FINAL REPORT

AN INVESTIGATION OF OPERATIONAL PROCEDURES FOR HIGHWAY ADVISORY RADIO SYSTEMS

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Standard Title Page — Report on State Project

Report No.	Report Date	No. Pages	Type Report:	Project No.:
VTRC 96-R4	September 1995	26	Final Report	3065-030
				Contract No.:

Title and Subtitle

An Investigation of Operational Procedures for Highway Advisory Radio Systems

Key Words

Highway Advisory Radio
Traffic Management
Incident Management
Intelligent Transportation Systems
Traveler Information Systems

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Supplementary Notes

Abstract

A key objective of Intelligent Transportation Systems (ITS) is to provide travelers with accurate, real-time information, helping them make better decisions about when to travel, what mode to use, and what route to take. An interface is necessary to convey this information. Currently, the AM radio is an interface available in nearly all automobiles. The Virginia Department of Transportation (VDOT) has deployed highway advisory radio (HAR) in several regions of the Commonwealth. This study reviewed previous research and technical information, examined the use of HAR in Virginia and other states by interviewing key personnel, and surveyed Virginia motorists to ascertain the public's perception of HAR. The results were used to develop the HAR Operational Guidelines, published in a separate document, and the policy recommendations contained in this report. Specifically,

* Proper HAR operation is personnel-intensive. To be of actual value to motorists, information must be gathered from many sources, consolidated rapidly and accurately, and frequently updated.
* Presently, information provided on HAR stations is of limited value to motorists. Consequently, motorists depend on commercial radio station traffic reports for most of their information, instead of tuning in to HAR broadcasts.
* Changeable message signs should be used to advise motorists when they are in an HAR broadcast area, directing specific messages to the appropriate audience.
* Conventional vertical antennae are more cost-effective than radiating cable systems, and should be used exclusively.

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

Charlottesville, Virginia

VTRC 96-R4
September 1995

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ABSTRACT

A key objective of Intelligent Transportation Systems (ITS) is to provide travelers with accurate, real-time information, helping them make better decisions about when to travel, what mode to use, and what route to take. An interface is necessary to convey this information. Currently, the AM radio is an interface available in nearly all automobiles. The Virginia Department of Transportation (VDOT) has deployed highway advisory radio (HAR) in several regions of the Commonwealth.

This study reviewed previous research and technical information, examined the use of HAR in Virginia and other states by interviewing key personnel, and surveyed Virginia motorists to ascertain the public's perception of HAR. The results were used to develop the HAR Operational Guidelines, published in a separate document, and the conclusions contained in this report. Specifically,

- Proper HAR operation is personnel-intensive. To be of actual value to motorists, information must be gathered from many agencies, consolidated rapidly and accurately, and frequently updated.

- Presently, information provided on HAR stations is of limited value to motorists. Consequently, motorists depend on commercial radio station traffic reports for most of their information, instead of tuning in to HAR broadcasts.

- Changeable message signs should be used to advise motorists when they are in an HAR broadcast area, directing specific messages to the appropriate audience.

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INTRODUCTION

Intelligent Transportation Systems (ITS) promise to significantly improve the safety, efficiency, and environmental soundness of Virginia's surface transportation system. A key objective of ITS is to provide travelers with accurate, real-time information, helping them make better decisions as to when to travel, what mode to use, and what route to take. While the Virginia Department of Transportation (VDOT) has decades of experience in providing static roadway information through signing, it has only recently expanded its efforts to provide travelers with dynamic traffic information. Developing this capability is important, and VDOT's Intelligent Vehicle-Highway Systems Strategic Plan identifies traveler information systems as a priority area.[1]

To provide travelers with up-to-date information, an interface must exist. A significant amount of ITS research is focused on developing in-vehicle digital display systems and other high-technology interfaces. However, the AM radio is an interface currently available in nearly all automobiles. Recognizing this, VDOT has deployed highway advisory radio (HAR) systems in several regions of the Commonwealth. HAR systems generally transmit low-power AM radio signals, and may use either a fixed-site antenna or a portable field antenna. VDOT is currently using HAR to advise motorists of traffic conditions in the Hampton Roads tunnels, to manage traffic during construction on Interstate 66 in Northern Virginia, and to assist in incident management and in work zones in other areas of the state.

HAR is an opportunity and a significant challenge. Providing accurate, real-time information is difficult. The system's hardware is important, but the ultimate success of HAR in Virginia depends on effectively providing the public with useful, reliable information.

PROBLEM STATEMENT

The VDOT Statewide Incident Management (SIM) Committee adopted a preliminary set of HAR operational guidelines in May 1994. These guidelines discuss some general

considerations for HAR usage, but do not offer specific recommendations for many aspects of HAR operations, including non-incident broadcasts, advance sign placement, message length, and detailed message development methods. To enhance and expand these guidelines, the SIM Committee and the Traffic Research Advisory Committee requested that the Virginia Transportation Research Council (VTRC) study HAR operations in Virginia.

Effective use of HAR requires operators to decide what information to provide, how to describe situations, and when to update information. Clear guidelines will help operators make these decisions consistently and effectively across the state. This will improve VDOT's credibility as a provider of real-time information, and pave the way for future ITS initiatives.

PURPOSE AND SCOPE

The purpose of this project was to investigate HAR technology and operations, to enhance VDOT's HAR Operational Guidelines and identify specific policy recommendations for improved HAR use in Virginia. The project was limited in scope to HAR stations owned or operated by VDOT. Five focus areas were identified: operations and personnel, transmitter placement and technology, advisory signing, message development, and equipment maintenance.

METHODS

Four tasks were undertaken to accomplish the study's objectives:

1. *Literature Review.* Past HAR research and implementation efforts, product information from HAR equipment manufacturers, and Federal Communications Commission (FCC) regulations were examined.

2. *Examination of HAR State-of-the-Practice in Virginia and Other States.* To thoroughly understand HAR technology and operations in Virginia, interviews were conducted with the operators of every HAR system, both portable and permanent, owned by VDOT. In most cases, the interviews were conducted with site visits, allowing the research team to inspect the HAR equipment and site conditions. A formal set of questions was not used for these interviews. The interviews were open discussions centered around the five focus areas.

In addition, active HAR programs in other states were interviewed (Appendix A). Representatives from other states were questioned about what HAR equipment they use, who makes operational decisions, what sort of information is broadcast, signing strategies, and any problems encountered with the system. To supplement these interviews, the research team examined deliverables from the I-95 Corridor Coalition's Project, *Coordinated VMS/HAR Strategies*. This material provided information ranging from suggested technical specifications and operational experiences, to suggested corridor-wide operational guidelines.

3. *Motorist Surveys.* Motorists were surveyed to understand the expectations of HAR's customers, the traveling public. The surveys were also designed to learn the current level of use of HAR by travelers. An exhaustive survey was beyond the scope and budget of this research, but three small surveys gathered information on a number of different situations. Motorists were approached in either a rest area or parking lot and were asked several questions about the specific application of HAR in the area, and more general questions about their information needs. The surveys were conducted at the following locations:

Virginia Polytechnic Institute and State University Football Game: This survey was administered at a college football game in Blacksburg, Virginia, where HAR was being used to direct traffic to parking areas. This particular survey provided insight into the use of HAR for traffic control at special events.

I-81 Rest Area, Fairfield, Virginia: This survey was conducted at a rural location on Interstate 81 just beyond an HAR transmitter offering work zone information, in order to gain input from long-distance travelers.

I-66 Rest Area, Manassas, Virginia: This survey was conducted at an urban location on Interstate 66 near the city of Manassas where a permanent transmitter is operated. This survey provided the study team with input from commuters.

The survey instruments used for each interview are included in Appendix B.

4. *Development of VDOT HAR Operational Guidelines.* Based on the results of previous tasks, and with careful consideration of the resources available to the Department, a new set of HAR Operational Guidelines was developed. Preliminary guidelines were distributed to field personnel for comment and were revised based on feedback.

RESULTS

The results for each task were categorized around the five focus areas described above: operations and personnel, transmitter placement and technology, advisory signing, message development, and equipment maintenance.

1. Literature Review

Operations and Personnel

The widespread use of HAR systems has generated a great deal of information on how to operate HAR effectively. Of foremost importance is meeting motorists' expectations. An FHWA study suggests that drivers will not place faith in a system that:

- broadcasts information contrary to existing conditions,
- broadcasts information that is not understood or cannot be heard in time to make appropriate maneuvers,
- recommends a course of action that—in the motorists' perception—is not significantly better than their intended action, or
- tells them something they already know.[2]

Avoiding these pitfalls requires regular message updates. A study done by the Frederic R. Harris consulting firm for the Florida Department of Transportation recommended that traffic condition messages be updated every 15 to 30 minutes,[3] while the Delaware Valley Regional Planning Commission, operating an HAR station in the Philadelphia area, suggested that messages be updated every 15 minutes.[4] Such updates are only possible with sufficient personnel. An Illinois HAR system used in a long-term work zone experienced personnel shortages. Numerous unplanned incidents occurred, yet operators were unable to abandon other responsibilities responding to the incident to update an HAR broadcast. The study concluded "the availability of manpower was the controlling factor determining the effective utilization of the system."[2]

Coordinating an effective HAR system is difficult. Several states have installed HAR control stations in central communications centers. The North Carolina DOT installed recording and broadcast equipment in the police department's communications center.[2] However, problems were encountered, including messages being inadvertently transmitted to traffic headed in the wrong direction, or the communications center not being aware of construction activities. In the North Carolina project, it was estimated that incorrect messages were broadcast 5 to 10% of the time, because of difficulties coordinating broadcast information. Several incident management programs have demonstrated that communications procedures are critical to the success of HAR. An Ohio DOT study recommended that an agreement be forged between the police, the contractor, the project engineer, the department of transportation, and local traffic engineers to supply real-time information 24 hours a day, and that procedures be established to contact control stations immediately.[2]

Transmitter Placement and Technology

As considerable capital and operating costs are associated with permanent HAR transmitters, they must be used only when justified. An HAR deployment test in Philadelphia recommended that the following criteria be met before a permanent HAR transmitter is installed:

- a minimum 20,000 average daily traffic volume,
- a minimum of one major highway route of arterial classification, and preferably multiple highway alternatives,
- at least one public transit alternative (the primary objective of the station was to encourage transit),
- availability of electric and telephone connections, and
- appreciable non-recurring congestion.[4]

Other criteria for deciding where to place HAR transmitters, established by a Texas Transportation Institute study, are that HAR may be useful if delay times on the primary route exceed those on alternate routes, if other communications tools are ineffective, or if accident rates are exceedingly high.[5]

There are also institutional limitations on the placement of HAR systems, including government regulations. The FCC Rules and Regulations, section 90.242, permits the establishment of traveler information stations (TISs), which operate at no charge to government agencies on available AM stations. Virtually all HAR stations in the United States operate as TISs. Restrictions include a maximum 10-watt power supply, minimum separation distances from other commercial stations on nearby frequencies and from TISs operated by other agencies, and maximum interference to other stations. Additionally, TISs are licensed on a *secondary* basis. This means that if a commercial station established later than a TIS experiences interference from the TIS, the TIS license may be revoked.

Finally, one HAR system manufacturer suggests that broadcast range can vary greatly with topography; obstructions such as trees, buildings, or power lines in the area; geology; and soil type.[6] All of these factors affect the decision to install a transmitter in a particular location.

Advisory Signing

Gatling demonstrated that 95% of motorists whose radios were off were able to tune to a radio station within 60 seconds.[7] Because the broadcast range of TISs is extremely limited, it is important for motorists to be tuned to the station for as much of the coverage area as possible. Several agencies have a policy of placing an advance sign 1.6 km (1 mile) outside the coverage zone, so all motorists have time to tune in before the broadcast begins. Figure 1 illustrates a typical sign of this nature, as used in a Missouri project.[2]

Figure 1. Typical HAR Advisory Sign.

However, Gatling's study was performed in 1975, before the advent of digital tuners. Considering the equipment now available in most automobiles, motorists are able to tune to a station in considerably less than 60 seconds. The practice of installing advisory signs with the station's frequency 1.6 km (1 mile) outside of the coverage area may be ineffective, and the first

advisory sign which includes the station's frequency should perhaps be located much closer to, or perhaps within, the coverage area.

Several HAR operators have had difficulty making drivers aware of HAR with only a single conventional sign. An Iowa study indicated that only 3% of motorists were tuned in to an HAR station when a single conventional sign was used. When additional signs were installed, listenership rose to 35%.[8] In a Texas study, motorists complained that they had not seen the advisory signs or that they were obstructed by other work zone or guide signs.[5]

One strategy to increase the visibility of HAR advisory signs has been to include flashing beacons that can be activated when urgent information is being broadcast. Figure 2 shows an example sign of this configuration, as used in the Philadelphia study.[4]

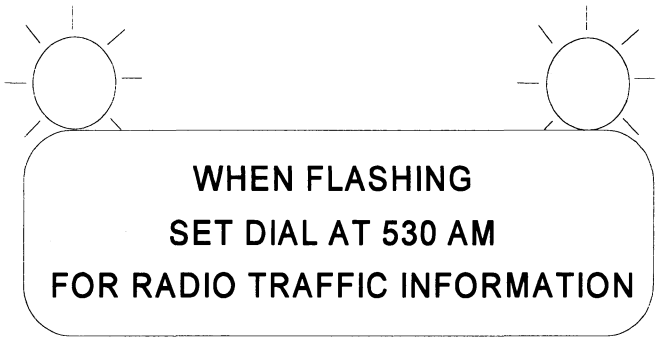

Figure 2. Advisory Sign With Flashing Beacons.

Changeable message signs (CMSs) are another strategy used to make advisory signs more visible.[5, 8] CMSs can also relay situation-specific information, so drivers can decide whether to tune in based on their perceived need for the information. For example, a general message such as "TRAFFIC INFORMATION" could be changed to "ACCIDENT," "TOURIST," or "DETOUR INFORMATION," depending on the situation.

Nationwide, there are several accepted guidelines for HAR advisory signs. Studies suggest that both the word "RADIO"[5, 9] and the band designation ("AM" or "FM") should always be included.[8, 10] Additionally, different attention statements can elicit different reactions from motorists. Dudek and Huchingson suggest that the word "ALERT" should be reserved for critical information, the words "TRAFFIC ADVISORY" are interpreted as routine traffic conditions, and "ROUTE INFORMATION" is interpreted as guidance for visitors, such as at a visitor center.[9]

Message Development

The FCC permits TIS broadcasts to convey "noncommercial voice information pertaining to traffic and road conditions, traffic hazard and travel advisories, directions, availability of lodging, rest stops and service stations, and descriptions of local points of interest." Within these limits, messages should meet travelers' information needs. A study by Virginia Tech's Center for Transportation Research showed that rural drivers want a variety of information, including information on road closures, congestion ahead, and warnings of approaching hazards such as obstacles or inclement weather conditions.[11] The "canned" messages that have been standard practice in many agencies do not meet motorists' information needs. Additionally, in urban areas, information broadcast during non-incident conditions has included traffic and roadway conditions, transit alternatives, upcoming special events, and guidance to parking facilities.[4, 12]

Several studies have investigated the amount of information that motorists can successfully assimilate. Gatling demonstrated that when the number of "informational units" in a message (a unit is a small piece of information that must be recalled to successfully execute the instruction, such as turning directions or street names on an alternate route) increased from four to five, driver error rate increased from 10 to 50%.[13] However, research suggests that with the use of repetition, most motorists can understand and successfully execute up to eight informational units.[14, 15] Table 1 presents an example of an eight-unit message which employs repetition. Advisories with 10 or more units were found to be too complex to be remembered by most motorists, and thus should not be broadcast. If the need arises for such a complicated diversion route, trailblazing signs should be used, and the HAR message should simply encourage motorists to use the diversion.[14]

Additionally, messages need to be heard in their entirety within the coverage area. An earlier VTRC study showed that some drivers did not divert to an alternate route described by an HAR because the entire message was not heard.[16] To ensure that HAR broadcasts will be heard in their entirety and will be understood, an FHWA report recommends a maximum message length for incident messages of 60 seconds.[8]

Literature also suggests that by using a standard format for message broadcasts, motorists will be able to process the information more quickly. Although there is generally room for alternative formats, the *Manual on Real-Time Motorist Information Displays*[17] states that incident and point diversion messages in particular should follow a standard format, and suggests the following:

- an attention statement, which alerts a user group on the facility,
- a problem statement, which states the nature of the problem and usually its location and effect upon motorists, and
- an action statement, instructing motorists what to do.

Table 1. Message "Units" and Use of Repetition.

Message Element	Information Unit
Take exit 25	1
to Harper Parkway.	2
Turn east.	3
Continue east	3, repeated
on Harper Parkway	2, repeated
to Rugby Road.	4
Turn left	5
onto Rugby Road,	4, repeated
and continue to Cherie Boulevard.	6
Turn left,	7
and follow Cherie Boulevard	6, repeated
back to the Interstate.	8

Another source suggests that including the time that the information was recorded will enhance credibility.[4] And finally, the FCC requires that the station be identified by its call letters at least every 30 minutes.

Equipment Maintenance

The only significant maintenance problem detailed in the literature was the tendency for cassette tapes to wear out rapidly. This problem has been overcome with the advent of digital recording equipment. Vandalism and problems with the power supply were other minor problems in some regions.

2. Examine HAR State-of-the-Practice in Virginia and Other States

Operations and Personnel

Interviews with HAR operators from VDOT and other states revealed that HAR is personnel-intensive. For example, at Virginia's Hampton Roads Bridge-Tunnel Traffic

Management System (TMS), a long-standing problem has been the lack of sufficient personnel to operate the HAR system effectively. The HAR system there generally operates with a limited number of prerecorded tunnel condition messages, because personnel are not available to provide regular, real-time traffic condition updates.

A number of states are dedicating staffs to HAR operations and locating them at traffic operations centers. For example, the Maryland State Highway Administration (MdSHA) has a staff dedicated to operating HAR located at its state operations center in Hanover, Maryland. The New Jersey DOT is planning to hire an HAR staff soon. Perhaps the most telling evidence of the need for an HAR staff comes from the New Jersey Turnpike Authority (NJTA). Originally, the NJTA used traffic operations personnel to operate its HAR, but found that it worked poorly. When the operations personnel were called on to manage an incident—a time when HAR information is critical—the HAR took last priority. This resulted in out-of-date messages containing inaccurate information. In response, the NJTA has dedicated a four-person staff to operate its HAR system of nine transmitters.

Transmitter Placement and Technology

Site visits in Virginia, and interviews with HAR operators in other states, revealed that the HAR transmitters currently in use do not generate high-quality signals. While careful attention to tuning and a properly-installed ground plane can improve signal quality, the primary problems are the low power and frequency restrictions imposed by the FCC. Some states, such as Minnesota, have solved this problem by using FM stations to provide traffic information. The Minnesota Department of Transportation has an arrangement with the Minneapolis Public Schools to use its FM station to provide traffic information during peak periods and incidents.

VDOT has also taken steps to address the problem of HAR signal quality. First, the Department has acquired a license to operate on 650 AM in Northern Virginia. This frequency alleviates some of the signal strength problems associated with broadcasting on the ends of the AM band (at either 530 AM or 1610 AM). However, the transmitter power is still limited to 10 watts. In addition, VDOT is attempting to procure new HAR transmitters in the Hampton Roads region which the manufacturer claims will have the capability of broadcasting up to 40 km (25 miles) without exceeding the FCC's 10-watt limit.

Another variable affecting transmitter placement is the quality of automobile radio receivers. During site visits in Virginia, it was discovered that radios in different automobiles can vary dramatically in their capability to receive HAR signals. For example, in one vehicle, the HAR signal was clearly received 8 km (5 miles) from the transmitter, while in another vehicle the signal was not received until it was well within 1 km (0.6 miles) of the transmitter.

Finally, two different antenna configurations available for HAR systems were investigated. VDOT currently uses vertical monopole antennae which have generated signals

intelligible 5 to 13 km (3 to 8 miles) from the transmitter, thus allowing messages to be heard for as long as 15 minutes. The monopole antenna represents about $1,000 of a system's total cost. However, another option some agencies have used is the "leaky" cable antenna, which is buried or hung along the roadway and radiates a weak signal just strong enough to be detected along the length of the cable.

Radiating cable antennae are restricted to a maximum length of 3.0 km (1.86 miles). Thus, they can broadcast messages that are heard by traffic for about two minutes, assuming motorists are tuned in as the coverage begins. Capital costs for cable antennae may range from $16 to $23 per meter ($5 to $7 per linear foot). A 3.0 km (1.86 miles) antenna may cost on the order of $50,000. In addition, installation and maintenance costs of cable antennae are very high. Trenching costs for burying the cable to protect against vandalism and the environment are approximately $5.75 per meter ($1.75 per linear foot) under normal conditions.

The Maryland State Highway Administration had a radiating cable system, but the cable was cut by construction activity, and MdSHA spent over $20,000 to fix the system. The Metropolitan Washington Airports Authority, which operates Dulles International Airport, also had a leaky cable HAR system. The cable has experienced cuts when compressed by machinery on the surface, and is susceptible to corrosion by water. Repair costs as high as $45 per meter ($15 per foot) have forced the Authority to consider replacing the system with a vertical monopole antenna system.

Cable antennae can, however, be used in areas where no frequency is available throughout a large region, or in tunnels. Radiating cables are being used in the Channel Tunnel linking France and Great Britain, for communication with trains. In most cases, though, it is more important to have HAR stations *in advance* of bridges and tunnels, to warn of congestion or incidents and divert drivers if necessary, than to have a station actually in the problem area. For example, in the Hampton Roads, Virginia area, HAR stations located on both sides of tunnels alert drivers to the congestion levels to expect in the tunnels and describe alternate routes that can be taken to avoid the congestion.

Advisory Signing

Advisory signing for HAR varies in wording both within Virginia and among other states. The interviews revealed that a particularly troublesome aspect of HAR advisory signing concerned the use of flashing beacons on signs. Typically, the beacons are activated when an "urgent" message is being broadcast on HAR. However, HAR operators often have difficulty determining when a message is sufficiently "urgent" to a large number of travelers to justify activating the beacons. In addition, some beacon signs (see Figure 2) are worded in a manner that causes some motorists to assume that when the beacons are not flashing, *no* information is being broadcast.

Many HAR advisory signs in Virginia and in other states are located beyond the range of the transmitter. This has been done to allow motorists time to tune in the frequency without "wasting" time within the coverage zone. However, operators interviewed expressed concern that in many cases, the advisory signs are placed too far outside of the coverage area. Motorists see the signs, tune in immediately, cannot hear a clear signal, and thus lose confidence in the system. Washington state has combated this by adopting a policy that all HAR advisory signs will be located within 3.2 km (2 miles) of the transmitter.

Finally, VDOT HAR operators were asked about the costs of their more sophisticated advisory signs. The static signs with flashing beacons installed on I-95 in the Fredericksburg District cost approximately $14,700 each. Much of this cost was due to the beacon's controller, and the need to install power and telephone lines at the sites. The portable LED CMSs that VDOT owns range from approximately $27,000 to $33,000, depending on added options.

Message Development

A particular challenge identified by HAR operators in Virginia was developing specific messages that did not require frequent modifications. For example, during construction operations, a contractor may frequently change the work zone configuration. In such situations, HAR operators attempted to develop messages that stated simply that lanes would be closed, without specifying which ones. In these instances, the level of specificity was sacrificed in order to prevent the need to change messages frequently.

Another major challenge, in Virginia and elsewhere, is selecting information to include in a message under "normal" conditions. In Northern Virginia, information such as safe driving tips and rules of the road were broadcast under normal conditions. MdSHA has used tourism and special event information in their messages in an attempt to provide the public with an incentive to tune to HAR regularly. North Carolina has used HAR to advise truckers of regulations. Other states provide weather conditions, time, or future construction schedules. Some states simply explain that no significant congestion currently exists.

Equipment Maintenance

VDOT HAR operators have had very few maintenance problems with HAR equipment. Nonetheless, they suggested that permanent sites be checked periodically for potential interference from vegetation, new construction, signs, or other antennae. Other suggested routine maintenance included regularly checking range and power supply, particularly for solar-powered units, because batteries can be drained so low that they cannot be recharged with the solar charger.

The most challenging aspect of HAR maintenance for VDOT operators is tuning portable units properly. The standing wave ratio (SWR), a measure of the forward power to reflected power in the antenna system, indicates how well the signal is being transmitted. Ideally, the SWR is 1.0, indicating that all power is being used properly; no power is lost because the antenna is not properly tuned or because of site conditions such as a poor ground plane or trees near the antenna. SWR values from 1.1 to 1.5 are reasonable and acceptable. When using the 530 kHz antenna on a portable unit, however, VDOT personnel have experienced extreme difficulty attaining an SWR below 5.0, even under ideal site conditions and with an excellent ground plane. This is because fine-tuning the antenna requires precise adjustments on the order of 1 to 5 mm (1/16 to ¼ inch). The 1610 kHz antenna can be tuned much easier, so portable VDOT systems that are outfitted with both the 530 kHz and 1610 kHz antennae will generally use the 1610 kHz antenna, although it offers significantly less range.

3. Motorist Surveys

Before this study, virtually nothing was known about Virginia motorists' perceptions of HAR. Three limited surveys were performed to get general impressions of whether people are tuning in, why or why not, and what sort of information they would prefer to get through HAR. The sample sizes of the surveys were relatively small, the subjects may not have adequately represented all motorists in Virginia, and statistically significant conclusions cannot be drawn, but the surveys provided valuable insight into the public's perception of HAR. Sample size and number of respondents who reported seeing the signs and tuning in to the broadcasts for each of the three surveys are presented in Table 2.

Table 2. Summary of Survey Responses.

	Blacksburg	**I-81**	**I-66**
Sample Size	165	44	31
Number of respondents who saw advisory signs	113	25	22
Number of respondents who tuned in	44	4	1

Advisory Signing

The signing strategies were different at each of the three survey sites. The Blacksburg site used a diamond-shaped static sign. The I-81 site employed a CMS, and the I-66 site—the only permanent HAR installation surveyed—used a ground-mounted static sign equipped with flashing beacons. The beacons were not activated the day the survey took place.

It was expected that the CMS used at the I-81 site would be more visible than the static signs used at the other two sites. However, only 57% reported seeing the CMS at the I-81 site, whereas 68 and 71% reported seeing the advisory signs in the other sites. This could be due to the extremely high percentage of truck traffic that uses I-81. Motorists in the left lane with trucks in the right lane might not see signs placed on the right side of the road. Placing signs on both sides of the road might help alleviate this problem.

While the CMS was seen by a smaller percentage of motorists than the large ground-mounted sign used on I-66, the percentage of those who tuned in after seeing the sign was higher on I-81. The CMS has not only the capability to alert motorists to the availability of HAR, but also to provide them with a reason for tuning in. This CMS message included "BRIDGE WORK AHEAD," while the I-66 sign had the general message "URGENT TRAFFIC INFO WHEN FLASHING." The results of these surveys seem consistent with expectations: motorists have greater motivation to tune in to a message describing a condition that they think will affect them. The specific information provided by the Blacksburg advisory sign, "FOOTBALL TRAFFIC INFO," attracted the greatest proportion of motorists, although the nature of the event may have contributed to this. Of those who saw the sign, 39% reported tuning in to the message.

A common reason motorists gave for not tuning in was that they did not know what type of information was being broadcast and therefore could not judge its relevance to their particular situation. Another reason given by respondents to the I-66 survey was that the beacons on the sign were not flashing and therefore they assumed that no information was being broadcast. Table 3 summarizes the reasons motorists did not tune in.

Table 3. Reasons for Not Tuning In.

Was there a particular reason that you did not tune in?	Blacksburg (68 responses)	I-81 (19 responses)	I-66 (17 responses)
Perceived no reason to seek information	23%	37%	23%
Listening to music/other audio	9%	21%	23%
Familiar with area	45%	16%	18%
Prior bad experience with HAR	6%	5%	18%
Other	16%	21%	18%

Message Development

Due to the small number of respondents who tuned in for the Blacksburg survey, the questionnaire was modified for the remaining two surveys. New questions were added that inquired about motorists' usual sources of traffic information and the types of information that they would like to hear broadcast on an HAR station. Tables 4 and 5 present responses given to these questions at two locations.

Table 4. Usual Sources of Traffic Information.

What is your usual source of traffic information?	I-81 (29 responses)	I-66 (27 responses)
Commercial radio	21%	59%
Television	3%	0%
HAR	10%	0%
CB radio	24%	11%
Other	3%	7%
None	38%	22%

Table 5. Preferred Type of Information for HAR Broadcasts.

What type of information do you think should be broadcast on HAR?	I-81 (28 subjects)	I-66 (24 subjects)
Location of work zones	61%	19%
Incident information	75%	33%
Tourist information	18%	0%
Congestion information	68%	70%
Weather information	61%	26%
Alternate routes	36%	26%
Special event information	18%	0%
Location of motorist services	11%	0%

A majority of the motorists surveyed responded that they either did not seek out traffic information at all, or got it from commercial radio stations. Several motorists said that they monitor CB radios, because they felt that other drivers provide real-time information. Very few motorists stated that they obtained traffic information from HAR stations on a regular basis.

Table 5 also indicates that travelers in different areas have different information needs. In addition to information on accidents, work zones, or congestion causing appreciable delays, rural travelers were more receptive to information on weather conditions, tourist attractions, and special events.

Responses indicate that information broadcast on HAR must be of real value to motorists. Motorists said that congestion should be reported only if the congestion would cause a significant increase in travel time. Respondents also said that if weather conditions are broadcast, slippery pavement, high winds, dense fog, or other conditions that impact driving conditions should exist within a reasonable distance of the broadcast area, yet current conditions that motorists could observe directly should not be broadcast. Information on work zones was

said to be useful, if it gave *specific* useful information as to the effect on motorists, and not simply that they should use caution.

Above all, survey respondents stressed that information must be timely and accurate. If a diversion route is given, the route should reduce travel time from the original route and must be capable of accommodating all diverted traffic. One motorist surveyed said he was once diverted from the freeway by an HAR message and encountered an underpass on the diversion route with insufficient vertical clearance. He told the surveyor that he would never listen to HAR again. This illustrates that public trust is very difficult, if not impossible, to regain once lost.

4. Development of HAR Operational Guidelines

The information gathered in the previous three tasks helped the authors formulate the HAR Operational Guidelines, organized into five focus areas (operations and personnel, transmitter placement and technology, advisory signing, message development, and equipment maintenance). The guidelines were reviewed by VDOT personnel statewide. Feedback from the Statewide Incident Management Committee, operators of HAR systems, and VDOT's Equipment Division was used to revise the guidelines, which were then adopted by the Statewide Incident Management Committee in July 1995. The guidelines are published in a separate document.[18]

CONCLUSIONS

This research is the basis for VDOT's HAR Operational Guidelines and specific policy recommendations. Several insights were gained into how HAR is currently used. Operational conclusions, such as how to construct HAR messages and specific textual recommendations for advisory signing, were incorporated in the guidelines. Policy-related conclusions are presented here.

1. *Proper HAR operation is personnel-intensive.* At present, VDOT operates HAR transmitters as isolated units. Linking them into a coherent traveler information system requires a concerted effort to consolidate information between multiple agencies. Moreover, updating broadcasts with information of value to motorists takes time. Updating HAR messages cannot be a secondary responsibility, yet field personnel generally have other, higher-priority duties, especially in an incident.

2. *Presently, information provided on HAR stations is of limited value to motorists.* Motorists want specific, up-to-date information on congestion levels and incidents that affect their travel. Situations that can be communicated with other traffic control devices or that do not affect motorists do not warrant HAR broadcasts.

3. *Motorists are not tuning in to HAR broadcasts.* Many motorists do not understand when they are in an HAR broadcast area, and what information HAR offers them.

4. *Motorists currently get most of their traffic information from commercial radio station traffic reports.* Commercial traffic reporters have decades of experience effectively providing regional traffic information in urban areas throughout the country. VDOT does not have the resources to provide this level of information, and should not attempt to compete in this market.

5. *CMSs offer considerable advantages as advisory signing for HAR.* Static HAR advisory signs offer a single, inflexible attention statement to drivers. Flashing beacon signs face the same problem, and are confusing to some motorists. CMSs can alleviate these problems, directing the message to the appropriate audience.

6. *Vertical antennae are more cost-effective than radiating cable systems.* Leaky cables are expensive to install and maintain, have limited lifetimes, and broadcast over a very limited area.

RECOMMENDATIONS

The HAR Operational Guidelines developed as a result of this research describe recommended practices for VDOT HAR operators. In addition, the following policy recommendations are offered to the Department.

1. VDOT should formally adopt and implement the HAR Operational Guidelines.

2. VDOT's current HAR personnel policy should be revised as follows:

   (a) Under normal conditions, all HAR transmitters, permanent or portable, should be operated from a traffic management/operations center.

   (b) Under incident conditions, or other abnormal local conditions, local VDOT personnel should have the option to take over HAR operations.

   (c) No new HAR equipment should be purchased without an operations plan. This plan should include the traffic management/operations center responsible for overseeing the equipment's operation, and an assessment of personnel availability at the center.

3. VDOT should initiate discussions with other state and local agencies to identify potential traveler information that could be broadcast over HAR systems. Such information may include tourist attractions, special events, abnormal weather conditions, or descriptions of alternative transportation modes.

4. If VDOT decides to use HAR as a major component of a statewide traveler information system, a public relations campaign should be undertaken to educate citizens about what HAR is, and what types of information they can expect to receive on HAR. This should only be done once recommendations 1, 2, and 3 have been implemented.

5. VDOT should consider contracting HAR operations in an urban area to a traffic information provider on a trial basis. The contract should be developed in such a way that the contractor operates the HAR under normal conditions, providing regional traffic information. However, during any abnormal events, VDOT would retain the right to preempt the contractor and operate the HAR.

6. In future HAR installations, VDOT should abandon the use of flashing beacon HAR advisory signs, and use either permanent or portable CMSs for advisory signing.

7. Due to extremely high capital and maintenance costs and the limited broadcast range associated with cable antenna systems, VDOT should use only conventional vertical antennae with its HAR systems.

8. VDOT should closely monitor the new HAR system being developed in the Hampton Roads area. In particular, the system should be monitored for signal quality and range, and convenience of PC-based digital message generation capabilities.

REFERENCES

1. Virginia Department of Transportation. 1993. *The Virginia Department of Transportation's intelligent vehicle-highway systems strategic plan.* Richmond, VA.

2. U.S. Department of Transportation. 1982. *Highway advisory radio message development guide.* Federal Highway Administration Report No. FHWA/RD-82/059. National Technical Information Service: Springfield, VA.

3. Frederic R. Harris, Inc. 1988. *Travel advisory radio system project report.* State of Florida Project No. 86070-1498.

4. U.S. Department of Transportation. 1978. *Highway advisory radio in the Philadelphia area.* Federal Highway Administration Report No. FHWA/RD-78-77. National Technical Information Service: Springfield, VA.

5. Texas Transportation Institute. 1981. *Feasibility of chanegable message signs and highway advisory radio for freeway maintenance.* Report No. FHWA/RD-80/176. National Technical Information Service: Springfield, VA.

6. Digital Recorders, Inc. 1992. *Travelers information stations and highway advisory radio.* Research Triangle Park, NC.

7. U.S. Department of Transportation. 1975. *Auditory material for route diversion.* Federal Highway Administration Report No. FHWA/RD-75/73. National Technical Information Service: Springfield, VA.

8. U.S. Department of Transportation. 1981. *Systems analysis and design guidelines for highway advisory radio.* Federal Highway Administration Report No. FHWA/RD-80/176. National Technical Information Service: Springfield, VA.

9. Dudek, C. L., and Huchingson, R. D. 1978. Advance road sign messages for highway advisory radio systems. *Transportation Research Record,* Vol. 683.

10. Dabney, J. C., and Dudek, C. L. 1981. Driver response to a highway advisory radio system in New Braunfels, Texas. *Transportation Research Record,* Vol. 808

11. Virginia Polytechnic Institute and State University. 1993. *Rural traveler information needs assessment.* Draft Report. Blacksburg, VA.

12. The Scientex Corporation. 1994. *State's policies, guidelines, and procedures for VMS/HAR systems.* Northeast Consultants, Rockville, MD.

13. U.S. Department of Transportation. 1976. *The effect of auditory and visual presentation of navigational messages on message retention.* Federal Highway Administration Report No. FHWA/RD-76/94. National Technical Information Service: Springfield, VA.

14. U.S. Department of Transportation. 1978. *Highway advisory radio message development guide.* Federal Highway Administration Report No. FHWA/RD-78/77. National Technical Information Service: Springfield, VA.

15. U.S. Department of Transportation. 1981. *Highway advisory radio user's guide.* Federal Highway Administration Report No. FHWA/RD-80/166. National Technical Information Service: Springfield, VA.

16. Virginia Transportation Research Council. 1979. *A highway advisory radio for construction and maintenance operations.* Charlottesville, VA.

17. U.S. Department of Transportation. 1986. *Manual on real-time motorist information displays.* Federal Highway Administration Report No. FHWA/RD-IP-86-16. National Technical Information Service: Springfield, VA.

18. Virginia Transportation Research Council. 1995. *HAR Operation Guidelines.* Charlottesville, VA.

APPENDIX A. AGENCIES SURVEYED

California Department of Transportation, Division of Traffic Operations
New Jersey Turnpike Authority
New Jersey Department of Transportation
Maryland State Highway Administration, Systems Design
Minnesota Department of Transportation, Metropolitan District Traffic Management Center
Washington State Department of Transportation, Seattle Area Traffic Management Center
I-95 Corridor Coalition

Members include transportation agencies in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, and the District of Columbia.

Pennsylvania Turnpike Commission
Metropolitan Washington Airports Authority, subcontractor
County of Fairfax (Virginia) Police Department, Emergency Services Section
VDOT Fredericksburg District
VDOT Hampton Roads Bridge-Tunnel TMS
VDOT Staunton District
VDOT Salem District

APPENDIX B. MOTORIST SURVEY QUESTIONNAIRES

(A) Virginia Tech Football Game

Highway Advisory Radio - Motorist Survey

Interviewer will approach person at game and say:

Hello, my name is _____. I am from the Virginia Transportation Research Council. We are conducting a survey on driver's perceptions of Highway Advisory Radio. Would you be willing to answer five brief questions?

If yes, ask the following:

1. Did you know that there is a special radio station operating in this area, providing traffic and parking information to people traveling to the football game? It is called highway advisory radio.

   Yes No

If they respond no to this question, explain briefly what HAR is and ask if they have ever listened to it before. If they have, go to question 4a, otherwise, thank them for their time and pick another person.

2. Did you see any signs telling you that you could get traffic information on the special HAR in the area?

   Yes No

If they answer no to this question, chances are that they did not listen. Ask them if they have ever listened before and if so go on to question 4. If not, thank them and move on.

3. Did you listen to the special traffic broadcast today?

   Yes No

If yes to #3 ask:

4a. How useful was the information to you?_____
What information was most helpful to you?_____

If no to #3 ask:

4b. To make the broadcasts better, we would like to get an idea of why people do not listen. Was there a particular reason you did not listen?

   Yes No

   If yes: What was that reason?_____

If the person seems interested, explain that we are working to make HAR better and more useful and ask if they would mind filling out an additional questionnaire. If they agree, ask the questions on the second page.

Please answer the following questions concerning the use of Highway Advisory Radio. *When more than one response is appropriate, please circle all that apply.* When you have completed the survey, please return it postage paid. Thank you.

1. Where do you get your traffic information most often?

   a. Commercial radio stations
   b. Television
   c. Newspaper
   d. Highway Advisory Radio
   e. Don't seek out traffic information
   f. Other_____

2. What do you like most about the source(s) of information?

   Source_____
   a. Convenient
   b. Comprehensive
   c. Accurate
   d. Other_____

   Source_____
   a. Convenient
   b. Comprehensive
   c. Accurate
   d. Other_____

3. What kind of information do you think should be broadcast via highway advisory radio?

   a. Location of construction/work zones
   b. Accident location and severity
   c. Tourist information
   d. Congestion information
   e. Other_____
   f. Location of alternate routes
   g. Weather conditions
   h. Location of motorist services
   i. Special event information

4. Have you heard information on a highway advisory radio broadcast that you did not like? If so, what?

   _____
   _____

5. Additional comments:

   _____
   _____

Thank you for your assistance in improving highway advisory radio in Virginia.

If you have any questions concerning this survey of would like to speak to someone about HAR, please call Eileen at the Research Council at (804) 293-1910.

(B) I-81 Rest Area (Fairfield)

Highway Advisory Radio - Motorist Survey

Interviewer will approach person in rest area and say:

Hello, my name is _____. I am with the Virginia Transportation Research Council. We are conducting a survey on driver's perceptions of highway advisory radio. Would you be willing to answer eight brief questions on highway advisory radio?

If yes, ask the following:

1. Did you see any signs telling you that you could get construction traffic information on a special highway advisory radio station operating in the area?

Yes

No
⇓
[Chances are that they did not listen today.]
Have you ever listened to highway advisory radio broadcasts before?

Yes
⇓
Go on to question 3a.

No
⇓
Thank them for their time and move on.

2. Did you listen to the special traffic broadcast today?

Yes
⇓
3a. How useful was the information to you?
_____
_____

What information was most helpful to you?_____
_____
_____
_____

No
⇓
3b. To make the broadcasts better, we would like to get an idea why people do not listen. Was there a particular reason you did not listen?

Yes ⇓
What was that reason?
_____
_____
_____

No

Explain to the person that the following questions have multiple choice answers and hand them the card with questions and answer choices on it. Tell them they may read along as you read each question.

Highway Advisory Radio - Motorist Survey

Read the following questions concerning the use of Highway Advisory Radio. Tell drivers that when more than one response is appropriate, to choose all that apply. Record their answers on your sheet.

4. How often do you travel on I-81?

a. Less than 1 day/month
b. 1-3 days/month
c. 1 day/week
d. 2-3 days/week
e. more than 3 days/week

5. Where do you get your traffic information most often?

a. Commercial radio stations
b. Television
c. Newspaper
d. Highway Advisory Radio
e. Don't seek out traffic information
f. Other _____

6. What do you like about the source(s) of information?

Source_____
a. Convenient
b. Comprehensive
c. Accurate
d. Other_____

Source_____
a. Convenient
b. Comprehensive
c. Accurate
d. Other_____

7. What kind of information do you think should be broadcast via Highway Advisory Radio? [Remind them that there may be more than one answer.]

a. Location of construction/work zones
b. Accident location and severity
c. Tourist information
d. Congestion information
e. Other _____
f. Location of alternate routes
g. Weather conditions
h. Special event information
i. Location of motorist services

8. May I ask your city and state of residence? _____

Thank motorists for their time to help improve HAR in the Commonwealth.

(C) I-66 Rest Area (Manassas)

Highway Advisory Radio - Motorist Survey

Interviewer will approach person in rest area and say:

Hello, I am with the Virginia Transportation Research Council. We are conducting a survey on driver's perceptions of highway advisory radio. Would you be willing to answer a few brief questions on highway advisory radio?

If yes, ask the following:

1. Did you see any signs telling you that you could get traffic information on a special highway advisory radio station operating on 650 AM in the area?

Yes ⇓ — No

1a. Did you tune in to the broadcast today?

Yes ⇓ — No ⇓

1b. How useful was the information to you?

_____
_____
_____

1d. Which information was the most helpful? _____
_____

1c. In order to improve the broadcasts, we are trying to get an idea as to why people do not tune in. Was there a particular reason that you did not tune in today? _____
_____
_____
_____

1e. Have you ever listened to highway advisory radio broadcasts before?

Yes ⇓ — No

1f. Where was this? *or* What was the information?

_____
_____
_____

1g. How helpful was the information?

_____
_____
_____
_____

Explain to the person that the following questions have multiple choice answers and hand them the card with questions and answer choices on it. Tell them they may read along as you read each question.

Highway Advisory Radio - Motorist Survey

Read the following questions concerning the use of Highway Advisory Radio. Tell drivers that when more than one response is appropriate, to choose all that apply. Record their answers on your sheet.

2. Where do you get your traffic information most often?

a. Don't seek out traffic info
b. Commercial radio stations
c. Television
d. Newspaper
e. Highway advisory radio
f. CB radio
g. Motor club (such as AAA)
h. Other _____

3. What do you like about the source(s) of information?

Source_____
a. Convenient c. Accurate
b. Comprehensive d. Other_____

Source_____
a. Convenient c. Accurate
b. Comprehensive d. Other_____

Source_____
a. Convenient c. Accurate
b. Comprehensive d. Other_____

Source_____
a. Convenient c. Accurate
b. Comprehensive d. Other_____

4. What kind of information do you think should be broadcast via Highway Advisory Radio stations along the roadway? [Remind them that there may be more than one answer.]

a. Location of construction/work zones
b. Accident location and severity
c. Tourist information
d. Congestion information
e. Alternate route information
f. Weather conditions
g. Special event information
h. Location of motorist services
i. Other _____

5. How often do you travel on I-66?

a. Less than 1 day/month
b. 1-3 days/month
c. 1 day/week
d. 2-3 days/week
e. more than 3 days/week

6. May I ask your city and state of residence? _____

Thank motorists for their time to help improve HAR in the Commonwealth.