ENHANCING HIGHWAY ADVISORY RADIO AS AN EFFECTIVE ADVANCED DRIVER INFORMATION SYSTEM INTERFACE

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SUMMARY

Alleviating urban traffic congestion is a problem faced by many state and metropolitan agencies. The problem is not in determining what to do, but how to accomplish it. ITS technology has emerged as part of the solution to the congestion problem. Implementing various ITS programs will collectively and ideally be an effective traffic management tool, and many agencies are well underway in solving the congestion problem.

One ITS technology used for traffic and incident management is Highway Advisory Radio (HAR). HAR applies a widely used and popular interface, the car radio, complemented with other emerging technologies, such as changeable message signs and advanced freeway surveillance techniques, to provide motorists with traffic information. There does remain, however, some limitations to HAR, especially those imposed upon state and metropolitan agencies by the Federal Communications Commission (FCC). This primarily includes the broadcasting limitations imposed upon the hardware, limiting HAR to a low-power, AM radio frequency. Government agencies are also limited in their capability to provide current and accurate traffic information. These limitations remain what they were years ago, and until this can be overcome, agencies will find it difficult to convince the public the importance and potential of HAR.

A study was conducted where five government agencies and one private company were contacted to determine their use of HAR, the problems that exist, and the issues that they are currently addressing. Based on the data collected, recommendations were made to enhance the current use of HAR as a more effective Advance Traveler Information System.

Recommendations for enhancing HAR were made on several issues. These issues include the need for inter-agency cooperation and an implementation plan that establishes fiscal and personnel responsibilities. Also recommended, to make the most of the limitations, is establishing hardware needs and signing techniques, operational strategies for continuous and non-continuous broadcasts, and recommendations for a small-scale implementation of HAR to determine its effectiveness. Finally, human factors considerations for providing standard HAR messages are identified and the need is established to effectively market the system to the motoring public. Each of these recommendations are critical to the success of Highway Advisory Radio.

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INTRODUCTION

With the advent of new technologies and the increased activity and funding for Intelligent Transportation Systems (ITS), more sophisticated motorist information systems are being developed, that being Advanced Traveler Information Systems (ATIS). The goal of the ATIS program is to communicate information to the traveler in a variety of interfaces, including in-vehicle visual and audio displays, such as video monitor displays or AM/FM radio broadcasts. The information that can be provided to the motorists includes routing information, travel time information, and congestion limits, as well as nearby food, lodging, and gas information. The video and audio interfaces in the vehicle can be enhanced by providing more accurate and timely traffic information to the motorists, especially information that will benefit the driving task and minimize their confusion and frustration. As a result, it can dramatically improve freeway corridor operations and safety.

BACKGROUND

An emerging component of ATIS is Advanced Driver Information Systems (ADIS), which focus on providing information to the driver of a vehicle. This is accomplished through a combination of sophisticated external and in-vehicle technologies, including navigation and guidance displays, the AM/FM radio, and dynamic route guidance techniques. Although the technology is not completely developed and tested, persons operating a fully-equipped ADIS vehicle should ideally experience less congestion and delay due to the information that is available to them. The overall system can eventually benefit from reduced fuel consumption, vehicle emissions, and vehicle accidents (1).

Emerging Technology

While ADIS hardware is being developed to its full potential, however, existing hardware components remain at the forefront to provide information services to the motorists. Some of the existing ADIS technology being tested already are in-vehicle, video and auditory interfaces, such as heads-up display (HUD) and video display terminals. The testing relies on a "static" database of information and is independent of real-time traffic conditions. Only prototype models being tested, such as the TRAVTEK system in Florida, is able to provide a more dynamic information source for the motorists (1).

Existing Technology

Several hardware components have been in existence and have been used for many years to provide traffic-related information to the motorists in the vehicle. In order to establish communication to the motorists, metropolitan agencies and State Departments of Transportation are using specific hardware components to assist in alleviating traffic congestion and improving the overall urban traffic conditions. The components used to provide this service include:

- Changeable message signs (CMSs),
- Lane control signals (LCSs),
- Commercial radio traffic reports,
- Highway Advisory Radio (HAR), and
- Cellular Telephones.

Agencies have become more dependent upon these components in recent years to assist in incident management. In order for it to be a successful incident management system, however, it must be flexible and provide accurate and timely information. A flexible ADIS system that can provide this type of information allows motorists to use the highway system more efficiently and safely (2). The components, also, have to work together as a system to provide accurate and timely traffic information. Whether the technology is new or old, "as long as the collection of technologies work as a system, not as a collection of isolated elements", and work successfully to provide accurate and timely information, then it is a successful ADIS system (3). This paper will investigate HAR and its potential to be an effective ADIS interface.

Research Objectives

This paper focuses on one of the existing components of ADIS, that being HAR, and its potential to be an effective ADIS interface. Limitations that currently exist will be investigated so that HAR can be more effectively used as an incident management tool. The three primary objectives of this paper are listed as follows:

1. Contact metropolitan and state agency personnel in various parts of the United States to assess current HAR applications and the extent of their HAR use;

2. Identify and summarize recurrent institutional, hardware-related, and operational problems with using HAR; and

3. Develop means to enhance HAR as an effective ADIS interface.

Scope of Research

The purpose of this paper is to provide an insight into current HAR operational issues that transportation agencies must manage. Furthermore, after investigating the HAR experiences of these agencies, it is the intent of this paper to recommend means of enhancing the use of HAR in order to make it more useful for a variety of ATIS applications. Enhancing HAR can only be accomplished by first identifying key issues, such as institutional, hardware and operational issues, and then applying engineering and human factors solutions to the application of HAR.

HIGHWAY ADVISORY RADIO

Introduction

The use of HAR has the potential of being an effective traffic management tool. It is used by State and local governments, and government affiliated agencies such as airport and park authorities, to provide motorists primarily with traffic information via their AM radios. HAR messages on the radio provide traffic warnings, advisories, and directions, and/or other non-commercial material of importance to motorists. The messages are transmitted from low-power roadside radio transmitters, and the use of the system (transmitter power, location) is licensed and restricted by the Federal Communications Commission (FCC) (4).

HAR technology requires minimal effort on the user-end. Motorists use their car radios extensively, and with the technology that is available today, radios are controlled with simple touch-controls. It requires little, if any, visual contact to make adjustments. Because of this, and because HAR can provide a considerable more amount of information than what can be provided by visual signing alone are the primary reasons HAR is such an attractive means of providing information.

Background

The initial use of HAR in providing motorists with pertinent driving- and travel-related information began in 1940 on the George Washington Bridge in New York City. An HAR system was installed that broadcast 1-minute pre-recorded messages providing lane directions for motorists crossing the bridge. It operated successfully, providing advisory information during the 1940 World's Fair. At the close of the Fair, it was discontinued (5). In 1951, the Port Authority of New York installed a similar system in the Lincoln Tunnel that operated until 1955. For the majority of the time, it broadcast popular music programs, only to switch to traffic advisory messages when warranted (6). In 1963, a system was tested in Georgia that required special in-vehicle equipment in order for motorists to receive a special radio transmission. The system received favorable response from participants, as long as useful information could be provided by the broadcast (5).

The Federal Highway Administration got involved in HAR research in 1971, and sponsored several successful studies and field implementations, including installations in Pennsylvania, Colorado, Minnesota, Wyoming, and Iowa by the mid- to late-1970s. Federally sponsored research into human factors considerations was also conducted to identify ways to make the system more user-friendly (5). Visual signing techniques were studied to determine optimal locations of signs so that motorists knew when they were within the broadcast range of an HAR system (5). Further research was also conducted in the early 1980s to determine the optimal length, style, presentation, and repetition of HAR messages (2,7).

The use of HAR has expanded today and plays an important role in the ATIS program of ITS. Over 23 freeway surveillance and management projects nationwide plus over 11 national/international airports are now utilizing HAR to provide motorists with:

- Warnings of roadway incidents and congestion,
- Adverse environmental conditions (fog, ice, etc.),
- Notification of highway construction and maintenance,
- Alternate route information,
- Advisories pertaining to transportation terminals (airports, bus and train terminals),
- Advisories pertaining to special events (sporting, music, and cultural events), or
- Dissemination of public park, historical site and other tourist information (4,8,9).

Table 1 lists typical users and applications of HAR systems.

HAR Operations

Transportation agencies all have basic operational issues that must be dealt with on a daily basis, including maintaining hardware components, updating message contents, and following FCC guidelines. This section will briefly cover these issues, and will be further investigated in the case studies.

Basic Hardware Components

The basic hardware components of an HAR system include a low-power, roadside AM transmitter, modulation (or playback) equipment, and a radiating, coaxial cable antenna system or vertically polarized monopole antenna system (see Figure 1). Agencies typically lease a telephone line to interconnect the AM transmitter to the modulation unit to allow for remote broadcasting (6,10). HAR messages are broadcast using these roadside radio transmitters. Pre-recorded or real-time broadcasts attempt to provide timely and accurate information on traffic conditions in a particular area to those motorists only traveling in that area and who have an immediate need of that information. The transmitters are placed at intervals along the freeway or at key trouble locations so that a broadcast signal can cover a two to three mile radius (10).

To complement the HAR system and to make motorists more aware of its existence, agencies typically install freeway signs that inform motorists that HAR messages are being broadcast. Motorists can then tune their car radios to the proper frequency to receive the message. The freeway signs must be adequate in terms of visibility and legibility, as well as be placed in advance so that motorists have ample opportunity to hear the broadcast message before driving decisions have to be performed (10).

There are two types of antenna systems that can be used to radiate the HAR broadcast. Each is described in the following paragraphs.

Vertical Antenna HAR Systems. Vertical monopole antenna systems are installed at locations along a freeway corridor and can either be stationary or portable. Stationary

Table 1. Users and Applications of HAR in 1993 (8).

Users	Applications									
	Parking / Traffic Conditions	Emergencies & Evacuations	Local Public Advisories	Schedule / Hrs. of Operation	Fees & Ticket Information	Events Listing	Safety Information	Weather	Road Conditions / Detours	Rules & Regulations
Departments of Transportation	■	■					■	■	■	■
Turnpike Authorities	■	■			■		■	■	■	■
Chambers of Commerce / Tourism			■	■	■	■		■		
Airports	■		■	■	■		■			■
Universities	■	■	■	■	■	■	■		■	■
Nuclear Power Plants		■	■				■	■	■	■
Industrial / Chemical Plants		■	■				■	■	■	■
Military Bases	■	■					■	■	■	■
Government Agencies	■	■		■	■	■	■	■	■	■
Special Events / Fairs / Arenas	■	■		■	■	■	■		■	■
Amusement Parks / Campgrounds	■			■	■	■	■			■
Police / Emergency Units	■	■	■				■	■	■	
Municipalities	■	■	■	■		■	■			

systems are permanently installed at fixed locations and portable systems are mounted on trucks and can be moved to different locations on a as-need basis (8). Both the stationary and the portable antennas use a single-whip antenna or several antennas spaced along the highway and may be electronically interconnected. Each antenna has the capability of radiating an omnidirectional broadcast radially outward from the antenna to a distance of approximately 1.5 km. These types of antennas are recommended in rural areas so as to minimize interference between other HAR frequencies (6).

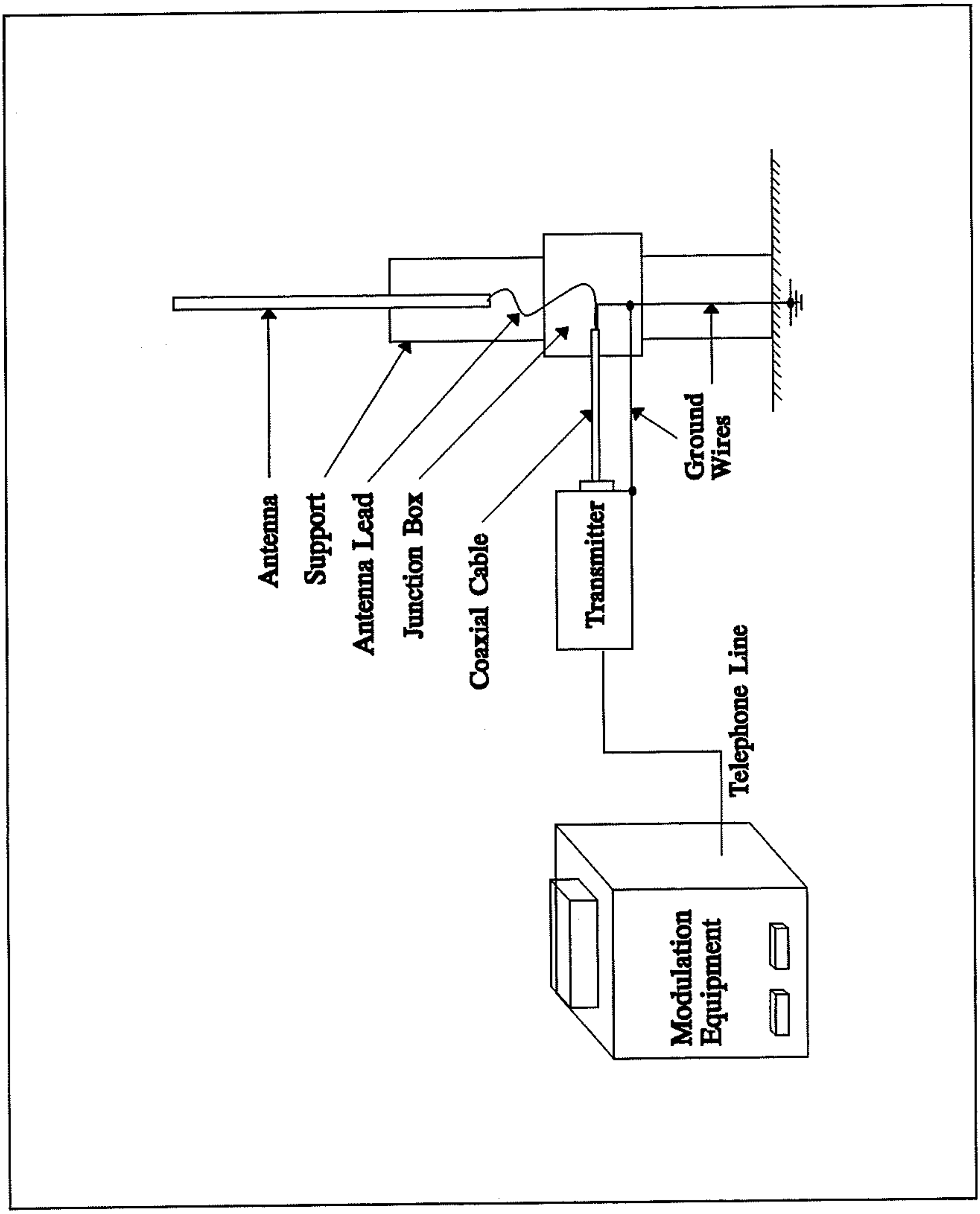

Figure 1. Basic HAR Hardware Components.

Induction Cable Antenna HAR Systems. An induction cable antenna system employs a roadside, coaxial cable instead of the conventional vertical antenna. The cable antenna system radiate a tunnel-like broadcast zone that is concentrated along the cable and extends to a distance of 60 meters normal to the cable (6). This proves sufficient to produce an adequate signal for the width of a multi-lane highway. The cable can be installed above ground, but typically is buried to protect it from vandalism and the environment. This system produces a strong, but highly localized, induction-type radio signal that can be received by virtually all typical automobile AM receivers. The system is also able to broadcast different messages over two separate frequencies on the same cable. Thus, the system can individualize messages by direction of travel (8). Transportation agencies also use this antenna system to broadcast messages in tunnels and on bridges, areas where monopole systems cannot broadcast because of the physical broadcast barriers.

Table 2 presents specific technical standards established by the Federal Communications Commission that must be followed. Tables 3 and 4 provide some advantages and disadvantages of each antenna system previously discussed.

Table 2. Technical Communication Standards Established by the FCC (8).

Hardware Component	**Technical Standard**
Vertical Monopole Antenna System	• Antenna height shall not exceed 15 meters • Transmitter power shall not exceed 10 watts
Cable Antenna System	• Length of cable shall not exceed 3.0 km • Transmitter power shall not exceed 50 watts

Table 3. Advantages and Disadvantages of Vertical Antenna Systems (8).

Advantages	• Physically small and can be installed in relatively small space • Relative easy to install • Can be installed in a short time • Can be easily relocated • Usually spaced several hundred feet from the highway • Can transmit over 80 square miles • Usually less costly to purchase and install than cable antenna
Disadvantages	• Usually visible • Subject to vandalism, environment • Circular coverage zone may interfere with adjacent coverage zones

Table 4. Advantages and Disadvantages of Cable Antenna Systems (8).

Advantages	• Provides continuous coverage through tunnels, buildings, and bridges • May be placed above or below ground • If below ground, it is not subject to damage by environment and vandalism
Disadvantages	• Must extend the full length of desired coverage zone • Must use either two pair of leased lines (one to modulate the transmitter and the other to monitor the broadcast), or a sensitive receiver to monitor the roadway's broadcast • Requires sufficient roadway traffic monitoring to assure that timely and credible information is being broadcast

Federal Communications Commission Guidelines

The Federal Communications Commission (FCC) imposes several restrictions upon the use of HAR. In 1975, an FCC rulemaking, Docket 20509, established Travelers Information Stations (TIS), or HAR. TIS applications are authorized only to state and local governmental agencies and to government affiliated organizations, such as airport and park authorities. Broadcast messages may contain information only pertaining to traffic hazards and travel advisories, alternate routing, and local points of interest (lodging, restaurants, rest areas, scenic and historic attractions). The broadcast was restricted to either the 530 KHz or 1610 KHz frequency on the AM radio band, but the restrictions were recently removed to allow HAR applications on any open AM frequency (11). Commercial messages and advertising are strictly prohibited under FCC regulations of HAR. Furthermore, the location of any HAR transmitter is restricted to the immediate vicinity of airports, train and bus terminals, public parks and historical sites, interstate highway interchanges, bridges, tunnels, and near major freeway construction projects (8).

HAR Messages and Human Factors Considerations

In order for HAR messages to be effective, they must be designed and broadcast in such a way that they provide motorists with accurate and timely information, but also presented in a manner that can be easily understood (7). If the message is understood, than good driving and routing decisions can be made. Quality equipment, although necessary, will not insure an effective HAR system. The message must be of a high quality, meaning it must be worded and broadcast so that the information is clear and easily understood.

Messages may be recorded for continuous play, the length being adjusted to allow motorists to hear at least two repetitions while passing through a particular transmittal zone at normal highway speeds. The agency, however, must monitor and maintain the system as well as be responsible for updating the message contents when the situation dictates (4).

Developing and maintaining driver credibility is an important consideration to a successful HAR system. Motorists view this system as one capable of providing them with reliable, accurate, and up-to-date information. They expect this and agencies must meet these expectations. Motorists can quickly develop negative attitudes about the system if it:

- broadcasts information contrary to existing conditions,
- broadcasts information that is not understood or cannot be heard in adequate time to make the appropriate driving maneuvers,
- recommends a course of action that is not significantly better than their intended action, or
- tells them something they already know (7).

Once drivers lose faith in the system, getting them to favorably respond or to even listen to the system in the future is difficult (7). System credibility must be maintained and the number and length of the messages must not exceed the motorists' processing capabilities.

The first consideration in message development is conciseness. The message should only contain the minimum number of words needed to convey the message of the roadway situation or condition. The language style should also be concise, especially if the message is to divert the motorists to an alternate route and then to back to the main route. Previous research (12) found that recalling route information by motorists was improved by simplifying the language in the message. Rather than using a long, wordy message with complete sentences, it was better using a "terse" message that contained only the information that needed to be recalled and using a "staccato" (brief) language style, rather than "short" or "conversational" style (2). Figure 2 depicts an example of these three different language styles.

Also discovered to be effective by Huchingson et al was the use of redundancy in the message, either internal or external (12). Internal redundancy, in a diversion message, refers to repeating a street name immediately after it is given the first time. The other technique, referred to as external redundancy, calls for mentioning the street names twice, but the second use of the street names comes after the first complete message and the words "I repeat...." (2). Figure 3 illustrates both of these forms of repetition.

The study that was conducted by Dudek et al (2) tested HAR messages with several combinations of length style, and redundancy on a mix of drivers within a metropolitan area who were either familiar or unfamiliar with the area. Language style was not found to be critical, but a terse message was preferred by most participating in the study. Route diversion messages were also understood if the message did not exceed in providing more that four turns and four street names. Redundancy, either internal or external, was also preferred by most of the drivers. Finally, it was found that using physical landmarks at turning locations was useful, especially if the driver was unfamiliar with the proposed alternate route (2).

Staccato

- ATTENTION EASTBOUND INTERSTATE 410 TRAFFIC
- OVERTURNED TRUCK AHEAD
- TO AVOID MAJOR DELAY,
- EXIT AT JACKSON-KELLER,
- TURN RIGHT ON JACKSON-KELLER,
- TURN LEFT ON SAN PEDRO,
- BACK TO INTERSTATE 410 WEST.

Short Form

- ATTENTION EASTBOUND INTERSTATE 410 TRAFFIC
- THERE IS AN OVERTURNED TRUCK AHEAD
- TO AVOID MAJOR DELAY,
- EXIT AT JACKSON-KELLER, AND TAKE THE FOLLOWING ROUTE:
- TURN RIGHT ON JACKSON-KELLER,
- TURN LEFT ON SAN PEDRO,
- AND PROCEED BACK TO INTERSTATE 410 WEST.

Conversational Form

- ATTENTION EASTBOUND INTERSTATE 410 TRAFFIC
- THERE IS AN OVERTURNED TRUCK ON INTERSTATE 410 AHEAD
- TO AVOID MAJOR DELAY,
- YOU ARE ADVISED TO EXIT AT JACKSON-KELLER ROAD AND TAKE THE FOLLOWING ROUTE:
- TURN RIGHT ON JACKSON-KELLER ROAD, AND CONTINUE TO SAN PEDRO AVENUE
- THEN TURN LEFT
- AND DRIVE BACK TO INTERSTATE 410 TO CONTINUE YOUR EASTBOUND TRIP

Figure 2. Example of Message Style (Six-Unit Diversion Route) (2).

Internal Redundancy

- ATTENTION EASTBOUND INTERSTATE 410 TRAFFIC
- THE FREEWAY IS BLOCKED AHEAD
- TO AVOID MAJOR DELAY,
- EXIT AT BANDERA,
  AND TAKE THE FOLLOWING ROUTE:
- TURN RIGHT ON BANDERA
- AND CONTINUE TO WOODLAWN
- TURN LEFT ON WOODLAWN
- AND CONTINUE ON ST. CLOUD
- THEN TURN LEFT ON ST. CLOUD
- AND CONTINUE ON BABCOCK
- THEN TURN LEFT AGAIN ON BABCOCK
- AND PROCEED BACK TO INTERSTATE 410 EAST

External Redundancy

- ATTENTION EASTBOUND INTERSTATE 410 TRAFFIC
- THE FREEWAY IS BLOCKED AHEAD
- TO AVOID MAJOR DELAY,
- EXIT AT BANDERA,
  AND TAKE THE FOLLOWING ROUTE:
- TURN RIGHT ON BANDERA
- TURN LEFT ON WOODLAWN
- LEFT AT ST. CLOUD
- AND CONTINUE ON BABCOCK
- LEFT AGAIN AT BABCOCK
- AND PROCEED BACK TO INTERSTATE 410 EAST

I REPEAT,

- EXIT AT BANDERA,
  AND TAKE THE FOLLOWING ROUTE:
- TURN RIGHT ON BANDERA
- TURN LEFT ON WOODLAWN
- LEFT AT ST. CLOUD
- AND CONTINUE ON BABCOCK
- LEFT AGAIN AT BABCOCK
- AND PROCEED BACK TO INTERSTATE 410 EAST

Figure 3. Example of Internal and External Redundancy In An HAR Message (2).

HAR Effectiveness

Even though HAR messages are optimized and advanced visual signing is adequate, there is no guarantee that the system will be utilized by all the drivers. In fact, it is quite the contrary. Previous research (9,13) has shown that only a small percentage of motorists see visual signing and tune to the HAR on their AM radio stations. In a study by Dabney et al, a survey was conducted to determine the number of motorists who tuned to the HAR. Out of a total of 424 motorists who took the specific route, only 116 saw the advance signing and tuned to the HAR (27%) (9). A much lower percentage of motorists (11%) surveyed by Polak et al listened to the HAR message in this research study (13). The actual percentage of motorists who listen and actually follow the message contents, however, is probably much lower. The impacts of such low percentages may be positive, enough to re-route this percentage of motorists and alleviate congestion during a major incident. But the question remains why HAR is not more frequently utilized by the motoring public.

Identification of HAR Problems

Engineers must determine what the optimal operating conditions should be given the physical and institutional constraints on HAR. The main problem affecting the use of HAR can be attributed to the FCC restrictions, which limits the operational capabilities. The current antenna systems have limited broadcast ranges and the HAR is limited to low-power transmission available AM radio frequencies. Because of these issues, the question remains if transportation agencies can still maintain an effective broadcast. The problems must be recognized, including the FCC restrictions and hardware limitations. Transportation agencies must take an engineering approach to solve the problem and provide the information that the public wants to know and that will benefit traffic operations.

STUDY DESIGN

In order to enhance HAR as an effective ADIS component, a study was conducted to gain insight into the uses and problems of HAR, and to obtain information on various HAR systems around the country. A 12-question telephone survey was developed and four State Department's of Transportation (DOTs), 1 governmental agencies, and 1 private industry operation were contacted and asked several questions concerning their HAR operations and the extent of their service. The DOTs from Illinois, Maryland, Minnesota, and Virginia were contacted, as well as the Transportation Operations Coordinating Committee (TRANSCOM) in the New Jersey/New York area, and United Services Automobile Association (USAA), a large insurance company in San Antonio, Texas. The contacts are presented in Table 5.

Table 5. Contacts for HAR Study Questionnaire.

State/Agency/Company	Entity
Illinois	Department of Transportation (Chicago)
Maryland	Department of Transportation
Minnesota	Department of Transportation (Minneapolis/St. Paul)
Virginia	Department of Transportation
TRANSCOM	Government Agency (New Jersey/New York Area)
USAA	Private Industry

The survey is presented in the Appendix and the following chapter summarizes each of these surveys.

CASE STUDIES OF HAR APPLICATIONS

Illinois Department of Transportation

Operations

The Illinois Department of Transportation (I-DOT) began operating HAR stations in 1979 for the Eden's Expressway Rehabilitation Project. The initial installation of two stations was an experimental project sanctioned by the Federal Highway Administration. Continuous broadcast, 24 hours a day, provided the motoring public with construction and traffic information, ramp closures, detour information, and general project information. Major incidents were reported as they occurred so motorists could make decisions regarding route diversion. Subsequent projects demanded further use of HAR, and today eleven stations are in operation throughout the Chicago area (14).

Each of the eleven stations use a vertical monopole antenna system, located at major problem locations, such as at major freeway interchanges. Each station operates in a real-time automatic update mode, made possible by freeway surveillance sensors continually producing digitized voice broadcasts for each of the sites. Five of the stations operate at 530 KHz on the AM radio band, broadcasting only estimated travel time information. The remaining seven stations operate on the 1610 KHz AM frequency, broadcasting only estimated congestion limits. Each AM station also has its own independent telephone line that motorists can call to receive the same broadcast (15).

Both the travel time and congestion reports are updated every 3-5 minutes. The travel time reports provide origin and destination arterial names along a particular freeway and provide the estimated number of minutes to travel between these arterials. The congestion reports, similarly, provide the congestion limit (typically in miles) between origin and destination arterials. Each of the 3-5 minute messages, in a computer-synthesized voice, also provide a salutation, a workzone safety message, and special event and weather advisory notifications (if necessary). Advanced signing and changeable message signs are tied in with the surveillance system to complement the HAR system. Flashing beacons on the signs inform motorists of the existence of the HAR broadcasts (15).

Issues Addressed

I-DOT is operating an HAR system with very sophisticated freeway technology complementing the main HAR hardware components. The traffic conditions are continually and automatically updated in the HAR broadcasts, and the message content follows an established and continuous pattern (15).

I-DOT did utilize a "leaky" cable HAR antenna system. A buried cable antenna was being used along a corridor for HAR message broadcasting. The system has subsequently been replaced with a vertical monopole antenna system because of the poorer transmission quality of the cable antenna (15).

I-DOT has received a positive feedback from the public with this system. Also, at anticipated congestion areas, congestion has been less than expected. I-DOT contributes this to the advancements in HAR and freeway surveillance and control technology (15).

Maryland Department of Transportation

Operations

The Maryland Department of Transportation has been operating Traffic Advisory Radio (TAR) systems since the late-1980s. These systems are the same as HAR, with the same restrictions and limitations, but only referred to as TAR. Most of the more than thirty stations are used in the Baltimore-Washington area, but the CHART program, a statewide ITS and TAR initiative planned for the future, will eventually have more than 400 miles of freeway installed with ITS technology, with many sections utilizing TARs. The existing stations are all broadcast by a vertical monopole antenna system. Most of the stations operate on the frequencies of 530 KHz or 1610 KHz on the AM radio band, but a few operate in-band (16).

All of the TAR stations in the Baltimore-Washington area provide a continuous, pre-recorded broadcast. The typical broadcast provides incident information, such as where an incident occurs, how many lanes are open, and the estimated congestion limits. Weather and special event advisories and construction information are also provided on an as-needed basis. The Maryland Department of Transportation does not recommend or provide alternate route information if conditions on these routes are not known. The broadcast messages are updated usually every minute, but no more than 3 minutes, and the system utilizes male and female computer-synthesized voices (16).

Because Maryland has not implemented freeway surveillance technology, they are highly dependent upon the state police and their own personnel in the field to continually provide traffic reports so that the traffic information can be made available to the motorists. They depend on the TAR stations, complemented by static and changeable message signs, because of the lack of freeway technology. The stations are limited by the technological shortcomings (i.e. FCC power restrictions) and are experiencing limited broadcast ranges (16).

Issues Addressed

Unlike I-DOT, the Maryland DOT does not have advanced freeway surveillance and detection to rely on to provide continual and automatic traffic updates. They must rely on manual updates, which, from a perceptual perspective, may be more accurate, but costs more time to obtain the information as compared to automated procedures. Some of the stations are also experiencing transmission problems, primarily due to weather, moisture, and the terrain in the vicinity of the antennas. The Maryland DOT recognizes the limitations of HAR, and are currently implementing an ITS initiative to improve not only HAR, but other freeway technology also (16).

Minnesota Department of Transportation

Operations

The Minnesota Department of Transportation (Mn/DOT) first experimented with HAR in 1977. In a partnership with the FHWA, an HAR demonstration project was conducted along one mile of IH-35W in Richfield. A buried coaxial antenna system was used, as well as a low-power transmitter. The system operated on a frequency of 530 KHz AM, and only broadcasted traffic management information. Advisory signs and flashers were used to alert motorists to tune to HAR when a message was being broadcast. They were provided incident type and location, congestion limits, and the advisability of diversion (17).

The project costs were low and it received a favorable response from the motoring public. Over 90 percent of the commuters were aware of the system and public acceptance was extremely high. About 20 percent of the commuters, however, did not tune to HAR and another 20 percent had radio hardware problems or were not aware of the system. They did provide suggestions for improvements, including upgrading the broadcast quality and providing more detailed traffic information. As a result of this study, the HAR was made permanent and remained operational until the late 1980s (17).

A second demonstration project was initiated in 1988 after a need was identified for improved motorist communication techniques to alleviate the growing congestion in the St. Paul/Minneapolis Metro Area. After realizing the limitations imposed by the FCC, Mn/DOT approached local commercial radio stations seeking their assistance in providing improved traffic reports. Mn/DOT sought a station that would provide traffic information every 10 minutes during peak periods and offer listeners continuous reports during major freeway incidents. The Minnesota Public Schools (MPS) indicated a willingness to take on the traffic reports, on its non-commercial student training station KBEM (17).

In September 1989, Mn/DOT and MPS announced the partnership to offer traffic information as part of a two-year demonstration project. KBEM 88.5 FM is operated by an MPS high school, staffed with professional and student announcers. The broadcast coverage area includes the entire seven county Metro Area, including St. Paul and Minneapolis. The partnership provides updates in this area every 10 minutes between 6:00 and 9:00 am and again between 3:30 and 6:30 pm. The cost to Mn/DOT is approximately $242,000 per year (17).

A year later, Mn/DOT initiated the second phase of this Traffic Radio program by installing 27 message signs equipped with flashing beacons ("wig-wag") in the Metro Area (see Figure 4). The signs were strategically located upstream of major congestion areas and high accident locations to alert motorists to tune to KBEM for the live and continuous, 10-minute broadcast (17).

The Traffic Radio is primarily used as a traffic management tool, but also provides public service announcements, such as transportation related topics and safety tips. During non-reporting times, KBEM 88.5 FM offers listeners a non-commercial jazz format (17).

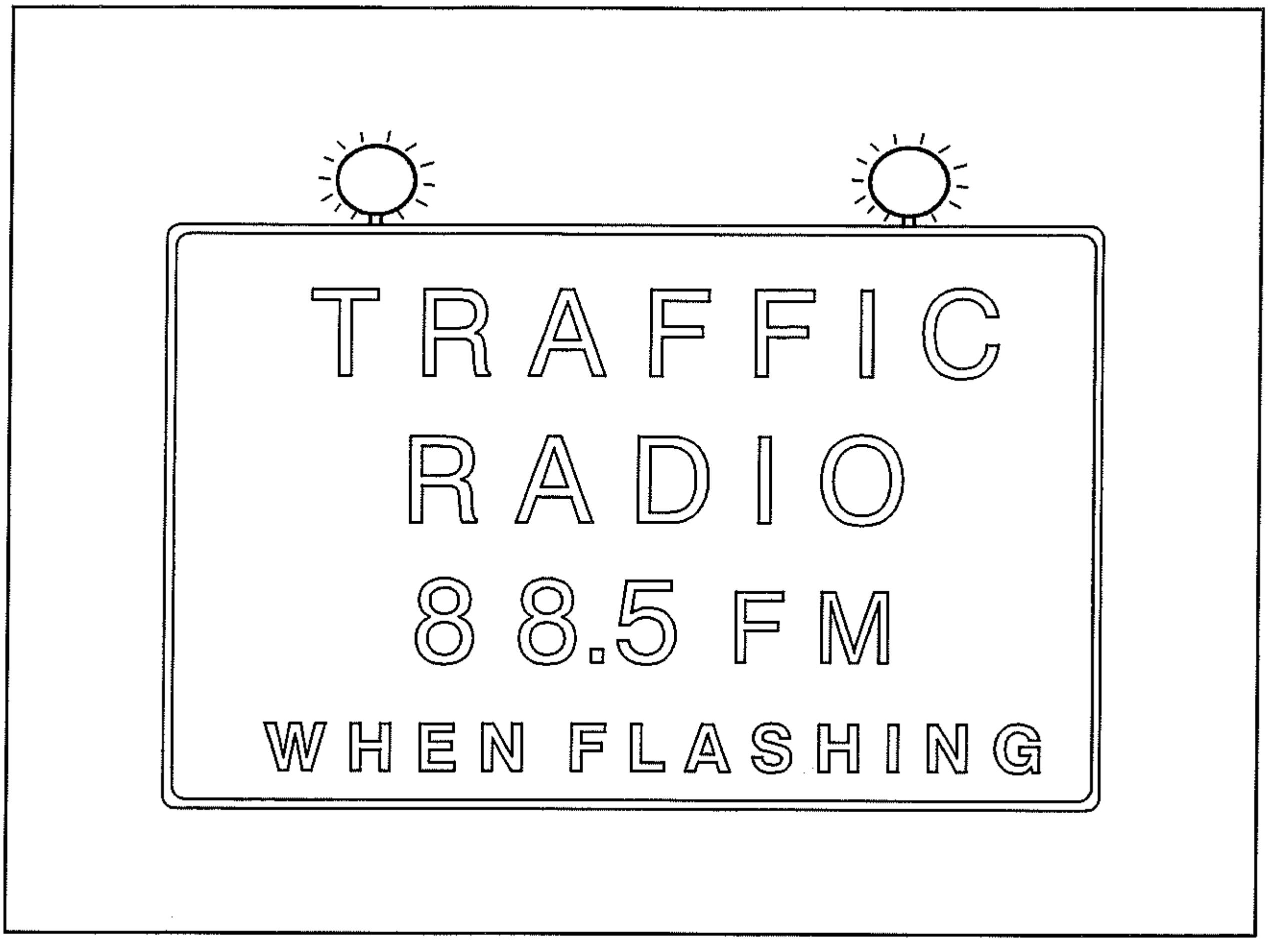

Figure 4. Example of Mn/DOT's Message Sign With Wig-Wag Type Flashers (17).

The broadcast is made possible by an FM antenna located in downtown Minneapolis, capable of transmitting on 2,160 watts power over 26 km radially. Furthermore, the Traffic Radio project has received positive responses from motorists believing that accurate traffic information is being provided. Arbitron ratings have drastically increased for KBEM 88.5 FM since the partnership began in 1989 (17,18).

In addition to the Traffic Radio program, Mn/DOT also developed and implemented a Cable TV Traffic Channel, providing viewers with real-time graphic map displays and the capability to mix live video from any of the freeway's closed circuit television cameras on line at the Traffic Management Center. A wide range of other ITS strategies are also in the planning stages (17).

Issues Addressed

This system is an alternative to HAR that Mn/DOT sought because of the broadcast limitations of conventional HAR stations. Mn/DOT feels that this system is far superior than other conventional HAR systems. The hardware has been very reliable and there has been no significant maintenance problems during the course of this Traffic Radio project.

Mn/DOT obtains traffic reports from field crews during the morning and evening peak broadcast times. They then convert congestion limit information from the field to travel time predictions, primarily based on empirical data previously obtained and analyzed.

TRANSCOM

Operations

TRANSCOM, or Transportation Operations Coordinating Committee, a 15-agency organization designed to meet the transportation needs of the New Jersey and New York area, currently manages and operates three of the agencies' HAR stations: for 1) the New Jersey Department of Transportation since the mid 1980s; 2) the New York State Thruway Authority for the last 2½ years; and 3) the Bergen County Police for about 1 year. Some of the other individual agencies of TRANSCOM do manage and operate their own HAR stations, independent of TRANSCOM authority.

The systems utilize both vertical monopole antennas and coaxial cable antennas for broadcast transmission, all on either a frequency of 530 KHz AM or 1610 KHz AM. Static freeway signs complement the HAR systems by advising motorists to tune to the respective AM stations on their car radios (19).

The HAR broadcasts are not continuous, but rather on an as-needed basis, providing pre-recorded broadcasts, that contain messages primarily based on phone calls received from the motoring public. No "library" of messages are kept by TRANSCOM and the length of the pre-recorded messages are not specific, but rather based on necessary information to be provided. The primary information provided in the broadcasts include incident locations, congestion limits, construction notifications, and special event advisories. Alternate routes are not recommended (19).

Issues Addressed

One of the more prevalent problems encountered by the Bergen County Police HAR system is interference with an adjacent AM frequency operating at 7,000 watts. The New York State Thruway Authority avoids this problem by overlapping synchronized signals, providing up to 15 miles of coverage on a single corridor. The systems are still limited because of FCC power restrictions and are currently transmitting up to 2 miles radially from each transmitter site (19).

United Services Automobile Association

Operations

United Services Automobile Association (USAA) is currently operating one HAR station in the vicinity of the USAA facility in San Antonio, Texas. USAA has over 10,000 employees and over 3,000 contractors and vendors entering the facility everyday, located on IH-10 on the north side of downtown San Antonio. Because of the amount of traffic generated by USAA, an HAR was installed on IH-10 near the facility to provide their employees with traffic-related information to and from work. Of course, the information is available to all motorists wishing to access the information that is broadcast (20).

The HAR station, licensed by the City of San Antonio, operates on a 1610 KHz frequency on the AM radio band, during morning (6:00 - 7:30 am) and evening (4:30 - 6:00 pm) peak conditions. A single, vertical monopole antenna is located near IH-10 and the USAA facility. HAR messages are broadcasts continuously during the peak periods, providing information on road construction projects, lane closures, and general traffic conditions (if available) on the IH-10 corridor (McDermott Freeway). Static signs provided by the Texas Department of Transportation inform motorists of the HAR station, but no flashing beacons are used to alert motorists during actual broadcast times (20).

Issues Addressed

During broadcast times, the messages are continually updated by traffic control personnel in the field. Traffic information is received from these mobile units who stay in constant communication with the traffic control office. Planned construction and lane closure activity is obtained from contractor reports that are not made readily available to the general public. Therefore, USAA is aware of construction and lane closure projects well in advance and can provide this information on the broadcasts. USAA maintains a standard broadcast format for all messages, usually no more than 70 seconds in length (20).

USAA believes the system is working effectively and that a useful service is being provided not only for their employees, but also to others who care to tune to the broadcasts. No major hardware problems have been encountered, and the monopole antenna is transmitting far better than expected. Depending upon the weather conditions, a 3-mile radius is sometimes transmitted (20).

Virginia Department of Transportation

Operations

The Virginia Department of Transportation (VDOT) has been operating 7 HAR stations over the last 7-10 years, primarily in the Hampton Roads area. The broadcasts are continuous, 24 hours a day, and are transmitted by vertical monopole systems on a frequency of 530 KHz AM. Static freeway signs with flashing beacons complement the HAR systems and advise motorists to tune to the AM frequency in their car radios (21).

The pre-recorded broadcast messages are 1-2 minutes in length, depending upon the information being provided. The primary messages pertain to incident management conditions. At tunnel approaches, if a delay more than 15 minutes is anticipated, the sign beacons will flash and the HAR will inform motorists of this anticipated condition. If a delay of 15-30 minutes is anticipated, the HAR will recommend to the motorists to take an alternate route. If a delay of more than 30 minutes is anticipated, the HAR will advise motorists to take an alternate route. Messages always begin with a salutation, and if traffic conditions are normal, then the HAR reports just this (21).

Issues Addressed

VDOT is currently in the process of upgrading antiquated equipment, especially out-dated transmitters and antennas. Recent use of fiber optics have eliminated communication problems with the static message signs, where problems were prevalent during adverse weather conditions. An initiative by the state is currently assessing the problems and the costs associated with upgrading the hardware (21,22).

VDOT receives feedback from the motoring public, especially if broadcast information is incorrect. Phone calls will "flood" the Traffic Management Center, and Metro Traffic Control, a private traffic reporting entity, will generally try to assist the motorists in these conditions (21).

STUDY RESULTS

A summary of the case studies is presented in Table 6. Of the six agencies or companies that were studied, only three provided an continuous HAR broadcast. Most utilize the vertical monopole antenna system and all provide freeway condition information (congestion, travel-time, delay) and construction information (locations, lane closures, etc.).

Table 6. Summary of Case Study Questionnaires.

Location	Antenna		HAR Broadcast		Motorist Information Provided					
	Monopole Antenna	Cable Antenna	Continuous Broadcast	Broadcast Frequency	Freeway Conditions	Construction	Alternate Route	Special Events	Safety Information	Weather Information
I-DOT	■		■	530/1610 AM	■	■			■	
M-DOT	■		■	530/1610 AM	■	■	1	■		■
Mn/DOT	2			88.5 FM	■	■	■	■	■	■
TRANSCOM	■	■		530/1610 AM	■	■		■		
USAA	■			1610 AM	■	■		■		
V-DOT	■		■	530 AM	■	■	3,4			

[1] Maryland DOT only provides alternate route information if the conditions on the alternate route are known
[2] Mn/DOT utilizes a single FM antenna and a 2,160 watt transmitter located in downtown Minneapolis
[3] Virginia DOT recommends an alternate route if 15-30 minutes of delay is anticipated
[4] Virginia DOT advises motorists to take an alternate route if anticipated delay is more than 30 minutes

Several issues were also addressed by those answering the survey questions. Most persons indicated the FCC restrictions and the resulting hardware limitations. It was noted that HAR could be improved with state-of-the-art equipment and less FCC restrictions. Also noted were the benefits of having advanced freeway technology to complement the HAR system. This advanced technology has the capability of providing automated updates to the broadcast messages. This is especially beneficial for continuous HAR broadcasts. For peak period broadcast stations (during morning and evening periods), it was noted that mobile personnel units in the field are able to provide fairly accurate traffic information. A constant communication must be established, however to continually update the HAR message content. Finally, relative to peak-period broadcasts, congestion information can be related to empirical travel time data and be broadcast to the public. The main issues found in this study are presented in Table 7.

Table 7. Main Issues Addressed in Study Questionnaires.

Institutional Issues	• Limitations of FCC are recognized • FCC now allows in-band stations • Monetary constraints, especially to provide a dedicated support staff and to upgrade hardware
Hardware-Related Issues	• Advanced freeway technology is beneficial in overall operations • "Leaky" cable antenna provides poorer transmission than monopole • Transmission interference with adjacent AM stations • Solid-state digital recorders provide superior recording and playback of messages over antiquated tape recorders • Tapes become heated if continuously played • The use of fiber optics minimize transmission interferences due to adverse weather • Freeway signs and flashing beacons mounted on the sign alert motorists of HAR existance and broadcasts
Operational-Related Issues	• Field personnel cannot provide automated broadcast updates • For non-continuous HAR broadcasts, field personnel are effective in reporting freeway conditions • If field personnel are used, apply their traffic reports to empirical data (queues→delay)
Human Factors-Related Issues	• 60-75 second message is ideal • Generally, no established message content is followed • Motorists are more passive of a continuous HAR broadcast • HAR is more widely listened to during a major incident (construction project, lane closure, special events)

METHODS OF ENHANCING HIGHWAY ADVISORY RADIO

Based upon the results of the study, several measures can be implemented in the planning, design, and operations stage to enhance HAR. The following sections will discuss these measures, divided into institutional, hardware, operational, and human factors considerations.

Institutional Considerations

The primary concern and limitation most agencies currently have is the restrictions imposed upon by the FCC. To overcome these restrictions, the agencies involved should seek a cooperation to best take advantage of hardware and personnel resources. Because a dedicated support staff to operate and maintain an HAR system is highly unlikely, this inter-agency cooperation will make the best use of available funds and personnel.

The agencies should also seek the support of private partnerships, similar to the way Mn/DOT did. The partnerships could include other AM/FM radio stations or large private industries, to assist in providing personnel and hardware and to assist in an operations and maintenance program. Since the goal of HAR is to provide accurate and timely information to all motorists, the private partnerships could assist in providing updated and accurate traffic and special event information.

HAR Hardware Considerations

Many agencies are or have experienced hardware problems that have resulted in restrictions upon their capability in providing real-time traffic information. The Illinois Department of Transportation has somewhat overcome this by installing a number vertical monopole antennas in key locations, and further enhancing this with state-of-the-art freeway surveillance and sign technology to achieve a desirable ITS and ATIS system. There are costs associated with implementing such a system, costs that states may not be capable of at the present time. Again, Mn/DOT has eliminated this problem, but at a substantial per-year cost to partner with a FM commercial radio.

The vertical monopole antenna systems are widely used by most agencies because they are operationally flexible. The monopole can be transported from site to site for special events and major construction projects, if necessary, or it can be permanently installed at key locations near freeway interchanges. Another advantage of the monopole system is that new technologies allow these antennas to be completely solar-powered, eliminating the conventional power and the backup power sources to the antenna (23).

If agencies choose to broadcast pre-recorded messages, solid-state digital recorders provide the best quality of recording, playing, and repeating messages. Also, no loss of quality will result if the messages are continually repeated. Recorders with tape mechanisms require more maintenance because the tapes (and the message content) will degrade after repeated use. Agencies have to replace the old tape by recording the message on a new tape. Also, a single tape cannot continuously broadcast the same message. The tape will become hot and eventually be ruined if continuously played (20).

Changeable message signs and/or static freeway signs with flashing beacons should be employed with the HAR system. Advance signing should alert motorists that they are entering the HAR transmission zone. Most agencies provide this service. Drivers should be made aware of when they enter a zone and when they exit the zone so that adjustments can be made on their car radio. The effective zone for a monopole antenna system typically radiates 1 miles, so advance signs should be placed accordingly, and allow a motorists a response time to turn their car radio on and tune to the HAR station or tune from another station. The response time is a function of sign legibility distance, the distance traveled during the perception time, and the distance traveled during the time to tune to the HAR. This response distance should proceed the 1 mile effective transmittal radius. Finally, a sign should be placed at the exit of the effective transmittal zone to alert the motorists that they are at the end of an HAR zone.

HAR Operational Considerations

The primary issue to resolve with HAR operations is whether or not to provide a continuous broadcast. A continuous broadcast requires extensive monitoring and continual updates, something that advanced freeway technology is capable of providing. This is, however, a very expensive alternative compared to providing intermittent, or peak-period, broadcasts. The hardware alone is state-of-the-art and very expensive. Some agencies are proving that peak-period broadcasts can provide accurate traffic information for the motorists. The source of information would primarily be based on reports from mobile personnel units in the field, continually calling and reporting the traffic conditions. This information could then be applied to historical or empirical data to estimate travel times and delay.

In order for agencies to apply empirical data from field reports to the HAR broadcast, a freeway operations study would have to be conducted. The study would determine key areas of congestion and the extent and duration of queues during recurrent or non-recurrent freeway incidents. Because personnel units in the field can easily identify queue limits during congestion, the limits could be applied to historical data and converted to travel time and delay estimates. Agencies can also routinely deploy pilot vehicles to travel the congested corridors to confirm these estimates.

Metropolitan areas should test HAR initially for short-term projects before a full implementation is carried out. An example would be to use HAR for a short-term construction project. The agencies involved in the operations could then assess the potential benefits, conduct surveys, and get an idea of what motorists perceive of the system and the involvement necessary to operate an HAR.

Human Factors Considerations

An established and consistent message format should be followed at all times. Motorists will then know what to expect when they tune to the HAR and will thus minimize their confusion. The HAR message itself should be no longer than 60 seconds in length, and should be repeated as long as necessary, or as long as it accurately reflects the traffic conditions. This will allow a motorists traveling through a 2 mile effective transmittal zone to hear the entire message at least once, given high speed operations. Solid-state recorders provide the best recording and playback capabilities, and messages should be continually updated as frequently as possible to maintain system credibility and to ensure that motorists continue to utilize HAR.

All of these issues should be addressed and implemented for HAR to be an effective ADIS. The agencies involved must work cooperatively, establish a need for HAR, and to efficiently maintain and operate the system. The goal is to maintain credibility by providing accurate and timely traffic conditions, and to continually provide what the motorists desire to know.

CONCLUSIONS

Traffic congestion in metropolitan areas and the need to solve this and other problems is of concern of many state and local agencies and government affiliated agencies in the United States. One way to solve this problem is to provide accurate and real-time information to the motoring public via communication techniques so that driving decisions can be made. The more fundamental means of communicating with motorists, while state-of-the-art technology is still being tested and optimized, include freeway message signs, static and changeable, and the use of the radio in the vehicle. This form of communication if Highway Advisory Radio, and this paper examined several applications of HAR throughout the country.

HAR is widely used in this country, but many agencies, not just the ones contacted for this study, are limited with its use. Current FCC restrictions, the lack of advanced technology, and the lack of support from the motoring public all combine to limit the use of HAR. Agencies must therefore realize and learn the best ways to use HAR and use the FCC restrictions to their advantage.

Enhancing HAR can be accomplished by consistently providing accurate traffic information. This can be done by employing field personnel to monitor traffic conditions and to continually update the information and providing peak period HAR broadcasts. If continuous broadcasts are to be used, more sophisticated freeway technology would be required. Advance signing with flashing beacons and terminal signing is also important and should be provided to alert motorists of HAR transmissions. Finally, to maintain credibility with the motorists, not only will the broadcasts have to be accurate, but they also must follow an established and consistent format so that driver expectancies are not exceeded. This will minimize their confusion, make their drive safer and more efficient, and will encourage them to tune to HAR the next time they see an advanced HAR sign.

Also, the need to improve FCC restrictions is a necessity. Agencies will continually to be operationally limited under current restrictions. Furthermore, a cooperation must be sought with other agencies and private partners to further enhance the system and to demonstrate the need for HAR in metropolitan areas so that the motoring public has, at their finger-tips, an effective ADIS interface: their car radios.

RECOMMENDATIONS

Several recommendations can be made for enhancing Highway Advisory Radio to make it a more effective Advanced Driver Information System. The recommendations cover a wide spectrum, from establishing and maintaining inter-agency cooperation, to specific hardware usage and small-scale operational testing, and to continually market the HAR system. These recommendations include:

Inter-Agency Cooperation

All governmental agencies, including the FCC, must work together to improve the nation's transportation system with ITS technology. Inter-agency coordination, on the federal, state, and local level, as well as with private partnerships, should be established and maintained so that the HAR system can operate and provide an established benefit.

Adopting an HAR Implementation Plan

Agencies wishing to apply HAR technology in metropolitan areas must currently seek approval from the FCC. Once granted, the system is limited to low-power transmission on the AM receiver. This restriction is the first major hurdle which must be overcome in order for HAR to be effective. The agencies must then establish an operation and maintenance plan. Costs and labor should be considered for either a continuous or intermittent (i.e.,peak-period) HAR broadcast. Also, personnel responsibilities should be established.

Establish Hardware Needs

Monopole antenna systems are operationally flexible and should be considered in the implementation plan. Advance signing with flashing beacons should be used to alert motorists of HAR transmissions. Exit signing should also be used, so that motorists know when they have exited the effective transmission zone. Advance signing should consider sign legibility and response time to adjust to the HAR station.

Establish Data Collection and Dissemination Techniques

Identify funding limits and determine how the field data, or the traffic data, is to be collected and then disseminated in an understandable format for the motorists. Freeway surveillance and detection can be used, or mobile personnel units could be dispatched to the field to report traffic conditions. The dispatched units could also participate in a motorist assistance program while in the field.

Small-Scale Testing of HAR

Agencies wishing to implement an HAR system must consider the possibility of implementing HAR on a small scale, such as for a short-term construction project, to evaluate it from all perspectives: operational aspects, motorists' needs, and overall effectiveness. After and evaluation only then should the agencies pursue an HAR system.

Identify Human Factors Considerations

Maintaining credibility is important for an HAR system. Provide accurate information in an comprehensible format. Following an established and consistent format will minimize driver confusion.

Effective Marketing

Once the guidelines for HAR have been established and inter-agency cooperation is established, the agencies operating HAR systems can effectively market the technology by providing invaluable information to the motorists. The first priority would be to make them aware that HAR exists on their car radios, and secondly, that it provides useful information. The current technological shortcomings hinder this process, but the system can be enhanced.

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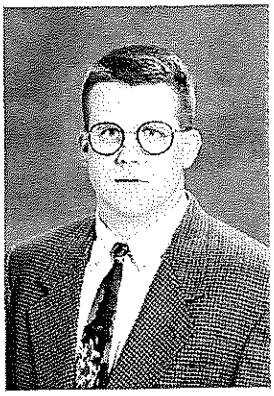

APPENDIX

QUESTIONNAIRE

Date ____________

Contact ____________ **Position** ____________

Agency ____________ **Phone** ____________

1. When was HAR implemented in your area? (*year*) ____________

2. When is HAR utilized in your area? *(during construction/maintenance/incidents, or continuous broadcast)* ____________

3. What general hardware components are being used? ____________

4. What frequency do you operate on (*AM 530, AM 1610, etc.*) and is it a continuous broadcast? Why? Why not? ____________

5. What messages are broadcast and is the information in real-time? ____________

6. How do you obtain the information to be broadcast? ____________

7. Are other types of motorist information used? (*signs, cable network, etc.*) ____________

8. If so, what? What are the messages displayed? ____________

9. What is the length of the HAR messages? (*time, words per minute, voice gender*) ____________

10. What non-incident messages are broadcast? ____________

11. Is the HAR system effective? ____________

12. Do you have knowledge of other HAR systems in your area or in the country and are you aware of any research on HAR? ____________