishing strong partnerships for the support of an automated enforcement program. By emphasizing the goal of using automated enforcement technology to make the City's intersections safer, partnerships with State Department of Transportation officials, State Police, and other vehicle safety groups (Anywhere Safety Council, Organization for the Improvement of Roadway Safety) were made. The decision was made to appoint an individual from each organization to form the Council for the Use of Automated Enforcement of Red Light Violations.

By establishing strong institutional partnerships, the Council was able to convince the City's mayor and other political figures that the use of automated enforcement technology was an effective method to improve the safety of intersections that would be accepted by the public. Gaining the support of the local government and all the agencies that would participate in the program allowed the Council to further research automated enforcement technology.

3. *Review applications in the United States and abroad.*

To understand the requirements and technology necessary to create and implement an automated enforcement program for red light violations, the Council conducted a thorough review of the relevant literature. From the literature review, the Council was able to study several applications in the United States and abroad and find contacts with working knowledge about those applications. By contacting individuals associated with automated enforcement programs, members of the Council were able to obtain a true understanding of the limitations of the available technology and gain valuable insight as to how to further plan their program to overcome institutional barriers that will be faced in the implementation stage. The literature review and information gained by contacting individuals associated with automated enforcement programs convinced the Council that automated enforcement programs for red light violations could improve the safety of intersections, make the public more aware of the danger associated with red light violations, and can be implemented and operated at a cost that is acceptable to the government officials of Anywhere.

4. *Create a public education and awareness campaign.*

In order to make the public more aware of the dangers of red light violations, a public education and awareness campaign was created and implemented. Because the Council was very inexperienced in organizing such programs and was under a very strict budget, they decided to use the FHWA's Red Light Running Campaign Strategic Planning Guide instead of hiring an outside advertising agency. The Council used the public service announcements, both audio and video, that were included in the guide and followed the step-by-step instructions on how to create and implement a public education program.

The program also served the purpose of making government officials more aware of the problems of red light violations. By educating the public and the government, the Council was able to make running red lights a serious issue that was discussed in the media. The goal of the public education campaign was to first make people aware of the problem of red light violations and then to follow the message with frequent law enforcement.

5. *Establish legislation to allow for the use of automated enforcement technology and processes.*

After completing the first four strategies presented in Table 4, the Council had the information and support necessary to approach local state representatives about introducing a Bill that would allow for the use of automated enforcement technology in the City of Anywhere. Based on the research about other automated enforcement programs for red light violations and the concern of government officials that the use of frontal photography would be viewed as an invasion of privacy by the public, the decision was made to draft legislation that treated violations detected using automated enforcement technology as a nonmoving violation. The classification of the violation as a nonmoving violation required that the legislation place responsibility for the penalty on the registered owner of the vehicle. This provision eliminated the use of frontal photography and the need for positive identification of the vehicle's driver.

In presenting its view of what needed to be included in the legislation, the Council used the paper published by the National Cooperative Highway Research Program (NCHRP) discussing the legal issues associated with automated enforcement technology. Copies of the legislation from other states, such as New York and Maryland, that held the registered owner of the vehicle responsible for violations detected using automated enforcement technology, were also carefully reviewed.

Before the Bill allowing for the use of automated enforcement technology was introduced to the State Committee, the Council made sure that all of the members of the Committee were aware of the seriousness of the red light running problem in the City of Anywhere. This task was accomplished by preparing fact sheets containing the information gathered in Strategy 1 and by assigning members from the partnerships formed in Strategy 2 a specific Committee member to contact. By being organized and unified, the Council was able to successfully work with the legislature and get a Bill passed allowing for the use of automated enforcement technology for red light violations.

6. *Advertise a Request For Proposal (RFP).*

By having legislation enacted that allowed for the use of automated enforcement technology, the Council was able to advertise Request For Proposals (RFPs) from vendors that supplied automated enforcement systems. The RFP was structured to allow the City to select the system that it believed would provide the best service within the overall city funding and budget, not necessarily the system that was the least expensive. The RFP procedure yielded three vendors, Company A, Company B, and Company C, that were willing to participate in a demonstration project. All three vendors proposed the use of 35-mm cameras and the two sensor per lane configuration traditionally incorporated into an automated enforcement system for red light violations.

7. *Begin a demonstration project.*

The City of Anywhere, with the assistance of a grant from the FHWA, initiated a demonstration project that would last one year using the three vendors selected in Strategy 6. Potential sites for the demonstration project were first chosen by law enforcement officials. A list of potential sites was created based on accident frequency and public complaints. A traffic engineer then reviewed the list to ensure that the red light running problem was not being caused by factors such as poor signal timing, geometric deficiencies, or a lack of signing. Each vendor was then assigned two specific intersections to implement its automated enforcement program.

Because Anywhere did not want to be responsible for the daily operations of the automated enforcement system, the decision was made to have the vendors be responsible for the system operations. The duties that the vendor would be responsible for included maintenance of the system, the daily loading, unloading, and developing of film, and the processing and tracking of notices of violation. The vendor would also be responsible for preparing photographs to be shown in court should a violation be contested.

8. *Evaluate the demonstration project.*

After the year long demonstration project, the results of the program showed a 25 percent decrease in the number of violations occurring at intersections where automated enforcement technology was present. The 25 percent reduction was based on a ratio where the number of violations photographed by the automated enforcement system is divided by the total number of vehicles traveling through the intersection approach(es) being monitored. The ratio was calculated for all six intersections and an average ratio was then calculated for the program. The average ratio for the first full month of system operation was compared to the same ratio taken one year later to determine the percent reduction in violations. All data necessary to determine the percent reduction was obtained from the automated enforcement system.

Public opinion and media coverage about the project were also positive. The large decrease in red light violations and the positive opinions about the project resulted in support and funding being given by the City for the implementation of an automated enforcement system.

9. *Implement selected vendor system.*

Following the conclusion of the demonstration project and based upon the evaluations conducted in Strategy 8, the decision was made to implement Company B's automated enforcement system at all of the intersections included in the demonstration project. The installation of the technology began one month following the conclusion of the demonstration project. This time period was chosen in order to maintain the positive public and government support gained from the demonstration project. The period of installation also coincided with expected warm weather. This factor was important in getting the system installed and having the cameras fully adjusted before facing freezing conditions.

10. *Expand the program.*

The City of Anywhere has not planned future expansion of its automated enforcement system at this time. Because the system has only been operational for approximately a year, program organizers and city officials want to allow more time in order to develop an accident database and to gather statistics about the success and costs of the program. The City has also become very interested in the potential of using Digital technology to limit the need for film handling and data processing. Based on the success of its current automated enforcement system and the results of field tests using digital technology, the City will decide when and what type of technology to use for future expansion.

CONCLUSIONS

Drivers committing red light violations are a very serious problem that is increasing in frequency. Traditional methods used by police departments to enforce red light violations are dangerous to the enforcing officer, other motorists, and pedestrians and bicyclists in the area. Enforcement methods, such as team enforcement, that involve the use of many officers at one intersection, are resource intensive and the high cost associated with the procedure does not allow for enforcement to be performed with the frequency necessary to significantly affect driver behavior. Although violations that are enforced by police officers are often upheld in court, the large number of violations that are not enforced requires that new methods to enforce red light violations be researched.

Several court decisions have established the precedence that the use of automated enforcement technology does not violate the Constitution and is not an infringement on an individual's right to privacy. Previous experience using automated enforcement technology has also shown that the photographs produced by automated enforcement systems can be used as valid evidence in court. In the case of using automated enforcement for red light violations, the police must usually establish that the photograph taken, the position of the vehicle in the intersection while the traffic signal was red, and the time shown were provided by an instrument which has been proven to accurately identify, photo, and synchronize these events. If the violation is going to be treated as a moving violation, the identity of the driver must also be clearly shown.

The use of automated enforcement technology for red light violations has been shown to reduce the number of red light violations occurring at intersections. The implementation and continued operation of automated enforcement programs for red light violations in Australia (since 1979) and New York City (since 1993) has proven that the overall benefits of an automated enforcement program are acceptable to local governments, law enforcement agencies, and contracted vendors who support the costs of implementing, operating, and maintaining such programs. More recent programs such as Howard County and San Francisco also show that the use of automated enforcement for red light violations is becoming a publicly accepted method to address the problem of red light violations at intersections.

A major decision that must be made when enabling legislation allowing for the use of automated enforcement technology is whether the violation will be treated as a moving violation or a nonmoving violation. Treating the violation as a moving violation will require the use of frontal photography in order to positively identify the driver and the penalty will usually be a monetary fine and the addition of points to the driver's license. If the violation is going to be enforced as a nonmoving violation with the usual penalty of only a monetary fine, the legislation must contain a provision holding the registered owner of the vehicle responsible for the violation.

Several applications of automated enforcement for red light violation systems in the United States and abroad have shown that many issues should be considered when creating and implementing an automated enforcement program for red light violations. These essential elements include if a public awareness program will accompany the use of automated enforcement systems, how violations will be processed and tracked, and whether the violation will be a moving violation or a non-moving violation. By following the strategies presented that are based on previous programs using automated enforcement technology, agencies will be able to implement a program that may improve the safety of intersections and that is acceptable to law enforcement agencies, supporting governments, and the general public.

Further research into the capabilities, requirements, and limitations of digital cameras is still needed. Court precedence should be examined to ensure that the use of digitally produced photographs will be admissible as evidence. Research should also be performed to determine if the extra cost currently associated with digital cameras is offset by the potential benefits of a digital system. The possibility of continuing to reduce the manpower associated with enforcing red light violations while improving the quality of photographs produced by automated enforcement systems warrants further research into digital camera use.

ACKNOWLEDGMENTS

This report was prepared for the graduate summer course CVEN 677 *Advanced Surface Transportation Systems* at the Texas A&M University. The author would like to thank the mentors for their participation in this program: Marsha Anderson, Ginger Gherardi, Thomas Hicks, Joseph McDermott, Colin Rayman, and H. Douglas Robertson. By donating your time and knowledge to participate in this program, you have truly improved the learning experience of many future transportation professionals. A special thanks is extended to Joseph McDermott and Thomas Hicks for the guidance and insight they provided throughout the creation of this paper.

The author would also like to thank Dr. Conrad Dudek and Ms. Sandra Schoeneman. Your hard work and dedication have made this a very rewarding experience. I would also like to thank the following individuals who took the time to share their personnel knowledge and provide me with the information necessary to complete this paper:

Sgt. Glenn A. Hansen - Supervisor, Research and Planning Section, Howard County, MD
Chief George M. Ferris - Fort Mead Police Department, FL
Officer Anthony Taylor - Bryan/College Station Police Department
Chief John Wintersteen - Paradise Valley Police Department, AZ
Richard A. Retting - Insurance Institute for Highway Safety
Richard A. Raub - Northwestern University Traffic Institute
Harold Lunenfeld - Federal Highway Administration
Mila Plosky -Federal Highway Administration
Rudy Popolizio - Chief of Red Light Camera Program for New York City, NY
C. Edward Walter - Chief, Traffic Engineering Division of Public Works of Howard County, MD
Tarek Tarawneh - Head of Red Light Camera Program for Lincoln, NE
Susan Law - Associate Project Manager, Nelson Nygaard Consulting, San Francisco, CA
Tom Fletcher - Manager of Traffic Management, Ontario, Canada
Paul Carlson - Texas Transportation Institute
Shawn Turner - Texas Transportation Institute

I hope in the future that I have the chance to assist students in the pursuit of knowledge as you have assisted me.

Finally, I would like to thank my parents, Stephen and Linda Passetti. Your support and encouragement have allowed me to pursue any goal I desire.

REFERENCES

1. Coleman, J.A., Paniati, J.F., Cotton, Maj. R.D., Parker, M.R. Jr., Covey, Lt. Col., R., Pena, H.E. Jr.,Graham, D., Robinson, M.L., McCauley, James, Taylor, Dr. W.C., and Morford, G. FHWA Study Tour for Speed Management and Enforcement Technology. FHWA, U.S. Department of Transportation, Washington, D.C., December 1995.

2. "Cameras Reduce Red Light Running Violations by 20-30%," The Urban Transportation Monitor, May 23, 1997.

3. Insurance Institute for Highway Safety, Internet Web Site, http://www.hwysafety.org/roadhigh/redlight.htm, Arlington, VA, 1997.

4. Retting, R.A., A.F. Williams, M.A. Greene. "Red Light Running and Sensible Countermeasures: Summary of Research Findings." Insurance Institute for Highway Safety. April 1996.

5. "Urban Crashes: Identifying Types Is 1st Step." *Status Report*. Insurance Institute for Highway Safety, Vol. 28, No. 2, February 6, 1993.

6. Red Light Running Campaign Strategic Planning Guide℠. Federal Highway Administration, Washington, D.C., 1994.

7. "Traffic Safety Division Position Paper - SB-155," Maryland Department of Transportation, State Highway Administration, January 24, 1996.

8. Retting, A.R. and A.F. Williams. "Characteristics of Red Light Violators: Results of a Field Investigation." Insurance Institute for Highway Safety. October 1994.

9. Ferris, George. Fort Meade Police Department, FL. Survey conducted July 1997.

10. Revised Running Red Light Campaign, Maryland Department of Transportation State Highway Administration, December 7, 1993.

11. Blackburn, R.R., D.T. Gilbert. *Photographic Enforcement of Traffic Laws*. Synthesis of Highway Practice 219. National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., 1995.

12. Dingle, J. "IVHS and the Law of Privacy." Proceedings, Pacific Rim TransTech Conference. Volume 1. American Society of Civil Engineers, New York, December 1993.

13. Frangos, George E. "Red Light Running Detection: A Building Block Technology For Intelligent Transportation Systems." Presented at the ITE District 2 Conference, October 22, 1996.

14. Gilbert, D.T., N.J. Sines, B.E. Bell, and J.B. McDaniel. *Photographic Traffic Law Enforcement*. Legal Research Digest. National Cooperative Highway Research Program, Transportation Research Board, Washington, D.C., December, 1996.

15. Wintersteen, John. Paradise Valley Police Department, AZ. Telephone interview conducted August 1997.

16. "Technology Being Used to Help Nab Red Light Runners in Some Communities." *Status Report*. Insurance Institute for Highway Safety, Vol. 30, No. 10, December 2, 1995.

17. Wing, Betsy. <u>'Photocops' May Help Drivers Get the Picture</u>. Tech Transfer, University of California, Berkeley, CA, Winter 1997.

18. Erickson, G. "Digital Traffic Cameras For Violation Enforcement." *Traffic Technology International*, Annual 1996, pp. 332-336.

19. Walter, C. E. "Automated Red Light Running Detection." Institute of Transportation Engineers, 1996 Annual Compendium of Technical Papers.

20. New York City Red Light Camera Program Information. November 1994. Obtained from Paul Carlson, Member of ITE Technical Committee 96-5: Automated Enforcement.

21. Popolizio, R.E. "New York City's Red Light Camera Demonstration Program." Institute of Transportation Engineers, 1995 Annual Compendium of Technical Papers.

22. Fitzpatrick, K. <u>A Review of Automated Enforcement</u>. Cooperative Research Program, Texas Transportation Institute, Texas Department of Transportation. Report 1232-5. November 1991.

23. U.S. Public Technologies Inc. promotional literature, as of December 1996.

24. Traffipax Traffic Surveillance Systems promotional literature, as of May 1995.

25. Truvelo Manufactures promotional literature, as of December 1996.

26. Dempsey, Paul. "A New Focus for Enforcement Cameras." Traffic Technology International. June/July 1997.

27. Schumacher, Pete. Sales Engineer, COHU Inc. Electronics Division. Telephone interview conducted July 1997.

28. Kodak promotional literature, as of December 1995.

29. New York State Law Section 1111-a. Copy received from R. Popolizio, Director, Manhattan Street Department, New York City Department of Transportation, July 1997.

30. Haugh, J. "New Video Technology Captures Red Light Runners." *Research and Technology Transporter*. July 1995.

31. Hansen, Sgt. G.A. "Testimony Regarding House Bill 249 Before the Delaware State Senate." June 19, 1997.

32. Maryland Legislation, House Bill 391. Copy received from C.E. Walter, Chief, Traffic Engineering Division, Department of Public Works of Howard County, MD, July 1997.

33. Walter, C.E. Chief, Traffic Engineering Division, Department of Public Works of Howard County, MD. Telephone survey conducted July 1997.

34. Red Light Cameras Fact Sheet - San Francisco. Copy received from Susan Law, Associate Project Manager, Nelson\Nygaard Consulting Associates, San Francisco, CA, July 1997.

35. Hans, M. "Cameras Catch Red-Light Runners." *Traffic Safety*. January/February 1997.

36. Yee, B.M. "San Francisco's Red Light Camera Enforcement Program Operating Well." The Urban Transportation Monitor. Vol. 11, No. 2, January 31, 1997.

37. "San Francisco Proposes Increasing Fine for Red Light Running to $250." The Urban Transportation Monitor. December 20, 1996.

38. Law, Susan. Associate Project Manager, Nelson\Nygaard Consulting Associates, San Francisco, CA. Survey conducted July 1997.

39. Tarawneh, Tarek. Representative of Nebraska Research Program. Survey conducted July 1997.

40. Nebraska Legislation, Internet Web Site, http://unicam2.lcs.state.ne.us/legdocs/comstmt/csLB881.txt, Lincoln, NB, 1997.

41. Fletcher, Tom. Manager of Traffic Management, Canada. Telephone survey conducted July 1997.

42. Victoria, Australia Red Light Camera Program, Internet Web Site, http://yarra.vicnet.net.au/~iana/html/redlight/htm, Victoria, Australia, 1997.

APPENDIX

The following table provides a listing of companies that manufacture automated enforcement systems for red light violations.

Table A-1. Manufacturers of Automated Enforcement Systems for Red Light Violations.

Company Name	Address of Company Headquarters
35-mm Camera Systems	
American Traffic Systems (ATS)	4141 N. Scottsdale Road Suite 335, Scottsdale, AZ 85251
Gatsometer B.V.	Tetterdeweg 10, 2050 AA Overveen, Holland
Multanova AG	Seestrasse 110, CH 8612 Uster 2, Switzerland
Traffipax - Vertrieb	4000 Dusseldorf 13, Hildener Str. 57
Truvelo	PO Box 92, Teddington, Middlesex, TW 11 9 BP, England
Video Camera Systems	
A.W.A. Traffic Systems	P.O. Box 161, Elizabeth South Australia 5112
Cohu, Inc./Electronics Division	5755 Kearny Villa Rd. San Diego, CA 92123
Econolite	3360 E. La Palma, Anaheim, CA 92806
Hughes	Bldg. M30, MS R10, P.O. Box 11337 Tucson, AZ 85734-1337
Peek Traffic Systems, Inc.	3000 Commonwealth Blvd., Tallahassee, FL 32303-3157
Syntonic, ATS Systems Division	1616 Broadway Kansas City, Missouri 64108-1208
Digital Cameras	
Eastman Kodak Company	11633 Sorrento Valley Road San Diego, California 92121

Karl A. Passetti received his B.S. in Civil Engineering from The Pennsylvania State University in December 1996. Karl is currently pursuing his M.S. in Civil Engineering at Texas A&M University and has been employed by the Texas Transportation Institute (TTI) since January 1997. Previous to his employment at TTI, Karl worked for the Pennsylvania Transportation Institute (PTI). As a member of a data collection team consisting of PTI and TTI students studying design consistency on rural two-lane highways, Karl collected data in Oregon, Washington, Minnesota, New York, Pennsylvania, and Texas. While at Penn State, Karl served as President (1996) for the Institute of Transportation Engineers student chapter and was a member of ITS America and Sigma Phi Epsilon fraternity. His areas of interest include: geometric design, ITS applications, and public transportation issues.

APPLYING SELECTED CURRENT ADVANCED TECHNOLOGIES TO HELP ALLEVIATE FREQUENT TRUCK ACCIDENTS

by

Kerry V. Perrillo

Professional Mentors
Marsha Anderson
Street Smarts

and

Tom Hicks, P.E.
Maryland State Highway Administration

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

There is a continuous large focus on truck safety, aimed at reducing the number of fatalities due to accidents involving trucks. Although safety in the trucking industry has increased, there are still a large amount of fatalities which are due to human factors causes which can possibly be alleviated. Human factors causes are often hard to study because the role of the driver in truck accidents is particularly hard to assess. It is not always possible to establish a driver's physical and psychological status at the time of occurrence of the accident.

There are currently several agencies that make strong efforts to reduce the amount and severity of truck accidents. Such efforts as the 1995 National Truck and Bus Safety Summit bring professionals together to develop ideas which, if implemented, may improve the safety of the motor carrier industry operations. These agencies analyze crash data to gain a perspective of the safety of motor carriers and to understand some of the contributing factors of crashes.

The objectives of this paper were to analyze the human factors causes of accidents and to study some of the new technologies that are being developed and implemented for trucks and other vehicles. By combining these two sets of information, it may be possible to "match" the technologies to the human factors causes, thus reducing the number of truck accidents due to some of the most frequent causes. Guidelines were created to establish methods of developing and implementing these technologies to give the best results that reduce human factors caused accidents. The final objective was to present the costs and benefits of the implementation of these technologies through a case study.

From the research it has become clear that three common human factors causes of truck accidents are alcohol, fatigue, and inattentiveness or human error. These contributing factors are often intertwined and there may be ways of reducing the effects of these factors. Also studied were three technologies that are currently being developed or marketed which "match" the three human factors causes mentioned above. These technologies, the alcohol ignition interlocks, fatigue sensors, and collision avoidance systems, may possibly reduce the number of accidents due to alcohol, driver fatigue, and inattention/driver error. All of these systems have components that need to be modified or studied for the most accurate results. Specifically, concern is given to false alarms that may discourage the use of these systems or credit them as unreliable.

The alcohol ignition interlocks serve as a pro-active device, as opposed to the other alarms, which act as reactive devices. The interlocks are capable of preventing those drivers who have drunk "too much" (this level is to be established by the trucking company) from entering the roads and creating a harmful and possibly fatal accident. The collision avoidance and warning systems and the drowsiness detectors act as warning systems for the driver while in a dangerous situation, as perceived by the sensors. With accurate warnings (not giving too many false alarms), the number of accidents due to fatigue, interaction with other vehicles, and driver errors may possibly decrease.

When applying these technologies for truck use, there is a possible match that will allow the technology systems to address some of the common human factors causes of truck accidents. Specific guidelines for the further development and implementation of these technologies have been

suggested to possibly result in a match of the causes and preventive measures that may reduce the number of truck accidents. These guidelines will be suggested for companies that are developing and manufacturing the products, and additionally for trucking companies to consider using these technologies. All of the technologies studied are either currently available for use or being developed. The collision avoidance systems have been developed and are currently available for truck use, the fatigue detectors are being developed for truck drivers however they are not yet currently available, and the alcohol ignition interlock is predominantly being used in passenger vehicles only.

AI Trucking is a fictitious company who is interested in purchasing the above mentioned devices to reduce the number of accidents within their 4,000 unit truck fleet. It is suggested that AI Trucking purchase ten alcohol ignition interlocks to be used randomly throughout their fleet of trucks. The interlocks would take the place of random alcohol testing, discouraging the use of alcohol, which causes inattentiveness, slower reactions, and fatigue. Fatigue sensors, which monitor the driver's steering patterns are suggested to be purchased for each truck in the fleet, in addition to the collision avoidance systems. These devices are both reactive, as opposed to the alcohol ignition interlock, which is a pro-active device, thus they will not necessarily reduce the potential of the accident by reducing the cause, but they will serve as an alarm immediately before there is a potential accident.

Costs and possible consequences of the purchases and use of these technologies are discussed for the benefit of the truck company. A benefit/cost ratio analysis has been performed to study the possible reduction in accidents and the economic return for each of the suggested investments of the devices. The alcohol ignition interlock has the highest benefit to cost ratio and the collision avoidance systems has the smallest ratio; the collision avoidance system is the only technology with a ratio less than one, showing an initial loss in money for the first year of investment. Suggested possible consequences and additional costs and benefits are discussed and are available for consideration by real trucking companies throughout the United States.

TABLE OF CONTENTS

INTRODUCTION

The Federal Highway Administration classifies large trucks as motor vehicles equipped for carrying property and having at least two axles and six tires and weighing more than 10,000 pounds (1). They may have many different configurations, sizes, weights, uses, and other characteristics. (In this paper, all references to trucks can be assumed to be referencing "large trucks" as described above.) Accident reports often do not distinguish among all of the different possible characteristics of involved trucks, although accident reports are becoming more descriptive with respect to information about the driver, roadway, vehicle, and environment.

The role of drivers in truck accidents are particularly hard to asses. It is not always possible to establish a truck driver's physical and psychological status at the time of the accident. Some of the characteristics that are significant in accidents are the age, driving experience of the truck driver, economic pressures that may be established by the individual drivers and/or the company, fatigue, and substance abuse. It appears that young and inexperienced drivers have higher accidents rates than others, as these two factors are related (2). Additionally, economic pressures affect some drivers and their driving practices. Truck drivers who are paid by the mile per unit of time may be more likely to take less time off for meals and rest, with the resulting fatigue increasing their likelihood of being in an accident. Finally, drug and alcohol use and fatigue may cause accidents. Driver medical conditions also have an affect on the number of accidents.

There are currently several agencies that make a significant effort to reduce the number and severity of truck accidents. Such efforts as the 1995 National Truck and Bus Safety Summit bring professionals together to develop ideas that improve the safety of the motor carrier industry. The professionals analyze crash data from the Federal Highway Administration (FHWA) to gain a perspective of the safety of motor carriers and to understand some of the contributing factors of crashes (3).

Truck safety and accidents have always been a large source of concern. Between the years of 1977 and 1983 there was a decrease in the percentage of total miles traveled by trucks (versus all vehicles) and an increase in the percentage of fatal accidents involving trucks (4). However, within the past ten years there has been an approximately 40 percent (a ratio of .866) reduction in the number of fatal accidents involving trucks, thus truck safety is improving (3,5).

Additionally, in the mid 1980s research led to the imposition of new guidelines about information needed in truck accident reports for evaluation purposes. Thus, over time the guidelines for the accident data recorded have been more descriptive about the driver, truck factors, roadway factors, traffic factors, and the environmental factors (6).

These data requirements have proven helpful for truck accident analyses and prevention. Current data show that a large percentage (84 percent) of the fatal truck crashes that occur are a result of multi-vehicle (not limited to trucks) accidents (3). The fatalities involved are usually due to the large difference in the size and weight of vehicles, which creates large impact forces resulting in more serious accidents. The National Truck and Bus Safety Summit reports that "large trucks dominate (are the most frequent type of vehicle involved in) the fatal crash statistics," and that passenger vehicle drivers (in accidents involving a passenger vehicle and a truck) are three times more likely than trucks to be cited by the police (3,5). Previous research supports that the truck type (semi trucks versus twin trailer trucks) does not matter when concerned with differences in safety, as measured by the involvement in traffic crashes (7).

The national data suggests the following frequencies and causes of truck accidents:

- Driver Error, 35 percent
- Driver Fatigue, 31 percent
- Alcohol Use, 3.1 percent
- Illnesses, 0.2 percent

The National Highway Traffic Safety Administration and the trucking industry are making efforts to address fatigue (7). It is also giving support for such issues as mandatory drug and alcohol testing, banning of radar detectors, and installation of anti-lock brakes, which may result in a decrease of accidents (5). However, additional safety related tactics are needed to decrease the number of truck accidents. Currently some on-board electronic vehicle systems are being suggested for use to improve safety of trucks. Work is currently being performed at the Trucking Research Institute to study more efficient and safer methods of operation for trucks (5). Further research of technologies that may be available for truck use to reduce the number of accidents is needed, particularly those accidents that are caused by human factors issues.

In summary, due to the high number of accidents involving trucks , truck safety is a major concern and many transportation organizations are currently taking action to research and better understand truck safety issues. Much data have been presented on human factors caused truck accidents, giving frequencies, causes, and contributing factors for accidents. By alleviating some of the accidents due to human errors and impairments, it may be possible to increase truck safety even more than it has already been increased throughout the past ten years. Additionally, current safety based technologies are being created and studied even though this may not necessarily involve application to trucks specifically. Research needs to be performed to determine technologies that are available to the trucking industry that may result in a reduction in the number of truck accidents due to human factors causes. Guidelines need to be developed for the evaluation and use of these technologies, to have an advantageous effect on the trucking industry.

Research Objectives

The overall objective of this research was to find possible technological solutions to help alleviate frequent human factors related truck accidents. More specifically, this main objective was divided into five detailed objectives as follows:

- Determine common causes of truck accidents;
- Determine current new technologies available for possible applications to truck operations;
- Suggest technologies currently available to possibly reduce the number of accidents due to human factors issues;
- Recommend guidelines for the use of identified technologies; and
- Apply these guidelines to a hypothetical situation.

Study Approach and Scope

The initial objective of this research created a need to analyze data on truck accidents and their causes. Truck accident data from professional societies were analyzed for common trends, frequencies, and causes of truck accidents. The data were obtained from organizations such as the American Trucking Association (ATA), the National Highway Traffic Safety Administration (NHTSA), the Insurance Institute for Highway Safety, and the Bureau of Transportation Statistics (BTS); the data included statistical data and facts about truck accidents and specific characteristics such as the frequency of probable causes, type of crash, severity of crashes, point of impacts, fatalities and injuries, driver conditions, and previous driving records of truck drivers in accidents. The reports also gave specific information about the drivers at the time of the accidents which allowed three common human factor causes of truck accidents to be established.

The second objective, to research current transportation related technologies, was performed to learn about how these current technologies work and their current development and/or applications. The information was then used to create guidelines for the possible applications for trucks and drivers. This information was provided through brochures and talking with people from technology manufacturers such as Rockwell and Collision Avoidance Systems. Additionally, on-line references such as the Trucking Technology magazine and technological websites were helpful to learn about current technologies that are being developed for trucks. Additional references included Trucksource and safety related journals.

The guidelines were used to present a case study. Methods of implementation of the technologies studied were suggested to maximize opportunities for accident reductions, particularly those accidents caused by human factors related issues. The results of the case study may be used as a future basis for the actual application of these technologies within the trucking industry, therefore improving the safety and possibly reducing the frequency of human factor related truck accidents.

Organization of Report

The report begins with background information giving the development of the safety concern and actions taken towards truck safety. Included in the background information are statistics of truck accidents and also methods of creating a safer environment. Following the background information is an accident analysis section. This section presents the analysis of recent statistics (1994 to the present), and considers causes and common trends of accidents. Following this section is a presentation of different vehicle technologies, some that are currently available to trucks and others that are not yet available. Applications of these new technologies are suggested and guidelines given for their use within the trucking industry. These applications may possibly result in a safer environment, with the ideal of lowering the number of human factors related truck accidents. Finally, a case study is used to suggest investments of these products for a fictitious trucking company. Through suggestions of the amount of new devices to purchase and how they should be used, hypothetical results of how a company may possibly benefit from these technologies are given.

TRUCK ACCIDENT DATA ANALYSIS

Truck accident data were analyzed to obtain common trends and causes resulting in an analysis of the frequencies of these events. The databases containing the national accident information were developed from the Federal Highway Administration's Office of Motor Carriers, Federal Estimates System file maintained by the National Highway Traffic Safety Administration (NHTSA), Fatal Accident Reporting System (FARS) which is also maintained by NHTSA, and Trucks Involved Fatal Accidents file compiled by the University of Michigan Transportation Research Institute (UMTRI). Additionally, recorded accident data from the Texas Department of Transportation (TxDOT) and Maryland's State Highway Administration's Office of Traffic and Safety were reviewed. These state data files had comprehensive information that at times were more in depth than federal data regarding some of the contributing factors of accidents. The national data will first be discussed, and then supported by the state data, which provides further details.

Truck Accidents

In 1978 the number of truck accidents peaked to its highest value and then began to decline, resulting in a 40 percent decrease in fatalities in 1987 (8). Between 1985 and 1995, the number of trucks involved in fatal crashes decreased from 5,153 to 4,453. The Insurance Institute of Highway Safety reported that the number of truck accident fatalities (note the difference between the number of trucks involved in a fatal accident and the number of truck accident related fatalities, which is the number of fatalities that result from any accident involving a truck) continued to decline to 4,815 in 1995. Of these fatalities, 13 percent of the deaths were truck occupants, 75 percent were people in cars and other passenger vehicles, and 10 percent were either pedestrians, bicyclists, or motorcyclists (2 percent were reported unknown). These values, which can be seen in Figure 1, reflect an overall decline of 40 percent in fatalities from truck accidents from 1978, with a 56 percent decline in fatality rate among tractor-trailer occupants and 14 percent decline of fatalities in passenger vehicle occupants.

In crashes involving a passenger vehicle and a large truck, 98 percent of the people killed in 1995 were occupants of the passenger vehicle. The differences in the size and weight of the vehicles (trucks are 20 to 40 times heavier than passenger cars and more resistant to deformation than passenger cars) cause the passenger vehicles to absorb more of an impact and crash force, thus often causing more harm to the passenger vehicles and occupants. Additionally, over the years passenger cars have been designed to be smaller and trucks have become heavier, resulting in greater impact forces and more severe consequences for the passenger cars and occupants. It is noted that most truck driver fatalities result from single vehicle accidents, as compared to accidents involving passenger cars, where the truck driver is often not hurt due to the crash impact that is absorbed by the passenger car (pc). Approximately 600 large truck occupants die annually, in comparison to 3,600 passenger car occupants involved in large truck crashes. Fifteen percent of fatal large truck crashes in 1995 involved 3 or more vehicles, as opposed to only 7 percent of fatal passenger vehicle crashes.

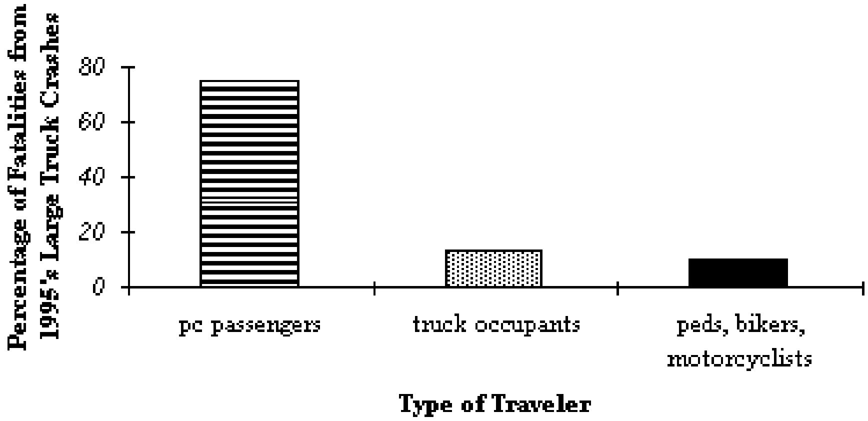


Figure 1. Fatal Accident Victims in Large Truck Crashes, 1995 (9).

Sixty-two percent of deaths in large truck crashes in 1995 occurred on major roads that are not freeways. Additionally, 26 percent occurred on freeways, 9 percent on minor roads, and 3 percent on unknown road types. More large truck crashes occur during the daytime (as opposed to night) and occur more often on weekdays, as opposed to weekends. Therefore, a safety problem exists when trucks are mixed with other vehicles on the roadways. The interaction between these two dissimilar vehicles tends to create a hazardous situation.

Efforts are being focused on giving attention to the driver characteristics of persons involved in truck crashes. Typically, the driver's age, experience, training, previous driving record, and hours of service are analyzed after each accident and much of these data have recently been analyzed. The Ontario Ministry of Transport, the Australian Road Research Board, and United States safety related organizations, such as the National Highway Traffic Safety Administration (NHTSA), the Insurance Institute of Highway Safety, the Federal Highway Administration's Office of Motor Carriers, and the National Transportation Safety Board (NTSB), have analyzed information and compiled statistics. Additionally, information available from the states of Texas and Maryland analyzed the data giving causes, results, and frequencies of accidents involving trucks, and more specific information about the truck drivers involved in these accidents.

The previous driving records of truck drivers have been analyzed for trends to possibly aid in finding ways to reduce driver-caused truck accidents. It is reported by the police who wrote the accident reports that 35 percent of truck drivers that were involved in fatal crashes in 1995 had one or more errors or factors related to their behavior associated with the crash (7). Some of the most common factors that were reported were excessive speeds (for the conditions of the roadway and the posted speed limit), failure to keep in the lane or from running off the road, and failure to yield to the right of way. However, it is additionally reported that in about three-fourths (72%) of the reported fatal crashes involving 2 vehicles (truck and other vehicle), one or more factors that caused the accident were the fault of the driver of the other vehicle involved, and that there were no errors or fault by the truck driver. Conversely, in 17 percent of the cases, the fault belonged solely to the truck driver for one or more factors that caused the accident (and none for the driver of the other vehicle). In 9 percent of the reports there were faults listed for both of the drivers, and only 2 percent attributed no fault to either of the drivers. Thus, it can be concluded that it is common that truck drivers' actions are often not the primary cause of truck accidents, however safety factors for trucks are important for defensive driving purposes. The information of the claimed at-fault drivers can be seen in Figure 2.

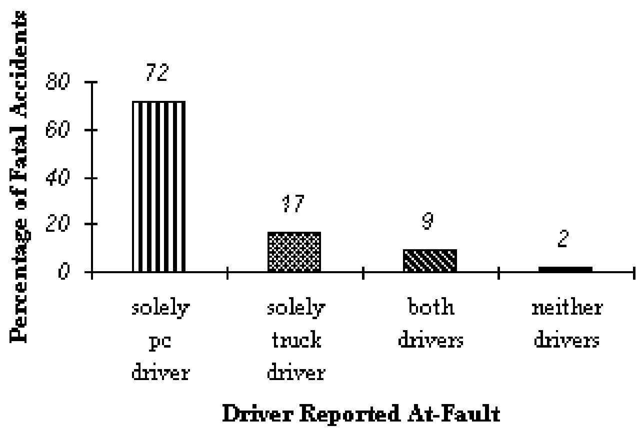


Figure 2. Faulty Driver of Truck-Other Vehicle Accident (9).

It is noted by the National Highway Traffic Safety Association that 30 percent of truck drivers in fatal crashes (in 1995) had at least one prior speeding conviction. The parallel rate for passenger car operators was 20 percent. However, only eight percent of drivers of large trucks have had a previous license suspension or revocation, as compared with 13 percent of passenger car drivers. Figure 3 shows the values of the recorded crashes, driving while intoxicated convictions, speeding convictions, and finally the recorded suspensions or revocations for drivers of four different vehicle types for 1995. Note that truck drivers have less violations (less DWI's and suspensions) than passenger car drivers which most likely is because driving their purpose of driving is for their profession as opposed to solely for recreational purposes. On the contrary, truck drivers have a higher amount of accidents and speeding convictions possibly because they travel a greater number of miles and are often more pressured by time constraints than passenger car drivers.

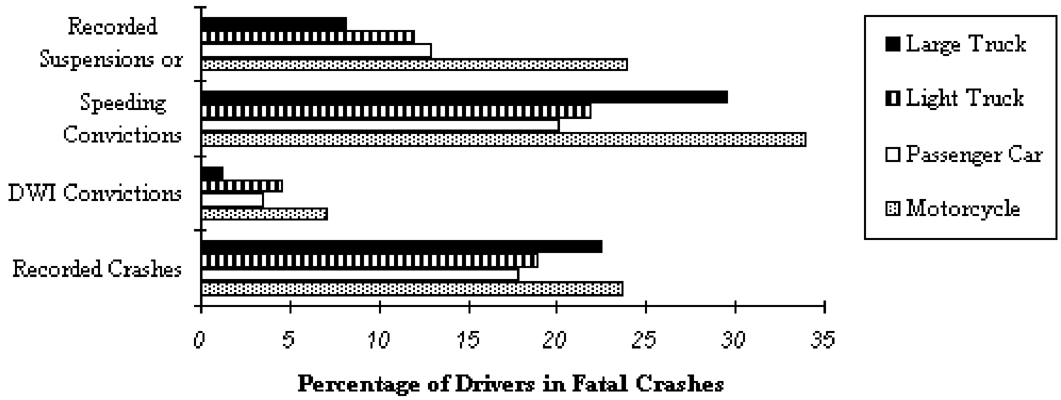


Figure 3. Previous Driving Record of Drivers Involved in Fatal Traffic Crashes, by Type of Vehicle, 1995 (7).

Additional Accident Factors

There are additional factors that are recorded at the scene of an accident that can give more information to the possible causes of the accidents. By analyzing previous driving records of truck drivers and the situation at the accident site, it is possible to analyze possible and actual driver related factors to accidents. Some of these factors include drugs, fatigue, inattentiveness, erratic and careless driving, and illness. Over time there has been a decrease in some of these causes, reaffirming a greater concern for safety and accident prevention in the trucking industry.

The National Transportation Safety Board (NTSB) found that one third of the 185 fatal crashes involving trucks from 1987 to 1988 were caused by driver fatigue, and one third of the drivers had drugs or alcohol in their system; alcohol and marijuana were the most commonly used drugs. Ten percent of the fatalities were caused by medical problems, the majority from heart attacks (10). Drugs/alcohol, fatigue, and driver errors, as they contribute to accident statistics, will be discussed further below.

Drugs/Alcohol

Alcohol is a depressant, increasing drowsiness. There is a great concern for the safety of alcohol from a fatigue factor in addition to it's other effects. Alcohol affects drivers, whether at a low level which may cause fatigue or at higher levels which causes a "drunken state." Congress directed the Transportation Research Board to study the level of alcohol concentration in blood (BAC) at which a person operating a commercial motor vehicle can be deemed to be driving under the influence of alcohol. The committee resulted in an assessment that the BAC limit for commercial drivers should be set at .04 percent. Shortly after this decision was made (in October of 1988), the Secretary of Transportation established by regulation a commercial driver BAC standard of .04 percent (11).

The alcohol involvement rate (nationally) is reported to be 3.1 percent for all truck drivers involved in all accidents in 1994, as opposed to the percentage of drivers of passenger cars that have used alcohol, which is much higher, at 8.5 percent (12). The Insurance Institute for Highway Safety researched alcohol involvement in fatal accidents. It was reported in 1995 that the percentage of large trucks in fatal accidents with a BAC greater than or equal to .10 was 4 percent (12). This amounted to a 62 percent decrease in the intoxication rates since 1985 (7). Comparatively, in 1995 the percent of intoxication reports in accidents were 19.2 percent for passenger cars, 22.4 percent for light (single unit) trucks, and 29.1 percent for motorcycles (7). Previously, alcohol involvement rates were much higher. Thus alcohol is still a significant contributing factor in truck accidents, although the problem has decreased throughout the past ten years.

In 1987 the Insurance Institute for Highway Safety surveyed 317 tractor-trailer drivers randomly and 29 percent had used drugs with potential use for abuse. Out of these 317 drivers, marijuana was detected in 15 percent of the drivers, nonprescription stimulants were detected in 12 percent of drivers, and fewer than one percent of drivers had alcohol in their blood (12). Additionally, in 1989 the Motor Carrier Safety Survey found that "the average truck driver believes that about one in four of his or her fellow drivers regularly drives under the influence of illegal drugs" (10). As a result, 84 percent of the nation's truck drivers approved pre-employment testing, 90 percent favored post-accident testing, and 68 percent supported random drug tests (10). Random testing has become more widespread and common for trucking companies and truck drivers. Pre-employment drug and alcohol tests are often given along with in-service tests for drivers, using medical examinations to screen for drugs and alcohol (13).

Fatigue

Fatigue as a cause of accidents has received much attention however it is difficult to define, measure, and quantify. Limitations have been implemented on driving hours to discourage drivers from driving when drowsy, to increase safety on the roads. Driving hour regulations generally state a maximum driving time before rest and a maximum driving time in various periods (14). The National Transportation Safety Board in 1990 examined the relationship between fatigue and driving problems, such as long hours of driving, driving in the middle of the night, and driving off the road due to dozing at the wheel. It has been suggested that fatigue is a "progressive detriment in performance, which if not arrested, will end in sleep (13)." Additionally, the American Automobile Association Foundation for Traffic Safety (AAA) suggested that fatigue was a probable cause of a crash if a driver was outside allowable hours of service and if the accident involved nonprofessional irrational actions, or if the attending officer at the scene of the accident suggested that fatigue was a problem. Another study suggested that the risk for a driver who had driven more than eight hours was double that of drivers who had driven for less than eight hours (14). Several sleep studies have identified that truck driver performance tends to deteriorate as hours of driving increase. Also, it has been noted that there are elevated levels of accident risk which have been associated with driving more than 12 hours straight and driving during early morning hours.

Driver fatigue, considered under reported, is considered one of the ten most frequent factors, involved in 2.8 percent of all accidents. The United States Bureau of Motor Carrier Safety in 1970 concluded that 30 percent of United States single-vehicle truck accidents appeared to have involved a driver falling asleep. A more recent National Transportation Safety Board (1990) study of post accident assessments concluded that 31 percent of fatal-to-the-driver accidents had listed fatigue as the most probable cause of the crash. It was also noted that one third of these fatigued drivers were affected by alcohol and/or drugs (13). Falling asleep at the wheel is second to alcohol for causes of single vehicle crashes. Statistics show that 69 percent of single vehicle crashes due to the driver falling asleep involve alcohol; however the effects of the alcohol may not have made the driver drunk, as much as making the driver tired and unable to stay awake. Sleep induced crashes are often the most destructive kind, because the driver usually does not try to avoid collision or correct the vehicle, often leading to greater injury. On the contrary, in the case of a driver who is awake and under the influence of drugs, the driver may still try to jerk back onto the roadway or correct his/her path, or may decrease speed (15).

Fatigue can be caused by many different combinations of physical and mental exertion, unchanging conditions, stress, alcohol, other drugs, sleep disorders or illnesses, essential medications, circadian rhythm, inadequate sleep, or the surrounding environment. Due to exhaustion, work pressures, and/or possible deadlines, it may be hard for drivers to make safe choices about when to stop driving or how long to sleep. It is also hard for a person to judge when he/she is too sleepy, as people depend on their environments to keep them awake. According to the Sleep Science Information Center in New York, 1 million tractor-trailer drivers in the United States suffer from inadequate sleep while driving. The center estimated that one-third of the truckers may be too tired to avoid a major crash. Additionally, truck drivers are ranked among the highest risk groups for occupational fatalities in the United States. Shift workers, whose internal clocks do not tend to coordinate with their work schedules, have twice the number of vehicle collisions as nine-to-five workers (16).

The data from the state of Maryland follow some of the same trends as the national data. Figure 4 shows the breakdown of causes of impairment for at-fault truck drivers involved in accidents from 1994 to 1996, as reported by the Maryland State Highway Administration's Office of Traffic and Safety. They stated that 21 percent of impaired drivers involved in truck accidents were impaired by fatigue. Additionally, they stated that 41 percent of impaired drivers while involved in an accident were apparently asleep (note the difference between fatigue and apparently asleep). Apparently asleep is the largest contributor to truck accidents, followed by 28 percent impaired by alcohol. Only 1 percent were impaired by drugs, 2 percentage were affected by a handicap, and 7 percent impaired by an illness.

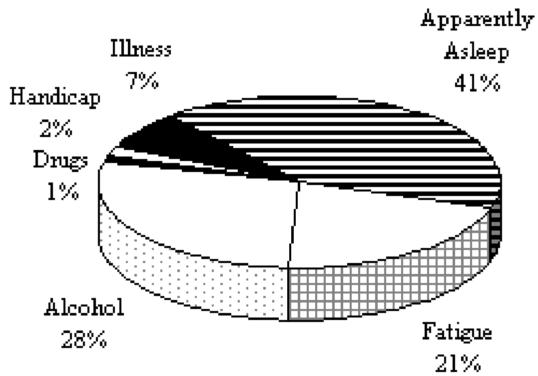


Figure 4. At-Fault Impaired Truck Drivers Involved in Accidents, 1994-1996 (17).

Not included in Figure 4 are the contributing factors that may be due to general driver errors, caused by erratic driving, inattention or aggressive behavior. Driver errors will be discussed further, as they contribute to many accidents.

Inattention/Driver Error

Police officers at the scene of an accident may assess the cause of the accident and the driver errors that were possibly involved. Drivers of large trucks were judged to be in error in 41 percent of the accidents involving trucks. Comparatively, police noted that passenger car drivers were noted to be in error in 63 percent of the cases. It must be kept in mind that these values are based on a subjective measure, however it is consistent that truck drivers have a much greater driving experience and are professional drivers. Some of the most common driver errors included not paying attention, following too close, not staying in the lane, speeding, and failure to obey signs.

Driver related factors for both drivers involved in two-vehicle accidents (truck and other vehicle) can be seen in Table 1. The Federal Highway Administration's Office of Motor Carriers separates some of the possible causes (driver related factors) according to both the truck driver and the driver of the other vehicle. Note that some of the factors are due to the driver and their specific traits or characteristics, while some of the contributing factors are due to the actual performance by the driver.

Table 1. Driver Related Factors for the Drivers in Two-Vehicle (Truck-Other Vehicle) Fatal Involvements (9).

Factors	**Truck Driver**		**Other Driver**	
	Num.	%	Num.	%
Failure to yield	200	13.2	791	21.8
Speeding	163	10.8	630	17.4
Failure to keep in lane	123	8.1	517	14.2
Failure to obey signs	100	6.6	323	8.9
Other non-moving violation	95	6.3	285	7.8
Inattentive (talking, eating, etc)	93	6.1	185	5.1
Non-traffic violation	89	5.9	137	3.8
Erratic, reckless, careless	67	4.4	102	2.8
Following improperly	44	2.9	83	2.3
Stopping in roadway	43	2.8	71	2.0
Improper turn	37	2.4	70	1.9
Operating w/o required equipment	35	2.3	56	1.5
Wrong side of road	35	2.3	52	1.4
Vision obscured by weather	29	1.9	44	1.2
Improper lane change	27	1.8	42	1.2
Other	273	18	162	4.5
Unknown	63	4.2	81	2.2
Total	1,516	100	3,631	100

Inattention and driver errors are causes that are important to focus on because they can be avoided. Systems are available which warn drivers of hazardous situations and may possibly reduce the number of accidents caused by interaction with other nearby vehicles, possibly limiting speeding above an appropriate limit, or lane drifting.

The Maryland data in Table 2 support the data of the contributing circumstances involved with truck accidents. Table 2 gives the Maryland statewide accident data naming the top five contributing circumstances involved in large truck accidents for 1996. Note the similarities between the state data and the national trends mentioned above.

Table 2. Maryland Statewide Accident Data of Contributing Circumstances (17).

Contributing Circumstance	**Average Amount (1994-1996)**	**Percentage of All Accidents**
Not Paying Attention	32,894	18.1
Influence of Alcohol	4,974	2.7
Followed Too Close	2,577	1.4
Fail to Obey Signal	2,361	1.3
Rain/Snow	1,996	1.1

Maryland data reveals that not paying attention is the most common contributing circumstance for drivers in accidents in 1996. Alcohol has previously been discussed, as have the other top three causes of inattention, following too close, and failure to obey a sign/signal. Additionally, adverse weather may affect drivers and their performance, however in-vehicle technology is not now available to help prevent accidents that are caused by weather conditions. By keeping the driver attentive it may be possible to improve performance in adverse driving conditions.

CURRENT AND FUTURE TECHNOLOGIES

Human factors is the study of the relationship between technologies and machines that accommodate the limits of the people who use them (18); it is the process of designing and applying technologies for the most efficient human use. Therefore, "the ultimate success of Intelligent Transportation Systems (ITS) will depend on the match between the characteristics of the systems (technologies) and the capabilities and limitations of the drivers," states William A. Leasure of NHTSA (16). Safety could suffer under a number of conditions: a poor match between the driver and technology, improper use of technology, and technology overload or distraction (19).

There are six areas that are focused on as main concerns for collisions:

- crash avoidance and human error;
- occupant protection;
- acute care and rehabilitation;
- highway safety management;
- driver information and vehicle control technologies, and
- highway design.

By focusing on and combining crash avoidance, human error, vehicle control technologies, and driving information, solutions can possibly be developed that address the deficient areas. There are currently many types of new technologies that are being developed specifically for either passenger cars, trucks, or for any type of vehicle. These technologies, when used properly may be able to provide a reduction in the number of truck accidents. The following three technologies are currently being made, manufactured, or tested:

- alcohol ignition interlocks;
- drowsiness detectors, and
- collision warning systems.

This report discusses each of the technologies and follows with guidelines for each of their uses.

Alcohol Ignition Interlocks

Alcohol ignition interlocks are currently being manufactured and sold separately for customers of various passenger vehicles. Typically they are hand held breath-alcohol analyzers that connect to the ignition system of a vehicle. The interlock registers alcohol at a molecular level, thus giving accurate readings of the Blood Alcohol Concentration (BAC), in percentages (20). Before starting the vehicle, the driver must complete a breath test verifying that his/her BAC is below a preset value. After ten seconds the results can be given and the vehicle will be ready to operate. The BAC will be given on a Light Emitting Diode (LED) readout, along with the signal of whether or not to start the vehicle. If the BAC level is above or at the preset value of an acceptable level, the vehicle will not start. Safeguards have been established in some of the alcohol ignition interlocks to prevent tampering or unauthorized use of the devices (21).

Current use of the alcohol ignition interlocks is primarily for DWI offenders. They are becoming a popular device for control of drinking and driving problems. Guidelines have been set by the National Highway Traffic Safety Administration for interlock devices; the guidelines intend to establish a level of accuracy, operating environments, reliability and stability, along with requiring features to discourage tampering or circumventing the device. These devices also have the ability to be programmed to give random "running re-tests" which prevents the vehicle from being started by a random third party and discourages any alcohol consumption on long trips. If the vehicle is started and a breath re-test is not completed, the vehicle's horn will begin honking and not end until the breath test is successfully passed. The devices are also capable of keeping an events log, including all uses and misuses, and this information can be summarized and downloaded to a personal computer.

The acceptable BAC percentage on the interlock can be changed for each individual user. A minimum level for an interlock is 0.020-0.025 percent BAC, as some food and drink products may have alcohol molecules in them which will be detected by the interlock (20). For example, the state of Illinois has a zero tolerance law, which establishes their maximum BAC level at .025. This value is equivalent to 2 to 3 drinks, thus preventing a person from driving after having very few drinks, providing zero tolerance for drinking and then driving. An additional example shows the need for a minimum level of tolerance at or above 0.020. If a driver uses mouthwash and at least five to eight minutes later tries to start the vehicle, the interlock will detect the alcohol molecules that have been consumed. However, it is reported that there are rarely false readings for the interlocks, excluding drink and food products that have alcohol molecules in them (20).

Currently ignition interlocks are rather easy to obtain and install. By calling a manufacturer, an appointment can be made to have an interlock installed within a day. The cost (as opposed to not being able to drive because of a DWI offense) is relatively inexpensive and they only require maintenance once every other month for calibration purposes. Currently, there is a very limited amount of use of alcohol ignition interlocks for trucks, however they are capable of being used in trucks, particularly to serve as random drug tests. It is suggested that a trucking company can lease or purchase an interlock and move it from one truck to another at any time, without needing to bring the truck to the manufacturer (20). If the trucking company has a mechanic who can install the interlocks, then there is ultimately no cost for the company to move the interlocks from one truck to another.

The Department of Transportation in the 1990s began random drug testing for truckers nationwide. The tests detect if the following drugs are in a person's body: alcohol, marijuana, cocaine, opiates, amphetamines, and phencyclidine (PCP). Transportation Department officials expected that eventually half of the work force in safety-related transportation jobs would be tested each year (22). Ignition interlocks would be a good method of random alcohol testing if the interlocks were randomly supplied in trucks. By keeping a computerized log the ignition interlock is able to record and secure the test results which could be reported to the company. Additionally, it is a safety device that is decreasing the number of drunk drivers and possibly decreasing the number of fatal accidents.

Collision Warning Systems

Collision avoidance and warning systems have become standard in cockpits of commercial aircraft, and counterparts for cars and trucks are currently being developed and manufactured (19). NHTSA began research on four different types of collision warning systems:

- rear end;
- merging/backing as a combination;
- intersections, and
- single vehicle road departures (23).

Prevention of highway accidents using advanced vehicle controls is becoming more widespread and common for manufacturers. The focus of vehicle safety is more and more from crash protection to crash avoidance," explains Gennry Conover, manager of external technology liaison at Ford Motor Company (24). The purpose is to reduce the chances of crash causing errors in the first place, mostly due to human errors. Research at Ford has shown that reducing the driver's reaction time by a half a second may reduce the number of incidents by as much as 60 percent (24).

One development named the Near Obstacle Detection System (NODS), uses microwave radar in the rear bumper to detect movement behind the vehicle. Microwave can additionally be used to signal a warning if a driver's closing speed and distance on a vehicle ahead is dangerous, in addition to a warning for objects that are too close to the trucks. Both a verbal warning and an automatic tap on the brakes are used to signal to the driver of the hazards ahead. When the transmission is in reverse, the NODS uses both audio and video alarms to alert the driver of possible danger. NODS additionally is used for lane changing and blind-spot detection.

Blind spot detection is an important aspect of collision avoidance, as not all accidents are due to inattentiveness by the drivers. Blind spot detection is the most realistic near-term collision avoidance system to be developed and applied to many vehicles (25). Radar is used for object detection particularly as a truck changes lane or is moving in reverse. The system can sense moving objects in the driver's blind spots, giving an audio or image on a video to caution the driver to check again before changing lanes. Systems for detection for both blind spots and the rear are being developed for objects within 15 feet of the vehicle which will trigger an alarm, and also give the location of the object (19). Also inclusive in some of the new technologies are a departure and lane position warning system; as a drowsy driver begins to let his/her vehicle drift, the warning system observes this and signals to the driver.

Drowsiness Detectors

A separate entity of the collision avoidance system is the lane positioning sensor. As a driver becomes drowsy and begins to drift off the road, a drowsiness warning system is activated which monitors the driver's eyes to detect the onset of drowsiness and inattention, both precursors to falling asleep (25). Other drowsiness detectors include lasers to watch eye movements, small infrared cameras that photograph eye closure, monitors for seat movements, and steering movement monitors. NHTSA is testing these devices to see if steering movements and eye movements can be used to detect drowsiness. "As drivers become fatigued, they start to steer differently. People start moving around in their seats when they are tired," says Bill Leasure, director of NHTSA's Office of Crash Avoidance Research. He states that if there is an ability to monitor seat movement and combine it with steering wheel reversal, then there might be some type of tool that works (23).

In Phoenix a computerized fatigue test was developed to gauge a driver's mental fatigue and possibly prove whether he/she has falsified his logs. This device was developed using funds by the Motor Carrier Safety Assistance Program and by the Arizona Department of Public Safety (the agency responsible for its development), however it can be used for other preventive safety reasons. The driver submits to an eight minute test on a driving simulator that measures twenty areas of performance, such as lane deviation, steering and throttle activity, acceleration, speed, and response to request for turn signals. It compares the test performance to a base line established by hundreds of test drivers in all stages of their duty cycle. Taken into consideration for the test are the driver's age, time on duty and time since last rest, and the place that the driver last slept. Models are being made that are small enough to fit with a joy stick in a small area of a vehicle. Developments were possibly being made for Arizona police to carry these simulators, however they could be used as a preventative measure for drivers to establish, using an unbiased scale, their degree of fatigue (26).

A large concern is focused on products which do give many false alarms because of reliability and safety reasons. A device is currently being developed by TravAlert which is intended to reduce the number of false alarms by functioning an alarm based on the driver's steering performance. TravAlert is currently developing a device that analyzes course corrections (steering patterns) for fatigue. It looks at a sampling of the drivers steering pattern over time, and looks for a lapse in the course corrections. An alert driver will drive with constant course corrections, while a fatigued driver will initially have many course corrections, then they will lapse, and then there will be a large course correction to account for the loss of control of the wheel. When a lapse in the course corrections is noted, an audio alarm will continuously warn the driver until the course correction is made.

The unit additionally has a computer which stores the information of the driver performance profile. It is possible to have these data in a hard copy format, so that the safety managers of trucking companies can assess the bottom and top percentage of fleet drivers and note the performance of their drivers. The driver does not have access to the unit with a particular type of installation so that the data can not be tampered with or changed by the driver. The unit automatically turns on when the vehicle approaches a highway speed of approximately 42-45 miles per hour. The system can also make adjustments depending on the type of truck that is being driven, as each truck type requires different steering patterns (27).

An important idea to note is that the warning systems need to be developed to prevent false alarms which may ultimately lead to distracting and confusing the drivers? False alarms need to be taken into consideration by manufacturers, as they need to be kept to a minimum for safety and efficiency reasons. If there are too many false alarms, then the system will be considered unreliable and real alarms may be ignored. Additional problems may include false detections, where the system is working correctly and there is physically an object that is being detected, however the object may not be a desirable object to detect. For example, the collision warning systems will not be effective if they detect air movements and debris on the ground as obstacles that may be dangerous, thus setting off the alarm. Also, it must be kept in mind that warning systems need to be complementary and clear to the drivers. Questions are posed when the driver receives more than one warning at a time. At this point, which warning gets the priority? Will it be confusing to the driver if one type of warning gives a buzzer and the other gives a light? The compatibility of the different technologies located in the same cab and giving information to the same driver needs to be seriously considered. The technologies need to be clear and complementary to each other.

RECOMMENDATIONS FOR THE DEVELOPMENT AND USE OF TECHNOLOGIES

As a result of the research of the three technologies discussed above and special concerns for each technology, the following recommendations have been made by the author for the development and use of the new technologies to result in a possible reduction of the number of accidents. Three common human factors causes of frequent truck accidents include alcohol, inattention/driver error, and fatigue. The alcohol ignition interlocks may possibly reduce the number of alcohol related accidents, if used as suggested below. The collision avoidance systems can possibly warn drivers of hazardous situations and reduce accidents due to driver errors or inattention. Finally, the drowsiness detectors may be used as a safety mechanism to prevent fatigue related accidents. Listed below are recommendations for the development and use of the three current technologies to result in the most beneficial uses of these technologies and safest results of their use.

Alcohol Ignition Interlocks

- Alcohol ignition interlocks should be placed and used randomly in trucks. Random use will lower costs (as opposed to supplying each truck with an interlock) for companies, yet provide accurate drug testing without using additional time or personnel to perform these tests.
- Due to the importance of being alert and non-drowsy, the alcohol ignition interlocks should be set at a very low BAC level (adopting zero tolerance), such as .025 percent, which is equivalent to approximately two to three drinks.

Collision Avoidance Systems

- Many developmental efforts must be made to reduce the number of false alarms in collision avoidance systems to a minimal amount for maximum effectiveness and reliance.
- The collision avoidance system's hardware developers should take into consideration the differences in rear, frontal, and side object detection systems. Vehicles will tend to naturally and more consistently be physically closer to the sides of trucks as opposed to the front and back ends of nearby trucks.
- Considerations must be made when developing the collision avoidance systems for the difference between front/rear and side detection and alarm systems. Research on side versus frontal air bags should be studied for further information on the differences in speeds and distances that need to be taken into account.
- Considerations need to be made about the effects of wind movements and debris on the ground that the system may detect as an obstacle. The systems need to "know" these objects/movements to reduce the number of false alarms.
- Collision avoidance systems should ideally be installed in each truck because of the common occurrence of problems such as blind spots, interaction with different sized vehicles, driver errors, and inattention.

Drowsiness Detectors

- Before the drowsiness detectors are marketed, the glitches which create false alarms must be removed for a worthwhile and reliable safety system.

- The drowsiness detector systems should initially monitor the individual driver's wheel, seat, or eye movements (when the driver is not fatigued) to use as a comparative reference for drowsiness measures throughout the trip. Otherwise differences in individual drivers could create false or inaccurate readings.
- Focus should be on the development of tests that are based on the drivers performance throughout the trip to make the monitors and tests accurate to what is occurring to the truck driver.
- Drowsiness detectors should ideally be used in all trucks, if possible, to serve as a reactive device to alarm each driver of upcoming problems. All drivers experience fatigue at times, thus they are a wise investment for each truck.

CASE STUDY

A case study was performed for an evaluation of the three technologies suggested for use in trucks, to result in a reduction of accidents caused by alcohol, fatigue, and inattentiveness/driver error. The given recommendations were applied to provide the best resulting investments of the new technologies for a trucking company.

Background

A trucking company, AI Trucking, is a medium-large company with approximately 4,000 tractor-trailers in its fleet. AI Trucking's accident history is proportional to the United States accident data; their frequencies and causes of accidents will be discussed in the benefit/cost analysis section. The owner of AI Trucking, who was discouraged with the high number of truck accidents that were caused by human factors related issues, such as drowsiness, careless errors, and fatigue due to alcohol, decided to review the guidelines suggested, then research and invest in the following three technologies:

- alcohol ignition interlocks;
- collision avoidance systems, and
- drowsiness detectors.

Information about the costs, applications, and benefit/cost ratios will be provided for each technology.

Alcohol Ignition Interlocks

To reduce the number of alcohol-related accidents, considerations were given to purchase alcohol ignition interlocks for the purpose of random drug testing. Additionally, AI Trucking will adopt a zero tolerance, thus creating a safer staff and making attempts to increase safety. Due to concern that alcohol can not only create a drunken state, but can also cause drivers to become fatigued, the ignition interlocks will be used as a proactive safety device to discourage against any drinking. As a continuum, it is possible for the interlock to perform a rolling re-test, randomly testing the drivers every few hours of continuous driving, to monitor if there is intake of alcohol throughout the trip. To provide the greatest amount of safety to all roadway users, AI Trucking will set the ignition interlock at a very low BAC level (zero tolerance), 0.025, which is equivalent to two to three drinks, because of the possible effects of even low doses of alcohol, making a driver fatigued even though the driver is not "drunk".

Each of the ignition interlocks costs approximately $2 per day (for rental use), and approximately $75 to be initially installed in each truck; the initial installation takes little time and can be performed at the alcohol ignition interlock company (21). It is possible for the mechanic of AI Trucking to reinstall the interlocks at no cost to the company. Thus the interlocks can be rotated throughout the company's trucks for the purpose of a random alcohol monitor/test at no additional cost (20). Additionally, every three to four months the ignition interlocks need to be calibrated. It is suggested that the owner first rent the ignition interlocks for sixty days before investing in purchasing the devices. Benefits from first renting the interlocks include being able to monitor the results, to assess their service, and also the maintenance costs (i.e. calibration costs) are waived by the rental company. To purchase an interlock AI Trucking must pay approximately $1500 per vehicle plus maintenance costs (21).

The data from the ignition interlock (giving the failures and successes of each use of the interlocks) can be checked as often as needed, suggesting every 30 days for the owner of AI Trucking. If there are not a significant number of drivers who fail the test, then perhaps AI Trucking is not in need of keeping the ignition interlocks. However if there is a significant failure rate, then the company can take action as it wishes (with those drivers, since it will be logged who was driving the vehicle when the test failed) and also plan to purchase the interlocks.

It is suggested that for a fleet size of 4,000 trucks, 10 alcohol ignition interlocks be initially rented/purchased. This number allows the ignition interlocks to be randomly placed in trucks within the company. The random placement of the interlocks allows the interlocks to serve as a random type of alcohol testing and monitoring. This application of the ignition interlock would prove to be the most useful for the company.

Although the use of the interlocks sounds very positive for AI Trucking and may possibly create a safer environment on the roadways, it may cause truck drivers within AI Trucking to become angry and feel as though they are not trusted. This issue needs to be addressed, as AI Trucking does not want to lose responsible drivers because of the implication of the ignition interlocks. By educating the drivers on the effects of small amounts of alcohol (i.e., fatigue), it may be possible to create an understanding by the drivers of why the interlocks and zero tolerance are important and being used for safety purposes. If the drivers understand that the interlocks are being used to save labor (for the people who usually perform the alcohol tests) and create a safer environment due to the effects of the consumption of alcohol, they may be more likely to accept the use of the interlocks. Caution is advised with the presentation of the issue of these proactive safety devices.

When weighing the costs and benefits of the alcohol ignition interlocks, one may conclude that if the information is presented to the truck drivers in a clear and educational manner, the benefits may outweigh the costs. The costs and benefits are listed in Table 3.

Table 3. Costs and Benefits of Alcohol Ignition Interlocks for Use in Trucks.

Costs	Benefits
Their monetary cost is approximately $1500 per interlock.	They may reduce the amount of alcohol and fatigue related accidents.
There is a possibility of offending the staff if caution is not used when presenting the need for the interlocks.	They encourage drivers to not consume alcohol (zero tolerance).
	They allow alcohol use to be monitored.
	They can reduce the amount of manual labor needed for random drug testing
	They can be reinstalled free of cost and are low in cost for rental "trial periods".

Collision Avoidance Systems

AI Trucking is also investigating the purchase of collision avoidance systems. The systems can be purchased from many manufacturers that are currently selling these products, as most of the brands have similar systems. The systems consist of monitors to install on the exterior of the truck, a main computer source, and the alarm system in the cab.

Each system includes detection for four types of accidents:

- rear end;
- merging and backing (and a combination of these);
- intersections, and
- single road departures.

The systems are reactive, warning the driver when an obstacle is nearby. At this time, it is the responsibility of the driver to react in a timely manner.

Each complete unit costs approximately $1300 with low maintenance costs (24). Ideally, the company should purchase a system for each vehicle, as there is no bias as to which driver may or may not use or need the system more than other drivers. Due to the blind spots on trucks and also human errors, the collision avoidance systems will possibly result in a lower number of accidents, both at high and low speeds.

However, due to the costs, it is not likely that AI Trucking can afford a collision warning system for each vehicle. Careful consideration needs to be given to which trucks are equipped with the systems. Prioritization due to accident history may seem like a wise choice for safety and economic purposes, however it may disgruntle and offend drivers.

Truck drivers are aware of the difficulties with blind spots and interaction with other vehicles on the roadway; this needs to be the main focus when discussing the use of the collision warning systems with the employees, as opposed to the driver errors and inattentiveness. However, the collision avoidance systems may reduce those accidents caused by inattentiveness. Table 4 lists some of the costs and benefits of the collision warning systems. It is noted that if the placement of the collision avoidance systems is carefully considered, they will be likely to have a positive effect for AI Trucking and the safety of roadways in general.

Table 4. Costs and Benefits of Collision Avoidance Systems for Truck Use.

Costs	Benefits
They cost $1300 each.	They may reduce a large number of accidents due to blind spots, vehicle interaction, driver error, and inattention.
Due to their high costs, it would not be possible for AI Trucking to initially purchase a system for each vehicle, as suggested.	

Drowsiness Detectors

AI Trucking is also interested in lowering the amount of accidents in the company caused by driver fatigue. The alcohol ignition interlock, as previously described, would possibly lower the amount of accidents caused by fatigue that results from the effects of consumption of alcohol. Additionally, fatigue sensors may reduce the number of accidents related to fatigue and driver errors. The sensors serve as a safety feature to alarm the driver of lapses in their course corrections (steering movements). These sensors are constantly monitoring the driving pattern, thus there is constant protection for the driver. It is possible for the data of the drivers performance to be stored and monitored at a later time through a computer, with the results being sent to the safety manager of AI Trucking. As a result, the safety manager could monitor the levels of fatigue of drivers, and possibly change the demands that are placed on drivers.

The cost of the fatigue tests based on the steering movements of the driver (and lack thereof) are approximately $200 for the systems that were previously described which follow the driver's pattern of steering and monitor for areas of lapse of course corrections (27). This alternative is rather economical, as $200 per vehicle is more affordable than the cost of the alcohol safety factors and other fatigue tests that have been studied (27). Most of the other types of fatigue sensors (those not based on course corrections) have a large cost, including maintenance costs, which are very minimal with a course correction warning system. It is suggested that AI Trucking, for the purposes of monitoring the fatigue levels and serving as fatigue warnings, invest in the course corrections warning system. The number of systems that should be purchased depends on the financial situation for AI Trucking. A fatigue warning system to furnish each vehicle would be ideal, as all drivers at times encounter fatigue. The sensors, if used properly, would possibly result in a smaller number of drivers who are driving while fatigue, a greater awareness of the driver's fatigue, and/or a lower amount of accidents and higher level of truck safety related to fatigue.

It should be considered that drivers may not be happy with their driving patterns (and therefore shift lengths and patterns) being recorded and possibly reviewed by a manager. This may result in angry employees, and considerations need to be made as to not upset or offend the employees. It must be noted that both with and without the use of the steering monitors, the responsibility to rest and not drive when the fatigue level is high is placed solely on the truck driver. It is important that in addition to the devices that warn the driver of their fatigued performance, educational sessions are given about the dangers of driving when fatigued, and how the drivers should react to the sensor's assessments. Without education of the dangers of driving when fatigued, these sensors will not be an effective safety device.

Additionally, these educational sessions need to remind drivers that all drivers at some time become fatigued. Therefore, the devices are beneficial in each vehicle and should appear as a safety feature and additional aid, not as an accusation or threat. Table 5 lists the costs and benefits for AI Trucking's purchase and use of the fatigue sensors.

Table 5. Costs and Benefits of Fatigue Sensors for AI Trucking.

Costs	Benefits
They may upset drivers that their sleeping and driving habits are being monitored.	They may reduce the number of accidents due to fatigue.
They are reactive devices, not proactive.	The cost of the fatigue sensors is very low, particularly when compared to the other technologies possibly being purchased.
	Due to the low cost of the fatigue sensors, it would be more likely that they can be installed in each truck.
	They provide a log for managers to observe driving, sleep, and fatigue patterns.
	They are based on each individuals's performance.
	The most frequent human factors cause of accidents at AI Trucking is fatigue, therefore the fatigue sensors would be a wise investment.

By looking at all three investments, AI Trucking should weigh the importance of investments for each of the devices. The alcohol ignition interlock may provide additional safety and reduce the amount of manpower needed (for people who usually conduct the alcohol tests), however the other devices may be used more regularly than the interlocks. Therefore, there may be more advantages to the other devices that would result in a better use of the company's money. The fatigue sensors will possibly reduce accidents that usually occur more frequently, as seen in the accident statistics analysis, and may be a wiser investment of the company's money. This is true particularly if there is a small budget allotted for these new technologies. It also must be kept in mind that the fatigue sensors can be quite costly to implement into each vehicle, however they will possibly prevent a larger number of accidents based on the frequency of fatigue related accidents. The collision avoidance systems can also be quite costly, due to the amount of systems that should be installed (as many as possible), however they too may reduce the accidents more so than the alcohol ignition interlocks. A cost-benefit analysis of each of the different technologies has been performed to evaluate the economical impact that these technologies will have for AI Trucking.

Cost-Benefit Analysis

To perform the cost benefit analysis, the costs of the accidents at AI Trucking before the use of the technologies were calculated. AI Trucking has the same proportion of accidents and frequencies of the causes as the national data. The national data states that in 1995 there were approximately 4,815 fatalities resulting from 4,453 accidents involving large trucks. Furthermore, there were 6,435,965 large trucks registered in 1995. Alcohol was the cause in 3.1 percent of accidents, while driver fatigue and driver error were the causes 31 and 35 percent of the time, respectively.

Table 6 shows the number of accidents calculated for AI Trucking in a normal year. These values are based on the proportions provided by the 1995 Motor Vehicle Crash Data from the Fatal Accident Reporting Systems (FARS), including the degree of severity of the accident (fatality, injury, or property damage) and the cause of the accident (alcohol, driver fatigue, or driver error) (28). Additionally, Table 7 gives the costs per accident type, using values from the Federal Highway Administration's Technical Advisory on Motor Vehicle Accident Costs, 1994 (29). These values were used to apply a cost to the accidents within AI Trucking, using general truck accident costs for the United States. An average value for the cost of the injury classification of accidents was used.

Table 6. Severity of Large Truck Crashes.

Cause of Crashes	Crash Severity		
	Property Damage	Injury	Fatality
National Data			
Alcohol	8,990	2,573	150
Driver Fatigue	89,900	25,730	1,493
Driver Error	101,500	29,050	1,685
Total	290,000	83,000	4,815
AI Trucking			
Alcohol	6	2	0
Driver Fatigue	56	16	1
Driver Error	63	18	1

Table 7. Costs per Accident Type (29).

	Severity of Accident		
Cost (1994 $)	**Property Damage**	**Injury**	**Fatal**
FHWA Comprehensive Costs	2,000	19,000-180,000	2,600,000

Using the above values and assumptions of the effectiveness of each device, calculations were performed to result in the number of reductions of accidents using the three different technologies. Ten alcohol interlocks were considered for purchase (costing the company 15,000 dollars), having an approximate effectiveness rate of fifty percent (assuming that with the random use, only fifty percent of alcohol related accidents were prevented). The drowsiness detectors, due to their low cost, were considered for purchase for each vehicle, costing the company 800,000 dollars. Their assumed effectiveness rate was much higher, at 90 percent. Finally, the collision avoidance systems, with an assumed 90 percent effectiveness rate, were considered for purchase for half of the vehicles, possibly costing the company 2,600,000 dollars.

The results for each of the technologies can be seen in Table 8. Included in the table are the reduction in the number of accidents and costs due to the reduction in accidents for each type of accident. Additionally included in the tables are the total savings for the companies (from the combination of all three types of accidents) and the cost to reduce one accident that otherwise would result in an injury. This value shows the investment that is needed to prevent this type of an accident. Finally, the benefit/cost ratio is calculated. Values over 1.0 for the benefit/cost ratio prove to be a good investment, as they reduce the number of accidents and have a return for money that is invested by the company. Values less than 1.0 may still reduce the number of accidents (and increase safety) however they result in an initial loss of money for the first year. Thus even though some of the technologies may result in an initial cost investment for the companies, safer roadways and less accidents are still a result.

A review of the assumptions used for the calculations of the benefits and costs of the technologies are as listed below:

- AI Trucking has the same proportion of accident causes as the national data
- The accident causes are as follows:
  3.1 % due to alcohol
  31 % due to driver fatigue
  35 % due to driver error
- The following amount of technologies were considered for purchase and for the benefit/ cost analysis:
  10 alcohol ignition interlocks
  4,000 drowsiness detectors
  2,000 collision avoidance systems
- The following values of effectiveness were used for each technology:
  alcohol interlocks had a 50 percent effectiveness for the entire fleet due to their random use
  drowsiness detectors had a 90 percent effectiveness when installed in each truck
  collision avoidance systems had a 50 percent effectiveness when installed in half of the trucks
- An average cost value $32,000 was used for injury accidents due to the range that depends on the severity of the accident

It must be noted that AI Trucking is a large trucking company that can afford the costs to keep up-to-date with technology. Out of the 30,000 trucking companies in Texas, 80 percent (24,000) of the companies operate less than 10 trucks *(30)*. Thus many trucking companies may not be able to invest in these technologies, but a large number of the larger trucking companies can possibly afford to equip many of their trucks, making a difference on the trucking industry and safety. For the private owners of large trucks, the dynamics due to the employees reactions of these devices will not be a focus, and thus the importance of the systems for safety reasons will be the main focus. This is an important aspect, as the owners can weigh the values of safety and invest in those systems that they feel would be the most advantageous.

Table 8. Benefits and Costs for the Suggested Technologies.

		Alcohol Interlock	**Drowsiness Detector**	**Collision Avoidance System**
Reduction in Accidents for AI Trucking	Property Damage	3	15	32
	Injury	1	14	9
	Fatal	0	1	1
Reduction in Costs		148,176	2,667,161	1,672,950
Cost of Technologies		15,000	800,000	2,600,000
Cost per (Injury) Accident Reduction		**15,000**	**53,333**	**260,000**
Benefit/Cost Ratio		**9.9**	**3.3**	**.64**

**Please note that the prices given were supplied by the following companies:*

Alcohol Ignition Interlock - CST, Inc.
Collision Warning System - Collision Avoidance Systems, Inc.
Drowsiness Detectors - TravAlert Safety International, Inc.

CONCLUSIONS

Human factors related issues are the cause of a large percentage of truck accidents; fatigue, alcohol use, and driver inattention/driver errors are frequent causes of these accidents. By understanding the causes of the errors which result in the accidents, it is possible to consider ways to alleviate the accidents.

New technologies were studied and three were focused on that would help to reduce the number of accidents caused by fatigue, alcohol use, and driver errors. As a result, the alcohol ignition interlock, drowsiness detector, and collision warning systems were studied. The alcohol ignition interlock, when randomly placed in trucks, can serve as a random alcohol test for trucking companies. Not only does it combat the problem of drunk driving, but it discourages even low levels of alcohol use which can affect drivers by causing fatigue. It is a very good tool as it is a pro-active device, attempting to alleviate a bad situation before it happens instead of reacting to the situation. The drowsiness detector monitors the driver's steering patterns in cases of high levels of fatigue and drowsiness, leading to the driver falling asleep. This helps to alleviate both single vehicle accidents and multi-vehicle accidents. It is most opportune for the drowsiness detector to be placed within each truck of a fleet. Finally, collision avoidance systems, similar to drowsiness detectors, are used as an alarm for the driver when encountered with a threatening situation. Both the drowsiness detector and the collision avoidance system are safety devices that are intended to alarm drivers of their errors before there are extreme consequences.

A main focus when manufacturing and developing the two alarm systems is the reliability, providing a lack of false alarms. False alarms serve as a large concern because of the danger of losing confidence and ignoring the system due to previous false alarms. It is important that the technologies are reliable and accurate with their instrumentation and measuring devices. This is a key in order to produce an effective safety device. Additionally, there are many concerns with the reactions of truck drivers to the use of these technologies. As the technologies are installed, educational material or courses are needed to present how the technologies are most effective and how they can benefit each individual driver and the trucking companies.

The positive results from these technologies will be the possible reduction in accidents due to alcohol use, driver fatigue, and/or driver inattention and error. Additionally, they may create a greater awareness in the trucking industry of the importance and need for these technologies to be used. Finally, both the alcohol ignition interlock and the drowsiness detector has shown an economical return by a high benefit/cost ratio.

ACKNOWLEDGMENTS

This paper has been written for the *Advanced Surface Transportation Systems*, a graduate course in Transportation Engineering at Texas A&M University. The author would like to thank the instructor of this course, Dr. Conrad Dudek, for his encouragement, efforts, and for providing the opportunities to learn from him and the Advanced Institute program. Sandra Schoeneman is also acknowledged for the time and efforts that she has invested in this program. The author expresses gratitude to Marsha Anderson, Ginger Gherardi, Thomas Hicks, Joseph McDermott, Colin Rayman, and Doug Robertson for their time, encouragement, and exposure to the professional views of current transportation issues. The author would also like to extend special thanks to Marsha Anderson and Tom Hicks for providing their time, efforts, and resources that they put towards this project. Additionally, the author extends thanks to Robert Perrillo for his time and technical assistance. Finally, gratitude is extended to the following people who were very helpful in providing information needed for this paper through phone interviews and articles that were provided:

Elisa Braver, Insurance Institute for Highway Safety
Fred Hallowell, Collision Avoidance Systems, Inc.
Kevin Kleeneier, CST, Inc.
Ron Knipling, Federal Highway Administration's Office of Motor Carriers
Dan Middleton, Texas Transportation Institute
Jeffrey A. Stone, TravAlert Safety International, Inc.

REFERENCES

1. MCSAFE: Motor Carrier Safety Analysis, Facts, & Evaluation. Vol. 2, No. IV, February, 1997.

2. Gorys, J. And G. Little. Characteristics of Commercial Vehicle Drivers in Ontario. In Transportation Research Record 1376, TRB, National Research Council, Washington, D.C., 19, pp.19-26.

3. 1995 Truck and Bus Safety Summit Web Site. http://www.dot.gov/dotinfo/fhwa/omc/tbssapxc.html

4. Moon, S. A. Keeping Up with Big Trucks: Experiences in Washington State. In Transportation Research Record 1052, TRB, National Research Council, Washington, D.C., 1986, pp.17-22.

5. The American Trucking Association Safety Page on the Internet. http://www.trucking.org/safety/safety_stats.html

6. McGee, H. W. Accident Data Needs for Truck Safety Issues. In Transportation Research Record 1052, TRB, National Research Council, Washington, D.C., 1986, pp.146-150.

7. National Highway Traffic Safety Administration. Traffic Safety Facts 1995: A Compilation of Motor Vehicle Crash Data from the Fatal Accident Reporting System and the General Estimates System. National Center for Statistics and Analysis, Washington D.C., 1996.

8. Today's Traffic. Traffic Safety, September/October 1990. Vol 90, No. 5.

9. *Truck and Bus Accident Factbook 1994.* The Federal Highway Administration's Office of Motor Carriers. Prepared by the Center for National Truck Statistics, University of Michigan Transportation Research Center, October 1996.

10. Shortcuts, Drug-Free Truck Drivers. Traffic Safety, Sept/Oct 1990. Vol 90, No. 5.

11. Commercial Driver Blood Alcohol Concentration Limit Study, Transportation Research Board, Special Projects Division, November, 1987. Washington, D.C.

12. Large Trucks. Pamphlet from the Insurance Institute for Highway Safety, August, 1996.

13. Cairney, P.T. *Action and Research Strategy: Australian Truck Safety Study, Research Report 200.* Australian Road Research Board, June 1991.

14. Ogden, K.W. and R.A. Pearson. *Review of Issues Relating to Drivers, and Enforcement: Australian Truck Safety Study Task 3, Research Report 203.* Australian Road Research Board, June 1991.

15. Mitler, M. Snoozing Almost Worse than Boozing. Traffic Safety, May/June 1989. pp17-18. Vol 89, No.3.

16. Today's Traffic. Traffic Safety, March/April 1990. P7. Vol 90, No 2.

17. Maryland Heavy Trucks/Statewide Accident Profiles. Maryland State Highway Administration, Office of Traffic and Safety, April 1997.

18. Wickens, C. *Engineering Psychology and Human Performance.* Harper Collins Publishers, New York, 1992.

19. Ankrum, D.R. IVHS-Smart Vehicles, Smart Roads. Traffic Safety, May/June 1992. pp 6-9. Chicago Illinois. Volume 91 no 3.

20. Meyer, Eric. Consumer Safety Technology, Inc. Personal Interview, July 30, 1997.

21. Kleeneier, Kevin. Consumer Safety Technology, Inc. Personal Interview, July 1, 1997.

22. Casteli, J. Wimpy Light Trucks Forced to Get Tough. Traffic Safety, March/April 1990. p 16-17. Vol 90, No. 2.

23. Bone, Jan. Truck Cab Design Aims for Comfort, Safety. Traffic Safety, May/June 1993. p 16-19. Vol 93, No. 3.

24. Hallowell, Fred. Collision Avoidance Systems, Inc. Personal Interview, July 1, 1997.

25. CVO Update. ITS World, July/August, 1996. pp 8.

26. Patton, O.P. Measuring Fatigue with a Machine. Transport Topics, March, 1991. p 41.

27. Stone, J.A. TravAlert Safety International, Inc. Personal Interview, July 9, 1997.

28. Traffic Safety Facts 1995: A Compilation of Motor Vehicle Crash Data from the Fatal Accident Reporting Systems and the General Estimates System. National Highway Traffic Safety Administration, 1996.

29. Technical Advisory, Motor Vehicle Accident Costs. Federal Highway Administration, Washington, D.C., 1994.

30. Woodard, Tommy. Texas Motor Transportation, Association. Personal Interview, July 7, 1997.

Kerry V. Perrillo received her B.S. in Civil Engineering from the Pennsylvania State University in May 1996. While working towards her M.S. degree in Civil Engineering from Texas A&M University, she is currently employed by the Texas Transportation Institute as a Research Assistant. Previously, Kerry has had work experience at the Federal Highway Administration, the Pennsylvania Transportation Institute, and the Penn State Civil Engineering Department. University activities have included membership in the Institute of Transportation Engineers (ITE), Vice-President of the Penn State student ITE chapter, and New Student Coordinator for the Texas A&M University student ITE chapter. Other activities include membership in ITS America, ASCE, and the Society of Women Engineers. Her areas of interest include geometric design, speed management, and human factors.

THE ROLE OF ADVANCED TECHNOLOGY IN FACILITATING TRANSIT USE FOR TOURISTS

by

Cristina Borja Slabic

Professional Mentor
Ginger Gherardi
Ventura County Transportation Commission

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad Dudek, Ph.D., P.E.

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

August 1997

SUMMARY

The use of advanced technologies to effectively distribute all types of information to the public is widely seen in marketing and advertising for numerous products and services. In particular, effective distribution of transit information is essential to the success of transit. Information distribution efforts would benefit all potential riders if they allow a tourist, a person who is likely the least familiar with the transit system and with the geographical layout of the city, to successfully use transit.

Through this research, the author sought to identify cities which are using advance technologies to provide transit information; determine which advanced technologies are being used and what type of information is being provided; assess the effectiveness of the technology and the information; summarize the data to identify the characteristics of the advanced technologies and of the information; identify criteria for effective transit information distribution; and apply findings to a case study by making suggestions for improving the means or manner for supplying transit information.

In order to provide the context for assessing agencies' efforts, information needs of potential transit users, then in particular tourists, were explored. Then the role of advanced technology in distributing transit information, along with a brief discussion of media available, was used to provide the framework for discussion of the findings. Through the assessment of the eleven agencies, evidence emerged of the potential for standardizing *what* information is provided without infringing on the creativity of *how* it is provided. Recommendations for improving transit information distribution efforts include:

- Maximize benefits of current advanced technology efforts by simplifying information format; providing relative locations; categorizing information provided; incorporating real-time information when possible; providing interactive capabilities; addressing the needs of various rider types; increasing the awareness of information system; and providing contact information.
- Deploy additional media when warranted and when consistent with organization goals for providing transit information. Collaborations with other agencies should be explored (not limited to transportation industry), and others' experiences should be considered.
- Document efforts for the sake of other agencies and for predecessors within the agency.
- Evaluate the performance of the information system and whenever possible work to incorporate improvements. Constant self-examination will help an agency maintain the course for meeting their desired objectives.

The Metropolitan Transit Authority of Harris County (METRO) was the case study for application of the findings of this research. METRO's only use of advanced technology media to distribute transit information is the World Wide Web. METRO currently has plans to make the Web site user-friendlier and is investigating on-line route planning. Overall, METRO's Web site provides helpful information, and re-packaging it has the potential to increase the effectiveness of the Web site. Potential future deployment of other media should be consistent with METRO's current goals for information the public about their services and coordinated with their current efforts.

TABLE OF CONTENTS

INTRODUCTION

Advanced technologies to effectively distribute information to the public are widely used today. They are seen frequently in marketing and advertising for commercial products and services on television, electronic billboards, and the Internet. Disseminating information about a product or service increases exposure and ultimately increases sales. Marketing and advertising efforts are justified by the awareness that information about a product or service is fundamentally linked to its use.

There is then a valid argument that this relationship also exists in the transit industry. Information about transit services properly distributed to potential riders would benefit both the users and providers of transit services. Confidence in transit services would increase because information is being provided to the potential patron. Ideally, this increase in confidence would lead to increased use. Even though the service provided in this case is done so by a public entity, and information distribution efforts are likely fiscally constrained, ridership levels and positive public awareness could increase if transit agencies sought to distribute accurate and timely information to the public. Although traditional means for informing riders about transit services are still necessary, increasing the use of advanced technology should be explored.

In particular, persons unfamiliar with the transit system, namely tourists, not only need general information about the availability of service between their origin and destination, but need information to help orient themselves in an unknown city. Although persons traveling to an unfamiliar city for business purposes are not considered *tourists*, some of the relevant behavior is encompassed by the description, and the term will be used throughout the paper.

Problem Statement

For a tourist, the need for information begins when the decision is made to visit a city. Persons are able to plan how to travel to a city, what attractions they wish to visit, at which hotel to stay, and how to traverse a city. Information on the transit system, such as schedules, routes, and fares, available to the soon-to-be tourist at this stage is also desirable and may allow them to forgo a rental car if they know the hotel they choose is located near a transit stop and routes that will allow them to visit popular attractions. Whether they arrive by air, train, bus, or drive their own car, tourists that have reliable information on the transit system and where it can take them are more inclined to use the system during their visit.

Some persons, however may not have the resources to pre-plan the trip to such a level of detail, thus their need for information is intensified upon their arrival to a city. At a terminal, such as an airport, the tourist needs information not only on how to access the system from the terminal, but on how to use the transit system in order to reach a desired destination, such as a hotel, just as tourist driving into an area needs information on a city's street network in order to drive to a destination. Providing the location of hotels relative to transit stops and to attractions may aid in the hotel-selection process. Once the tourist arrives at the hotel, information is needed to assist in travel between the hotel and other possible destinations, such as museums, restaurants, shopping areas, and local attractions. Providing similar information at intermediate destinations would also allow more flexibility for the tourist.

Therefore, it seems beneficial for transit providers to take advantage of the available technology to provide transit information to a varied audience. First, it is necessary to identify transit information needs of riders who are not familiar with the transit system. It is then necessary to assess the practice for disseminating transit information by means of advanced technologies. If transit information is made accessible to tourist, the least informed of the potential riders, then the logic follows that information about the transit service in an area can be accessed and understood by all types of riders (i.e., occasional riders, frequent commuters).

Research Objectives

Through this research, the author sought to:

- identify cities that are using advanced technology to provide transit information;
- determine which advanced technologies are being used and what type of information is being provided;
- assess the effectiveness of the technology and the information;
- summarize the data to identify the characteristics of the advanced technologies and of the information which is provided;
- identify criteria for effective transit information dissemination using advanced technologies; and
- apply findings to a case study by making suggestions for improving the means or manner for supplying transit information.

Study Approach and Scope

This research focused on collecting information from a dozen cities, including the case study, concerning the manner and means by which they are providing transit information. The data collected from a review of the transit agency's web site and by means of personal interviews were summarized and used to identify criteria for effective transit information dissemination. The assumption was made that the use of advanced technologies for information distribution was indicated by, at a minimum, the use of the Internet. Cities were then identified as candidates for an interview if the review of the web site was favorable. The premise of this study was that a city or region that provides easy to understand information for tourists also facilitates use by all transit riders. Findings applied to a case study yielded suggestions for improving transit information dissemination for the city of Houston, Texas.

Organization of Report

In order to assess the technologies which are being used across the United States and the format in which the information is being distributed, the appropriate context for this research must first be established. In the second section, the information needs of transit users, with particular emphasis on tourist information needs, will be discussed. Likely transit trips for tourists will also be listed. This information will provide the framework for discussion of the findings for this research.

The author then addresses the role of advanced technologies in the dissemination of transit information in the third section. Capabilities which are possible through the use of advanced technology media will be discussed. To conclude the section, discussion of the efforts being undertaken by the agencies surveyed were described.

In the fourth section, an approach to improving transit information presentation was formulated and then applied to the transit information distribution system in Houston, Texas.

TRANSIT AND TOURISTS

In order to establish the context for use of advanced technologies for transit information distribution, the information needs of potential transit users must first be explored. These basic needs are independent of the manner in which the information is distributed, whether it is via traditional or advanced means. First-time tourists also need information above and beyond what local infrequent riders need because they are not only unfamiliar with the transit system, but are likely unacquainted with the geographical layout of the city which they are visiting.

Information for Transit Use

Because the primary need of all potential transit users is to determine if transit provides a reasonable connection between a planned origin and destination, information is an essential part of transit services. Previous market research efforts have shown that ineffective user information systems provide barriers to increased transit ridership (1). Therefore, the manner in which information is managed and presented affects the image, the appeal, and ultimately the use of transit by the public. Travel by means of transit requires the users to acquire and interpret schedule and fare tables to plan a trip. Persons considering use of the transit system must know information, such as the route which will service their trip, and the time they need to arrive at their stop. The complexity of this task increases with the size of the transit system, the number of transit modes, and the number of transit providers.

Before transit can be the mode of choice for a trip, a potential rider needs to acquire the following information (2,3):

- origin and destination of the available transit routes;
- frequency and hours of operation;
- departure time from an origin and arrival time at a destination for desired trip;
- availability of a return trip on transit;
- fares (exact change, pass, discounted fare); and
- possible boarding and alighting locations.

If this information is provided in an easily accessible and timely manner, there might be a higher probability that transit will be the mode of choice. The source of the information must also be credible and foster confidence in the would-be rider. The subsequent decision then requires specific information, such as the transit mode to use, the specific routes to take, the total fare, the location of transfer points, the time involved in transferring, and the total trip time (2,3).

All of this information can effectively be organized into four groups (3):

- general information;
- schedule information,
- trip itinerary preparation, and
- en route information.

General information includes availability of services, names and types of services along with phone numbers, an explanation about the transit network, and possibly the numbering scheme for the bus routes. *Schedule information* includes timetables for routes, route maps with location of stops along the route, important landmarks and their relationship to transit stops, fare amount for each route, and transfer requirements. *Trip itinerary preparation information*, once given the desired trip ends and time, will include departure time from origin and arrival time at destination, the number of the route which will be used, transfer points and the arrival and departure times at each transfer point, and possible alternative routes and schedules that will serve the desired trip. *En route trip information* includes current operating status (actual arrival time, delays, cause of delays, occupancy status) to help the user decide whether to change mode or route.

The information needs as discussed previously are met by the first three groups of information. En route information can provide the specific details that are necessary for travel on transit, especially when a transfer from one route to another is necessary. However, if the rider pre-plans his entire trip and real-time information is not available, then en route information is redundant because it does not provide any *new* information, but it does increase the confidence in the information which the user has already gathered (provided no inconsistencies exist).

Although the following sections will have an in-depth discussion of the role of advanced technologies, it can be seen that information distribution can be expedited and even automated, thus help meet the information needs of potential transit users. As stated in the latest Advanced Public Transportation System (APTS) State of The Art Update (4):

> "Traveler Information Systems provide travelers with information on one or more modes of transportation to facilitate decision making before their trip and during the trip."

These new systems take advantage of today's technology to allow easy retrieval of information by transit users of all experience levels.

As users become familiar with the routes they typically use, their dependence on *static* transit information (e.g., route map, stops, fares) decreases. Although this is the case with a commuter's trip, there is still a need for *dynamic* transit information (e.g., schedule adherence, incident information) that may affect trip time, route, or mode choice. Riders unfamiliar with a city's transit system, however, are still likely to encounter the steep portion of the learning curve, and steeper still if they are unfamiliar with transit use altogether. This situation is further aggravated when the necessary information is not easily accessible and when the rider is also unfamiliar with the graphical layout of an area.

Tourist Needs and Characteristics

On their first trip to a city or region, tourists are typically unfamiliar with the transit system and services provided in the city or region they are visiting. At this time, such persons not only need information about the availability of service between their planned origin and destination and the relevant details (i.e., route number and fare), but they need information to help them orient themselves in an unknown city. This need for information begins when the tourist decides to visit a city and it is intensified upon the tourist's arrival. Furthermore, if the information is provided early enough, it may affect the tourist's choice of hotel and the means by which they will traverse the city (i.e., forgo a rental car). An additional benefit of providing a wider variety of information about an area is the increased likelihood that more tourism dollars will be spent in that area (5). This benefit could lead to innovative collaboration among affected and interested parties for deploying information-distributing advanced technology media.

A tourist arriving at an airport will find most information well presented. Typically, overhead signs are used to mark gates, restrooms, food stands, and baggage claim areas. At this time, the information supply is notably deficient of transit details, such as stop locations within the airport complex, schedules, and fares for transit routes serving the airport (3). This is a significant contrast to the amount of information available to guide people toward the counters of rental car companies. This exemplifies the difference in the way each service is depicted. Rental car agencies take advantage of clear, well-presented information to guide potential users to their counters.

Although a rental car is characteristically more convenient, it may not always be necessary or desirable. Tourists must be provided with information on all their transportation options so that they can make educated choices about how they will traverse the city. Similarly, tourists arriving in their own vehicle may find information at a visitors information center or at their hotel about whether their planned destinations are served by transit then choose to leave their personal vehicle at the hotel parking facility. Although other information is necessary for making this type of decision, such as parking availability and cost at the hotel and planned destinations, it can be readily seen that a visitor is better prepared to make educated transportation choices when relevant and reliable information is provided.

Table 1 shows the order of importance placed on transit information when visiting an unfamiliar city. These are results of a survey of the decision process of a transit user as conducted by Kikuchi, et. al. (3). For six different situations, survey subjects were asked to imagine they were going to use some mode of public transportation and then asked to grade the importance of each information item (where 2 is the least important and 9 is the most important). The situation of interest to this research is the one in which the person wanted to use public transportation to go from the airport (terminal) to a hotel (destination).

Failure to provide information on transit services at terminals (e.g., airports, train stations) and visitor information centers eliminates the transit choice for the individual. Effective and efficient delivery of accurate and timely information is, therefore, essential to encourage the public to consider transit as a valid transportation choice. Development of a system that will deliver this information to the least informed would then benefit every potential user.

In order to provide information that a tourist can use, the location of transit routes and their stops must be shown in relation to likely destinations. Table 2 is not meant to include all possible destinations, but rather provide context by which tourists may evaluate transit service. Will transit take them from the airport to their hotel? Will it take them from their hotel to a restaurant?

Table 1. Importance of Transit Information When Visiting an Unfamiliar City (3).

Information	Importance (Normalized Average)
Departure time from a terminal	0.89
Stop location	0.73
Requirement for transfer	0.70
Transfer time	0.70
Cost	0.66
Arrival time at a destination	0.63
Availability of return trip	0.63

The following table lists likely tourist destinations. Information relating a city's or region's transit services to such destinations would not only benefit tourists who may want to use transit to get to them, but local persons who know where these places are located and will be able to deduce where transit services are provided.

Tourist behavior for using transit can be characterized by their likely destinations and by the time of day in which they are likely to travel. Because tourists cannot access any services until such locations are staffed, tourists would likely not travel during peak morning times. From the vantage point of transit properties, tourists' concerns are also likely to take a back seat to commuter issues during these times.

Table 2. Likely Tourist Destinations.

Topic	Destination/Purpose	Examples
Basic	Lodging	hotel, motel
	Food	restaurant, diner, fast-food stand
	Shopping	drug store, antique shop, shopping mall
Entertainment	Performing Arts	theater, music hall
	Exhibit	museum, zoo
	Recreation	amusement park, night club
	Spectator Sport	stadium, baseball park, arena
	Participation Sport	golf course, ski resort
Local Interest	Historic Sites	monument
	Natural Features	lake, beach
Transportation	Terminals	airport, train station
	Transfer Point	park and ride lot, rental car lot, bus/train stop
Education	Higher Education	university, college campus
	Supporting Services	book store, library
Professional Services	Medical	hospital emergency room
	Financial	bank, ATM
	Public	city hall, police station, post office
	Miscellaneous	convention center, CBD

ROLE OF ADVANCED TECHNOLOGIES

Advanced technology has allowed for many changes in the way society functions. Televisions and telephones are commonplace today. The use of personal computers (PCs) and cellular phones is increasing dramatically. All of these devices can be used as tools for distributing information to the public. For example, automated telephone systems, where customers can use their touch tone phones to access information, have freed up customer service representatives from the monotony of dealing with frequently asked questions. These systems have allowed direct interaction between the customer and an agency's database, which expedites the customer-inquiry process.

In conjunction with the personal computer, a tool which has acquired much popularity is the Internet, a world-wide network of computers. Specifically, information on a wide variety of topics is made available over the Internet using the World Wide Web (Web), a client-server protocol for information retrieval (6). Using a standardized communication convention called Hypertext Transfer Protocol (HTTP), a client program (e.g. Netscape Navigator™ or Microsoft Explorer™) can access information on any Web site. Documents are transferred in a standardized language known as Hypertext Markup Language (HTML), which includes commands for formatting text, accommodating graphics, implementing fill-out forms, and adding links to other Web sites.

Many types of organizations and individuals have taken advantage of the Web's capability and flexibility by developing Web sites and posting information on a wide range of topics, from general interest topics such as the weather forecast for an area to extremely specific material, such as collections of Topps™ baseball cards. This has been particularly beneficial for entities that rely on information dissemination to meet their objectives.

The use of many types of advanced technologies to effectively distribute information to the public is seen frequently in marketing and advertising for commercial products and services. Increasing the available information increases the awareness and seeks to positively affect consumers' behavior. Efforts to inform and educate the public about services available, whether they are in the private or the public sector, rely on the effective distribution of information. Communication within an industry is also important and necessary for presenting consistent information to the public, but the exchange of information between an agency and the general public will be discussed in the remainder of this section. In particular, information distributed to the public about transit services will be discussed.

Media for Information Distribution

The use of advanced technology is seen in the information collection and management systems *behind* the dissemination, and in the *media* which is interfacing with the end user. Although the location of these media is a crucial issue which must be addressed, the topic is outside the scope of this research. Locations can be argued to be *strategic*, such as airports or other terminals if the opportunity to transfer onto transit is heightened. Sites mentioned throughout the paper are examples and solely for illustration and clarification purposes. Media that can be use to distribute information are (4, 7):

- touch-tone telephone information systems;
- pagers;
- kiosks (touch-screen terminal) and other wayside systems;
- in-vehicle displays (e.g., electronic signs in transit vehicles) and enunciators;
- wireless, hand-held devices;
- interactive television;
- dedicated channel on cable television; and
- on-line services (e.g., Internet).

The use of such media that access automated or broadcasted information results in efficient distribution of information to a large audience of potential users.

Capabilities of Advanced Technologies

Because the success of the transit industry, depends on the timely, accurate, and efficient distribution of route, schedule, and fare information to patrons, advanced technology systems have been developed to replace or amplify the traditional methods of distributing transit information (6). These systems are known as advanced traveler information systems (ATIS) and can include information on various modes. The transit industry's participation in and experience with ATIS has been monitored through the Federal Transit Administration (FTA) Advanced Public Transportation Systems (APTS) program. In an effort to increase the transit industry's knowledge of successful applications of advanced technology, the 1996 Update of the State of the Art focuses on APTS implementations in four types of services (4):

- Fleet Management;
- Traveler Information;
- Electronic Fare Payment; and
- Transportation Demand Management.

Of these services, information on traveler information systems was pertinent to this research. These information systems are then further subdivided into three categories: *pre-trip; in-terminal and wayside;* and *in-vehicle*. The Update also includes a separate category for *multimodal traveler information system*, which are typically pre-trip information systems, but integrate traffic and transit information. This category involves material outside the scope of this research, and only the first three categories of systems will be discussed.

Although originally directed toward riders that were fairly familiar with the transit system and only needed updates on schedules and transfers, traveler information systems now provide information to the most inexperienced riders in an easily-accessible manner. These systems allow customization of information to an individual's needs by supporting itinerary planning and providing detailed information for the entire trip. By automating repetitive tasks, ATIS has enabled reduction in the time and cost of handling customer requests. In conjunction with other advanced technology (e.g., automatic vehicle location), ATIS has the capability to incorporate dynamic, real-time information, such as (7):

- projected bus arrival times;
- service disruptions and delays;
- accidents; and
- recommended alternative routes or services.

Incorporating such real-time information would increase the value of the information by making it useful for someone choosing a mode, time, or route of travel. For example, a person aware of an accident that will affect her planned trip will be able to choose an alternate route to circumvent the incident. This additional real-time information affects her decision, thus reinforces the ATIS goal: provide information to facilitate decision making throughout the trip.

Other capabilities associated with the use of advanced technology include increased processing speed which leads to time savings; parallel processing capabilities that allow more persons to be served at any given time; and with an ever-increasing number of people becoming computer literate and comfortable around different types of advanced technology, a larger audience for information provided via such media.

Importance of Timely Information Delivery

Before persons will take advantage of transit, information about the available services in an area must be communicated to patrons when they need it. For example, a person will not board a bus with the *hope* that it will travel toward the place he is going. He will board a bus that he knows will take him to his desired destination. In order for him to *know* which bus will take him where he wants to go, he must have confidence in the information that he has gathered about the route of the bus. (The specific information which is necessary has already been discussed in the previous section.) The timeliness and authenticity of the information fosters confidence in the information. These issues are important, and how advanced technology can address them must be considered. Anyone contemplating use of the transit system must feel confident that they have obtained up-to-date information from a reliable source. The capability of advanced technology to deliver current information in a manner which suggests authenticity should be utilized. For example, an agency's logo can be used to validate information and an effective date to denote its validity. Uniform and consistent information presentation also increases confidence in the information. The potential user then feels confident he has acquired authentic, up-to-date information which is relevant to his trip.

Agencies Surveyed

The 1996 State of the Art Update contains descriptions of notable and innovative APTS applications across the United States and Canada (4). However, for this research, it was necessary to identify agencies that were providing information in a "tourist friendly" manner. "Tourist friendly" systems contain elements which not only provide information which is necessary to use the transit system, but help the tourist orient himself in an unfamiliar city. Such elements could be landmarks on a system map or a list of points of interest.

In an attempt to identify agencies which were providing information in this manner, an initial review of transit agencies was conducted. The original list included agencies with Web sites of which FTA was aware (8). The complete list available on the FTA Web site is included in Appendix

A. In order to justify this preliminary review, a basic assumption was necessary: the existence of a Web site was a good indicator that the agency was likely using other advanced technology to distribute information. Eleven agencies were contacted for further information via a short interview (list of questions included in Appendix B). Table 3 lists agencies which were contacted and the cities in which they are located. The transit modes for which they provide information are also noted.

Table 3. Agencies Contacted.

Agency	Location	BUS	LRT[1]	CR[2]	Other
Bay Area Transit Information Project	California	●	●	●	Ferry
Chicago Transit Authority, CTA	Illinois	●	●		
King County Department of Metropolitan Services, King County Metro	Washington	●			Ferry
Lane County Transit District, LTD	Oregon	●			
Central Florida Regional Transportation Authority, LYNX	Florida	●			
Massachusetts Bay Transit Authority, MBTA	Massachusetts	●	●	●	CB[3]
Metropolitan Atlanta Rapid Transit Authority, MARTA	Georgia	●	●		
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T	Maryland	●			
People Mover	Alaska	●			
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit	Oregon	●	●		
Ventura County Transportation Commission, VCTC	California	●		●	

1. LRT: Light Rail Transit
2. CR: Commuter Rail
3. CB: Commuter Boat

Survey Results

The size and nature of the agencies surveyed varied significantly. For example, the Bay Area Transit Information Project, with a staff of two, compiles and provides transit information over the Web for over 40 agencies representing various modes serving the San Francisco Bay Area (9). On the other hand, a large transit property with the oldest LRT system, the Massachusetts Bay Transit Authority (MBTA) provides information on buses, light rail, commuter rail, and commuter boats serving Eastern Massachusetts on their Web site, with additional information at some stations and in some of the cars of the Red Line (10, 11). These two agencies are examples of the two types of agencies distributing transit information: the agency that takes a multi-jurisdictional approach and deals with a collection of transit providers; and the larger transit property that distributes information on its own numerous services. Two of the eleven agencies are in transition: they currently provide information about their own services, but are moving toward a more regional view.

Media that were being used at each of the agencies contacted included the Internet, kiosks, automated telephone systems, terminal/wayside devices, in-vehicle devices, television, and radio. Table 4 shows what advanced technology media is being used at each agency. The following paragraphs are brief descriptions of the agencies which were contacted. Unlike the tables, where agencies are listed in alphabetical order, the order of the descriptions groups agencies by nature (as discussed in the previous paragraph), transition status (moving toward changing the focus), and system complexity.

San Francisco Bay Area Transit Information Project

The founders of the Bay Area Transit Information Project Web site saw the potential for making transit information available over the then-new World Wide Web and came online in March 1994 (9). The Project is currently only using the Web to distribute all types of transit information, including information on Bay Area Transit Interest Groups and the California High Speed Rail Commission. There are no plans to deviate from their original focus and employ other media to distribute the information.

However, there are now links to the Web sites of some of the agencies for which the Project provides information, even though the essential information about each transit provider can still be found on the Project's Web site (12). Information on an agency includes: their logo; announcements; general information; schedules; fares, passes, tickets; maps; telephone numbers; and where to submit comments and suggestions. This type of consistency helps users better maneuver the site because they gain familiarity with the format. Work is currently underway to include transit routing capabilities for riders in the San Francisco Bay Area.

Table 4. Media Used by Each Agency.

Agency	Web site	Kiosks	TV	Radio	In-vehicle Device	Automated Telephone	Wayside Device[1]
Bay Area Transit Information Project	●						
Chicago Transit Authority, CTA	●	demos					
King County Department of Metropolitan Services, King County Metro	●	●					
Lane County Transit District, LTD	●	future					
Central Florida Regional Transportation Authority, LYNX	●	future					future
Massachusetts Bay Transit Authority, MBTA	●	future			on few LRT cars[2]		in some stations[3]
Metropolitan Atlanta Rapid Transit Authority, MARTA	●	●			●[4]	●	●
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T	●	future	●[5]	●			
People Mover	●	future					
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit	●						●
Ventura County Transportation Commission, VCTC	●				●[6]		

1. Other than kiosks
2. LED signs and automated PA system in some cars of the Red Line
3. LED signs
4. Electronic signs coordinated with PA system on buses.
5. Local channel broadcasts peak-hour traffic conditions
6. On VISTA (inter-city service) buses: all have automated PA; some have LED signs.

Ventura County Transportation Commission

The Ventura County Transportation Commission (VCTC) provides information on several transportation providers in Ventura County via the Web, including taxi cab companies and inter-county services, such as Metrolink, Amtrak, and Greyhound (13). Phone numbers to contact the individual providers are listed, but additional information is scarce. In one instance, maps for local routes are not provided on the Web site because individual providers hold the rights to those images (14). VCTC, however, provides on-line transit routing capabilities by allowing the user to enter an origin (street address or landmark), a destination, a departure time, and other specific information about a trip. An itinerary, with detailed transfer directions, is then prepared for that trip. The relevant portion of schedules are also provided for the routes that will be used for the trip, in case a transfer is missed. Although it is currently under construction, the option to view walking maps between bus stops will be provided to facilitate transfers between services of different providers.

VISTA buses, which provide inter-city transit service, are equipped with automated PA systems which announce stops (15). Additionally, some are also outfitted with LED devices that complement the PA system. Both these systems are bilingual.

King County Metro, Riderlink

King County Metro's Web Site, Riderlink provides bus information and links to the Washington Department of Transportation's site for ferry information (16). They also provide vanpool, carpool, accessible transit, and park-and-ride lot information. In conjunction with the Overlake Transportation Management Association, an organization of eight major, high-tech employers, King County Metro originally designed Riderlink to help employers meet Washington State's Commute Trip Reduction law by providing easy access to information about a broad range of alternative transportation options (17). Although the site currently provides mostly information in Metro's jurisdiction (except for ferry information), there are plans to include transit information from three additional and adjacent transit providers and help Riderlink become truly regional in nature (18).

The original focus was on work-site kiosks accessing the Web site, but the rapid expansion of Web use, and the increased number of persons accessing it from locations other than the kiosks has since shifted Riderlink's focus away from kiosk deployment. However, Metro still has kiosks, which access the Web site, located in the lobby of the Exchange Building (Metro headquarters) and soon to be at the Boeing Everett plant (a major employer) and the ferry dock (18).

Montgomery County Department of Public Works and Transportation

Another agency which can potentially move toward incorporating information on other jurisdictions is the Montgomery County Department of Public Works and Transportation (DPW&T) (19). They presently have links to MARC and to the Washington Metropolitan Transportation Authority's Site, which gives basic information on the transit system in Washington, D.C.: Metrobus and Metrorail. Efforts to include information on transit providers in adjacent areas have not progressed because the adjacent counties are not embracing the capabilities of the Web (20). From the Montgomery County DPW&T Web site, information on current traffic conditions, including incidents and real-time video can be accessed.

Another way the DPW&T is providing information to the traveling public in Montgomery County is by broadcasting peak-hour traffic conditions over the local television channel, which is also available at hotels in the area for visitors to access. Knowing about traffic conditions on local streets will allow visitors to make educated transportation choices. Travel Advisory Radio is also in place, but is targeted at persons already in their personal vehicle. Montgomery County DPW&T is also planning to deploy a kiosk, displaying the Web page, at a shopping mall in the area.

People Mover

People Mover has been providing transit information via their Web site for Anchorage, Alaska, since October 1996, and are working to re-design the site (21,22). A marketing group's research showed that a high number of households in Anchorage had PCs and designed a Web site to inform the population of the available transit services. People Mover's objectives are to increase ridership, especially among the disabled and elderly. The Web site therefore provides information about these special-needs transportation services, along with route and schedule information for their bus system.

Lane Transit District

Because of the desire to take advantage of a new communications medium and open new forms of communication with the public, Lane Transit District (LTD) in Eugene, Oregon, began to provide some transit information over the Web in July 1995 (23,24). There are plans to increase the amount of information provided via the Web on the still-young and underdeveloped site (25). Slow development of the Web site can be attributed to the fact that LTD still relies heavily on traditional means of distributing information. Their Readers' Digest, an 80-page, 8½ x11-inch book containing individual route maps and timetables, has been used as an example for other properties. Independent of the medium, however, the driving force for providing information is to encourage increased use of the system and help residents better understand LTD services. "If information is provided to the right people in the right way at the right time, ridership could increase and vehicle miles traveled could decrease" (25). This type of philosophy corresponds to the goal of an ATIS.

LYNX

The Central Florida Regional Transportation Authority has shifted away from their original focus from tourism toward providing information via the Web to LYNX riders and other agencies who might need it (26,27). The youngest site of those reviewed, the LYNX Web site has been on line since approximately April 1997 (28). The site's appearance is notably different from the rest and is effective at conveying the Authority's desire to have a "fun" site.

In collaboration with the City of Orlando, changes to LYNX's current free downtown parking shuttle will include a variation of the current route, sign-post detectors to monitor the shuttle's location, and communicating this information to stops. Persons arriving at stop will be able to tell if a shuttle just left and how long it will be before it returns to that stop.

Tri-Met Transit

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) has been providing information over the Web since August 1995 to increase the awareness of environmentally-friendly transportation choices for getting around Portland (29,30). The Web site is not only seen as a communication medium with the public but as the beginnings of an Intranet within Tri-Met that will allow the appropriate departments to update their information. A central control check, however, will still be necessary to maintain consistency.

Another medium which is being used at Tri-Met is monitors located at major bus shelters that display arrival times for buses (similar to what is seen at airports) (31).

CTA

The Chicago Transit Authority (CTA) Web site provides information on its bus and light rail transit system, paratransit services, transfer points and transit centers, and other related information, such as commuter options for carpooling and vanpooling (32). CTA has been on line since the Summer of 1996, when it sought to take advantage of publishing their transit information in an alternative medium (33).

CTA also deployed two kiosks as part of a demonstration project: one kiosk at the airport, and the other in a Hispanic neighborhood where the kiosk provides information in English and Spanish. There was no available information about future plans for the CTA kiosks.

MBTA

The Massachusetts Bay Transit Authority (MBTA) provides information about its transit services via the Web (10). What began as a 30-page pilot to "try out" the new technology of the Web in December 1995, has turned into a 1000-page undertaking (34). Information on the site not only includes the essential information for use of the bus, light rail, commuter rail, and commuter boats, but MBTA history, points of interest index, general information, and job opportunities. Detailed station information, which provides address, parking availability, and a list of routes which service that location, allow the user to conceive the relationship among modes in the absence of a system map for bus service.

Although a limited deployment of advanced technology, some of the LRT cars of the Red Line are equipped with automated, coordinated LED displays and public announcement (PA) systems which announce stops, and similar displays at some of the stations (35).

MARTA

The Metropolitan Atlanta Regional Transit Authority (MARTA) provides information about its transit services via various media. Although the Atlanta Traveler Information Showcase was announced by Transportation Secretary Federico Peña on April 1994, it was not until May 1995 that MARTA's involvement became more than that of an information provider (36). The transit information that was provided for the Showcase included bus and train frequency, schedules, operating hours, and fares; MARTA general information; wide-area travel and park-and-ride lot information; and transit itinerary planning via personal communication (hand-held) devices, interactive television, on-line services, and interactive kiosks (37).

MARTA's Web site still provides this information (except transit planning capabilities) and 39 of the kiosks (owned by Georgia Department of Transportation) are located at MARTA rail stations providing similar information (36,38). Other media used by MARTA to communicate transit information to its patrons include passenger information displays (PIDs), an automated telephone system, direct-line schedule information telephones at intermodal stations, and in-vehicle electronic signs coordinated with the PA system. Because of all of the devices being used to distribute information, the chances that a visitor will find the information they need via a device they are comfortable using increases.

Observations

Regardless of the differences between the agencies contacted, the survey of agencies revealed several notable trends in the design of and purpose for which they distribute transit information via advanced technology media. These commonalties indicate that there is potential for developing guidelines for the use of advanced technology in distributing information. In order to satisfy the information needs of potential transit riders, information to show that transit could provide a reasonable connection between a planned origin and destination must be provided.

All agencies were using the Web to distribute transit information. All sites provided either a system map or routing capability to determine if transit served a planned trip. In addition, MBTA, LYNX, King County Metro, and Tri-Met Transit have either a POI or “popular destinations” listing. All the agencies surveyed provide route schedules and maps except for the two that provided routing capabilities: LTD and VCTC. However, VCTC did provided a short portion of the schedule in the case a transfer was missed. LTD routing simply provided the routes and transfer points for connecting an origin and destination, but was independent of time, while VCTC provided a detailed itinerary with a total travel time. LTD is currently working to place route schedules and maps online to aid in the itinerary-building process.

Because the rate at which Web use is increasing surpasses the rate at which other technologies can be deployed, an agency’s use of the Internet was not a good indicator that other advanced technology media were being used to distribute transit information. Of the eleven agencies surveyed five were using advanced technology media to inform potential riders: King County Metro, MARTA, Montgomery County DPW&T, Tri-Met Transit, and VCTC; and two others had limited deployment of such media: CTA and MBTA.

King County Metro’s kiosks display the Riderlink Web site, which has been on line since December 1994. MARTA’s involvement in the Atlanta Traveler Information Showcase during the summer of 1996 was a tremendous catalyst for the development of a regional, multi-modal ATIS and now provides edifying examples. Kiosks, in addition to MARTA routes and schedules, display other pertinent information to aid travelers and tourists. Video images of traffic conditions in Montgomery County are also available on the Web.

The nature of the advanced technology being used at Tri-Met Transit, VCTC, CTA, and MBTA is quite different than those mentioned previously and are not currently linked to the Internet, although several of the applications have a potential for incorporation onto the Web site. Tri-Met Transit currently has a DOS-based trip planner (virtual kiosk) which can be downloaded from their Web site, and is working to incorporate the capabilities on line. The real-time information that is currently provided at Tri-Met's monitors and MARTA's PIDs could also be posted to supplement the information on the Web site. CTA's demonstration kiosks are providing transit information and have the potential to mirror web site information if CTA revisits kiosk deployment. Additionally, MARTA's and VCTC's VISTA buses and some of MBTA's LRT cars have in-vehicle devices that automatically signal stops and/or major cross streets, which would not be adaptable to use on the Internet.

When questioned about future plans, most agencies stated that they are working on deploying kiosks and/or providing interactive, on-line routing capabilities. Agencies are also considering "face lifts" and other improvements to the appearance and structure of the Web sites. Specific information available on each agency's "front page" can be seen in Appendix C.

IMPROVING INFORMATION DISTRIBUTION

Communicating the information necessary to successfully traverse the transit system can be done through the use of various advanced technology media. As the transit industry explores and experiments with technology and format for providing information, several guidelines should be considered. In particular, care should be taken to present a constant visual format, which will not only foster confidence in the information, but will facilitate use because potential rider recognizes the format and knows where to search for the information. Another critical issue is the inclusion of contact information to encourage comments and feedback from the users. Transit agencies provide services for individuals and their opinion and comments should be noted and used to improve information distribution practices.

Approach for Improving Transit Information for Tourists

In order to improve the content and method in which transit information is provided, especially to tourists, the following represents a framework for evaluating and improving an agency's current information distribution process.

Assess current capabilities and maximize benefits.

Recognizing that transit agencies are likely fiscally constrained, efforts to first maximize the use of currently available resources should take place before further investments are made. Whether information is presented visually (i.e., Web) or audibly (i.e., telephone systems), the following list applies for improving information distribution.

- <u>Simplify information format</u>. User should be spared information overload and only be given necessary information, with an option for further detail. A menu-driven, nested information system can present information in smaller, digestible groups. Options to cancel requests and re-trace steps are also desirable to ease information searches.
- <u>Provide relative locations</u>. Including orientation elements within route and station descriptions helps persons unfamiliar with the available transit services or with the geographical layout of a city or region. In particular, when information is presented visually route maps or transfer locations should be shown in relation to street network and other landmarks (e.g., body of water, monument).
- <u>Categorize information provided</u>. User should be able to easily and quickly find desired information. Information should be grouped together in logical categories. Furthermore, development of a standard list of "basic" information to be provided by such systems would help users familiar with one system to be able to successfully maneuver another.
- <u>Incorporate real-time information</u>. As data collection systems (e.g., traffic proves, AVL) are installed, efforts should be made to incorporate such information which will affect transit operations, thus increasing the value of the information.
- <u>Provide interactive capabilities</u>. This will allow the user to customize information to meet his particular needs. This capability will also ease itinerary building by allowing the user to enter an origin and destination (fill-out forms on Web browser or coded locations on touch-tone telephone system). "Registration" with an agency will also allow for mass

mailings of pertinent information (i.e., commuters can be notified of changes to their frequently-traveled route).

- Address needs of various rider types. Realize that riders with different characteristics place value on different types of information. An agency should provide information to facilitate transit use in general, but realize that some riders are concerned with specific routes and real-time status of the transit system.
- Increase awareness of information distribution systems. Persons will not likely use transit unless they have information on its services, and they cannot gather information unless they know where it is and how to get it. This can be considered marketing of transit service or as public education about alternative modes of transportation. Considering the strategic placement of media may also work toward increasing the public's awareness of the existence of the information system. Specifically, agencies trying to inform riders and woo potential patrons should consider designing a visually appealing Web site.
- Provide contact information and use criticism constructively. The opinions of persons using the information distribution system should be noted; their interaction with it will determine its effectiveness. Constant change to adjust to the demands of the persons using the information system will benefit the system by ensuring it is providing the information transit users want. When phone numbers are included, it is important to include area codes since not all users may be in the area.

Deployment of additional media must be warranted.

Once agencies have fully taken advantage of the capabilities of the media already in place, it may still be necessary to expand information distribution efforts by investing in additional media or systems. This may also symbolize expanded deployment of existing technology, which is also represents additional investment.

- Clearly define objectives. Investing in additional media should be warranted; knowing what needs to be accomplished will guide the selection of the appropriate medium for accomplishing the desired objectives. Particular care should be taken to avoid the "solutions-in-search-of-problems" phenomena.
- Review others' experience. Although documentation is scarce, it is necessary to learn from the mistakes and successes of other agencies and not to "re-invent the wheel." In particular, APTS State of the Art and State of the Practice reports from the FTA are serving to inform the industry about what is being done. Lessons learned will also provide better information on strategic placement of advanced technology media.
- Explore collaborations and partnerships. Agreements with other agencies or entities which have similar objectives or audiences may lead to resource savings. A transit agency does not need to repeat the efforts of other agencies to provide information to a specific audience. For example, an agency can provide transit information to be included in efforts already in place to inform tourists about a city's or region's other available services (e.g., hotels, restaurants, shopping).

Documenting efforts is crucial.

Whatever it does and however it does it, an agency should document good and bad experiences in order for other agencies, and more importantly, for predecessors within an agency to understand the motivation for the development and deployment of certain media and the information systems. This will allow people to learn from and possibly build on proven successes and avoid common mistakes. In particular, documenting a system's objectives will ensure consistency in future development. Documenting changes in circumstances and their affect on the agency and its information distribution system will also benefit system evaluation.

Evaluate periodically.

Constant self-examination should lead to constant improvement. Periodic evaluations will also allow agencies to re-visit their objectives and ensure that the system has not deviated from its original focus. If changes in circumstances alter the effectiveness of an information system, an evaluation of the objectives may lead to modification of the driving force.

Application to Case Study: Houston, Texas

The Metropolitan Transit Authority of Harris County (METRO) currently has a Web site that has been providing information on-line since late 1995 about the extensive transit system which serves the metropolitan area around Houston, Texas (39,40). Additionally, there are plans for future deployment of an automated telephone system and discussion has occurred with the Texas Department of Transportation to deploy kiosks, which would use maps and schedule information from the METRO Web site.

Much of the information METRO provides on their Web site can be classified as "tourist friendly" but the packaging of the information does not foster curiosity in what may be behind the redundant buttons. Information which deals with the bus system is denoted with a picture of a METRO bus, except for an animated button (with the word "NEW") which announces the recent addition of METRO's Stored Value Card. METRO also provides its large and intricate system map, which requires several screens to be viewed entirely. Maintaining a sense of direction (i.e., toward downtown, or away from the airport) is difficult when all that can be seen is a maze of color-coded lines with arrows pointing to the adjacent map section. Also, the user of the site must find the route he wishes to use, then retrace his steps back to the main menu in order to find the button linking to information on the individual routes, maps and schedules. From the schedule page, he can go to the fares page, but he must remember the route's type of service (i.e., commuter, local, express) in order to find the corresponding fare.

Improving Web site design

Because METRO's only current use of advanced technology media to distribute information is the Internet via the World Wide Web, the first step toward improving information dissemination efforts is to address the design of the Web site. METRO is currently providing valuable information via the Web, and relatively simple re-packaging efforts would increase the Web site's effectiveness.

- Limit use of images. Currently, METRO's "front page" contains too many images and too much time is required to load page. Use pictures or other symbols that require less memory.
- Eliminate "clone" buttons. Images mentioned above include repetitive pictures of a METRO vehicle, a hard hat, METRO headquarters, and vehicles in traffic. Although they are used to categorize the information, there is room for variety while still maintaining all bus system information together. Ideally, each button should contain its own unique picture or symbol. If there is not one that can easily depict the subject matter, a short text phrase can be used or perhaps that indicates that the information should not be presented on the "front page."
- Simplify system map. Current map is too intricate and discourages casual viewer from investigating the extent of METRO's services. Providing a "skeleton map" of the metropolitan area on which users can "zoom in" to the area of interest would facilitate the use of the system map. Once they have arrived at the level of detail the current system map provides, including descriptive phrases, such as "East- toward Downtown," on the arrows that take the user to the next map section would also help the user maintain her sense of orientation, especially if she is not familiar with the area already. METRO's current system map does include landmarks and major street names, which is a positive attribute of a system map.
- Include interactive capabilities. As with several of the agencies surveyed for this research, the idea of providing on-line routing capabilities is being explored by METRO. Another form of user underaction would be accomplished by allowing the user to "click" on the system map to access information on the individual bus route: schedule, map, and fare. This would eliminate the back-and-forth nature of accessing information, where the route is identified on the system map then the user must re-trace her steps to be able to access the list of routes for individual route information.
- Present information together or in logical sequence. As stated in the above recommendation, the back-and-forth nature of many Web sites does not allow the user to view all the relevant information at once. Although placing a route's map and schedule all on one page may not be appropriate because of information overload, providing a link from one to the other and to fare information is certainly possible.
- Provide Web site map or Table of Contents. Mapping the location of information on a Web site or providing a Table of Contents will in general make it "user friendlier" by decreasing the amount of time necessary to "learn" how to maneuver a site.
- Include Points of Interest List. A list of points of interest within an area are generally valuable since they orient persons unfamiliar with the area, and give the non-transit user familiar with the area reference points they recognize.
- Provide contact information and LISTEN. METRO currently provides phone numbers and some E-mail addresses, but these are not all listed near the corresponding information. User feedback should be encouraged, perhaps listed as a main menu item.
- Include Frequently Asked Questions (FAQs) section. Providing a list of FAQs saves the user the time they would have spent articulating their concern and contacting the organization, and also saves the organization response time.
- Promote existence of Web site. All types of METRO riders and potential riders should be made aware of the Web site and of the information which is available on it. Information about this transportation choice should be included whenever would-be tourists search for

"ways to get around Houston." Announcing the Web site address on METRO literature and vehicles would also increase public awareness. METRO should also seek to include a "link" to its Web site from related Web sites such as Houston's Web site (http://www.ci.houston.tx.us/) or Houston's real-time freeway speed map (http://traffic.tamu.edu/traffic.html).

Deploying Other Media

- Telephone System. METRO is planning to deploy an automated touch-tone telephone system to provide basic route information (e.g., schedules), but should consider providing a telephone number where users of that system can call and express their opinions, good or bad. Such customer feedback will lead to development of an overall better product. Posting this phone number with the Web site address would give users an option for the media which they will consult for information.
- Kiosks. When and if kiosks are deployed (whether METRO will deploy the hardware is unknown) and they display METRO information, the format should remain consistent with what is on the Web site. Developing an information format specifically for the kiosks would seem redundant because information is already provided in a visual format on the Web site. However, further simplification may be necessary for information on kiosks since persons using such a medium are not in the same situation as a person accessing METRO information from a PC.

METRO could benefit from improving the manner in which it is currently providing transit information via advanced technology media. Because the first step in this process involves maximizing the benefits of its current efforts, there is minimal additional investment toward these ends.

CONCLUSIONS

The use of advanced technologies to effectively distribute information to the public is seen frequently in marketing and advertising for commercial products and services on television, electronic billboards, and the Internet. Marketing and advertising efforts are justified by the awareness that information about a product or service is fundamentally linked to its use. Likewise, effective distribution of transit information is essential to the success of a transit provider. In particular, clear and simple information distribution efforts would benefit all potential users of a transit system.

The information needs of potential patrons were discussed in order to provide the context for the recommendations for improving the use of advanced technologies in transit information distribution. Regardless of the media used to distribute it, potential riders must first gather information to determine if transit provides a feasible connection between two trip ends. Various advanced technologies are now being used to supplement traditional information distribution efforts in order to help potential riders make educated transportation choices. The agencies contacted for this research were chosen from FTA's Web site and are providing transit information via the Web, kiosks, wayside devices, and in-vehicle devices.

The basic recommendations for improving transit information distribution efforts include:

- Maximize benefits of current advanced technology efforts :
- Deploy additional media when warranted;
- Document efforts for the sake of other agencies and for predecessors within the agency; and
- Evaluate the performance of the information system periodically.

The Metropolitan Transit Authority of Harris County (METRO) was the case study for application of the findings of this research. METRO's only use of advanced technology media to distribute transit information is the World Wide Web. METRO currently has plans to make the Web site user-friendlier and is investigating on-line route planning. Overall, METRO's Web site provides helpful information, and simply re-packaging it has the potential to increase the effectiveness of the Web site. Potential future deployment of other media should be consistent with METRO's current goals for information the public about their services and coordinated with their current efforts. Specifically, any METRO information available on a kiosk should maintain be true to the format seen on the Web site.

ACKNOWLEDGMENTS

This report was prepared for the graduate summer course CVEN 677 *Advanced Surface Transportation Systems* at Texas A&M University.

First and foremost, the author would like to thank God, without Him nothing is possible. The author would also like to express her gratitude to Dr. Conrad Dudek, the course instructor, for providing the opportunity to interact with the diverse group of transportation professionals. Sincere thanks are extended to each of the mentors: Marsha Anderson, Tom Hicks, Joe McDermott, Colin Rayman, Doug Robertson, and especially, Ginger Gherardi, who served as the professional mentor during the preparation of this report. The author would also like to thank Sandra Schoeneman for her attention to detail which kept the summer program running smoothly. A loving thanks goes to my husband Michael for his love and support.

Gratitude also goes to the following individuals who in one way or another contributed to this effort:

- Mikael Sheikh, Bay Area Transit Information Project
- Jim Mulqueeny, Chicago Transit Authority
- Robert Wade and RuthKay Andrews, King County Department of Metropolitan Services
- Dan Tutt and Cosette Rees, Lane Transit District
- Tori Iffland and Michelle Ranalli, Central Florida Regional Transportation Authority
- Carl Cederquist, Massachusetts Bay Transit Authority
- David Allen, Metropolitan Atlanta Rapid Transit Authority
- Rich Palmieri, PBT-TA
- John Riehl, Montgomery County Department of Public Works & Transportation
- Liana Hanson, People Mover
- Dareth Murray, Tri-County Transportation District of Oregon
- Steve DeGeorge, Ventura County Transportation Commission
- Ted Taveras, Metropolitan Transit Authority of Harris County
- Harriet Smith, ITS America
- Mark Hickman, Texas A&M University

Finally, the author would like to thank Dick McCasland, Darrell Borchardt, and the rest of the TTI Houston office for providing space, resources, and support during this summer endeavor.

REFERENCES

1. Blattber, R.C., and S.R. Stivers, "A Statistical Evaluation of Transit Promotion," *Journal of Marketing Research*, Vol. 7, no. 3, August 1970, pp. 293-299 and Lovelock, C.H., *Consumer Oriented Approaches to Marketing Urban Transit*, PB-220 781, National Technical Information Service, Springfield, Virginia, 1973.

2. Barba, Rose A. and Steven Rittvo. *Guidelines for Developing Transit Information Systems*. New York State Department of Transportation, Albany, New York: August, 1972.

3. Kikuchi, S with S. Aneja, P. Cakroborty, A. J. Hofmann, M. Machida, and V. Perincherry. *Advanced Traveler Aid Systems for Public Transportation: The Intelligent Transit Mobility System (ITMS),* Federal Transit Administration, U.S. Department of Transportation. Washington, D.C.: September 1994.

4. Schweiger, C. "Advanced Public Transportation Systems: The State of the Art UPDATE 1996," Federal Transit Administration, U.S. Department of Transportation: January 1996.

5. Dean, Lisa H. and Roy C. Loutzenheiser. "Automated Information Systems at Interstate Welcome Centers as Element of Intelligent Vehicle-Highway Systems" *Safety and Human Performance: Human Performance and Safety in Highway, Traffic, and ITS Systems, Transportation Research Record 1485.* Transportation Research Board. Washington, D.C.: January 1995.

6. Gildea, D. and M. Sheikh. "Applications of Technology in Providing Transit Information," *Public Transportation 1996: Planning, Management, Marketing, New Technology, and Safety and Security*, Transportation Research Record No. 1521, Washington DC: 1996.

7. Goeddel, D. "Benefits Assessment of Advanced Public Transportation Systems (APTS)" U.S. Department of Transportation, Research and Special Programs Administration, Cambridge, MA: July 1996.

8. Federal Transit Administration listing of transit agencies with Web sites: http://www.fta.dot.gov/other/#transit.

9. Sheikh, Mikael. Bay Area Transit Information Project. Telephone interview. July 7, 1997.

10. Massachusetts Bay Transit Authority, MBTA: http://www.mbta.com/

11. Cederquist, Carl. MBTA. E-mail correspondence: July 29, 1997.

12. Bay Area Transit Information Project: http://www.transitinfo.org/

13. Ventura County Transportation Commission: http://www.goventura.org/

14. DeGeorge, Steve. VCTC. Telephone interview: July 9, 1997.

15. Gherardi, Ginger. VCTC. Personal conversation: August 3, 1997.

16. King County Metro, Riderlink: http://transit.metrokc.gov/

17. Bradshaw, Catherine, Jean Wong, Betsy Morton, Robert Wade. Riderlink Demonstration Project Evaluation Report. King County Department of Transportation, Seattle, Washington: February 1996.

18. Wade, Robert and RuthKay Andrews of King County Metro. E-mail correspondence: July 7, 1997.

19. Montgomery County DPW&T, Ride On: http://www.dpwt.com/TransSvcDiv/intro.html

20. Reigh., John. Montgomery County DPW&T. Telephone interview: July 11, 1997.

21. Hanson, Liana. People Mover. Telephone interview: : July 8, 1997.

22. People Mover: http://www.peoplemover.org/

23. Tutt, Dan. LTD. E-mail correspondence: July 11, 1997.

24. Lane Transit District: http://www.efn.org/~ltd/

25. Rees, Cosette. LTD. E-mail correspondence: July 9, 1997.

26. Ranalli, Michelle. LYNX. Telephone interview: July 11, 1997.

27. Central Florida Regional Transportation Authority, LYNX: http://www.golynx.com/

28. Iffland, Tori. LYNX. Telephone interview: July 15, 1997.

29. Murray, Dareth. Tri-Met. E-mail correspondence: July 15, 1997.

30. Tri-County Metropolitan Transportation District of Oregon, Tri-Met: http://www.tri-met.org/

31 Murray, Dareth. Tri-Met Transit. Telephone interview: July 7, 1997.

32. Chicago Transit Authority, CTA: http://www.transitchicago.com/

33. Mulqueeny, Jim. CTA. Telephone interview: July 12, 1997.

34. Cederquist, Carl. MBTA. Telephone interview: July 9, 1997.

35. Cederquist, Carl. MBTA. E-mail correspondence. July 29, 1997.

36. Palmieri, Rich. PBT-TA. Telephone interview: July 15, 1997.

37. Information Bureau "The Atlanta Traveler Information Showcase: Fact Sheets" Walcoff & Associates, Inc., Fairfax, Virginia: May 1996.

38. Metropolitan Atlanta Rapid Transit Authority, MARTA: http://www.itsmarta.com/

39. Taveras, Ted. METRO. Telephone interview: July 15, 1997.

40. Metropolitan Transit Authority of Harris County, METRO: http://www.hou-metro.harris.tx.us/

APPENDIX A

List of agencies on FTA Web site

Albuquerque, New Mexico - Albuquerque's Transit Department
Anchorage, Alaska - Anchorage Transit System
Ann Arbor, Michigan - Ann Arbor Transportation Authority
Appleton, Wisconsin - Valley Transit
Atlanta, Georgia- Metropolitan Atlanta Rapid Transit Authority (MARTA)
Austin, Texas- Capital Metro

Baltimore, Maryland- Maryland Mass Transit Administration (MTA)
Bay City, Michigan - Bay Metropolitan Transportation Authority
Bellingham, Washington- Whatcom Transportation Authority (WTA)
Blacksburg, Virginia- Blacksburg Transit
Bloomington, Indiana - The Bloomington Transportation Corporation
Boston, Massachusetts- Massachusetts Bay Transportation Authority (MBTA)
Bremerton, Washington - Kitsap County Transit Information

Champaign, Illinois - The Champaign - Urbana Mass Transit District
Charlotte, North Carolina - Charlotte Transit
Chelan and Douglas Counties, Wenatchee, Washington - LINK Public Transportation
Chicago, Illinois - Chicago Metra Commuter Rail System
Chicago, Illinois - Chicago Transit Authority
Chicago, Illinois - PACE (Suburban Bus)
Clark County, Washington - C-TRAN
Cleveland, Ohio- Greater Cleveland Regional Transit Authority (GCRTA)
Columbia, Maryland - Mass Transit Administration service operated by Eyre Bus Service (selected schedules) between, Washington, DC, Columbia, MD and Baltimore, MD.
Columbus, Ohio - Central Ohio Transit Authority (COTA)
Conway, South Carolina - Coastal Rapid Public Transit Authority (CRPTA)

Dallas, Texas - Dallas Area Rapid Transit
Dayton, Ohio - Miami Valley Regional Transit Authority
Denver, Colorado- Regional Transit District

Eugene, Oregon- Lane Transit District (LTD)

Fairfield, Connecticut (Westchester, Orange, Dutchess, Putnam, and Ulster Counties in New York) - MetroPool
Fort Collins City, Colorado - Transfort
Fort Smith, Arkansas- Ozark Regional Transit
Fort Wayne, Indiana - Fort Wayne Public Transportation Corporation

Hennepin County, Minnesota - Public Works Department, Transit and Real Estate Division, Transit Unit
Honolulu, Hawaii - The Bus

Houston, Texas- Metropolitan Transit Authority of Harris County
Huntington, WV- The Tri-State Transit Authority

Ithaca, New York - Tompkins consolidated Area Transit

Jefferson Parish, Louisiana - Jefferson Transit

Lansing/East Lansing, Michigan - Capital Area Transportation Authority
Long Island, New York- MTA Long Island Bus
Los Angeles, California- Los Angeles Rail Transit
Los Angeles, California- Los Angeles County Metropolitan Transportation Authority

Madison, Wisconsin- Madison Metro
Mankato, Minnesota- Mankato Heartland Express Bus Schedules
Maricopa County, Arizona - Valley Metro
Maryland- Marc Commuter Rail
Medford, Oregon - Rogue Valley Transportation District
Michigan City, Indiana - Northern Indiana Commuter Transportation District
Monterey-Salinas, California - Monterey-Salinas Transit (MST)
Montgomery County, Maryland - Transit Services Division
Myrtle Beach, South Carolina - Coastal Rapid Public Transit Authority

New Orleans, Louisiana - Regional Transit Authority: Transit Police
New York, New York - Metropolitan Transportation Authority (MTA)
New York City/New Jersey - The Port Authority of New York and New Jersey Trans-Hudson (PATH) Corporation
Newark, New Jersey - New Jersey Transit
North Carolina Department of Transportation - Ferry Schedules
Norwalk, Connecticut - Norwalk Transit District

Olympic Peninsula, Washington - Olympic Peninsula Transit Services
Orlando, Florida - Central Florida Regional Transportation Authority (LYNX)

Philadelphia, Pennsylvania- Southeastern Pennsylvania Transit Authority (SEPTA)
Pierce County, Washington - Pierce Transit
Phoenix, Arizona Transit
Pittsburgh, Pennsylvania- Port Authority of Allegheny County (PAT)
Plymouth, Massachusetts - Plymouth & Brockton Street Railway Co. Inc.
Pompano Beach, FL - Mass Transit Division
Portland, Oregon- Tri-Met Transit Station

Richland, Washington - Ben Franklin Transit
Riverside, California - Riverside Transit Agency
Rochester, New York - Regional Transit Service

St. Louis, Missouri - Bi-State Development Agency
Salt Lake City, Utah - Utah Transit Authority
San Diego, California- San Diego Transit Corporation
San Diego, California- San Diego Trolley
San Francisco, California - San Francisco Bay Area Transit Information
San Francisco, California - Golden Gate Transit and Ferry
San Francisco, California- San Francisco Bay Area Rapid Transit (BART)
San Francisco, California- CalTrans
San Francisco, California - Muni Railway
San Jose, California - Santa Clara Valley Transportation Authority

San Mateo County, California - SAMTRANS
Santa Barbara, California- Santa Barbara MTD
Santa Cruz, California- Santa Cruz Metropolitan Transit District
Seattle, Washington- Seattle Metro RiderLink
Seattle (Metro Area), Washington - Washington State Ferries
Seattle, Washington - Central Puget Sound Regional Transit Authority
Stanislaus County, California - Stanislaus Regional Transit (StaRT)

Tallahassee, Florida - TALTRAN
Tempe, Arizona - Free Local Area Shuttle (FLASH)

Vancouver and Clark County, Washington - C-TRAN
Ventura County, California - Ventura County Transportation Commission

Walla Walla, Washington - Valley Transit
Washington D.C. - Metrobus and Metrorail (WMATA)
Westchester County, New York - The Bee-Line System
Wilmington, Delaware- Delaware Area Regional Transit (DART)
Woodbridge, VA- Potomac and Rappahannock Transportation Commission (PRTC)
Woodbridge, VA- Virginia Railway Express

York County, Pennsylvania - Community Transit

APPENDIX B

List of questions for interview

Contact information:

- Name, Title
- Agency Name, Department
- Mailing Address
- Phone/Fax Numbers
- E-mail address

Basic information:

- How often is the information updated (especially if it is real-time information)?
- What media (specifically advanced technologies) is used to distribute the information?
- Where are the media typically located (i.e., airports, transfer centers)?
- What are special capabilities of your system (i.e., routing, clickable system map)?
- How “tourist friendly” is the information format and media used to distribute it (also location)?

Background information:

- What was the driving force for initially providing this information?
- What is (are) the objective(s) now?
- To what extent, do you believe you are meeting it (them)?
- What more is there yet to be done?
- Has there been a major shift in the direction this effort has taken? If so, what?
- What would you have done differently?
- Was there an agency (or system) that was used as an example? (Contact information if available.)

Present operations and future plans:

- What are major future plans (i.e., deployment of equipment, re-formatting or standardizing information, inclusion of other modes or capabilities)?

APPENDIX C

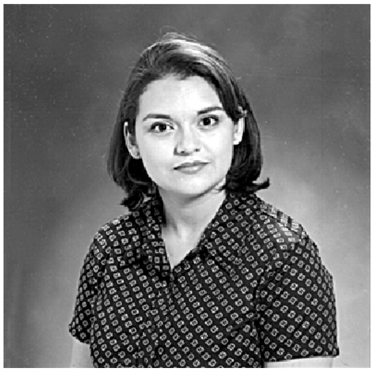
Information found on "Front Page" of Web site

AGENCY	GENERAL INFO	SYSTEM MAP	ROUTE MAPS	SCHEDULE INFO	POI LIST	ROUTING / ITINERARY PLANNING	STATIONS / STOPS	DESTINATIONS SERVED
Bay Area Transit Information Project	About project	Locate agencies					Transit Center Diagrams	In Region
Chicago Transit Authority, CTA	Welcome Aboard CTA	LRT, BUS	•	•				
King County Department of Metropolitan Services, King County Metro	•	BUS, FERRY	•	•				
Lane County Transit District, LTD	•					No Time Element	•	
Central Florida Regional Transportation Authority, LYNX		BUS (SHUTTLE)	•	•	Central Florida Info			
Massachusetts Bay Transit Authority, MBTA	•	LRT, CR	•	•	•			•
Metropolitan Atlanta Rapid Transit Authority, MARTA	•	LRT	•	•				
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T		BUS	•	•				
People Mover		BUS	•	•				
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit		BUS (LRT)	•	•				
Ventura County Transportation Commission, VCTC						•		
Metropolitan Transit Authority of Harris County, METRO		BUS	•	•			Transit Center Info	

AGENCY	"WHAT'S NEW"	NEWS / ANNOUNCEMENTS	"HOW TO RIDE" GUIDE	HOURS OF OPERATION	FARES	TRANSFERS	SPECIAL NEEDS TRANSPORTATION
Bay Area Transit Information Project	●	●				From Airports	●
Chicago Transit Authority, CTA		●			●	From Airports	
King County Department of Metropolitan Services, King County Metro					●		●
Lane County Transit District, LTD		●	Finding and Riding Your Bus	●	●		●
Central Florida Regional Transportation Authority, LYNX	●	●			●		Mobility Services
Massachusetts Bay Transit Authority, MBTA					Transit Pass Info		●
Metropolitan Atlanta Rapid Transit Authority, MARTA		●	●	●	●	●	
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T							
People Mover	●		●		●		●
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit	●	Public Notices	●		●		●
Ventura County Transportation Commission, VCTC	●						●
Metropolitan Transit Authority of Harris County, METRO	●	Public Notices			●		

AGENCY	OTHER COMMUTER OPTIONS	PARK AND RIDE	BIKE INFO	TRAFFIC INFO	F.A.Q.,	CUSTOMER SERVICE	COMMENT / FEEDBACK
Bay Area Transit Information Project	RIDES, Get Paid to Ride		•		•		•
Chicago Transit Authority, CTA							Post New Comments
King County Department of Metropolitan Services, King County Metro	Vanpool / Carpool	•	•		•		•
Lane County Transit District, LTD	Commuter Solutions	•	•			•	•
Central Florida Regional Transportation Authority, LYNX						•	
Massachusetts Bay Transit Authority, MBTA							•
Metropolitan Atlanta Rapid Transit Authority, MARTA	Let Your Boss Pay	•				•	Webmaster
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T				Incidents, Cameras			•
People Mover	Share-a-Ride						•
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit	Employer Transportation Programs						•
Ventura County Transportation Commission, VCTC	Rideshare	•	•	•			•
Metropolitan Transit Authority of Harris County, METRO	METROVan Rideshare		•				Webmaster

AGENCY	CONTACT INFO- NOT E-MAIL	ORGANIZATION INFORMATION	BUSINESS / JOB OPPORTUNITIES	PLANNING, DESIGN, & CONSTRUCTION	MISCELLANEOUS
Bay Area Transit Information Project		•			Register with Project, Site Stats, Transit Interest Groups, Regional Info
Chicago Transit Authority, CTA	•	Welcome Aboard CTA	Advertised Bids		Related Web Sites
King County Department of Metropolitan Services, King County Metro					
Lane County Transit District, LTD	•			•	Slide Show
Central Florida Regional Transportation Authority, LYNX	•	Company Info	•	•	Marketing, Bus Art Gallery, Upcoming Events
Massachusetts Bay Transit Authority, MBTA		History	•		Internal Search
Metropolitan Atlanta Rapid Transit Authority, MARTA		History	•	•	Distance & Travel Times, Trivia & Interesting Information
Montgomery County Dept. of Public Works & Transportation, Montgomery County DPW&T	•				
People Mover	•				Places to Visit on the Internet
Tri-County Metropolitan Transportation District of Oregon, Tri-Met Transit	•	Honors & Awards	•	•	Facts & Stats, Reports Special Programs, Pictures
Ventura County Transportation Commission, VCTC	•	About VCTC			Meeting Agenda, Other Agencies, Free Goodies
Metropolitan Transit Authority of Harris County, METRO	•	•	•	•	HOV system, Properties for Sale, Info on Other METRO ventures



Cristina Borja Slabic received her B.S. in Civil Engineering from the Massachusetts Institute of Technology in May of 1996 and is currently pursuing her M.S. in Civil Engineering at Texas A&M University. She was awarded an Undergraduate Transportation Engineering Research Fellowship during the summer of 1995, which introduced her to the Texas Transportation Institute. Cristina has been employed by TTI as a Graduate Research Assistant with the TransLink™ Research Center since January 1997. She is involved in the following university activities: ITS Texas A&M, ITS America Student Chapter; Institute of Transportation Engineers, Student Chapter. Cristina's areas of interest include: public transportation, transportation management, and intelligent, multi-modal transportation systems.

USING VARIABLE SPEED LIMIT SIGNS TO MITIGATE SPEED DIFFERENTIALS UPSTREAM OF REDUCED FLOW LOCATIONS

by

Julia K. Wilkie, P.E.

Professional Mentors
Thomas Hicks, P.E.
Maryland Department of Transportation

and

Colin A. Rayman, P.E.
Ontario Ministry of Transportation

Prepared for
CVEN 677
Advanced Surface Transportation Systems

Course Instructor
Conrad L. Dudek, Ph.D., P.E.

Department of Civil Engineering
Texas A&M University
College Station, Texas 77843

August 1997

SUMMARY

Variable speed limits systems are an alternative traffic control technique designed to reduce speed variance and encourage stable traffic flow. These systems attempt to prevent incidents from occurring by reducing the variation of speeds in the traffic stream through advanced information on traveled speeds.

Experience gained from installations in urban areas in the United States, Britain, France, Germany and the Netherlands is used to recommend a sign display design and a control strategy for future installations. Evaluations of the English, German and Dutch systems have found that speed variation is reduced, more uniform headways are present between vehicles and all lanes of the highway are used more efficiently with the variable speed limit system. Drivers in these countries are satisfied with the systems and recognize the benefits of more stable traffic flow.

The proposed speed management system is not intended to be a speed trap. It is intended to provide information to drivers so they can adjust their vehicle speed and position as they deem appropriate. This assumes that the majority of motorists would like to avoid accidents and would prefer driving in a uniform, sometimes slower, traffic stream instead of stop-and-go traffic. Legislation will be required in most states to allow speed limits to change based on real-time traffic conditions.

The system proposed in this paper recommends a flexible display which combines static and dynamic signs to provide better information to drivers. The static portion of the sign will display a regulatory (black on white) SPEED LIMIT sign, an advisory (black on yellow) ADVISED SPEED sign or a blank sign by rotating a segmented display into the correct position, similar to advertizing displays in some sports arenas. Below the static sign, the recommended speed limit will be displayed in increments of 5 MPH. Next to the speed limit sign, a dynamic message sign will display supplementary messages, providing added meaning to the dynamic speed limit. Although special signs have been designed for variable speed limit systems, existing dynamic message signs may be used to convey advisory speed messages.

The proposed speed management system combines shockwave prediction algorithms, average speed measurements and environmental factors to determine the speed limit display. It is expected that this system will achieve significant reductions in speed variance, however, applications in the United States are not expected to be as successful with driver compliance as some European systems which maintain 98 percent compliance. Before the proposed system can be installed at any location, additional study must be completed on the control algorithm and the effects of changing variables such as sign spacing, detector spacing and detector sampling rate.

Variable speed limit systems are recommended to be installed on sections of highway with an existing speed-related problem, such as is typically found upstream of reduced flow locations. Systems should only operate when traffic flow conditions merit additional control. Speed limit displays in free flow conditions may not reflect traveled speeds and could cause the system to lose credibility similar to existing static sign displays. Sign stations should be placed at locations which allow drivers adequate time to respond to system recommendations.

The potential benefits of speed management systems were evident in a cost-benefit analysis of a section of the Capital Beltway in Maryland. The cost savings in the first year, from accidents alone, is expected to be almost eight times the cost of the system. With the potential of these systems being realized in Britain, Germany and the Netherlands and substantial benefits calculated on the Capital Beltway, the United States should actively pursue installation of variable speed limit systems to reduce speed-related accidents and alleviate stop-and-go traffic conditions on freeflow facilities upstream of reduced flow locations.

TABLE OF CONTENTS

INTRODUCTION

Speed limits have been imposed on motor vehicles since the start of the Twentieth Century when automobiles began demanding room on streets that were already crowded with pedestrians, horses and carriages. Fast cars would frighten horses as they sped by, often causing the horses to become distempered and bring chaos to the street. City bosses imposed arbitrary speed limits to regulate traffic and keep their city streets safe.

Speed limits were extended to rural areas because of the frequency of accidents occurring at locations where the highway curved. Advisory speed limits were posted in advance of these locations to warn motorists that reduced speeds were necessary for safe travel on that section of road. Other segments of rural roads were controlled with speed limits after the relationship between speed variance and accidents was confirmed.

Many researchers have found a strong correlation between increasing speed differentials and increasing probability of being involved in an accident. Some of the key findings of these studies include:

- The probability of being involved in an accident is smallest when the driver travels close to the average speed (1,2,3,4,7,8,9).
- The greater the differential between the speed of a vehicle from the average speed of all traffic, the greater the chance of that vehicle being involved in an accident (4,8).
- Motorists who drive 15 MPH above or below the average speed have an accident involvement rate which is more than six times that of drivers with less than 15 MPH variation (7,9).
- Accident rates do not necessarily increase with an increase in average speed, but do increase with an increase in speed variance (1,3,7,9).

The most widely referenced study of the relationship between speed and accidents was completed by David Solomon in 1964 (8). Solomon documented, scientifically and statistically, the relationship between speed variance and accidents on two- and four-lane main rural roads (primary rural arterials) in 11 states, on 600 miles of roadway and almost 10,000 accident records. Solomon concluded that a primary cause of accidents was the speed differences between vehicles (8). A study in 1968 concluded that accident rates on interstate highways are lower than main rural roads when traveling near the mean speed. The interstate highway accident involvement rate, however, increased at a faster rate as speed variance increased; such that comparable accident involvement rates were observed on all freeflow facilities when speeds are 25± MPH from the average speed (1). Both of these studies concluded that the lowest accident involvement rate was a few miles per hour higher than the average speed, approximately the speed at which 85 percent of the traffic stream was traveling at or below or the 85th percentile speed.

A national effort to reduce speed variance resulted from these studies and other social pressures. Efforts focused on the driver since the driver receives speed information from either roadway or vehicle stimuli and responds by adjusting the speed and/or path of the vehicle. Failure of the driver to respond correctly leads to conflicts with other vehicles or the roadside. Some of the methods that have attempted to reduce speed variance include:

- posting the 85th percentile speed or recommended design speed for each section of highway;
- posting maximum and minimum speed limits;
- establishing differentiated speed limits by vehicle type, day/night, etc.;
- installing climbing lanes in hilly and mountainous areas;
- designating separate lanes for slow and fast vehicles;
- promoting driver education;
- increasing police enforcement of speed limits; and
- modifying highway pavement markings (5).

The above methods were successful in some areas but unsuccessful on other highway segments because, in a typical driving situation, drivers tend to ignore information they perceive as irrelevant. Posted speed limits lose credibility when highway traffic travels at average speeds which exceed the posted speed limit, such as 65 miles per hour (MPH) in a 55 MPH zone. Static speed limit signs also lose credibility and increase driver frustration when traffic speeds are reduced to 30 MPH and the sign on the side of the road still reads "55 MPH."

Drivers want realistic, reliable information based on existing conditions. In response to the demands of reasonable drivers, and in hope of reducing speed variance, highway engineers proposed a system of variable speed limits to operate on sections of highway where a speed-related problem exists. The system is intended to operate only when traffic flow conditions merit additional control devices. Variable speed limit signs should be placed to provide the driver with adequate time to respond to the situation (5).

Objectives of a Variable Speed Limit System

Variable speed limit systems (VSLS) attempt to reduce speed variance by providing drivers with realistic, reliable and real-time speed recommendations. This concept involves setting speed limits based on real-time monitoring of prevailing traffic and/or weather-related roadway conditions.

Compliance to variable speed limits would theoretically result in reduced speed differentials in the traffic stream and more uniform traffic flow. If these systems are installed upstream of reduced flow or speed-related problem locations as proposed, they could achieve the following objectives.

- Reduced speed variance;
- More stable flow within congested regions of the traffic stream;
- Advanced warning to motorists of congestion forming ahead;
- Realistic, reliable and real-time information on average or 85th percentile speed; and
- Additional information about roadway conditions, lane closures, incidents and slow traffic provided through a dynamic message sign, to assist drivers in decisions to adjust speed, change lanes or take a different route.

Other benefits to the highway network are anticipated to include:

- Increased driver compliance to regulatory and warning signs;
- Fewer accidents resulting from high-speed traffic encountering the end of a queue;

- Fewer accidents resulting from stop-and-go traffic behavior;
- Reduced emissions through diminished acceleration and deceleration maneuvers;
- Dampened effect of shock wave traveling upstream; and
- Better driver understanding and less aggressive behavior.

Congestion upstream of reduced flow locations in urban areas is the primary focus of the proposed speed management system. Many factors related to road geometry, traffic flow characteristics, traffic control and driver behavior can cause the capacity of a roadway to be reduced to something less than the capacity of an upstream location. Some of the factors which reduce flow include:

- Bottlenecks such as narrow bridges, tunnels, lane reductions, etc.;
- High traffic flow volumes;
- Inclement weather;
- Disabled vehicles and accident scenes;
- Roadway construction and maintenance areas;
- Exit and entrance ramp activities; and
- Roadways with a large percentage of recreational vehicles and/or large trucks in the traffic stream.

Frequently, traffic demand will exceed the roadway capacity at a reduced flow location resulting in congested traffic conditions, reduced vehicle speeds and increased vehicle density. Congested conditions move further upstream, away from the reduced flow location in a phenomenon known as a shock wave. High speed vehicles encounter slow or stopped vehicles at the shock wave and are forced to decelerate suddenly to avoid collision. This sudden deceleration creates another shock wave within the traffic stream which contributes to unstable flow conditions. More gradual deceleration creates less severe internal shock waves that dissipate more quickly than those caused by sudden deceleration, resulting in more uniform flow. Variable speed limit systems provide drivers with advanced information which promotes gradual deceleration in these situations.

Several agencies have attempted to use variable speed limit systems to meet the objectives described above, however, there is little consensus on the design or operation of these systems. In general, each system described in the following pages consists of a data collection component, a data processing component and a display component working in a continuous feedback system. The experience gained through installed systems is combined in a speed management system proposed for future installations. The potential impacts of the proposed system are then considered on the Capital Beltway, near Washington D.C., in Maryland.

EXPERIENCE WITH VARIABLE SPEED LIMIT SYSTEMS

Many countries have experimented with variable speed limit systems on freeflow highway facilities in urban areas. The systems studied change the speed limit display based upon real-time traffic flow and/or weather conditions and are listed chronologically in Table 1. Weather warning systems have similar equipment and logic to variable speed limit systems, but are not described here because they either do not include specific speed recommendations or are not located in urban areas.

Table 1. Variable Speed Limit System Experience in Urban Areas.

Year	Location	Type of Speed Control*	Data Processing Input	
			Traffic	Weather
1962	U.S. - Detroit, Michigan	Advisory	Primary	
1960s	U.S. - New Jersey Turnpike	Regulatory	Primary	Planned
1972	Germany	Regulatory	Primary	
1985	France - Marseille	unknown	Primary	Secondary
1989	U.S. - Albuquerque, New Mexico	Regulatory	Primary	Secondary
1992	Netherlands - Amsterdam	Regulatory	Primary	
1995	Britain - London	Regulatory	Primary	

* *Regulatory speed limits are enforced as the legal maximum speed on that section of road. Advisory speed limits are conditionally enforceable, but are normally perceived as the recommended travel speed.*

The following summaries were gathered from available literature which may or may not represent the current status of the system. A summary table with characteristics of all of the systems is included in the appendix.

United States - Detroit, Michigan
Michigan Department of Transportation, May 1962

System Location and Current Status

The system in Detroit was located on the John C. Lodge Freeway (M-10) between the Edsel Ford Freeway (I-94) and the Davison Freeway. The Lodge Freeway was, and still is, a primary transportation corridor between downtown Detroit and northwest suburbs. Variable speed limit signs and lane control signals were dismantled sometime after 1967 (the date of the most recent report reviewed for this study).

System Objective

As part of the *John C. Lodge Freeway Traffic Surveillance and Control Research Project*, the goal of this system was to "provide an opportunity to conduct unlimited research in numerous aspects of driver and vehicle behavior on a heavily traveled freeway" (11). The variable speed limit portion of the system was intended to warn motorists to decelerate before reaching a congested area and to indicate to motorists leaving a congested area to increase their speed to help disperse the congestion.

System Description

The study section included 5.2 km (3.2 miles) of six- and eight-lane freeway with nine off-ramps and nine on-ramps. The following traffic control devices were installed in the corridor.

- 21 variable speed sign locations (11 northbound, 10 southbound) at 500 m (0.3 mile) spacing;
- 11 lane control signal locations (6 northbound, 5 southbound) at 800 m (0.5 mile) spacing; and
- 14 television cameras spaced at 0.4 km (0.25 mile) intervals.(10)

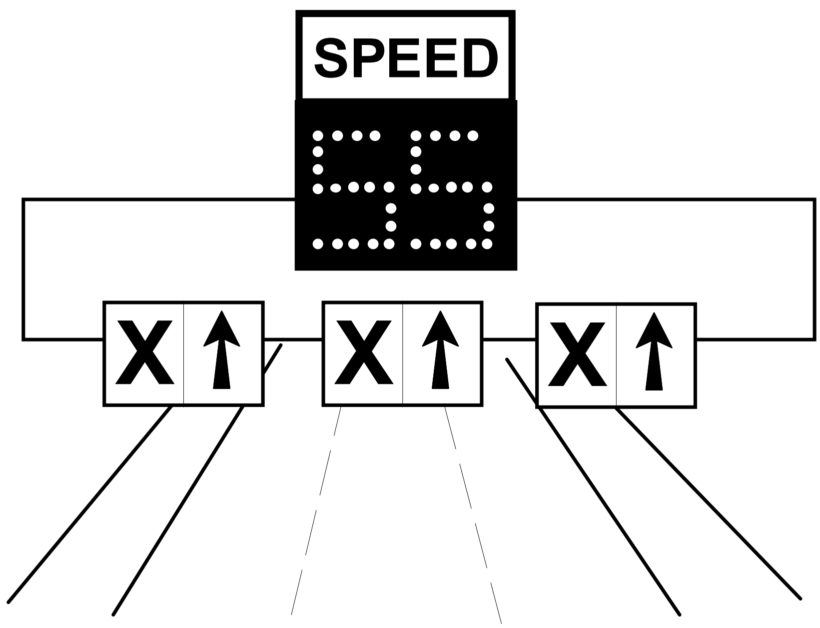


Figure 1. Typical Lane Control Signal and Variable Speed Sign Installation in Detroit.

The sketch in Figure 1 illustrates the configuration of matrix and blankout signs used to communicate changing messages to motorists on high speed facilities. Blank out signs used for lane control were designed and modified for best illumination of green arrows and red "X"s under all conditions for this project, however, their visibility was still poor under some lighting conditions, making it difficult to determine which sign was illuminated and which sign was dark. Variable speed signs were installed at 11 of the 21 locations without lane control signals. The remaining locations were accompanied by lane control signals as shown in the figure.

Control Strategy

Ultrasonic sensor for vehicle detection were loaned to the highway department by a railroad company. This equipment was capable of providing speed, volume and occupancy by individual lane and for all freeway lanes every minute. Total vehicle counts, number of passenger vehicles and large trucks could also be provided. Two detector stations were installed with sensors in each travel lane. The impulses from these sensors were transmitted to analog computers located at the control center.

The ability to collect the above data at one time on a freeway facility was a first. Utilization of this data was limited by the requirement of computers to process the information. As a result, operators relied heavily on the closed circuit television images and real-time pen plots of freeway speed, occupancy and volume data to control the signals. Engineers were able to effectively use sensor and TV data in research analysis.

Speed limit signs and lane control signals were controlled by manual switching at the television control center. Variable speed limit signs could display speeds in increments of 5 MPH from 20 to 60 MPH. Upon detection of an incident on the freeway via TV surveillance, the operator selected the necessary function in order to alleviate whatever situation had occurred, such as closing a lane, changing the speed limit or closing a ramp.

Evaluation

- Closed-circuit television was extremely important in the operation of the freeway control system to determine conditions on the freeway (due to the limited number of detector stations) and to verify the effects of system operation (11).
- Increases in efficiency were attributed to lane control signals which provided advanced warning to motorists of a lane closure (11).
- Michigan officials felt the variable speed displays did not significantly reduce or increase vehicle speeds (11).
- Some motorists incorrectly interpreted the green arrow to mean that the lane is open and free of traffic stoppages instead of its actual meaning that the lane was not blocked by an incident or maintenance activities (11).
- Variable speed signs were intended to warn motorists to slow due to congestion ahead or to indicate to the motorists that the problem had been passed and to increase speed. The display conveyed these messages somewhat indirectly, with the advance warning function possibly being confused with the speed limit function by some motorists (12).
- The design of the system circuitry, with multiple variable speed limit signs being ganged on one switch, prevented operators from having the flexibility to post speeds where desired without changing upstream or downstream signs (11).

Lessons Learned

- Lane control signals with green arrows were misinterpreted by some motorists to mean the lane was clear of stoppages.
- Lane control signals with red Xs were generally understood to mean the lane was closed ahead.
- Variable speed displays with no accompanying message were not understood by motorists and did not get the desired driver response.
- Control of individual speed displays will enhance the speed control system.
- Sun glare is a problem that needs to be considered in sign design and placement.

United States - New Jersey Turnpike
New Jersey Turnpike Authority, Late 1960s

System Location and Current Status

This variable speed limit system is located on the New Jersey Turnpike which extends nearly the entire length of the state, from New York City to the State of Delaware. Variable speed limit signs and speed warning signs were installed in the late 1960s and are still in operation. The addition of weather sensing equipment is planned in the near future.

System Objective

The primary objective of this system is to provide early warning to motorists of slow traffic or hazardous road conditions ahead.

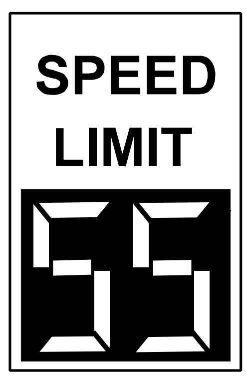


Figure 2. New Jersey 7-Vane Variable Speed Limit Sign.

System Description

The current system includes 120 speed limit signs using a seven-segmented vane arrangement similar to the sketch shown in Figure 2. Variable speed signs are accompanied by a neon sign which displays the message “Reduced Speed Ahead” plus the distance to the congestion when illuminated. Speed limits between 30 and 55 MPH are displayed in 5 MPH increments.

Control Strategy

Speed limits based on average traveled speed are displayed automatically, but manual override is used for lane closures or construction zones. Speed and volume data are collected through inductive loop detectors. Communication between the control center and sign stations is completed through radio and microwave links.

Evaluation

No evaluation reports were available, however, the accident rate on the New Jersey Turnpike is lower than the state and national average (13). State police officers felt that motorists pay attention to the signs and that they do affect traffic flow. One of the officers observed that the speed limit is only lowered when the reduced speed ahead message is also illuminated (14).

Germany
1972

System Location and Current Status

Several systems have been installed in Germany including: a 30 km (18.7 mile) long installation on the A8 highway (autobahn) between Salzburg and Munich, a 13 km (8.1 mile) section of the A3 between Siegburg and Cologne, and a section of the A5 near Karlsruhe. A 1991 article about the A5 describes the control algorithm proposed for determining posted speed limits, but few other details were available in English written articles. Descriptions of the two other systems are gathered from a 1979 article on self-sufficient speed control.

System Objective

The objective of self-sufficient speed control in Germany is to stabilize traffic flow even under heavy traffic flow conditions, thus reducing the probability of accidents, improving driving comfort and reducing environmental impacts (16).

System Description

Variable speed signs on the A8 and A3 highways are installed roughly every 1.5 to 2 km (0.9 to 1.2 miles) and display speed limits of 100, 80 or 60 km/h (60, 50, or 40 MPH) in accordance with the Road Traffic Code.

Control Strategy

Control strategies for the A8 and A3 were not described, however, the control algorithm proposed for the A5 installation attempted to predict reduced travel speeds by monitoring the standard deviation of speeds (15). The proposed control logic calculated real-time mean speed, density and standard deviation of speed for its speed selection decision. Mean speed and density are the primary variables used to select speed. In higher speed traffic conditions, standard deviation is the third decision variable because the calculated and measured traffic densities for high speed traffic exhibit strong fluctuations (15).

Evaluation

An assessment of the A8 highway revealed the following.

- Many drivers do not consider the posted speed limit to be an upper limit, but rather consider it to be a recommended speed;
- Displaying reasonable speed limits with a variable speed limit system resulted in a slight increase in the mean speed of traffic when compared to areas of comparable traffic density that didn't have the benefit of a variable speed display;
- The difference in speed of consecutive vehicles, the speed dispersion and the frequency of dangerously short headways were reduced with the operation of the variable speed limit system;
- Reductions in speed differences lead to a uniform, stabilized traffic flow which was characterized by a lower probability of becoming unstable; and
- Observations indicated that a graduation of speed limits in increments of 10 km/h (5 MPH) would be an effective way of adapting the control system to the prevailing traffic situation (16).

France - Marseille
1985

System Location and Current Status & System Description

The variable speed limit system is located on 8 km (5 miles) of the southbound lane of a major highway in Marseille. The northbound lane was being instrumented at the time of the report, in 1985.

Control Strategy

Speed and volume data are collected via radar mounted on overhead trusses. Television surveillance of the traffic stream is also used. Speed limits are posted based on prevailing speed and weather conditions. Manual override of the displays is possible (5).

Additional information about this system was not available in the literature reviewed, however, it is important to recognize that France is experimenting with variable speed limit systems.

United States - Albuquerque, New Mexico
Federal Highway Administration and New Mexico Department of Highways, 1989

System Location and Current Status

The FHWA Variable Speed Limit System Prototype was located on I-40 eastbound in Albuquerque, New Mexico. The system began operation in 1989, but has since been dismantled due to roadway widening in the mid 1990s.

System Objective

This installation was intended to provide a U.S. test bed for variable speed limit system roadside equipment and control algorithms. The two primary objectives of the variable speed limit system were to post speed limits which will minimize accident risk and to advise motorists of downstream hazards (21).

System Description

The site was selected because of cooperation with the New Mexico Department of Highways and the scheduling of a long-term work zone on the Second Street bridge deck. The work zone increased the likelihood that traffic would experience speed-related problems that may be affected by displaying variable speed limits.

The beginning of the study area was marked with an informational sign on I-40 eastbound which warned "Notice: Experimental Variable Speed Limit Study Ahead." The first station, located near Coors Road, could be seen 400 m (0.25 mile) after the informational sign, on top of a retaining structure on the right side of the freeway. The next station was 3.2 km (2 miles) further downstream near the right shoulder at Rio Grande Boulevard. The last station, near Second Street, was 1.6 km (1 mile) past the Rio Grande station. Figure 3 provides an overview of the system layout with an example of the system operating in linked mode, posting an environmental warning, "WET AHEAD."

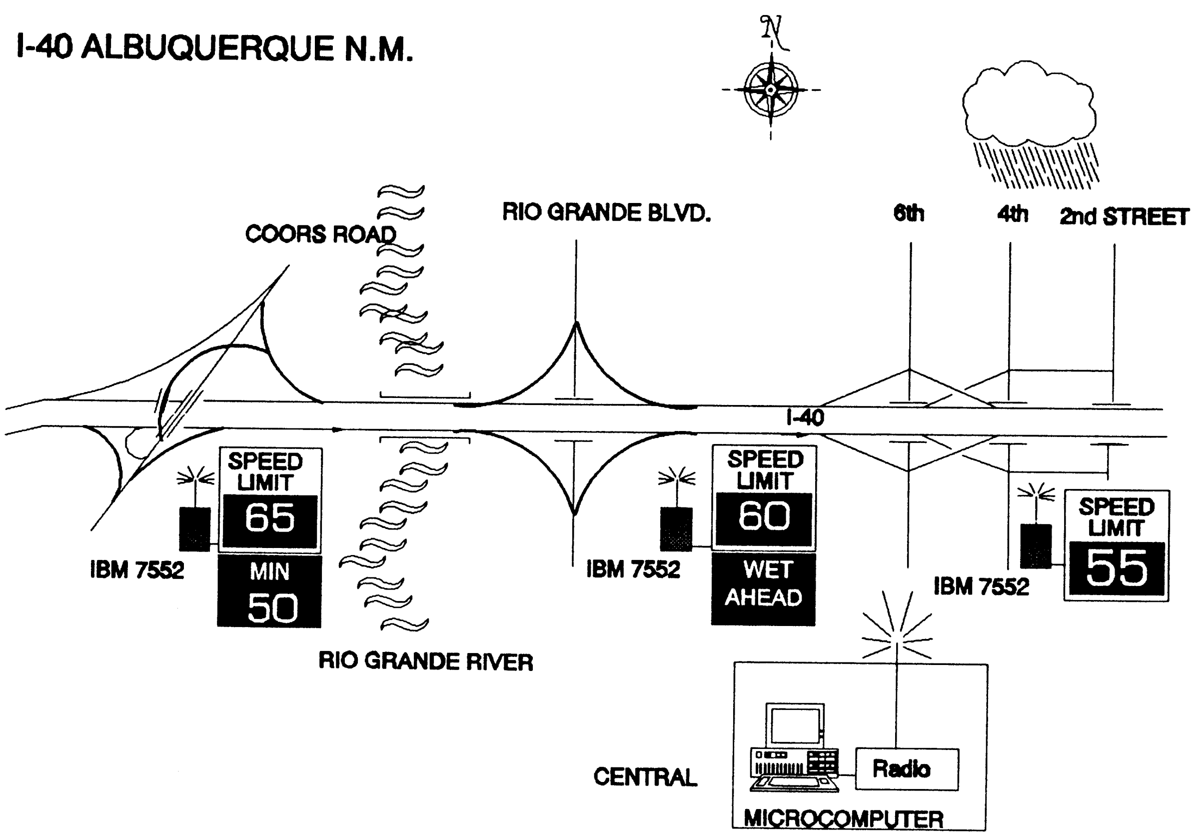


Figure 3. Layout of VSLS Prototype in Albuquerque, New Mexico.

Sign stations in this system were similar to the sketch in Figure 4. Each station included a dynamic message sign to display the maximum speed limit; another dynamic message sign to display warning messages or the minimum speed limit; environmental sensors for precipitation, temperature and light; inductive loop detectors; communication equipment and a roadside processing unit. The variable message sign technology was a reflective, flip-disk matrix with internal front lighting (a florescent light in the bottom of the sign case, inside the plexiglas cover).

Posted speed limits ranged between 30 and 55 MPH. At the time of the study, the National Maximum Speed Limit Law permitted a maximum limit of 55 MPH on this section of highway since it was within the Albuquerque metropolitan area. The speed limit display is modified automatically as traffic flow and environmental conditions change. Typical warning messages which accompany the speed limit sign include SLOW AHEAD, WET AHEAD, ICY BRIDGE and FOG AHEAD.

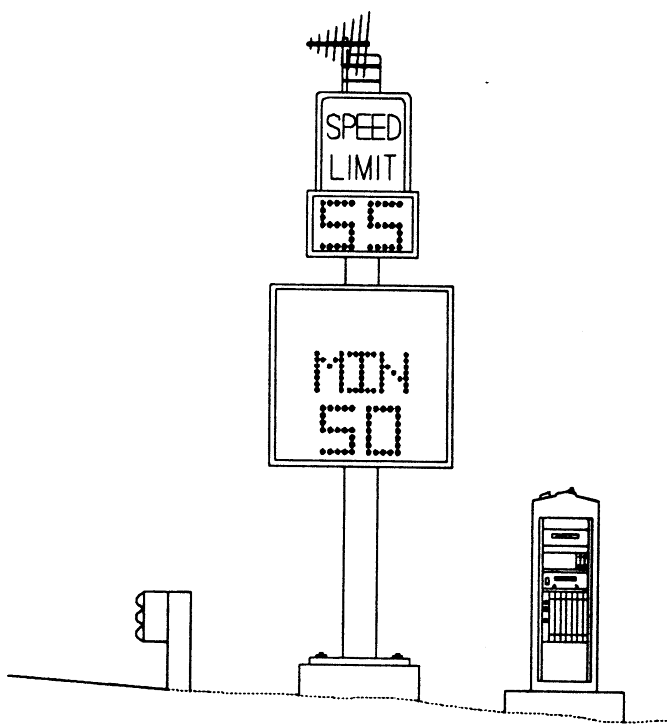


Figure 4. Roadside Station in FHWA Prototype.

Control Strategy

Traffic data was collected from inductive loop detectors placed in each lane perpendicular to the roadside station equipment, for an average spacing of 1.5 miles. Loop data was reported every ten seconds and processed to calculate speed, volume, length of vehicle, and standard deviation of speed. The smooth speed was used to approximate the moving mean speed of traffic, but is more stable during periods of high volume than the moving mean.

Table 2. Environmental Constants.

Environmental Condition	Constant
Light	+ 7.5 MPH
Dark	+ 5.0 MPH
Light and Precipitating	+ 2.5 MPH
Dark and Precipitating	+ 0.0 MPH

The posted speed was calculated by adding the smooth speed and an environmental constant (see Table 2) and rounding to the nearest 5 MPH increment every one minute. The environmental constants were empirically established so that the posted speed would more closely approximate the 85th percentile speed.

The prototype system had several different operational modes and corresponding sign displays. The system normally operated in linked mode with signs communicating with each other through the central computer, however, when communication failures would occur, the signs would operate in isolated mode, posting the speed limit and messages based on conditions at that roadside station.

Evaluation

The variable speed limit system prototype was, overall, a success. The equipment and algorithm ultimately functioned as designed and many important lessons were learned for the design of future installations.

Driver compliance evaluations were hindered by sign visibility, the National Maximum Speed Limit Law and algorithm design. Sun glare was a problem for all of the signs and the first sign in the system was placed outside of drivers' normal range of view, making it difficult for drivers to comply with messages they could not read or did not see. The maximum speed display of 55 MPH was arbitrarily low for this section of roadway; average speeds rarely dropped below 55 MPH except during work zone periods. Compliance to the posted speeds was not an effective measure of effectiveness for this system since the algorithm controlling the speed limit signs reacted to traveled conditions at that location, so if the sign changed to 35 MPH it was because traffic was already traveling 35 MPH at that location.

Accident analysis performed by the New Mexico Department of Highways found a slight reduction in accidents as compared to other work zone areas. It may be assumed that the accident study results were affected by the same factors as the driver compliance study.

Lessons Learned

- Visibility of the signs is critical to the effectiveness of any variable speed limit installation. The prototype had problems placing signs within the drivers normal view, sun glare and sign technology which lacked the "punch" needed to attract drivers' attention in an urban environment.
- The arbitrarily low maximum speed limit determined by the National Maximum Speed Limit law removed credibility from the system. Ideally, the maximum speed limit should be determined from the design speed of the roadway.
- Although the speed limit calculation was satisfactory for the prototype installation, Davey Warren, the project manager, would consider using environmental factors that were a percent of the smooth mean speed instead of a constant value. A calculated percent may more closely approximate the 85th percentile speed.
- Future systems should consider a data collection station without a sign as the last station in the system since the last station in this system had no downstream data.

Netherlands - Amsterdam
Rijkswaterstaat (Dutch Ministry of Transport), 1992

System Location and Current Status

The Dutch speed management system was installed in 1992 on the A2 highway connecting Amsterdam and Utrecht. It was installed as an experiment, was well received by drivers and is still in operation.

System Objective

The variable speed limit system was expected to create uniformity of speeds and volumes within and between lanes and thereby reduce the risk of shock waves, accidents and congestion. It was emphasized that the main goal of the system was not the reduction in speed, but rather the reduction of speed variance (24). The system was implemented as part of a nationwide initiative to improve traffic flow and reduce traffic accidents.

System Description

The experimental stretch of roadway extends about 20 km (12.4 miles) and includes three on/off ramp connections. Severe speed-related problems usually occur near the Vinkeveen on-ramp, a single lane on-ramp with 1600 veh/h during the peak hour.

The standard speed limit is 120 km/h (75 MPH), but variable speed limit signs post speed limits of 50, 70 and 90 km/h (30, 45, and 55 MPH). Fiber optic signs display the speed limit above each lane on the motorway and are sometimes accompanied by flashing lights. If an incident is detected, a speed limit of 50 km/h is posted, taking priority over any other speed measures in effect. Initial system tests measured different levels of hystereses, or lagging of effect behind cause, and applied them to the control algorithm to reduce the amount of switching between posted speeds. The analysis found that speed signals of 70 and 90 km/h were adequate for effective control. Since 80 km/h was not very useful, it was omitted from the control system

The displayed speed is enforced with photo radar devices as the maximum legal speed for that section of motorway. Fiber optic signs are also able to display a diagonal arrow to indicate a lane change is required or a red "X" to indicate lane closure.

Control Strategy

Sign stations are spaced approximately 1 km (0.6 mile) apart and consist of a local processing control unit for the loop data and fiber optic, matrix-type signs for each lane mounted on an overhead truss structure. Inductive loop detector stations are spaced approximately 500 m (0.3 mile) apart as part of the Dutch Motorway Control and Signaling System and measure one-minute averages of speed and volume across all lanes for the system control algorithm. Sign status information and incident detection messages are also available to the control algorithm.

The Utrecht-Amsterdam motorway was divided into six homogenous sections for automation of the control task. This means that speed display are identical across an entire section and do not vary by individual station.

Evaluation

A before and after study was conducted on peak hour data collected in 1991, before the system was installed, and in 1992, after it had been operational for four months. There was a significant rise in traffic demand between data collection periods. The major findings of the before/after study are separated into driver acceptance, driver behavior, motorway performance and technical operation headings (25). Quantitative results were not provided in the literature.

Driver acceptance
- A large majority of 1,300 drivers interviewed said they had adjusted their driving behavior due to the variable speed system.
- A large majority of the same drivers felt they had benefitted from the measures.
- Eighty percent of the respondents were familiar with the purpose of the speed signaling device.

Driver behavior
- Speed control measures effectively reduced vehicle speeds in all lanes.
- The number and severity of shock waves decreased.
- In the inside lanes, in particular, the percentage of headways of less than one second was lower during the speed control, and the average headway between vehicles increased.
- The variation in headways dropped and the headway differences between lanes became smaller.

Motorway performance
- The average speed was reduced and the average occupancy increased during system operation.
- Differences in volume, speed and occupancy between and within lanes became smaller; variations decreased.
- Speed control measures did not increase or decrease the capacity of the roadway.

Technical operation
- In general, the speed signs were complied with by the drivers.

- Problems arose when congestion occurred on the boundary between two sub-sections which were displaying different speeds.

Lessons Learned

- The results of the experiment seem to indicate that speed control is not a suitable instrument to eliminate congestion at bottlenecks since capacity of the roadway is not increased, but the effects of bottlenecks on traffic upstream can be mitigated by the speed management system (25).
- The use of groups of signs displaying the same message on a continuous section of roadway seems to indicate that signs were placed too closely and that the same message could be transmitted with fewer sign stations.
- Concerns about section boundary areas, combined with experience in Detroit with grouped sign control, reaffirm that future systems should provide independent control of individual sign stations.

Britain - London
Department of Transport, 1995

System Location and Current Status

The Controlled Motorway Pilot Scheme is located on the London orbital, M25. The pilot section included a 22.6 km (14 mile) section in the southwest quadrant of the M25, between Junction 11 (Chertsey) and Junction 15 (M4 and Heathrow), and was extended to Junction 10 (A3) in late 1995.

System Objective

The primary objective of this system is to eliminate stop-start driving conditions. System operators also expect to observe more relaxed drivers, lower fuel consumption and reduced noise emissions.

System Description

The southwest quadrant of the M25 carries 200,000 vehicles per day and volumes of 10,000 vehicles per hour have been recorded in the peak direction. Controlled Motorway Indicators (CMI), or variable speed display stations are spaced at 1 km (0.6 mile) intervals. Fiber optic signs are mounted on an overhead structure similar to the sketch in Figure 5. Photo radar devices are mounted behind the signs on the same structure.

Control Strategy

The M25 is one of the most instrumented highways in Europe. Loop detectors are placed at 500 m (0.3 mile) intervals in the travel lanes and hard shoulders. Loops are required to provide basic data on traffic volumes, speed, headway and occupancy. In addition, the M25 is closely monitored through closed-circuit television.

The initial control strategy was to change speed limits according to detected vehicle volumes. This strategy is based on the finding that the volume of vehicles in the same direction is the most important single factor for the hourly variation in mean speeds. Speed displays change from 70 MPH to 60 MPH when the volume reaches 1,650 vehicles per hour per lane (vphpl), and when volumes exceed 2,050 vphpl, the speed limit will be lowered to 50 MPH.(26) The system is set up for automatic control, but the police may also change the posted speed. Posted speed limits are mandatory and are enforced by photo radar such that motorists receive a ticket in the mail with a photograph of their vehicle, their vehicle speed and the posted speed at the time of the violation.

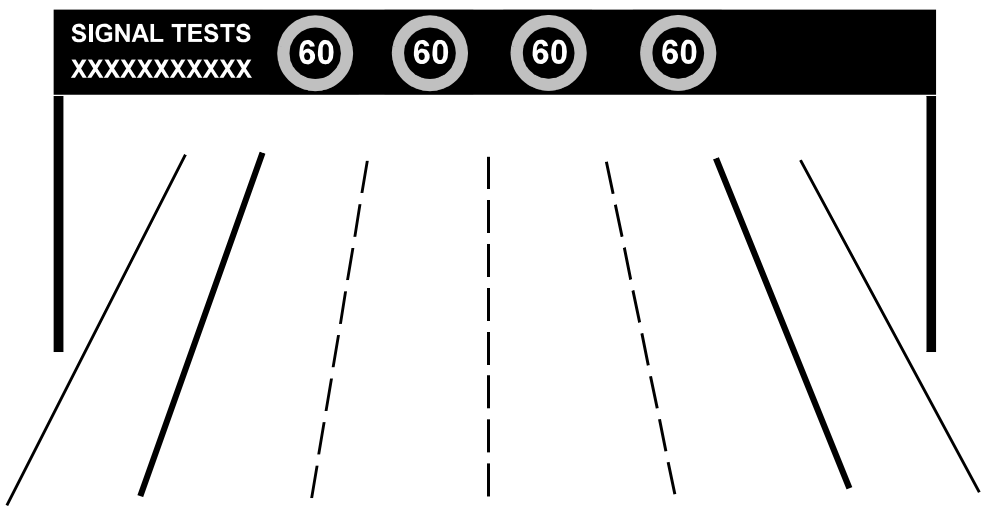


Figure 5. Controlled Motorway Indicators in Britain.

Evaluation

An evaluation study is being contracted to the Transportation Research Laboratory, but initial observations have revealed the following (26).

- Ninety-eight percent of drivers comply with the variable speed limit signs.
- Police have been impressed by the system and surprised by the obedience of drivers.
- Lane usage appears more even and headways, on average, have increased.

Lessons Learned

It is important to shield motorists from viewing messages that weren't intended for them. Initial tests on the orbital were operated at fixed times. They would confuse motorists and make the system lose credibility because lower speed limits were being posted when there was little traffic on the road.

PROPOSED SPEED MANAGEMENT SYSTEM

Variable speed limit systems have reduced speed variance and stabilized traffic flow according to previous system evaluations. Experience with installations in the United States and other countries has provided a foundation of technology and lessons learned for future system designs.

The speed management system proposed in this section combines dynamic speed limit and message displays to improve traffic flow and safety upstream of a reduced flow location on a freeflow facility in an urban area. This system is a practical approach to future applications in the United States, but could be extrapolated to other countries.

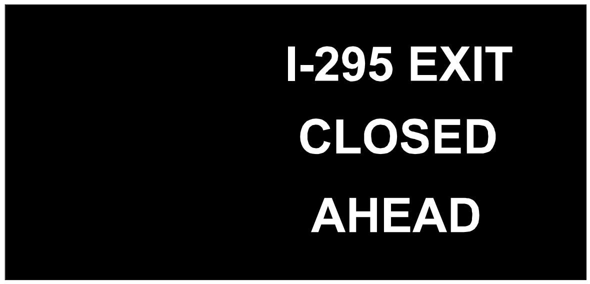
System Objective

The proposed speed management system objective was described in-depth in the introduction. The primary objective, however, is to reduce speed variance and accidents upstream of reduced flow locations by providing drivers with better information on traveled speeds.

System Description

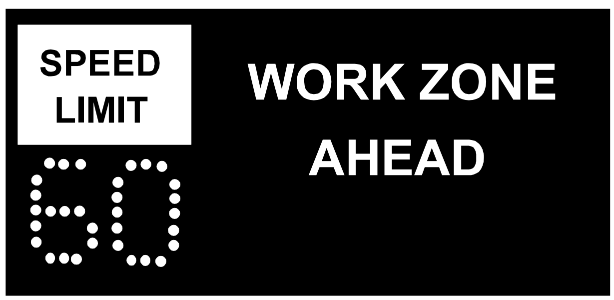
The proposed speed management system should operate in a similar fashion to European systems with displays changing according to traffic flow conditions. Under freeflow conditions, the sign should display no regulatory or advisory speed limits, however the dynamic portion of the sign can be used for other messages. By displaying no speed control message, drivers will be expected to comply with the normally posted maximum speed limit. When average traveled speeds are below the maximum speed limit on the freeway, advisory speeds should be displayed to warn motorists of the slower condition. The black letters on yellow background, advisory-type sign will reinforce that the sign is a warning device and that there is a risk if the driver ignores it's message. When special conditions exist, such as a construction zone, the automatic speed limit display can be manually controlled to display a lower than the maximum, regulatory speed limit. The system should be set up to allow the lower regulatory speed to be removed to post advisory speeds when traveled speeds slow below the new regulatory limit.

German and Dutch systems were well received by drivers when using the approach of displaying no speed limit until traffic conditions warrant a special message. It is expected that this approach will also be well received by American drivers. Additional operation guidelines were designed to maintain the credibility of speed limit displays and the perception of the system as an aid to drivers instead of another government regulation. American drivers have lost respect for regulatory speed limits because of the arbitrarily low speeds posted with the National Maximum Speed Limit law and because of the inability of police to monitor every section of highway. By highway engineers acknowledging the advisory nature of speed limits in non-freeflow situations, the credibility of the variable speed signs should automatically increase.



(a) Freeflow traffic conditions.

(b) Traveled speeds below the maximum limit.



(c) Special conditions for manual control..

Figure 6. Proposed Displays for Different Traffic Conditions.

The proposed system will not display minimum speed limits and lane control signals. Studies completed prior to installing the FHWA prototype system determined that motorists liked the display of a minimum speed limit when no other message needed to be posted, but they have not proven to significantly reduce speed variance and the system is intended for a section of roadway with frequently unstable flow. Minimum speed postings may confuse motorists, causing the system to lose credibility.

Although many systems included lane control signals in their variable speed limit system, they are not recommended in future systems. Lane control signals have been proven effective, but current LED and fiber optic signs often have visibility problems on interstates. When the signs are visible, roadway curvature often impairs the drivers ability to discern which lane is closed. Most motorists readily comprehend equivalent messages, like RIGHT LANE CLOSED AHEAD, without the hesitation of mentally processing a red "X" symbol. When visibility and comprehension issues are combined with the cost of an overhead structure, it is easy to eliminate lane control signals in favor of a changeable message sign.

Sign Displays

Signs recommended for future systems have static-looking and dynamic portions of the display and the flexibility to display regulatory, advisory and other messages in a manner clearly understood by the motorist. Experience in New Jersey and Albuquerque has demonstrated that U.S. drivers readily recognize variable speed limit signs with a static SPEED LIMIT message and dynamic limits. The proposed system continues with that design.

The static-looking portion of the sign will display a regulatory (black on white) SPEED LIMIT sign, an advisory (black on yellow) ADVISED SPEED sign or a blank (solid black) sign by rotating a segmented display into the correct position, similar to advertizing displays in some sports arenas. The "static" sign should also be illuminated to increase visibility in low-light conditions. Below this static sign, the recommended speed limit will be shown on a matrix-type, flip-disk, LED or fiber optic illuminated, dynamic message sign.

Speed limits will be displayed in increments of 5 MPH. While many motorists will not change their behavior with only a 5 MPH change in posted speed, they will become aware of the possibility of slower traffic ahead and will prepare to react to it. Within the queue, 5 MPH increments are more appropriate for traveled speeds and motorists may build confidence in the system by verifying that their speedometer matches the display.

Next to the speed limit sign, a dynamic message sign with three rows of at least ten characters each will be mounted to display supplementary messages. This sign is also recommended to be matrix-type, flip-disk and LED or fiber optic illuminated even though the sketch in Figure 10 does not illustrate this portion of the sign as a matrix type. The dynamic message sign provides added meaning to the dynamic speed limit. Messages should be predetermined by the system to avoid confusing drivers with non-standard messages.

Sign Mounting

As previous evaluations have shown, the visibility of the system to drivers is critical to the effectiveness of the system. Signs types should be used which have proven to be effective for all traffic lanes, under all lighting conditions and over a long enough distance for motorists to read and comprehend the message. After observing many different types of signs under different lighting conditions and roadway configurations, back-lit flip disk signs appear to offer the best visibility.

Two placement options are recommended relative to the roadway; 1) place one set of signs on a cantilevered structure on the right side of the road as shown in Figure 7 or 2) place variable speed limit and message signs at standard sign mounting heights on the shoulders of each side of the road. These two options are preferable to an overhead structure for the following reasons.

- Roadside mounted signs are less expensive than overhead structures.
- The benefits of overhead signs include lane control signals and posting different speeds in different lanes, but the main purpose of this project is to reduce variability in the traffic stream, so different speeds for different lanes are not recommended, since they introduce variability. Lane control signals have been proven effective, but they were eliminated from consideration due to visibility, comprehension and flexibility considerations.
- Maintenance of overhead structures is, in itself, a hazard to motorists and workers. Side mounted signs are easier to maintain and maintenance is less distracting to motorists. A cantilever sign should be able to be rotated to the roadside for maintenance and system testing.

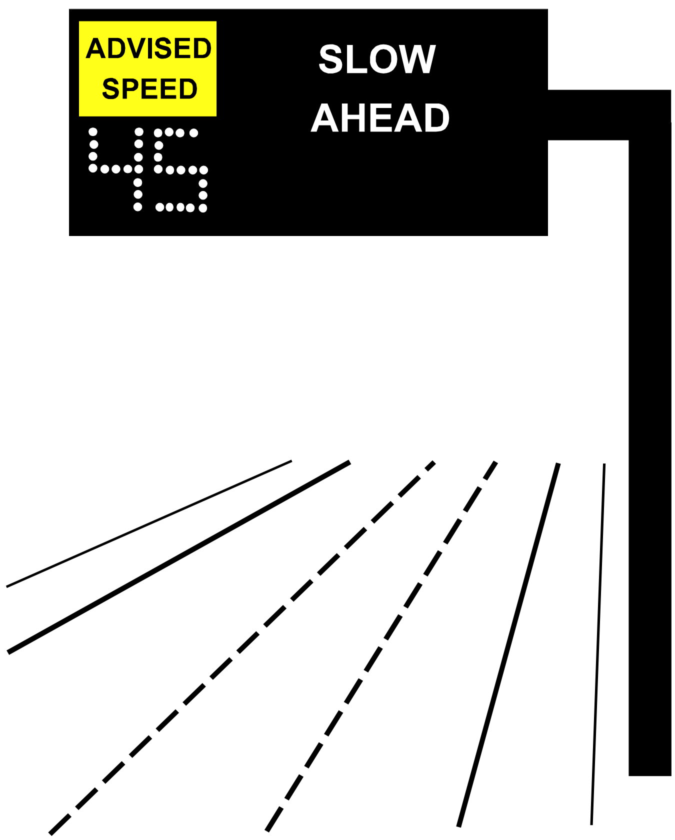


Figure 7. Proposed Cantilever Mounting.

Cantilever signs similar to the recommended design have been installed on I-90 in Washington State as part of a rural variable speed limit system which warns motorists of weather conditions on a mountain pass. It is unknown if these signs can be rotated to the roadside for maintenance.

Existing dynamic message signs on overhead structures could be used to post advisory speed messages, however, driver understanding and reaction to this type of speed warning should be studied.

Sign Spacing

Signs should be spaced frequently enough to provide adequate warning to drivers but not so frequently that drivers begin paying more attention to their speedometer than the traffic conditions around them. Sign stations at 1.6 km (1 mile) intervals are recommended as a minimum distance in a congested area. This provides a motorists traveling at 60 MPH a new message once per minute or a frustrated person traveling at 30 MPH will receive an new message every two minutes. More frequent spacing could distract drivers from other, more important, tasks and less frequent spacing may not be adequate to warn motorists of expected queues. Installing signs at intervals greater than 1 km (0.6 mile) also decreases the likelihood of sign spacing being too close for effective individual sign control. It is expected that sign spacing can increase as the distance increases to the reduced flow location.

Enforcement

The proposed speed management system is not intended to be a speed trap. It is intended to provide information to drivers so they can adjust their vehicle speed and position as they deem appropriate. This assumes that the majority of motorists would like to avoid accidents and would prefer driving slower over stop-and-go traffic.

Enforcement, however, will likely be necessary and legislation will be required in most states to allow speed limits to change based on real-time traffic conditions. Both regulatory and advisory speed limits can be enforced by the police under Prima Facie speed limit laws, but the proposed system would not burden police with increased enforcement to get compliance as done in the Netherlands and Britain. Changing the sign from regulatory to advisory should also alleviate comprehension problems, encountered in Detroit and the Netherlands, and increase compliance.

The use of dynamic speed displays will only be effective at increasing driver compliance if drivers believe their message to be relevant. Many static speed limit signs are perceived as irrelevant by drivers. Data provided on the Capital Beltway at one station showed that 94% of the drivers exceeded the posted speed limit.

Control Strategy

Limited manpower and funds in most transportation agencies mandates that dynamic systems operate autonomously with the ability for manual override as needed. The FHWA Prototype proved that current equipment technology and algorithms could operate reliably in this fashion. Each sign will be controlled independently within the system; subsections developed in the Detroit and Netherlands schemes do not provide enough flexibility for the envisioned system. The system will operate 24-hours per day since incidents may cause traffic to slow at any time.

Detector Technology and Spacing

To date, inductive loop detectors have proven to be the most reliable and inexpensive vehicular traffic detection technology. In a dual-loop (or speed trap) configuration, loop detectors collect occupancy and volume data used by the control algorithm. Loop data can also be processed to provide speed, vehicle classification, standard deviation of speeds, kinetic and internal energy of the traffic stream, the traffic flow rate and other measures of effectiveness.

Detectors stations should be installed at 800 m (0.5 mile) intervals; this is the industry standard in the United States. Detector installations at this spacing are used for incident detection in many traffic management systems and were also used in a shock wave prediction system in Houston, Texas, in 1972 (29). Additional study would be required to justify different spacing.

Data sampling intervals should be less than or equal to 30 seconds. More frequent data sampling stabilizes the smoothed data calculations by basing one-minute smoothed values on more than one or two samples. Ten-second intervals were used in the FHWA Prototype, however, algorithms could be modified to use other sampling intervals, such as the 20-second intervals used in San Antonio's TransGuide system. As data sampling interval becomes larger, not only do smoothed values become more unstable, but the shock wave warning prediction time decreases, such that there may be no advance warning and the shock wave may travel upstream of the sign before the algorithm detects it.

Weather Detection

Sensors for the detection of temperature, precipitation and light should be placed at each sign station. Data collected from environmental sensors can warn upstream motorists about wet or icy conditions. Light sensors can also be used to determine when the static portion of the sign needs to be illuminated. Environmental sensor data should be used by the control algorithm to determine the appropriate speed limit.

Last Station

The last station in the system should only collect traffic and weather data as recommended by the FHWA Prototype experience in Albuquerque, New Mexico. If the last station were a sign installation, it would not be able to inform motorists of any upstream conditions.

Communication

If no other communication infrastructure is in place, digital packet radio appears to be an economical and reliable communication medium. Digital radio allows communication over long distances without installing a continuous infrastructure along the highway. It was used successfully in Albuquerque and has tested well in Washington State.

Control Algorithm

The control algorithm combines Houston queue prediction algorithm, German speed selection algorithm and components of the FHWA prototype and Dutch algorithms. Only through the combination of these algorithms can the proposed system provide warning about a shock wave ahead and advise motorists of the safest speed to travel. The flow chart in Figure 8 and following descriptive text outline the components of this algorithm, however, additional work is required to fully develop each decision block and the interactions between each step.

The proposed logic begins with the collection of real-time traffic data that indicates the type of traffic flow occurring on each section of highway in the system. Speed and volume in each lane, average speed and total volume will be collected at each detector station at sampling intervals of 30 seconds or less. Speed displays, however, should only change once per minute and sign displays should be displayed long enough for drivers to read and comprehend the message.

The next step manipulates collected data through predefined equations to better describe the traffic stream. The one-minute smooth speed is calculated to stabilize the speed limit and decrease the likelihood of switching between speeds. Kinetic energy of the traffic stream, standard deviation of speeds and total volume are used to determine the posted speeds and messages. Other measures may be calculated, such as vehicle classification, but they are not required for the proposed algorithm.

The first decision made in the algorithm is whether or not a shock wave is forming. If a shock wave is forming at the sign location or at the detector station immediately upstream of the sign, special messages should be communicated to drivers, such as SUDDEN SLOWING AHEAD. It is expected that the prediction of a shock wave will affect the determination of posted messages only. Speed limit displays will not be determined by the speeds in the shock wave, however, the presence of the shock wave may be a variable considered. Logic similar to Houston's shock wave detection algorithm could be used for this decision block, but German methods of using standard deviation to predict congestion could also be used. Additional analysis is necessary to determine the optimal shockwave detection algorithm.

The next step in the algorithm is to determine what the posted speed should be for existing conditions. Speed messages should be based on information from the two loop detector stations assigned to each sign; other upstream speeds should not be considered since they do not directly affect drivers viewing the sign. This decision block should combine the German method of using standard deviation of speed, speed density and average speed to recommend a speed limit and the FHWA method of adding environmental factors to determine the appropriate speed limit for current environmental conditions. Maximum speed limits in the United States are typically equal to the 85th percentile speed. A dynamic speed limit should also reflect the 85th percentile speed.

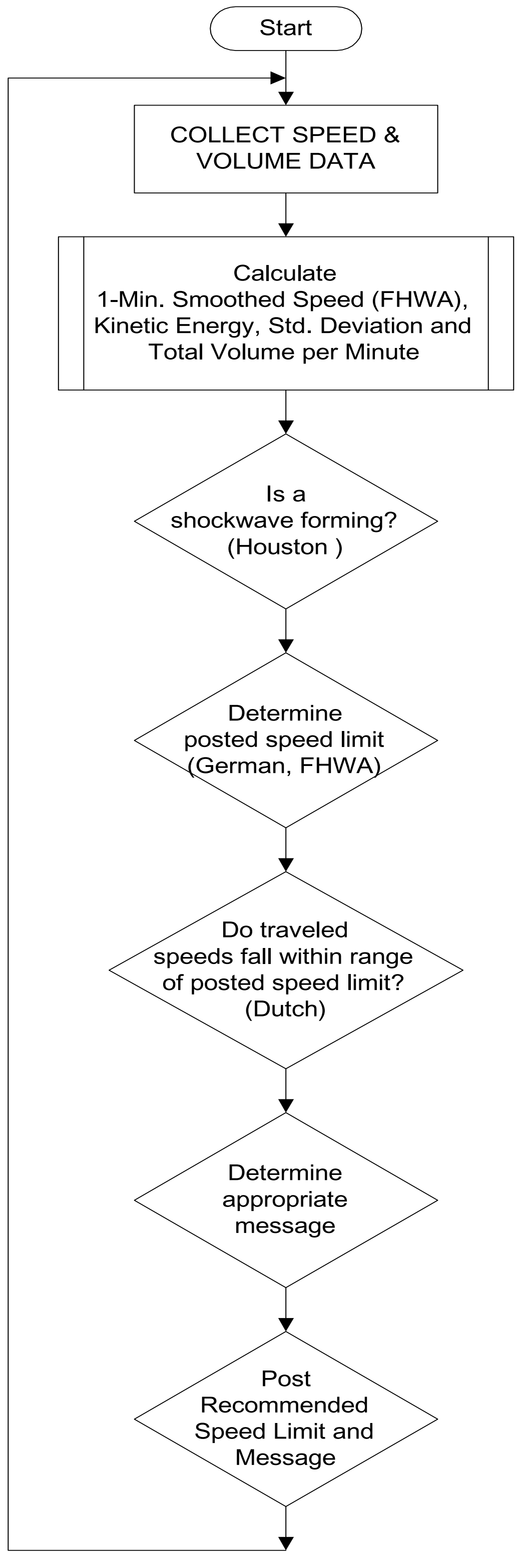


Figure 8. Proposed Algorithm.

If traveled speeds are within the range of the current posted speed limit, the limit should not be changed. The Dutch algorithm may be referenced to resolve differences between the two detector stations linked to each sign. This check is performed to reduce the likelihood of the speed display changing when traveled speeds are near the threshold dividing two different speed displays.

The message decision block determines the display on the dynamic message portion of the sign. The posted message can be automatically determined from traffic data, weather data or data relayed from upstream roadside stations. Environmental and slow traffic warnings are based on traffic and environmental detector information. Information from upstream stations can be displayed automatically with messages on the distance to the hazard, such as SLOW TRAFFIC 1 MILE AHEAD when a shock wave is detected at the upstream sign station. Lane closure and accident messages can be recommended to system controllers, but these messages should be verified by video cameras or police communication before posting.

The final decision in the algorithm is to post the recommended speed and message. Speed displays should only change once per minute (as in the FHWA Prototype system) and sign displays should be displayed long enough for drivers to read and comprehend the message. If these criterion are met, recommended speed and message displays will be posted. The algorithm begins again with a new set of detector data, so the time to run the algorithm should be less than the detector sampling rate.

Further Analysis

Before the proposed system can be implemented, the algorithm needs to be fully developed. A study of shock wave prediction methods and the effects of changing different parameters, such as sign spacing, detector spacing and detector sampling rate, must be completed. The interaction of shock wave prediction and speed limit displays should also be studied to determine how shock wave prediction can effect the posted speed limit.

Proposed speed management displays should also be studied to confirm driver comprehension and acceptance. Since all of the 42 state operated traffic management centers listed with ITS America include existing dynamic message signs (31), use of existing changeable message signs should be strongly considered in a speed management system. Human factors studies should examine driver response to advised speed messages on these signs.

APPLICATION TO THE CAPITAL BELTWAY

The Capital Beltway is a freeway which encircles the Washington, D.C., metropolitan area. One section of the Beltway is being considered for installation of the proposed speed management system because of its speed-related problems. The section under study includes the southbound lanes of I-95/495, immediately north of the Woodrow Wilson Bridge in Maryland. The Woodrow Wilson Bridge carries 170,000 vehicles per day. During peak hours, southbound speeds near the bridge are about 15-20 MPH while speeds upstream of the queue are 60-65 MPH. The posted speed on this section of interstate is 55 MPH but, on an average day, 94 percent of motorists drive faster than 55 MPH. The Maryland Department of Transportation expects to raise the maximum speed limit to 60 MPH soon.

Peak hour speed reductions are due primarily to the reduction in lane capacity at the Woodrow Wilson Bridge and, on occasion, all traffic is stopped when the drawbridge is raised. North of the bridge I-95/495 has four lanes in the southbound direction. One of these lanes is dropped at the exit to I-295 at approximately the highway milepoint (MP) 2.0. The remaining three lanes continue to the south end of the bridge at the Maryland-Virginia border at MP 0.0. This problem is compounded by the addition of southbound traffic from I-295 merging into the three-lane section at approximately MP 1.3. Congestion caused by changes in geometry and heavy traffic demand often result in accidents. Minor incidents occur 2-3 times daily during peak periods and major incidents occur about once every two months. Accident rates on the southbound lanes are significantly higher than the Maryland statewide average as denoted by asterisk in Table 3.

Sign Location Considerations

Before assigning locations for sign station installations, five criteria should be considered for logical and cost efficient placement of speed management signs.

1. Recommended spacing for system design;
2. High accident locations;
3. Entrance ramp locations;
4. Existing overhead sign locations; and
5. Detector station locations.

Spacing recommendations for the proposed system were 1.6 km (1 mile) spacing immediately upstream of the reduced flow location and longer distances further upstream. The frequency of accidents in the study area supports this conclusion. Accident frequency was charted by half-mile sections in Figure 9; southbound traffic travels from MP 10.78 toward MP 0.0. High accident segments are noted at one mile intervals immediately upstream of the bridge and become spaced further apart further upstream from the reduced flow location. Based on the first two criteria, system design recommendations and high accident frequency sections, a need for sign displays is indicated near or upstream of milepoints 1.0, 2.0, 3.0, 4.5, 7.5 and 10.0.

Table 3. Accident Experience on Southbound I-95/495, Milepoint 0.00 to 10.78.

	1994	1995	1996	Total	Study Area Accident Rate	Statewide Accident Rate
Accident Severity						
Fatal	2	5	3	10	* 1.19	0.60
Injury	148	132	155	435	* 51.78	30.40
Property Damage	109	93	134	336	* 40.00	29.00
Total Accidents	259	230	292	781	* 92.97	60.00
Collision Type						
Angle	1	0	0	1	0.12	0.30
Rear End	129	100	124	353	* 42.02	21.90
Fixed Object	45	53	67	165	* 19.64	15.20
Opposite Direction	0	0	3	3	0.36	0.40
Sideswipe	59	40	52	151	* 17.97	11.40
Pedestrian	2	2	0	4	0.48	0.30
Parked Vehicle	7	6	7	20	* 2.38	1.60
Other	15	26	37	78	9.28	8.70

** Denotes accident rates significantly higher than statewide accident rate.*

When entrance ramp locations and existing overhead signs are reviewed, sign location recommendations change to milepoints 1.2, 2.5, 3.5, 5.0, 6.5, 8.0 and 10.0. There are no detector stations that need to be considered on this section of highway for future system operation. The study section, ramps and signs are depicted in a sketch in Figure 10; each line represents one travel lane.

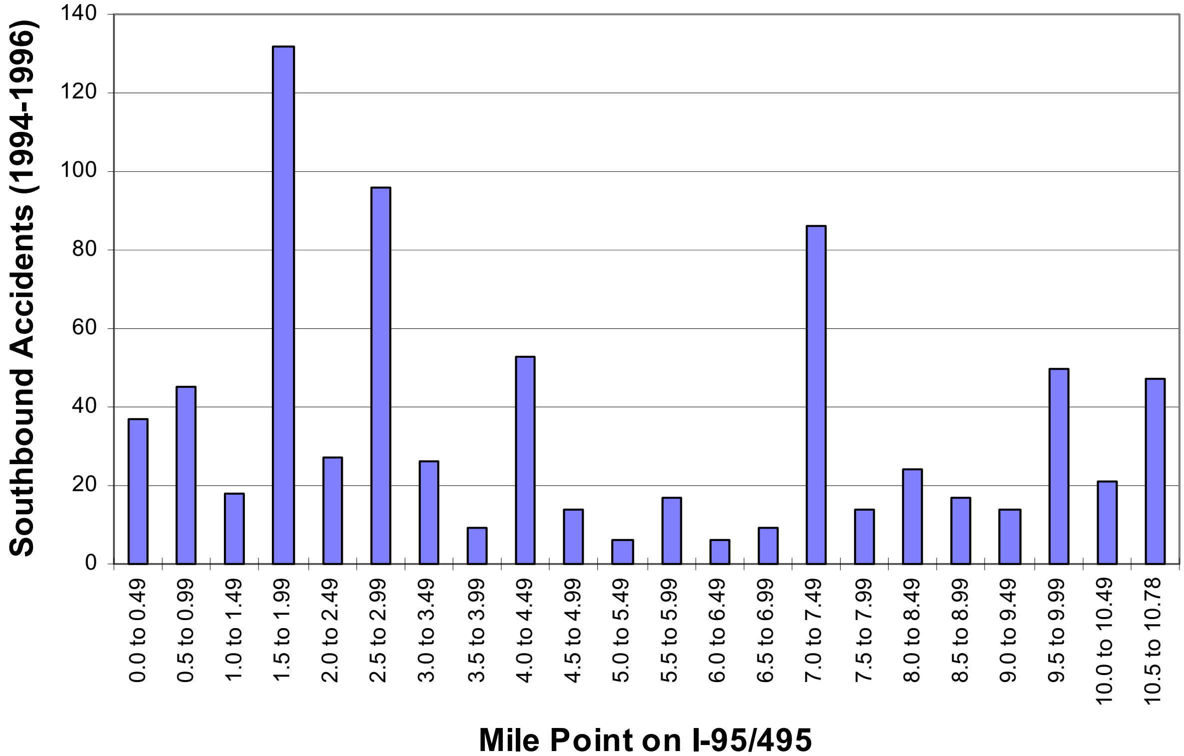


Figure 9. Accident Experience in I-95/495 Southbound Lanes, 1994-1996.

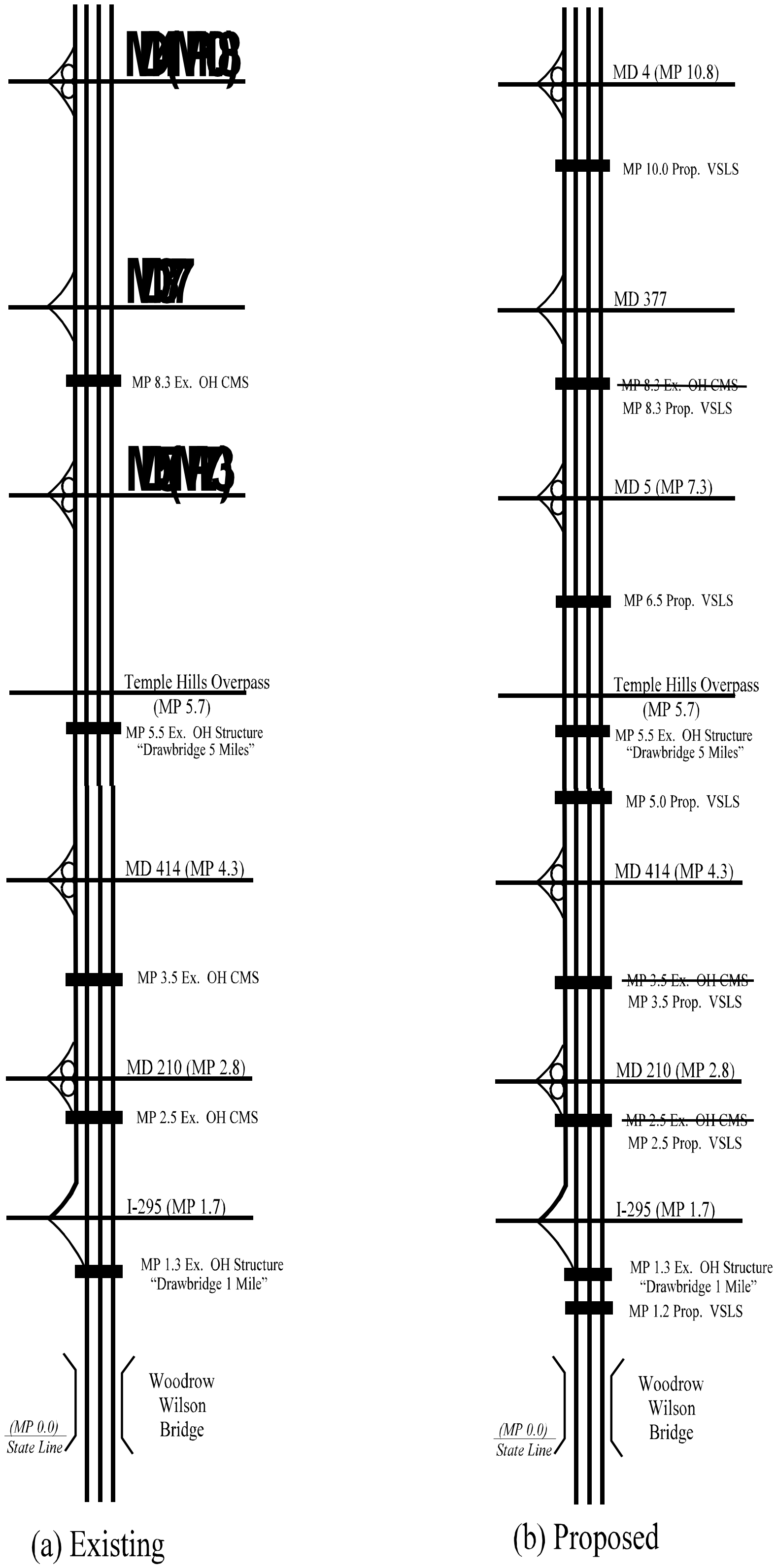


Figure 10. Existing and Proposed Sign Locations on the Capital Beltway.

Cost-Benefit Analysis

The total accident rate in the study area is almost 93 accidents per million vehicle miles. When that accident rate is compared to the accident involvement rate curve developed for interstate highways in Cirillo's report for the Bureau of Public Roads (1), speed deviation on the southbound lanes appears to range between -10 to +25 MPH from the mean speed. Cirillo's curve determined that the lowest accident involvement rate was about 10 MPH above the mean speed, or approximately the 85th percentile speed. So speeds on the southbound lanes deviate about -20 to +15 MPH from the 85th percentile speed.

It is reasonable to assume that a variable speed system in the United States would not have the 98 percent compliance rate experienced in Britain. If speed variance was reduced by only 5 MPH, both above and below the mean speed, to -5 to +20 MPH, the accident involvement rate would be reduced to about 57 accidents per million vehicle miles or 61 percent of the current rate. This reduction would prevent 100 accidents from occurring per year, as well as 1.3 fewer fatalities and 82 fewer injured people each year. Using the MicroBENCOST estimates of the costs associated with accidents on interstates ($1,111,000 for a fatal accident, $24,900 for an injury accident and $2,140 for a property damage accident (33)), accident cost savings due to the variable speed limit system would be $2,930,720 per year. This estimate is especially conservative since it does not account for the increasing numbers of accidents observed on this section of highway or the reduction in delays to thousands of other motorists due to accidents.

The Federal Highway Administration estimated that future installations similar to the prototype installed in Albuquerque would cost $30,000 per combined sign and detector station and $20,000 for the central installation. The proposed system includes a more expensive mounting for the sign, a larger sign and additional detector units upstream of each sign, so cost estimates should be higher for each station. Since the desired sign configuration has already been in production for the Washington State system, development costs should not be included in the sign cost. An estimate of $50,000 per station (even though two stations already have sign support structures with dynamic message signs that could be used in this system) and $20,000 for the central control hardware and algorithms is used to estimate the cost of a system on the southbound lanes of the Capital Beltway north of the Woodrow Wilson Bridge.

The total cost for covering the entire study area would include seven stations and one central control, for a total cost of $370,000. Within the first year of operation, cost savings due to accident reductions alone would be 7.9 times the cost of the system.

CONCLUSIONS AND RECOMMENDATIONS

Variable speed limits systems have been installed on freeflow facilities in urban areas in many countries, providing experience to build on for future systems. The speed management system proposed combines shock wave prediction algorithms with the variable speed limit system. It is expected that this system will be as successful as recent European systems in reducing speed variance and encouraging more uniform flow. This will result in a reduction in accidents and delay.

Urban freeways with recurring speed-related problems are ideal sites for the installation of variable speed limit systems. It would not be practical or cost effective to install these systems uniformly on U.S. highways. Before the proposed system can be installed at any location, additional study must be completed on shock wave prediction, the effect that changing variables such as sign spacing, detector spacing and detector sampling rate, and the relationship between shock waves and speed recommendations. Future system applications in the U.S. will also require legislation to authorize changing legal or advisory speed limits based on real-time conditions.

The potential benefits of speed management systems were evident in a cost-benefit analysis of a section of the Capital Beltway. The cost savings in the first year from accident costs alone could be 7.9 times the cost of the system. With the potential of these systems being realized in Britain, Germany and the Netherlands and substantial benefits calculated on the Capital Beltway, the United States should actively pursue installation of variable speed limit systems to reduce accidents and stop-and-go traffic conditions on freeways with reduced flow locations and heavy congestion in urban areas.

ACKNOWLEDGMENTS

Special thanks are extended to Thomas Hicks and Colin Rayman for their thought provoking input and contribution of personal time as mentors to the author. Their correspondence was motivational, challenging and greatly appreciated.

Dr. Conrad Dudek and the remaining mentors, Marsha Anderson, Ginger Gherardi, Joseph McDermott and Douglas Robertson, also provided significant input which shaped the substance of this paper as well as the author. The support activities of Sandra Schoeneman and Lorelei Samuel were also an essential component of successful communication between the mentors and the author.

The following professionals provided information on their experiences with variable speed limit systems or helped the author gather information. The author appreciates their time and efforts.

- Robert Dale, New Jersey Turnpike Authority
- Elizabeth Harding, Michigan Department of Transportation
- Les Jacobson, Washington State Department of Transportation
- Greg Laragan, Idaho Department of Transportation
- Lt. Marconis and Sgt. Bill Wade, New Jersey State Police
- Tobey Nutt, Information and Technology Exchange Center
- Larry Senn, Washington State Department of Transportation
- Davey Warren, Federal Highway Administration

A final expression of gratitude is extended to my husband and parents who continually support my educational pursuits.

This paper was prepared for a graduate course in Civil Engineering at Texas A&M University, *CVEN 677 Advanced Surface Transportation Systems*.

REFERENCES

Speed-Accident Relationship

1. Cirillo, Julie Anna. "Interstate System Accident Research Study II, Interim Report II." *Public Roads*, Vol. 35(3), pp 71-75, August 1968.

2. Deen, Thomas B. and Godwin, Stephen R. "Safety Benefits of the 55 MPH Speed Limit." *Transportation Quarterly*, Vol. 39, No. 3, pp. 321-343, July 1985.

3. Garber, N. J. and Gadiraju, R. "Factors Affecting Speed Variance and Its Influence on Accidents." *Transportation Research Record 1213*, pp 64-71, 1989.

4. Hauer, Ezra. "Accidents, Overtaking and Speed Control." *Accident Analysis and Prevention*, Vol. 3, pp 1-13, 1971.

5. Parker, M. R. and Tsuchiyama, K. H. "Methods for Reducing Large Speed Differences in Traffic Streams, Volume I - Inventory of Methods." FHWA-RD-85-103, August 1985.

6. Parker, M. R. "Methods for Reducing Large Speed Differences in Traffic Streams, Volume II - Final Report." *FHWA-RD-85-104*, August 1985.

7. Research Triangle Institute. "Speed and Accidents - Volume II." National Highway Safety Bureau Contract No. FH-11-6965, June 1970.

8. Solomon, David. "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle." U.S. Department of Commerce, Bureau of Public Roads, July 1964.

9. West, Leonard B. and Dunn, J. W. "Accidents, Speed Deviation and Speed Limits." *Traffic Engineering*, pp 52-55, July 1971.

Variable Speed Limit Systems - United States - Michigan

10. Bushnell, Keith and Richard, Charles. "The Development of Blankout Signals for Freeway Traffic Control." Michigan State Highway Department, John C. Lodge Freeway Traffic Surveillance and Control Research Project, 1963.

11. DeRose, Frank. "The Development and Evaluation of the John C. Lodge Freeway Traffic Surveillance and Control Research Project : A Summary Report." Michigan State Highway Department, John C. Lodge Freeway Traffic Surveillance and Control Research Project, 1963.

12. Wattleworth, J.A. and Wallace, C. E. "Evaluation of the Operational Effects of an 'On-Freeway' Control System." *Texas Transportation Institute Research Report 488-2*, November 1967.

Variable Speed Limit Systems - United States - New Jersey

13. Dale, Bob. Director of Operations, New Jersey Turnpike Authority. Telephone discussion, June 1997.

14. Marconis, Lt. and Wade, Sgt. Bill, New Jersey State Police. Telephone discussion, June 1997

Variable Speed Limit Systems - Germany

15. Kuhne, Reinhart D. "Freeway Control Using a Dynamic Traffic Flow Model and Vehicle Re-identification Techniques." *Transportation Research Record 1320*, Transportation Research Board, National Research Council, Washington, D.C., pp. 251-259, 1991.

16. Zackor, Heinz. "Self Sufficient Control of Speed on Freeways." *ITE Proceedings of the International Symposium on Traffic Control Systems*, Vol. 2A, Berkeley, California, pp.226-247, 1979.

Variable Speed Limit Systems - United States - FHWA Prototype

17. Hoogerwerf, Julia. "An Evaluation of the Variable Speed Limit System." Term Paper, Michigan State University, December 1991.

18. "Variable Speed Limit System: System Design Task A Driver Requirements, Volume I - Mobile Laboratory Study - Final Report." Institute for Research, State College, PA, for FHWA DTFH61-86-C-00080, November 1987.

19. "Variable Speed Limit System: System Design Task A Driver Requirements, Volume II - HYSIM Study - Final Report." Institute for Research, State College, PA, for FHWA DTFH61-86-C-00080, November 1987.

20. Sumner, Roy. "A Variable Speed Limit System for Freeways." Compendium of Technical Papers, ITE 58th Annual Meeting, September 25-29, 1988, pp. 172-175.

21. Sumner, R. L. and Andrews, C.M. "Variable Speed Limit System." Publication No. FHWA-RD-89-001, March 1990.

22. Warren, Davey. Federal Highway Administration, Project manager of FHWA Variable Speed Limit System Prototype. Telephone discussion, June 1997.

Variable Speed Limit Systems - Netherlands

23. Kuciemba, Steve. "FHWA Sponsored European Scanning Tour - The Netherlands." Notes for the Maryland State Highway Administration, December 16, 1995.

24. Smulders, S. “Control by Variable Speed Signs : the Dutch Experiment.” *Proceedings of the 6th International Conference on Road Traffic Monitoring and Control* (London, England), Institution of Electrical Engineers, London, pp. 99-103, 1992.

25. van den Hoogen, Erick and Smulders, Stef. “Control by Variable Speed Signs: Results of the Dutch Experiment.” *Proceedings of the 7th International Conference on Road Traffic Monitoring and Control* (London, England), Institution of Electrical Engineers, London, pp. 145-149, 1994.

Variable Speed Limit Systems - Britain

26. Nuttall, Ian. “Slow, Slow, Quick, Quick, Slow : Taking the 'Stop-Start' Out of the London Orbital.” *Traffic Technology International*. pp. 46-50, Winter 1995

27. Rees, Ian. “Orbital Decongestant.” *Highways* (Croydon, London, England), Vol. 63, No. 5, pp. 17-18, 1995.

Queue Warning System - United States - Texas

28. Dudek, C. L. “Development of a Technique for Digital Computer Control of a Safety Warning System for Urban Freeways.” Development of Urban Traffic Management and Control Systems, Research Study Number 2-8-72-165, Texas Transportation Institute, May 1972.

29. Dudek, C. L. and Biggs, R. G. “Design of a Safety Warning System Prototype for the Gulf Freeway.” Development of Urban Traffic Management and Control Systems, Research Study Number 2-18-72-165, Texas Transportation Institute, May 1972.

30. Dudek, C. L. and Messer, C. J. “Detecting Stoppage Waves for Freeway Control.” *Highway Research Record 469*, Highway Research Board, 1973.

Miscellaneous

31. ITS America world wide web site, *www.itsa.org*, July 1997.

32. *Manual on Uniform Traffic Control Devices for Streets and Highways*. Federal Highway Administration, U.S. Department of Transportation, 1988.

33. *Micro BENCOST Users Manual*. National Cooperative Highway Research Program, Project 7-12, Texas Transportation Institute, 1993.

APPENDIX

Summary of Variable Speed Limit System Experience in Urban Areas.

Year	Location	Type of Speed Control*	Data Input		Length of System	Average Sign Spacing	Average Detector Spacing	Speed Control Strategy
			Traffic	Weather				
1962	U.S. - Detroit, Michigan (M10 - Lodge Freeway)	Advisory	Primary		5.2 km (3.2 mi.)	0.5 km (0.3 mi.)	unknown	Manual control based on lane closure or reduced speeds
1960s	U.S. - New Jersey (NJ Turnpike)	Regulatory	Primary	Planned	unknown	4.0 km (2.5 mi.)	unknown	Automatic control based on speed and volume data. Manual override used for lane closures.
1972	Germany (A8 - Salzburg to Munich, A3 - Siegburg to Cologne, A5 near Karlsruhe)	Regulatory	Primary		 30 km 13 km unknown	 1.5 km 1.5 km unknown	 unknown	Control strategy proposed for A5 uses automatic control based on speed, density and standard deviation of traffic flow.
1985	France - Marseille	unknown	Primary	Secondary	8.0 km (5.0 mi.)	unknown	unknown	unknown
1989	U.S. - Albuquerque, New Mexico (I-40)	Regulatory	Primary	Secondary	4.8 km (3.0 mi.)	2.4 km (1.5 mi.)	2.4 km (1.5 mi.)	Automatic control based on smoothed average speed plus an environmental constant.
1992	Netherlands - Amsterdam (A2 toward Utrecht)	Regulatory	Primary		20 km (12.4 mi.)	1.0 km (0.6 mi.)	0.5 km (0.3 mi.)	Automatic control based on detection of an incident, smoothed volume and average mean speed.
1995	Britain - London (southwest quadrant of M25)	Regulatory	Primary		22.6 km (14.0 mi.)	1.0 km (0.6 mi.)	0.5 km (0.3 mi.)	Automatic control based on volume.
	Proposed system	Regulatory & Advisory	Primary	Secondary		1.6 km (1.0 mi.)	0.8 km (0.5 mi.)	Automatic control based on smoothed speed, environmental factors and congestion prediction.

Julia K. Wilkie received her B.S. and M.S. in Civil Engineering from Michigan State University in December 1990 and March 1992. Julia is currently pursuing her Ph.D. in Civil Engineering at Texas A&M University while working in the TTI San Antonio office. She has been employed by the Texas Transportation Institute since September 1996. For the previous four years, Julia worked for Lockwood, Jones and Beals, Inc. as a transportation consultant. Before that she was employed by the South Carolina Department of Transportation. Julia is a registered professional engineer in Ohio and was recognized as the Young Engineer of the Year by the Ohio Section ITE in 1995. Her work on the Ohio Section ITE newsletter was recognized when she received the 1995 ITE Newsletter Award in Denver. Julia is a member of the Texas A&M Student Chapters of the Institute of Transportation Engineers and ITS America. Her areas of interest include: traffic operations, geometric design, transportation planning, and transportation policy issues.