TECHNICAL REPORT STANDARD PAGE

1. Report No. FHWA/LA.00/339	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Implementation of Highway Advisory Radio (HAR) for Construction Zones in Louisiana	5. Report Date May 1999	
	6. Performing Organization Code	
7. Author(s) Brian Wolshon, P.E., Ph.D. and Christopher Schwehm	8. Performing Organization Report No.	
9. Performing Organization Name and Address Louisiana State University Dept of Civil & Environmental Engineering Baton Rouge, LA 70803-6405	10. Work Unit No.	
	11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	13. Type of Report and Period Covered Final July 1997 – May 1999	
	14. Sponsoring Agency Code	

15. Supplementary Notes

Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

The project involved the installation of HAR transmitters in Baton Rouge and Lake Charles. The transmitter sites were located at key entry points to each metropolitan area. At the conclusion of the project all seven of the transmitter units were fully broadcast capable. They were, however, somewhat limited in terms of timeliness of broadcast information due to the lack of real-time traffic data and manpower limitations required to operate the system.

The project included a review of literature and practices related to the development and application of HAR systems in the United States to address the applicability of existing commercially available HAR systems as well as the specific planning, placement, and operational requirements necessary to implement an effective HAR system. The review also addressed the concept of using HAR in combination with other advanced technologies such as GPS, video surveillance, radar, and pavement loop detection to determine future means of integrating a real-time traffic data collection/processing capability with HAR.

The project also included the development of guidelines for monitoring the system, suggested message information content, and training for personnel responsible for the operation and maintenance of the system as well as equipment specifications, personnel operating requirements and the acquisition of a Federal Communications Commission (FCC) broadcast license.

17. Key Words highway advisory radio, construction, maintenance, ATIS, communication		18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.**	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

IMPLEMENTATION OF HIGHWAY ADVISORY RADIO (HAR) FOR CONSTRUCTION ZONES IN LOUISIANA

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LTRC PROJECT NO. 97-9SS
STATE PROJECT NO. 736-99-0463

conducted for

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
LOUISIANA TRANSPORTATION RESEARCH CENTER

May 1999

ABSTRACT

Information in the highway environment is commonly relayed to drivers using standard traffic control devices such as road signs. Static road signs are the preferred method of communication because of their low cost, durability, and familiarity to drivers. However, static signs do not always permit effective communication under dynamic conditions, such as those encountered in congested construction areas. Dynamic or "changeable" message signs (DMS) are help because they allow information to be changed based on current conditions. Unfortunately, DMS are also limited by the amount of information they can present to a driver during their short window of visibility.

To overcome the limitations of both of static and dynamic road signs, the Louisiana Department of Transportation and Development (DOTD) has installed highway advisory radio (HAR) networks to convey highway construction information zones in both Baton Rouge and Lake Charles. The DOTD HAR systems used low power AM radio broadcasts to convey information to drivers in their vehicles. The HAR broadcasts were targeted primarily at tourist or "pass-through" traffic and allowed motorists to receive construction and tourist-oriented information within highway work zones of these two areas. The research also evaluated the potential use of advanced traffic data collection and processing measures in combination with HAR.

ACKNOWLEDGMENTS

This project was completed under the support of the Louisiana Transportation Department of Transportation and Development (State of Louisiana Project 736-99-0463), through the Louisiana Transportation Research Center (LRTC Project No. 97-9SS), and under the administrative guidance of Arthur Rogers. The authors of this would also like to acknowledge the written and editorial contributions of Caroline Heifner, Prashanth Bachu, Kalyan Koppenedi, and Elba Urbina from the Department of Civil and Environmental Engineering at Louisiana State University.

IMPLEMENTATION STATEMENT

The project was divided into three primary phases, including a technical review of existing highway advisory radio systems, equipment implementation, and system testing and evaluation.

The first phase of the project involved a review of literature and practices related to the development and application of HAR systems in the United States. The review addressed the applicability of existing commercially available HAR systems as well as the specific planning, placement, and operational requirements necessary to implement an effective HAR system in Baton Rouge and Lake Charles. The Phase I review also addressed the concept of using HAR in combination with other advanced technologies such as GPS, video surveillance, radar, and pavement loop detection for the collection and processing of real-time traffic information. This was completed to determine effective and practical means to integrate a traffic data collection/processing capability with real-time highway communication.

In the second phase of the project, HAR broadcast transmitters were purchased and installed in Baton Rouge and Lake Charles. Equipment specifications and personnel operating requirements will be developed based on the results of the review of available information in Phase I. Suitable suppliers were determined based on the conformance to these specifications and price. The installation of the project also required the acquisition of a Federal Communications Commission (FCC) broadcast license.

After implementation, the final phase of the project evaluated the quality of each broadcast transmitter at the two test sites. The evaluation determined the ability of the transmitters to broadcast traveler information to drivers in terms of both broadcast coverage area and message content. Phase III also include the development of guidelines for monitoring the system, suggested message information content, and training for personnel responsible for the operation and maintenance of the system.

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INTRODUCTION

Each year a number of major Interstate highway construction projects are initiated in the state of Louisiana. These projects often result in traffic congestion, lane closures, detours, lane shifts, etc. To increase the level of public information associated with roadway construction, the Louisiana Department of Transportation and Development (DOTD) has spread the news of impending construction projects through various means of communication. In the past, the most effective methods of mass communication were newspapers, radio, and television reports. However, a significant percentage of motorists traveling on the Louisiana Interstate System are tourists with a limited knowledge of how to access these sources of local information.

Information related to the highway environment is typically relayed to drivers using traffic control devices such as road signs. Static signs are the preferred method of communication because of their low cost, durability, and familiarity to drivers. However, this method of communication is not effective during dynamic situations such as incident related congestion and inclement weather conditions. Many highway agencies now employ variable or dynamic message signs (VMS/DMS) to convey up-to-date and specific information on a dynamic basis. However, these devices bring additional costs for installation, operation and maintenance over conventional road signs and quantity of information conveyed by them is restricted by driver visual limits.

A more sophisticated type of communication currently used by several state highway agencies is highway advisory radio (HAR). HAR uses low power radio transmitters to convey information to travelers on AM radio frequencies. Motorists can tune their radios to a specific frequency inside of the broadcast zone to receive highway specific information.

To address the issue of highway communication in Louisiana, DOTD initiated a study to evaluate the use of radio communication techniques for highways within the state. Specifically, DOTD has lead the effort to use HAR in construction highway construction zones. It is expected that HAR will be a cost-effective method to provide accurate, near real-time traffic information to motorists within the urbanized areas of the State.

As part of this project, two networks of HAR transmitters were installed in the cities of Baton Rouge and Lake Charles. These two test networks were used to evaluate the utility of HAR and to develop use protocols for use in future HAR systems within the state. The second primary objective of the project was to investigate current HAR applications in the United States and the technical issues associated with integrating HAR with emerging data collection technologies. Ultimately, DOTD will seek to combine HAR with complimentary Intelligent Transportation Systems (ITS) to collect, process, and communicate traffic flow information in real-time.

OBJECTIVE

The objectives of this study were to:

1) Conduct a review of past and present HAR implementation projects and evaluate equipment requirements, licensing requirements, and operational strategies associated with these systems.

2) Define equipment needs, develop system specifications and implement highway advisory radio systems in Baton Rouge and Lake Charles.

3) Develop in-house DOTD technical expertise in HAR system project implementation and operation.

4) Review existing and emerging ITS technologies to determine promising avenues for the future development of real-time traffic data collection and dissemination systems in Louisiana.

The primary objective of this project was to implement HAR systems to provide travel information to motorists during the upcoming construction projects on the interstate highway system in Baton Rouge and Lake Charles. Since HAR is a new technology within DOTD, it was also necessary to develop a set of equipment and installation specifications, use protocols, testing, maintenance, and training procedures for the system. In addition to issues associated with the system hardware, issues associated with the multi-jurisdictional operation of the system also had to be explored.

Initially, a review of existing HAR practices was completed. The review included a search of published literature, trips to engineering conferences, site visits and tours of operational traffic management systems throughout the United States, as well as meetings with highway administration officials. The search allowed the investigators to review existing HAR policies, procedures, and equipment to be evaluated in order to make it a more useful tool in Louisiana. The review also included an examination of emerging traffic detection technologies such as video, radar, and sonar. This information will help to guide future actions of DOTD relative to the collection and processing of real-time traffic information and will determine which of these technologies will provide the most useful, cost-effective, and accurate real-time information in HAR broadcasts.

This report also details each of the critical steps involved in the development and approval process with the expectation that it will serve as a reference guide for future HAR implementation projects in Louisiana. As such, this report includes copies of all relevant documents that were created during the implementation process and copies of technical manuals and guides. The report also discusses many of the difficulties encountered during the completion of the Baton Rouge and Lake Charles projects in the hopes that they will not be repeated in future projects.

METHODOLOGY

Literature Review

An important task for highway engineers is the communication of roadway information to drivers. Highway agencies have a variety of methods to regulate, warn, or guide travelers. The most common of these is through the use of static traffic signs. Although these are the most widely predominant means of advising motorists, they have some deficiencies that hinder their efficiency. The main problem with guide signs is that they are not adaptable to changing conditions. The use of changeable message signs can sometimes alleviate this shortcoming, but they are often used on a limited basis because of the expenses involved in purchasing and maintaining them. An alternate method of conveying messages to drivers is through the use of relatively low power transmitters. A system of this sort is often referred to as Travelers Information Stations (TIS) or Highway Advisory Radio (HAR). HAR has been successful in various applications and does not have some of the difficulties that are associated with standard signs.

Highway Advisory Radio is not a new concept. The HAR technology has been used to disseminate information to drivers by numerous state and local highway agencies for more than 40 years. Recent published literature has highlighted HAR projects in the states of Texas, Minnesota, Florida, Virginia, Michigan, and New Jersey.

Highway advisory provides information to drivers via low power AM radio signals. The information that is broadcast over these signals is usually specialized information not normally attainable through static or variable message signing. Frequently, highway advisory radio messages relay information about traffic congestion, detour routing, incident management, and construction work zone activities. The significant advantage afforded by a highway advisory radio system is that it allows frequent updating of information to address frequently changing conditions which can not be achieved through more conventional means. This information can be received by nearly all motorists using existing hardware in the vehicles.

Many types of HAR systems are commercially available. These systems vary significantly in their costs and levels of sophistication. The basic concept of HAR involves the placement of a low power AM transmitter within an area of interest. A typical HAR transmitter has a broadcast range of two to seven miles. The low power requirement of a typical unit means an energy consumption rate approximately equivalent to a 25 watt light bulb. The broadcast range depends upon many factors including ground topography and conductivity. All HAR systems require Federal Communications Commission (FCC) licensing.

Commercially available systems come in three primary configurations: pole mounted, mobile self-contained units, and computer controlled networks. The most basic configuration is the pole mounted transmitter station. A single pole mounted unit costs approximately $20,000 and requires a utility pole as well as electrical and telephone service connections. These systems are typically equipped with back-up battery power supplies to allow them to function during periods of extended power interruptions. The broadcast messages can be checked and changed at the site or they may be modified remotely via telephone. Special pass codes are also used to prevent unauthorized tampering with broadcast messages. Several isolated units may be linked together to form a network or groups of networks operated from a single control station. For an additional cost of approximately $15,000 per unit, the pole mounted system can also be equipped with a solar power source and cellular telephone capability. These features are desirable for units that may be located out of the normal coverage area for electrical and telephone utilities.

HAR systems are also available in self-contained mobile unit configurations. The self-contained units are also portable and operate on a solar power supply and cellular telephone communication system. The solar power source has the ability to generate electrical power during all times of daylight and store enough power to remain fully operational in up to 14 days of total darkness. Because of their portability, the mobile units are often used for emergencies and incident management situations, often in conjunction with variable message signs. The two to five mile broadcast range of the mobile HAR system is somewhat less than that of the pole mounted configuration. The typical cost for the mobile device is approximately $40,000. Currently, various versions of the mobile self contained HAR units are in operation in the states of New York and New Jersey.

The third primary type of HAR is the network control system. The network system is considerably more sophisticated and costly than the pole mounted or mobile systems. Generally, these system are developed on a project-by-project basis and are customized to meet the needs of a particular user. A unique feature of the network system is that it allows the control of networks of broadcast units from a single remote location. This type of system significantly decreases the manpower requirements necessary to operate the system. Further, it allows the implementation of specific broadcast messages to be transmitted into a certain vicinity.

The control software is based on a Windows™ program allowing pre-recorded messages to be quickly and simply implemented on a real-time basis. Currently, a system like this is in use on the New Jersey Turnpike. The network control system also allows convenient integration into a real-time advanced traffic management system such as the one proposed for Baton Rouge. The cost for this type of system is considerably higher than that the previously described systems. However, the exact price depends upon the level of sophistication and coverage area of the network.

The applications for this technology are numerous. In addition to the aforementioned uses of congestion advisories, detour routing, and construction zone information, these systems can also be used to convey information about emergency evacuation instructions and tourist traveler information. Highway advisory radio systems have been tested in the states of Virginia, Florida, and Michigan using various types of information with various levels of success. The system to be investigated in this study involved use of a highway advisory radio system for highway construction projects in Baton Rouge and Lake Charles. The review of literature examined subjects related directly to HAR and its suitability for incorporation into other advanced traffic management and traveler information systems.

HAR History

The initial development of HAR began in the early 1940s. In the fifty years since, HAR systems have continued to improve. Prior studies have demonstrated that HAR projects have yielded mixed results. HAR has been shown to be useful for the communication of information in vicinity of airports, tunnels, and construction zones. However, many of these past projects have also demonstrated some of the deficiencies of HAR. With the growing interest in Intelligent Transportation Systems (ITS) and development of computer control systems, HAR is once again being explored as a method of real-time communication to drivers in the United States.

The first documented use of HAR using AM broadcast transmitters was in 1940. The project was centered on the George Washington Bridge between New Jersey and New York City. The system was installed as part of the New York World's Fair and was in use for less than a year. The station transmitted messages to fair attendees as they approached the fair vicinity. A one minute prerecorded message was broadcast using a 550 kHz (kiloHertz) transmitter and induction cable antenna. The message was transmitted on a low power basis and operated under FCC approval without a license *[1]*.

This initial installation was followed in 1951 by an HAR system in New York's Lincoln Tunnel *[2]*. The system combined musical programming with incident advisory messages. Like the World's Fair system, the Lincoln Tunnel HAR was a low-power broadcast and did not require a FCC license. The system was in operation for several years before its operation was suspended over concerns that the radio signals could detonate blasting caps during the construction of nearby tunnel.

The next documented HAR study was performed by the Georgia Institute of Technology in 1963. The Georgia Tech project involved several tests of HAR effectiveness on I-65, the Kentucky Toll Road. The study tested groups of randomly selected drivers, segregated into test and control groups. The test driver group was given a radio receiver that received HAR messages. Drivers were told to drive on a 10-mile section of the turnpike. The study group staged three separate incidents within this section of road. The first was a mock accident, the second incident was a mower in the roadway median, and the third was a patching crew, which obstructed a single lane of traffic.

Three separate HAR messages were transmitted to the test driver group. The first message warned that a set of special instructions would be broadcast in the event of an incident situation. The second warned of the staged situation that would appear some two miles ahead. As the drivers approached the incident location they were directed to use a specific lane. Once drivers had passed through the incident scene, a final message instructed the drivers to return the radio receiver to the test team. All test and control vehicles were monitored with cameras. The research team concluded that the test drivers had lower speeds and better lane placement than the control drivers who were only informed of the situation by signs and flashing lights *[3]*.

These radios were also used on Atlanta freeways during 1964 and 1965. The purpose of the study was to determine if there would be improved driver performance in the vicinity of exit ramps where traffic was very dense. The researchers concluded that drivers equipped with the radios maintained a higher speed and exited the freeway more promptly than those without the radios did.

The oldest HAR system, that is still in use today, was put in place on the approach and internal circulation roads of the Los Angeles International Airport in 1972. It was the first system to operate above 540 kHz; therefore, was the first to require a FCC license. Signs were placed on approach roads informing drivers to tune to the specific station. Unlike other systems, the Los Angeles airport system is not used to inform drivers of incidents or road conditions. Rather, it assists travelers in finding parking, particular terminals, and gates, returning rental cars, and broadcasting information about flight delays *[4]*.

Another example of an early HAR system was the Walt Whitman Bridge network installed in Philadelphia in 1975. Three advance message signs were posted and HAR messages were updated every 15 minutes. Helicopters provided traffic surveillance. A typical message would give estimated travel times through the corridor. In addition, suggestions were given concerning alternate routes and mass transit options that would help to minimize delays.

Philadelphia followed this system in 1976 with the installation of four additional systems on congested sections of the metropolitan freeway network. The main purpose was to reduce traffic delays for the bicentennial celebration. Some general information was provided, including mass transit telephone numbers, hotel and bicentennial information, upcoming events, and special street restrictions. The primary input came from helicopter surveillance with additional feedback from police patrols *[3]*.

There were some difficulties that arose with HAR systems that were installed soon after the Philadelphia system. In 1976, Wyoming installed an HAR system to compliment VMSs. Commercial radio station operators in Wyoming complained of interference. These complaints eventually led to the abandonment of the system. Iowa and Colorado installed HAR systems in 1977. The Iowa system covered five miles of freeway. Evaluations showed that only 10 percent of drivers tuned in during the summer. This number increased to 20 percent during winter operation when harsh weather conditions typically led to accidents. The Colorado system near the Eisenhower Tunnel experienced many technical problems with equipment, signal strength and detection. Problems also arose with a network that was installed in Illinois. This system was only used in construction zones. When messages were sent to the HAR transmitter via telephone lines, there was a serious signal loss *[5]*.

One of the most documented HAR systems was installed Minneapolis in 1978. Traffic detectors were located at 0.5-mile (mi) intervals along I-35W. Sixteen closed circuit television cameras and two ramp meters were also incorporated into the system. Unlike previous HAR systems, the Minneapolis network was activated solely in the event of an incident. Advanced warning signs with flashing lights alerted motorists to tune in. During the first year of operation, the system was activated 276 times. Eighty-six percent of the instances were related to congestion. Twelve percent resulted from accidents, while the remaining cases were for traffic diversion *[6]*.

Prior published literature has revealed that there are many merits and weaknesses of HAR. Early HAR systems encountered difficulty with equipment and broadcast quality. The primary reason for these difficulties was the result of "non-dedicated" equipment. Instead of installing equipment developed specifically for HAR, standard radio broadcast equipment was used. However, the modern equipment, such as more sophisticated antennas and improved automobile AM radios, have helped to address many of the difficulties of earlier systems. Evaluations of these prior systems indicate that, in general, motorists are interested in up-to-date and useful information about traffic conditions and to a lesser extent, in general travel information.

HAR Communication Issues

The success of HAR is dependent upon a number of elements. Among these are ample roadway signing, message reliability and accuracy, and message content. There should be adequate advance notice that the broadcast is available. If drivers are expected to use HAR, they must be aware that an HAR system is available within their route of travel. Advance notice of an HAR system may take many forms, although roadway signs are the most common. It is equally important that HAR messages are clearly structured so that listeners can understand them. Poor message content or structure may result in misinterpretation of announcements. In addition to sufficient publicity and good message content, drivers must be able to receive clear and audible broadcasts. If motorists find difficulty in hearing or comprehending messages, they may abandon HAR and rely on other means of traffic information.

Roadway Signing. Since roadside signs are the most prevalent method to alert drivers of broadcasts, adequate numbers of high visibility signs is one way to ensure publicity. A study funded by the U.S. Department of Transportation demonstrated that only three percent of motorists tuned to an HAR station when a single advance warning sign was used. The installation of additional signs increased usage to 35 percent. In a study conducted by the Texas Transportation Institute, it was observed that motorists did not frequently use

HAR because they did not see the signs, or the signs were obstructed by work zones or guide signs *[7]*.

To enhance the visibility of HAR advanced message signs, flashing lights have been used. Some highway agencies have combined signs with "constant operation" flashers. In "constant operation" mode, sign beacons are in use on a 24-hour a day, seven-day a week basis. Other agencies use flashing beacons on a "by exception" basis. Under this type of operation, the beacons are not activated unless warranted by an incident situation.

In the past, some agencies have experienced trouble with the "by exception" flasher operation. The most common difficulty involves making determinations of what circumstances are severe enough to classify as an "exception". As a result, these agencies are required to establish use protocols to evaluate the severity of a situation and respond to it. An additional dilemma of the "by exception" flasher operation is the assumption on the part of drivers that when the lights are inactive, no information is being broadcast. Depending on the highway agency, this may or may not be the case. Therefore, to avoid confusion, many state and local agencies that continually broadcast messages also feel that constant operation flashers allow for a more effective use of the system.

To further increase the effectiveness of HAR advanced message signs, some highway agencies have incorporated variable message signing (VMS). VMS presents an effective method to direct specific information to drivers on a dynamic basis. These signs are used to inform drivers of an HAR broadcast and reinforce the content of HAR messages. One example is the use of VMS and HAR in combination to alert drivers of impending lane closures and lane shifts.

The I-95 Coalition report provides recommended guidelines for the combined use of highway advisory radio and variable message signing *[8]*. The report documents standard VMS message formats and abbreviations for VMS statements, including spacing and location requirements for VMS signs. The guidelines and practices report also details recommended response actions to special situations such as multiple event occurrences and hazardous waste spills.

Successful HAR is also the result of accurate, timely, and useful broadcasts. The information broadcast must be consistent with the existing conditions. Drivers do not need to be informed of something they already know. Alternatives should be announced while the drivers have adequate time to make decisions or reroute. The suggested course of action must be considerably superior to the drivers' original course. If a highway advisory radio system incorporates all these factors, it will be able to successfully inform users of road conditions and traffic congestion.

Message Reliability and Accuracy. Although radio is considered a useful means of disseminating traffic information by drivers, they must believe that the broadcast messages are reliable and useful. Researchers at the University of California studied user perception of traffic broadcasts in 1995. Researchers concluded that radio broadcasts were the primary means for drivers to learn about traffic conditions before leaving home and while driving. This was also confirmed in a survey of Seattle commuters. Almost 80 percent of the responses in the Seattle survey expressed a preference for radio over any other means of traveler information .

According to a congressional study, commercial radio broadcasts were often considered better than government-operated HAR. Also, government-provided radio reports were often considered to be inconsistent with the true traffic conditions. Motorists felt that the information broadcast was not credible if the broadcast was different than what they observed. This lack of information is associated with poor data collection, analysis, or evaluation. One way to increase credibility of HAR messages is to deliver them in a timely manner. Drivers need to have adequate time before reaching the incident so that they can decide on their course of action *[9]*.

Another shortcoming of government HAR messages is that they are sometimes too faint or too scratchy to be audible. This results because the HAR is broadcasts at the low end of the AM spectrum. Commercial radio broadcasts on the FM spectrum or higher end of the AM spectrum result in enhanced clarity of messages. Studies have shown that if messages cannot be clearly understood, drivers are likely to turn to traffic updates on commercial radio stations. User feedback from the North Carolina DOT indicates that although HAR is helpful, the stations often have too much static for messages to be understood correctly *[7]*.

One way to ensure accuracy of HAR messages is to regularly update them. Studies conducted in Florida and Delaware have suggested that messages should be updated every 15 to 30 minutes. The Delaware Valley Regional Planning Commission, responsible for an HAR system in Philadelphia, recommends updates no less often than every 15 minutes. However, they feel that repetition is the key for getting drivers to retain information, so they also advise that messages should not be updated too often. The highway advisory radio guide recommends that message length and updates should allow the driver to receive the messages at least twice while passing through the coverage zone *[7], [10]*.

The North Carolina DOT uses prerecorded messages to warn of expected construction delays. These are typically updated weekly but can be updated daily if necessitated by new detours. Messages are also updated immediately in the case of an emergency. The structure of the NCDOT messages allows updates without breaks in broadcasts. This is because the messages are composed of “blocks.” Each block is 256 seconds (about 4.5 minutes) long and deals with a single subject such as the weekly update, upcoming events, or emergency instructions. Two or three blocks are strung together for a complete series of messages. If it is necessary to update a block, the other blocks can still be broadcast without interruption.

Accuracy of the messages is another element of successful HAR. Systematic procedures are necessary to coordinate HAR. NCDOT found its broadcasts to be incorrect five to ten percent of the time. Errors included sending messages to traffic in the wrong direction or the communications center being unaware of construction. To alleviate these mistakes, police, contractors, project engineers, departments of transportation, and traffic engineers should contact control stations immediately. The Ohio DOT had a similar problem and alleviated it by forging an agreement between the different highway maintenance and law enforcement agencies to relay information on a timely basis. This enabled them to supply real-time information 24 hours a day *[7]*.

An important point stressed repeatedly in nearly all HAR reports is the need for all HAR messages to be accurate, timely, and useful. A system which fails to address each of these criteria will encounter difficulty in gaining credibility with the driving public.

Message Content. Since relaying a specific message to drivers is the ultimate goal of highway advisory radio, it is important that the broadcast messages can be interpreted clearly by listeners. The content and structure of the HAR messages should allow them to be accurately understood. Messages should be concise enough for the driver to remember the message that is being sent. The structure of each message should be clear, first alerting the driver of the situation and then offering alternatives if necessary.

Several of the published reports documenting existing HAR systems have recommended guidelines for content and standardization of HAR broadcast messages. These recommendations are helpful for the development of incident, non-incident, general information, and construction detour messages. Some reports recommended that general traffic information be broadcast during non-emergency situations. A study conducted by the Virginia Tech Center for Transportation Research suggests that, in cases of non-emergency, HAR should broadcast information about upcoming events, parking, transit alternatives, severe weather, road closures, or road conditions *[11]*.

It is also important for advisory messages to be constructed simply and clearly. The Minnesota DOT messages inform motorists about the type and location of each incident. Messages should also relay information about the extent of congestion and diversion options. Incidents concerning accidents, construction, harsh weather conditions, or congestion are typical subjects of HAR broadcasts. In most cases, the Minnesota HAR operators select from 22 pretaped advisory messages. Although, in a unique situation, they may also create new messages *[6]*.

A report by the Virginia DOT included general guidelines for use in the development of broadcast messages. Suggestions for increasing the clarity of the messages were also given. These included a speaking rate of 175 words per minute, a maximum message length of one minute, and the use of time statements and FCC call signs. The I-95 Coalition project included a Quick Reference Guide detailing event specific messages for HAR broadcast action *[12]*. The reference guide provides "canned" message formats for different types of events such as construction, weather, and accident advisories.

The Virginia Tech Center for Transportation Research conducted a study that found the "canned" messages that some agencies use are deficient to motorists' needs. They believe that messages should be incident specific.

A typical incident message is composed of the following seven elements:

(1) Attention Statement - Indicates to whom the message is intended.
(2) Problem Statement - Brief statement of the problem and how it effects the drivers.
(3) Location of incident - Allows drivers to make individual diversion decisions.
(4) Reasons to Follow Advisory - Gives delay or consequence of not following message.
(5) Give the Advisory - Informational or the action required by the driver.
(6) Time Statement - Indicate when the message was last updated.
(7) FCC Call Letters - FCC rules require the letters to be broadcast at least every 30 minutes.

The format for non-incident messages is somewhat similar and includes the following:

(1) Attention Statement
(2) Purpose Statement - Brief statement of the purpose of the HAR.
(3) Local Traffic Conditions
(4) Regional and/or Educational Message
(5) Date Statement - Indicate when the message was last updated.
(6) FCC Call Letters

Successful highway advisory radio systems are considered reliable because they combine sufficient advance notice, and accurate broadcasts with a clear and brief message format. In order to accomplish this, all aspects of the system need to be adequately checked and maintained. Therefore, it is imperative that there are adequately trained personnel to operate the system, collect incident information, update broadcasts, and monitor the performance. For these reasons, many studies have concluded that adequate personnel is the driving force behind successful HAR.

Personnel Requirements

The personnel requirement of HAR systems in the United States varies considerably. However, the manpower requirements of most systems are substantial. The personnel requirements of any particular system are a function of the level of accuracy and timeliness of broadcast information desired by an agency. The level of technical sophistication, data acquisition and message transferring equipment also impact personnel needs.

HAR practice dictates that messages should be updated regularly, which requires a large personnel commitment. The North Carolina DOT claims that it takes only one or two people at a time to run their HAR system because their transmitters can be operated by a cellular phone. They suggest that changing messages and small-scale maintenance can be done by those who have other duties. However, a similar type of operation in the Illinois HAR system led to personnel shortages. This was due to operators not being able to leave their other responsibilities in the case of unexpected events.

In 1995, two reports were prepared by the Virginia Department of Transportation (VDOT) to document their experiences with HAR on several state highways and Interstate freeways. These reports included a documentation of operational guidelines and motorists surveys to identify driver impressions of HAR. The operational guidelines manual also revealed the critical importance of manpower requirements in these types of systems *[13]*.

The personnel requirements of the VDOT system were substantial. Each HAR station in the network had a dedicated HAR officer responsible for insuring the accuracy, timeliness, and utility of the broadcast message. The officer provided service on a 24 hour-a-day, 365 day-a-year basis and monitored the broadcast range of the transmitter on a weekly basis. This practice is not uncommon among state highway agency HAR users. Several other states maintain continuous operation and message updating of their HAR systems.

The Michigan Department of Transportation (MDOT) has implemented an HAR system in Detroit. The HAR system is a part of an overall real-time freeway monitoring and information dissemination system. The MDOT HAR broadcast center is housed in the Michigan Department of Transportation's Intelligent Transportation Systems Center in Detroit. Real-time traffic flow and volume information is collected through a network of pavement based vehicle detectors. This negates the need for field data collection personnel.

Real-time traffic incident information is collected and transmitted using a system of wireless and closed circuit television cameras positioned at critical locations within the freeway network. An additional source of real-time information comes from the State Police dispatch center, located in the same office suite. Thus, manpower requirements for the system are reduced through inter-agency cooperation.

Performance Surveys

While the published information contained studies about uses and applications of highway advisory radio, studies relating to it effectiveness were more difficult to locate. This lack of information could be related to the fact that the systems are relatively new and that there are no standard methods to determine the usefulness of the system. Mail-in surveys and interviews can be a time consuming and expensive way to receive feedback about the system. However, if there is good reception and participation, this can be a good way to learn what the users' opinions of the system are.

A survey of the experiment conducted by the Georgia Institute of Technology on the Kentucky Toll Road gave insight into the drivers' perception of HAR. A post-experiment interview showed that 90 percent of the test drivers considered the added use of radio with the signs to be better than signs alone. Over 80 percent were receptive to using the radio for high traffic areas. Only 70 percent felt that it would be helpful in scenic or historical areas. Most of the test drivers said that they would have been willing to pay $30 (equivalent to $120 in 1990) for a radio that would have permitted them to hear highway advisory radio broadcasts.

A survey of HAR system at the Los Angeles International Airport concluded that only 20 percent of motorists used it on the days the survey was taken. Most of those surveyed found it to be a useful way to find terminals, return rental cars, and learn of flight delays and weather conditions. Further surveys of these users indicated that over half of the drivers used the HAR system in times of heavy congestion or severe weather *[4]*.

Evaluation of the HAR system on the Walt Whitman Bridge in Philadelphia proved to be inconclusive although several attempts to evaluate it were made. Two thousand postage paid questionnaire postcards were distributed to motorists who passed through the tollbooth. Only four percent of the survey postcards were returned. Of the responses, 64 percent saw the signs and 74 percent of these tuned in to the broadcast. Since there was such a small pool of respondents, the results were not considered to be very accurate *[14]*.

The "Headlights On" survey was one means used to evaluate the HAR system in Minneapolis. During three separate one-hour periods, signs indicating the broadcast of a traffic advisory were activated. A message informing the drivers of the test was transmitted and requested that the drivers turn on their headlights in order to determine the size of the audience. Although this type of survey is inexpensive and requires almost no preparation, there are several drawbacks. A "Headlights On" survey will not work after dusk or in times of poor road visibility since many people will turn on their headlights anyway. If this method is used to estimate the size of the listening audience, it must be assumed that all the cars upstream of the broadcast message already have their headlights turned off. However, this is not necessarily the case. Also, this test gives no indication of those members of the audience who will consider the information to be helpful and utilize it *[6]*.

Further surveys of the Minnesota DOT (MnDOT) found that 70 percent of drivers who made at least three trips per week through the corridor during peak periods had used the HAR. Half of those admitted to diverting off the freeway after being advised to do so by the HAR message. Two-thirds said that they preferred a system that only broadcast in response to a serious condition, as opposed to a continuous broadcast. Those surveyed gave the system a high credibility rating, which could have been due to the superior surveillance along the stretch of freeway. Overall, 60 percent of respondents liked the system and only 11 percent advocated its removal.

The surveys of the VDOT study were used to evaluate the general perception of motorists to the HAR system. The surveys centered on drivers' reasons for listening, or not listening, to the broadcasts. The surveys also gave insight into the type of information that drivers thought was important in an HAR message. The survey showed that the majority of drivers saw the HAR roadside signs. However, much smaller percentage actually tuned in. The survey found that the site with the highest percentage of listeners (39 percent) was one system that provided traffic information for a college football game *[11]*.

In almost all of these cases, the fundamental reason for not tuning into the HAR station was that drivers did not know it was available. Other reasons include a perceived lack of need to seek traffic information, a lack of familiarity with the area, or a lack of wanting to switch from listening to music or other radio broadcasts. The survey also showed that the information drivers mainly seek from HAR broadcasts are the location of work zones, incident information, and congestion and alternative route suggestions.

Current Practice

The cost, utility, and availability of highway advisory radio systems have made them a popular means of communication for many highway agencies in the United States. The results of several completed projects have been documented in research literature. However, agencies in other states are still in the process of developing or expanding HAR systems as a means of relaying traffic information. Even though the primary focus of HAR is to inform drivers of conditions on highways, there is documentation from reports suggesting that HAR can benefit motorists in other ways.

Active HAR Systems. Several states are planning to install HAR systems along corridors that depend on other traffic control devices. Commercial radio broadcasts are often used as a means of traffic control, but these are not always as route specific and timely as government HAR. Some agencies feel that the addition of an HAR system, in combination with a signing system, will enhance the efficiency relaying traffic information.

Agencies in New York and Connecticut feel that static and variable message signs alone are no longer adequate enough to provide effective traffic information to drivers. INFORM, an agency in Long Island, New York, is currently planning to add HAR coverage to their VMS system along a twenty-mile stretch of the Southern State Parkway. The Connecticut DOT also plans to add to their static and variable message signing system. There are currently two transmitters in the Connecticut system that presently broadcast ride share information. These, in combination with new transmitters, are being considered to provide drivers with traffic information.

The Ministry of Transportation in Ontario is planning to add HAR coverage to manage traffic on a network of freeways, but is also considering the installation of Dedicated Short Range Communications (DSRC) or digital radio in place of traditional HAR devices.

HAR System Expandability. It is not always necessary to install an entirely new HAR system when it is decided that a present system is no longer adequate. In many cases, highway agencies will expand on existing systems or combine their system with another agency. This allows a system to gain broadcast area or power without the expense of a completely new system.

Systems are usually combined in two ways. The first is to increase coverage by the merging of two highway agencies. This was done by the Colorado DOT and City of Denver. They coupled their existing HAR systems and coordinated broadcasts with each other. This gave each agency more coverage without added cost. The second way to expand an HAR system is for a highway agency to absorb an existing radio information system. For example, the Wisconsin DOT agency gained access to the radio system used by the Milwaukee County Stadium and added portable HAR units to expand the system. This allowed them to incorporate a full HAR system for the surrounding area without installing an entirely new system.

With the success of HAR systems, some agencies feel that expanding an existing system will increase the efficiency of HAR. The Kentucky Transportation Cabinet currently uses HAR and VMS to relay traffic information to motorists as part of the Louisville Incident Management Program. However, because of the systems effectiveness, the cabinet plans to expand the HAR system to cover an area slightly larger than the VMS system does. The Ohio DOT also plans to extend their HAR broadcast area to cover a larger area of in-bound traffic than what is covered by VMS alone.

The expansion of HAR systems may involve coordination between different centers. This is the case of two Indiana HAR systems. The LaPorte District, in Indiana, and the Indiana DOT both use HAR and plan to expand their systems. These systems are integrated into the traveler information expert system, which allows messages to be developed automatically. Direct access to the HAR transmitters is provided to the Dunes National Lakeshore and Lake County Bureau of Tourism by the LaPorte District. Direct access in the Indianapolis District will be provided to the Columbus Area Visitor center and the Evansville Traffic Engineering Department.

However, some agencies do not feel that larger coverage should not necessarily result in greater participation of other offices. The Washington DOT already has some HAR systems running but plans to expand this system to cover all the major highway interchanges in Seattle. Broadcasts will include information about weather events such as floods, avalanches, etc. The Washington State Patrol already has direct access to the HAR transmitter in some regions. However, HAR messages will only coordinate with other agencies in special cases which involve major construction projects.

Other highway agencies still feel that HAR is not the best way to relay traffic information to drivers. The Illinois DOT (IDOT) uses mostly commercial radio stations and HAR to broadcast travel time information. In the current system, the messages are developed manually or automatically, and travel times are updated every five minutes. There is already extensive commercial coverage in northeast Illinois and IDOT plans to further expand the system.

Another example of a state agency which does not currently use HAR is MnDOT. They have no plans to add HAR to their present system of relaying traffic information. However, the use of portable HAR transmitters by construction crews is included in construction contracts so that they may relay information to commercial stations. The traffic management system has formed a partnership with a FM radio station to broadcast traffic information during peak periods.

Implementation of HAR in Louisiana

The implementation of highway advisory as part of this project represented the Department of Transportation's first attempt to incorporate a system of radio communication on state highways. As such, there were a number of first time experiences that were attempted. While the majority of these experiences were relatively uncomplicated to complete, there were also a number of unforeseen events and circumstances that occurred as part of the project. None of these circumstances were major however, they did slow the completion of the project, and, now that they have been recognized and solved, they may be anticipated and more recognizable on future projects, as well as less likely to slow project development.

The implementation phase of the project incorporated several elements which can serve as the basis for other systems in the state. These included the development of technical specification to govern the purchase of future systems, a set of installation guidelines to help in the selection of future implementation sites, a project development schedule checklist to identify and chronologically order each of the critical steps in the HAR implementation process, and a suggested use protocol governing the operation of the system.

System Specifications

HAR is a system that has been in use by many state and local highway agencies for some time. As such, several private companies have developed "off-the-shelf", "ready-to-use" systems specifically for highway traveler information. To make better use of the funds available and to limit the amount of hardware development effort, an off-the-shelf system was sought.

The two largest suppliers of specific use HAR equipment are Information Systems Specialists based in Zeeland, Michigan and Digital Recorders Incorporated from Research Triangle Park, North Carolina. A careful review of sales literature, conversations with technical representative and product presentations from the companies showed that both of these companies manufactured equipment that met the needs of the DOTD.

Both suppliers offered a wide range of systems with varying capabilities for a range of prices. Both of these companies also offered a range of technical support options to provide continuing services to assist in the initial implementation of the system as well as after its installation and operational testing. However, aside from the specific features that differentiated the two manufacturers, the basic systems offered by the two were relatively comparable.

Equipment specifications were developed from the literature supplied by both HAR equipment suppliers. The equipment specifications covered all of the technical and hardware elements of the system including: transmitters, antennae, recorder/player, enclosures, and beacon sign flash activators. The general specification included the installation and warrantee aspects of the system, including time of performance for installation. Also included in the general specifications were issues such as the application of an FCC license, pre-installation site survey, testing, training, and equipment documentation. A copy of the equipment requisition package, including the bid specification used for the purchase of all the HAR equipment used in the project, has been included as appendix A of this report.

Since most highway advisory radio incorporates relatively specialized equipment and its performance is significantly effected by the quality of installation, most suppliers prefer to install the equipment themselves. As such, the specification was written primarily as a "turn-key" purchase in which the bid price included both equipment and installation. This was helpful to DOTD since it did not require any additional in-house training in the installation of the equipment. Additionally, the bid price included the costs associated with the application and administration of a FCC license. This license was required to be signed a representative of DOTD.

The project was nearly "turn key", although several elements were not provided by the equipment supplier. These included the installation of the transmitter pole, HAR advance signs, utility connections, nor right-of-way. Each of these elements was required to be supplied by DOTD. All transmitter stations and advance signs were installed within DOTD right-of-way. Therefore, no additional costs were required as a result of property acquisition. The utility connections, transmitter pole and HAR advance sign installation were completed or coordinated by through DOTD Traffic Services Division. A contractor was hired to install the transmitter pole and dig the holes for the transmitter grounding system. The photographs in Figures 1 through 3 illustrate the installation of the pole and grounding system. The HAR

Figure 2
Technician installs copper grounding rods (Baton Rouge)

Figure 3
Installation crew backfills grounding rod hole (Baton Rouge)

watts. This field strength is measured independent of the broadcast power. If, for example, a two miliVolts per meter field strength at 1.5 km is attained at six watts, the six watts power level becomes the operating maximum. In rare cases, the FCC may grant an "exception" license. Under extreme situations, such as those that threaten loss of life, the FCC will allow increases of HAR output power above ten watts.

Project Equipment

HAR equipment is available in a variety of different configurations with various options designed to meet the specific needs of a user. Transmitter stations may be stationary or mobile, transmitter components have varying capabilities and features, and systems may be expanded or automated with the addition of various control systems. With these optional packages come a variety of costs, as well as operational requirements and maintenance needs. The following sections summarize some of the more popular commercial HAR systems in use and detail some of the specific features and capabilities of the systems installed in Baton Rouge and Lake Charles.

HAR Transmitter Station Configurations. All of the hardware systems for the Baton Rouge and Lake Charles HAR projects involved commercially available equipment designed specifically for highway information use. Highway advisory radio systems currently available in the U.S. are sold in three primary configurations: pole mounted, mobile self-contained units, and computer controlled networks. Each of these configurations have advantages and disadvantages associated with it.

The simplest configuration is the stationary pole mounted transmitter station. All DOTD installations in Louisiana were the pole mounted type. In its least complicated configuration, a single pole mounted unit is composed of a single HAR transmitter, a player/recorder, and an antenna. These stations typically costs around $20,000, not including the cost for a utility pole, electrical and telephone service connections, or installation labor costs. A pole mounted HAR transmitter station in both standard AC and solar powered configurations is shown in Figures 5 and 6.

Figure 5
Standard AC powered HAR transmitter station (Moss Bluff, Louisiana)

Figure 6
Solar powered HAR transmitter station (located at the I-10/LA 415 interchange, West Baton Bouge Parish)

Stationary systems are typically equipped with back-up battery power supplies to allow them to function during periods of extended power interruptions. A pole mounted battery back-up system is illustrated in Figure 7. Several isolated units may be linked together to form a network or groups of networks operated from a single control station. For an additional cost of approximately $15,000 per unit, the pole mounted system can also be equipped with a solar power source and cellular telephone capability. Solar power and cellular telephone service were incorporated into the three Baton Rouge stations. These features are desirable for units that may be located out of the normal coverage area for electrical and telephone utilities or subject to intermittent utility interruptions. However, the use of cellular telephones may present difficulties in operation due to cell phone clarity issues.

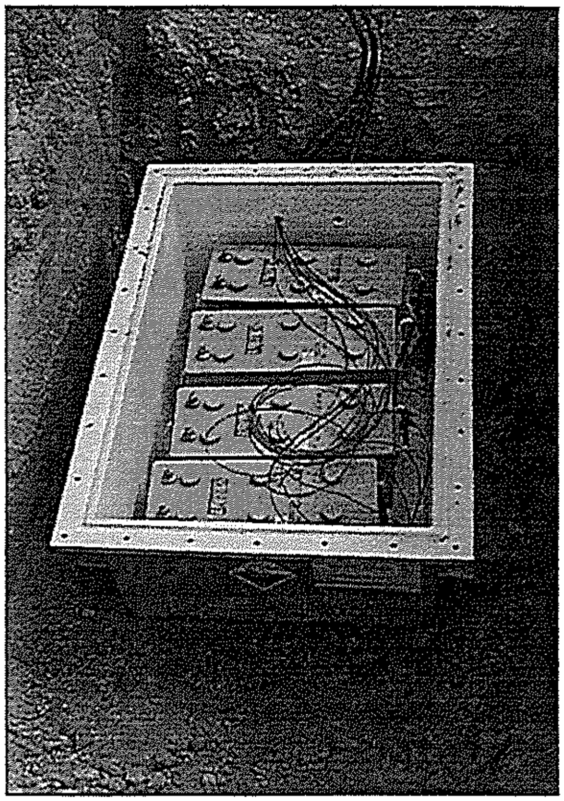

Figure 7
Underground battery back-up system

HAR systems are also available in self-contained mobile unit configurations. The mobile units are mounted on a small trailer and operate on a solar power supply and cellular telephone communication system. The solar power source has the ability to generate electrical power during all times of daylight and store enough power to remain fully operational in up to 14 days of total darkness. Because of their portability, the mobile units are often used for emergencies and incident management situations, often in conjunction with variable message signs. The two to five mile broadcast range of the mobile HAR system is somewhat less than that of the pole mounted configuration. The typical cost for the mobile device is approximately $40,000.

The third type of HAR is the network control system. The network system is considerably more sophisticated and costly than the pole mounted or mobile systems. Generally, this type of system is developed on a project-by-project basis and customized to meet the needs of a particular user. A unique feature of the network system is that it allows the control of networks of broadcast units from a single remote location. This type of system significantly decreases the manpower requirements necessary to operate the system. Further, it allows the implementation of specific broadcast messages to be transmitted into a certain vicinity.

Typically, the control software for network systems is based on a Windows™ operating system. The software allows pre-recorded messages to be quickly and simply implemented on a real-time basis. A system like this is in use on the New Jersey Turnpike where real-time traffic data permits frequent updates of HAR messages. Network control systems facilitate convenient integration into traffic management centers and can be added to existing HAR systems such as the ones in Baton Rouge and Lake Charles. The cost for this type of system is considerably higher than that the previously described systems. However, the exact price depends upon the level of sophistication and coverage area of the network.

Hardware Components and Capabilities. The transmitter stations installed in Baton Rouge and Lake Charles were the Black Max™ by Highway Information Systems, Inc. The transmitter unit resides in an environmentally sealed, pole mounted cabinet. The Black Max units included four modules; a power module, a transmitter module, a recorder player, and a weather receiver. Each of these modules is "rack mounted" for ease of accessibility and maintenance. A detailed description of the system specifications can be found in the Black Max Operations Manual *[16]*. The Black Max station both in AC and solar powered configurations is shown in Figures 8 and 9.

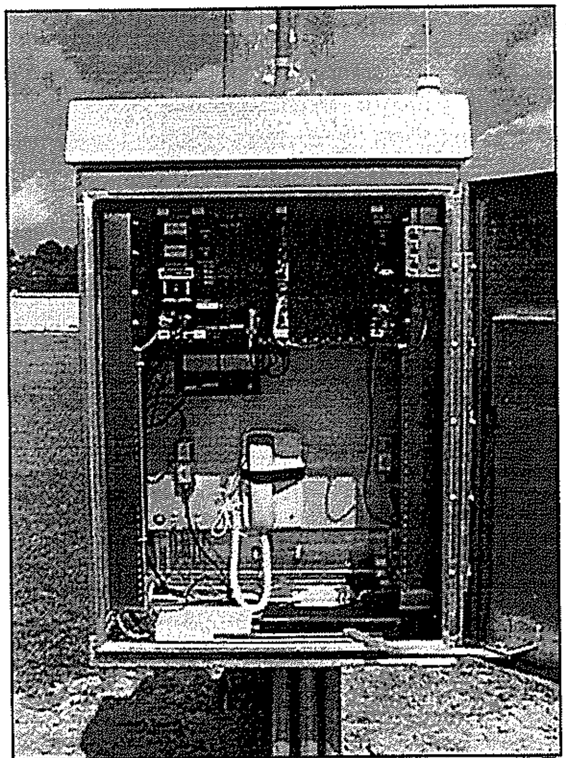

Figure 8
Black Max station (AC powered configuration)

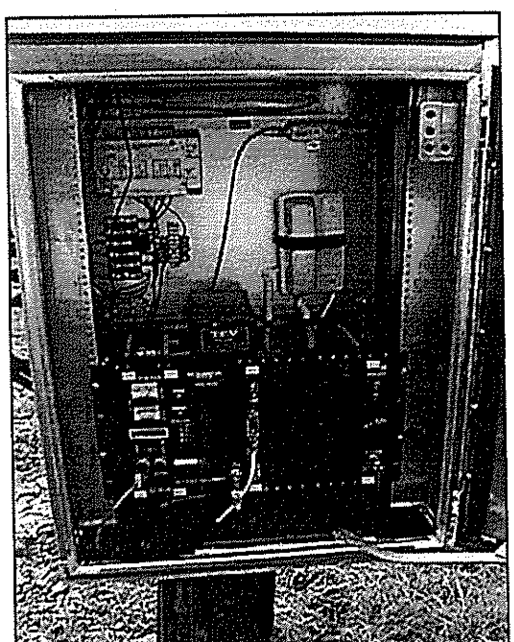

Figure 9
Black Max station (solar powered configuration)

The power module controls the electrical power to the entire system. It contains the power supply switch, which allows the system to switch from AC (or solar) power to emergency battery back-up power in the event of power interruptions. The power supply regulates the charge in the battery back-up and displays the battery charge level. The module also displays the DC voltage and houses a fuse to prevent damage from power surges. The power supply also incorporates an on-off switch to control the state of the transmitter.

The transmitter module provides the actual AM broadcast. It houses the frequency crystal and incorporates a series of indicator lights to identify the status (modulation) of the broadcast. The recorder/player is the "brains" of the system. This module stores all of the recorded messages in a digital format. It also stores and initiates all of the operational commands of the system including play lists, message schedules, and input-output properties. The Black Max recorder/player features storage for up to 256 individual messages and up to 100 message lists (each with a sequence of up to 100 messages). It allows messages to be entered through via telephone, microphone, stereo cable, or computer, and listened to telephone or headphones. The weather receiver is designed specifically to provide weather information from the US National Weather Service (NWS). The unit is tuned to seven NWS frequencies and these broadcasts can be integrated with routine HAR broadcasts *[16]*.

One of the distinct advantages of the DOTD's HAR stations is that they allow remote access to all system functions. Messages maybe be recorded, stored, arranged, and scheduled for broadcast via telephone. This feature allows the broadcast to be activated, deactivated, or modified from any location with telephone access, including cellular phones. This gives the system an "adaptive" aspect that allows it to be modified to meet the dynamic conditions of the highway environment. This aspect also allows the system to be controlled by anyone with pass-code access to the system.

The remote control capability of the system also extends beyond message control. Operational features, such as flash activation, transmitter power switching, pass-code control, and memory status inquiries, can all be controlled via telephone line. This capability allows complete control of the system without the need to make a trip to the field sites. A complete description of the all operational commands and controls is given in the manufacturer's operational guide *[17]*.

Advance HAR Information Signs

An additional feature incorporated into both the Baton Rouge and Lake Charles test sites were advance HAR information signs with flashing lights and a HAR controlled flasher activation system. Advance road signs are used to alert drivers to the presence of HAR broadcasts. Decisions regarding exact location, type, information, and use of these signs should be made on a specific site-by-site basis.

Figure 10
Pole mounted RC 200 flash activation system

System Costs
The purchase price of HAR equipment varies significantly based on the features and capabilities of a particular system. Another factor that can effect the purchase cost of a system is the amount of technical support and installation assistance provided by the equipment manufacturer. In addition to the equipment price costs for utility connections, a right-of-way must also be considered. Once the system is installed, continuing costs required for the operation and maintenance of the system must also be considered.

The equipment used in the Baton Rouge and Lake Charles projects was purchased through a competitive bidding process. The bid was structured to allow DOTD maximum flexibility in selecting which equipment and feature were to be included in the two systems. Bid items for cellular phone and solar power capability were included as separate items so that they could be incorporated or deleted from the system, as need and cost would allow.

A low bid for both the Baton Rouge and Lake Charles systems was received from Highway Information Systems, Inc. (formerly Digital Recorders, Inc.) of Raleigh, North Carolina. It was concluded that the Baton Rouge system would include three pole mounted transmitter units, along with three accompanying sets of solar power supply systems, three tone-in-broadcast flash activation systems, and cellular telephone capability for all transmitters. The total price for this system was $76,617.77. A list of the bid items and their corresponding bid prices is shown in Table 1.

Table 1
HAR Equipment Bid Prices (July 10, 1997)

Item	Qty.	Unit	Description	Unit Price	Qty. Price
1	2	Each	Highway Advisory Radio System (complete)	$14,671.66	$29,343.32
2	3	Each	Same as Item #1, except quantity	$14,012.26	$42,036.78
3	1	each	Cellular Telephone Capability	$1,595.00	$1,595.00
4	2	each	Same as Item #3, except quantity	$1,395.00	$2,790.00
5	3	each	Same as Item #3, except quantity	$1,395.00	$4,185.00
6	1	each	Solar Power Option for Item #1	$9,985.00	$9,985.00
7	2	each	Same as Item #6, except quantity	$8,737.00	$17,474.00
8	3	each	Same as Item #6, except quantity	$8,737.00	$26,211.00
9	2	each	AC Powered Beacon Control System	$1,595.00	$3,190.00
10	3	each	Same as Item #9, except quantity	$1,395.00	$4,185.00
11	2	each	Solar Powered Beacon Control System	$6,100.00	$12,200.00
12	3	each	Same as Item #11, except quantity	$5,490.00	$16,470.00

The operating costs of the Baton Rouge system were diminished through the use of solar power for all transmitters. The use of solar power negates the need for electrical service at the transmitter. However, electrical service is required at the sign locations to power the flashing lights and the flash activator. Monthly service at these locations averages approximately $20 per month. Another savings was realized through the donation of cellular telephone service at each of the four Baton Rouge sites. This service was donated by Cellular One of Baton Rouge. A typical monthly-service fee for a system such as HAR would cost between $30 and $50 per month, depending on usage.

No additional costs for right-of-way were necessary for either project. Six of the seven transmitters and all advance signs were located on DOTD property. The lone transmitter not installed on DOTD right-of-way was placed on the site of Calcasieu Parish public library. The Parish was amenable to the installation on their property because of the joint-use nature of the project.

Since all transmitter systems are covered by a limited five year warranty, no data on maintenance costs are available. Since these systems are all solid state, it is expected that maintenance costs should be relatively low. However, some of the system elements (battery vaults, solar panels, antennae) may be susceptible to vandalism or acts of nature. However, none have occurred in the first year after installation.

HAR Messaging

The HAR systems selected for installation in Baton Rouge and Lake Charles allow operation from both on and off-site locations. This capability allows for increased operational flexibility and permits DOTD to incorporate computer control operation for message loading, as well as playing in the future. On-site operation can be accomplished by input switches integrated into the system hardware. A complete listing of all operational commands and procedures was given in the manufacturer's operational guide *[17]*.

In addition to the basic operation of the system (i.e., message recording, storage and retrieval, play-list scheduling, and transmitter settings), another important aspect of system operation is message development. Three critical aspects of message development include are message content, length, and broadcast philosophy.

The content of messages is the most critical of the three. The information transmitted by the HAR system is the key to whether or not the system is useful to motorists and whether or not they will tune in the future. The three key elements of all HAR messages is that they ***must*** be ***timely, accurate, and useful.*** Without all three of these key factors addressed in every message, motorists will not give attention to the broadcasts.

The content of HAR messages is governed by FCC regulations *[15]*. HAR message may not contain references to specific commercial enterprises or music. They must also contain a station identification at least once per half hour. The length of a message depends on several factors, including broadcast range and the amount of information relayed to the drivers. Typically, it is suggested that a message be created to allow two play cycles during the trip through the broadcast area. Therefore, a driver can have time to tune into a broadcast and listen to the content of a minimum of one complete message in its entirety or in segments.

The content of messages is also dictated by the type of information being relayed. HAR messages are commonly divided into incident and non-incident message types. While they may be similar, incident messages must be more specific, and for credibility, a time stamp must be included. A typical incident message is composed of the following seven elements:

(1) Attention Statement - Indicates to whom the message is intended.
(2) Problem Statement - Brief statement of the problem and how it effects the drivers.
(3) Location of incident - Allows drivers to make individual diversion decisions.
(4) Reasons to Follow Advisory - Gives delay or consequence of not following message.
(5) Give the Advisory - Informational or the action required by the driver.
(6) Time Statement - Indicates when the message was last updated.
(7) FCC Call Letters - FCC rules require the letters to be broadcast at least every 30 minutes.

Non-incident messages should include the following:

(1) Attention Statement

(2) Purpose Statement - Brief statement of the purpose of the HAR.
(3) Local Traffic Conditions
(4) Regional and/or Educational Message
(5) Date Statement - Indicates when the message was last updated.
(6) FCC Call Letters

The operational guide also offers several incident-specific message templates for use under specific conditions. The creation of additional templates for location specific events in Baton Rouge and Lake Charles is also suggested.

Another important aspect of HAR operation is the message broadcast philosophy. Specifically, this addresses the question of how the transmitters will be used. The two most common types of broadcast use are continuous and "by-exception."

Continuous broadcasting makes use of constant message broadcasting. In this mode, messages play on a 24 hour per day, seven day a week basis. There are several advantages and disadvantages to broadcasting in continuous mode. Continuous broadcasting allows the transmitters to be used constantly to broadcast information to drivers. If the broadcast information is not related to urgent traffic emergencies, it can be used to inform motorist of tourist destinations (as in the case of Baton Rouge), traffic safety information, or other transportation-related public information messages. Many highway agencies find continuous broadcasting to be an effective means of communication during non-emergency periods. However, many highway agencies find that continuous broadcasting leads to reduce levels of system effectiveness and credibility. As a result, these agencies use the transmitter to broadcast on a "by-exception" basis.

Broadcasting on a by-exception basis involves the use of HAR broadcasts for emergencies only. Such events include traffic accidents, construction work zone operations, non-recurrent congestion, and civil emergencies (chemical spills, hazardous weather, etc.). By-exception broadcasting is thought, by some highway agencies, to be the preferred method of HAR operation because of its impact. Under continuous broadcast mode, motorists become accustomed to HAR broadcasts which yield very little useful information. When used in an exception mode, drivers know that important information is being offered when the transmitters are active. This condition is reinforced when the HAR is used in conjunction with advanced signing and flashing beacons. The drawback to exception operation is the perception by some motorists that the system is non-functional when no information is broadcasting.

DISCUSSION OF RESULTS

Implementation Results

The results of the experimental phases of the Louisiana HAR have yielded a great deal of information that will be useful in the development of future systems in the state. Among other things, the project revealed the need for multi-jurisdictional cooperation. It also developed equipment specifications, formalized operational practices, experienced increased levels of expertise in DOTD technical staff, and allowed pass-through traffic in the project areas to gain valuable information about travel conditions through the project work zones. The project was also instrumental in revealing and addressing institutional and operational problems associated with HAR in Louisiana. All of these positive aspects have been discussed in previous sections of this report.

In addition to the discovery and documentation of this information, a number of additional, unanticipated issues arose during the completion of the project. These unexpected issues could be grouped into two separate categories; those that dealt with the HAR equipment and those that dealt with public perceptions and expectations. The following sections detail some of the major unexpected issues with equipment and perception, as well as how they were addressed.

System Installation

The installation of both the Baton Rouge and Lake Charles HAR systems were completed through a joint effort of the Louisiana DOTD and Highway Information Systems, Inc., the HAR equipment manufacturer. A joint effort for system installation has been demonstrated to be most effective because it allows the owner to select the best transmitter locations within the operational constraints of the actual system. HAR manufacturers prefer the joint selection effort because it gives them better control over the final broadcast quality. Typically, the cost of installation is included in the purchase price of the systems.

A typical HAR installation encompasses a number of steps that can be categorized into pre-installation, installation, and post-installation project phases. Typically, the installation process takes up to six months to complete and each category requires effort from both the owner and the equipment supplier. With effective coordination and advanced planning between these two parties, the installation time can be significantly reduced. The installation time required for the Lake Charles HAR system was reduced by half becoming three months. This significant reduction in system development time was due to knowledge gained in Baton Rouge and the coordination efforts of the installation personnel.

The accelerated project implementation schedule used for the Lake Charles HAR system is shown in Table 2. The accelerated schedule originally called for full project completion in six weeks. However, due to both manmade and weather delays, this schedule was lengthened to approximately three months. The following sections summarize a typical installation process and detail the critical items of work, as well as cooperative efforts required for the Baton Rouge and Lake Charles installations.

Table 2
Lake Charles HAR Project Implementation Schedule

Lake Charles Highway Advisory Radio System
Project Implementation Schedule*

Work Item	Target Completion Date	Responsible Party	Actual Completion Date
Kick-off Meeting	August 6, 1998	DOTD	August 6, 1998
Submit HAR Equipment List for Approval	August 12, 1998	Contractor	August 17, 1998
Approve HAR Equipment List	August 17, 1998	DOTD (Peter)	August 20, 1998
Purchase HAR Equipment	August 18, 1998	Contractor	August 18, 1998
Conduct Site Survey	August 21, 1998	HIS, Inc.	August 12, 1998
Select Transmitter Sites	August 21, 1998	HIS, Inc./DOTD (Ronnie)	August 12, 1998
Select Preliminary HAR Advance Sign Location	August 21, 1998	HIS, Inc.	August 12, 1998
Evaluate and Select Frequencies	August 21, 1998	HIS, Inc.	August 12, 1998
Approve Broadcast Frequencies	August 26, 1998	DOTD (Steve)	August 19, 1998
Apply for FCC License	August 28, 1998	HIS, Inc.	August 20, 1998
Sign and Submit FCC License	September 15, 1998	DOTD (Steve)	September 14, 1998
Approve Transmitter Location	August 28, 1998	DOTD (Steve)	August 13, 1998
Approve Preliminary HAR Advance Sign Location	August 28, 1998	DOTD (Steve)	August 13, 1998
Fabricate HAR Advance Signs	September 18, 1998	DOTD (Peter)	September 29, 1998
Install Transmitter Pole	September 24, 1998	Contractor	September 24, 1998
Provide AC Electrical Power Feed for Transmitter	October 26, 1998	Contractor/Utility Co.	October 22, 1998
Provide Telephone Feed for Transmitter	October 20, 1998	Contractor/Utility Co.	October 23, 1998
Install Transmitter System	October 23, 1998	HIS, Inc.	October 27, 1998
Test Operation of Transmitters (Broadcast Range and Field Strength)	October 26, 1998	HIS, Inc./LSU	October 28, 1998
Confirm Broadcast Range for Preliminary Sign Locations	October 26, 1998	HIS, Inc.	October 26, 1998
Provide AC Electrical Power Feed for Flashing Signs	October 26, 1998	Contractor/Utility Co.	October 22, 1998
Install Signs and Flashers	October 12, 1998	DOTD (Steve)	October 22, 1998
Install Flash Activation System	October 12, 1998	HIS, Inc.	October 22, 1998
Test Operation of Flashers	October 28, 1998	HIS, Inc./LSU	October 28, 1998
Conduct Training for System Operation	August 11, 1998	LSU	August 11, 1998
Conduct Training for System Maintenance	August 11, 1998	LSU	August 11, 1998
Select "Reader" for Standard Messages	September 5, 1998	DOTD (Steve)	September 8, 1998
Develop "Non-Emergency" Message Content	September 15, 1998	DOTD/LSU	September 10, 1998
Approve "Non-Emergency" Message Content	September 20, 1998	DOTD (Steve)	September 16, 1998
Record "Non-Emergency" Messages	September 23, 1998	LSU	September 29, 1998
Load "Non-Emergency" Messages into Recorder Memory	October 23, 1998	DOTD/LSU	October 28, 1998
** Select Operator for "Emergency" Messages	November 1, 1998	Calc. Parish	
** Develop "Emergency" Message Content	November 1, 1998	Calc. Parish/LSU	
** Distribute "Emergency" Contact List	November 1, 1998	Calc. Parish	
** Select Location for Automated HAR Control Station	November 1, 1998	DOTD (Steve)	
** Install Control Station Software & Hardware	November 1, 1998	HIS, Inc./LSU	
** Conduct Training for HAR Control Software System	November 1, 1998	LSU	

Note: The task item list is in a typical sequence of completion. The sequence for this project has been modified to meet the accelerated project schedule.

* This schedule is based on a "best-case" accelerated task item sequence.
** These items are not critical to "basic" operation of the system

Revised: October 30, 1998

Pre-Installation Phase. The pre-installation effort is critical to the effective operation of the HAR system. Pre-installation activities include all of the planning and administrative tasks, as well as the field data collection activities that are vital to the clear transmission of HAR broadcasts. Depending upon the initial amount of familiarity, experience, and information available to the owner, the pre-installation effort may be reduced. In the case of the two Louisiana HAR systems, the Lake Charles installation involved substantially less effort because of the lessons learned in Baton Rouge.

The owner's pre-installation involvement comes primarily in the areas of project definition and equipment specification. Prior to installation activities, the owner(s) need(s) to specify the objectives. Issues such as coverage area, target audience, right-of-way availability, and utility access need to be addressed since each will be critical to drafting the system performance specifications. In the case of the Louisiana installations, the performance specifications were developed to meet the needs of multiple users (including DOTD, CVB, OEP, DPW/Police Jury, etc.) and to provide highway construction information to pass-through traffic. Further specification development was necessary to acquire system power through solar power units and communication service through wireless telephone connections.

Another of the key issues in the pre-installation phase of HAR system installation is the coordination of utility services. Utility services required for HAR include electricity and telephone services. In Baton Rouge, utility service coordination was somewhat decreased since all four of the transmitters used solar power. In Lake Charles, all three transmitters were powered by standard AC power. As a result, one of the critical factors in selecting a transmitter location (and advanced signs) was access to electrical power. Electrical service must be coordinated through the local service provider. Billing agreements are similar to those used for traffic signals and highway lighting. Telephone service in Baton Rouge was wireless so transmitter location was not influenced by access to land telephone line. Free cellular phone service was provided as a public service by Bell South Mobility, Inc. Telephone service in Lake Charles was provided over conventional land-lines and phone charges were paid by DOTD.

After many of the basic issues of system design and expectation are defined and the system is purchased, the owner's pre-installation involvement is reduced and the equipment supplier takes the lead role in pre-installation activities. The supplier, by specification, is responsible for a number of administrative tasks, including site survey and FCC license application. The site survey is the critical task in the pre-installation program. Site selection requires a joint effort between the HAR system owner and supplier. The supplier takes an active role in site selection because the site will directly affect the quality of the broadcast signal.

Initially, a listening test was performed to assess the existing nature of broadcasts on the AM frequency band. Listening tests are conducted under both daytime and nighttime conditions since AM broadcast conditions change substantially between these two periods. The listening test is used to identify frequencies on the AM band that are clear of existing broadcasts. Frequency interference is also checked through a search of FCC records.

Listening tests are helpful to identify powerful radio station broadcasts from Mexico and Cuba which propagate into the land areas to the United States.

The selection of suitable operating frequencies for the system is not always a simple process of elimination. As evidenced in both the Baton Rouge and Lake Charles systems, the only suitable frequencies in the AM band may lie in the extended (1630 to 1720) band. Only one frequency (AM 1620) was found to be clear and available for use in either Louisiana system. The broadcast frequencies for both systems and their locations are shown in Table 3.

Table 3
Louisiana HAR Transmitter Station Frequencies and Locations

Transmitter Location	**Frequency**
Baton Rouge	
Southbound Interstate 110 and US 190	*1610*
Eastbound Interstate 10 and LA 415	*1630*
Westbound Interstate 12 and Millerville Road	*1650*
Westbound Interstate 10 and Siegen Lane	*1670*
Lake Charles	
Eastbound Interstate 10 near Exit 23	*1620*
Westbound Interstate 10 at mile marker 39	*1640*
Calcasieu Parish Library (near LA 378 and US 171)	*1660*

(note: frequencies shown in italics are in the extended AM band)

The major difficulty is that extended frequencies are not necessarily available to all drivers. The installation of AM radios with extended band capability was not made standard on most American made passenger cars until 1992. Thus, the potential to eliminate a significant percentage of the HAR listening audience exists in both Baton Rouge and Lake Charles.

The critical decision to move the broadcasts to the AM extended band was based on several following factors. First, clear frequencies were found in the standard AM band, but these frequencies were only clear during daytime operation. Also, during night conditions, all of these frequencies were over-run with broadcasts from distant high power radio stations. The extended band frequencies gave clear broadcast quality at all times of the day, but they do not have the ability to reach the full potential audience. Based on the desire to provide clear information on a 24 hour a day basis, the final decision to use the extended band frequencies was made. Furthermore, more and more vehicles will be equipped extended band capable as time goes on.

The selection of a suitable location for the HAR transmitters and advance signs, in both Baton Rouge and Lake Charles, was completed through a joint effort of both DOTD and the HAR equipment supplier. Both groups are required for site selection due to the nature of the selection process. The supplier is primarily concerned with the site-specific features of the proposed transmitter and beacon sign locations. Such features are associated with the basic operation of the system and can significantly impact the broadcast quality, range, and clarity. Items critical to the site-specific evaluation include:

- **The proximity of the transmitter to tall trees, buildings, and metal structures.** All of these impact how far the signal will carry within the broadcast radius. The clearer the site, the more distant the signal is expected to carry. This concept is also true with terrain obstructions like hills and mountains. Such topographic features can also diminish the ability of a driver to pick up a signal at great distances.

- **The proximity of the transmitter and sign beacon flash activation system to electric power lines.** Power lines may introduce static into the broadcasts thereby reducing their clarity in radios and reducing the flash activator's ability to distinguish and initiate a flash command.

- **The soil composition and elevation of ground water table in the vicinity of the transmitter.** The soil conditions significantly impact the grounding characteristics of the transmitter. Soils with a high metal content and high ground water table are optimum for broadcast quality. Although the transmitter system is installed with it own grounding system , so poor soil conditions and lack of ground water will not negate the use of HAR.

- **The proximity of the transmitters and flash activation system relative to utility services.** AC power and telephone, unless cell phones and solar power will be used.

DOTD has concernes with the strategic aspects of site selection. One such concern includes the proximity of the transmitters and signs relative to the specific vicinity of interest or route of alternative passage through a construction zone. DOTD needs to be concerned with the placement of the transmitters in advance of a particular point of interest. Advance placement allows the messages to be heard and understood while alternative travel routes may be ascertained. An additional site selection concern of DOTD's is the availability of right-of-way for the placement of the transmitters. They may be placed outside of the road right-of-way. However, the placement of transmitters laterally off of the roadway decreases the longitudinal distance that the signal will be able to carry down the road corridor. Finally, safety must be considered in the placement of the transmitter and receiver hardware must be safety. All poles must be located outside of critical safety run-out areas.

A total of four transmitters were installed at the critical freeway entry points to metropolitan Baton Rouge. These exact sites were selected based on a joint site selection survey performed by the equipment manufacturer and DOTD. The primary considerations for the site locations were based on the need to provide visitor and traffic information to motorists entering Baton Rouge, as well as to inform them of Interstate Highway construction zones.

Each location was selected to provide advanced warning to drivers while also permitting the possibility of selecting an alternative route in the event of serious congestion delay. The location of the eastbound HAR transmitter provides an example of this philosophy. The west entry point transmitter was located within the interchange of Interstate 10 and Louisiana State Road 415. This location was selected because it was far enough outside the construction limits to allow for the broadcast of advanced warning information. It was also located so that its messages would reach drivers well in advance of the Mississippi River Bridge. In the event of a bridge closure or serious condition which would restrict flow on the bridge, a message could be broadcast to suggest an alternative route across the river, such as the US-190 Bridge over the Mississippi River north of the city. This concept of advanced warning was also carried out on the north, east, and south entry points to the metropolitan area.

The locations of all four of the Baton Rouge transmitters and their accompanying advance signs are shown in Figures 11 and 12. Figure 13 shows the same information for the Lake Charles HAR implementation project.

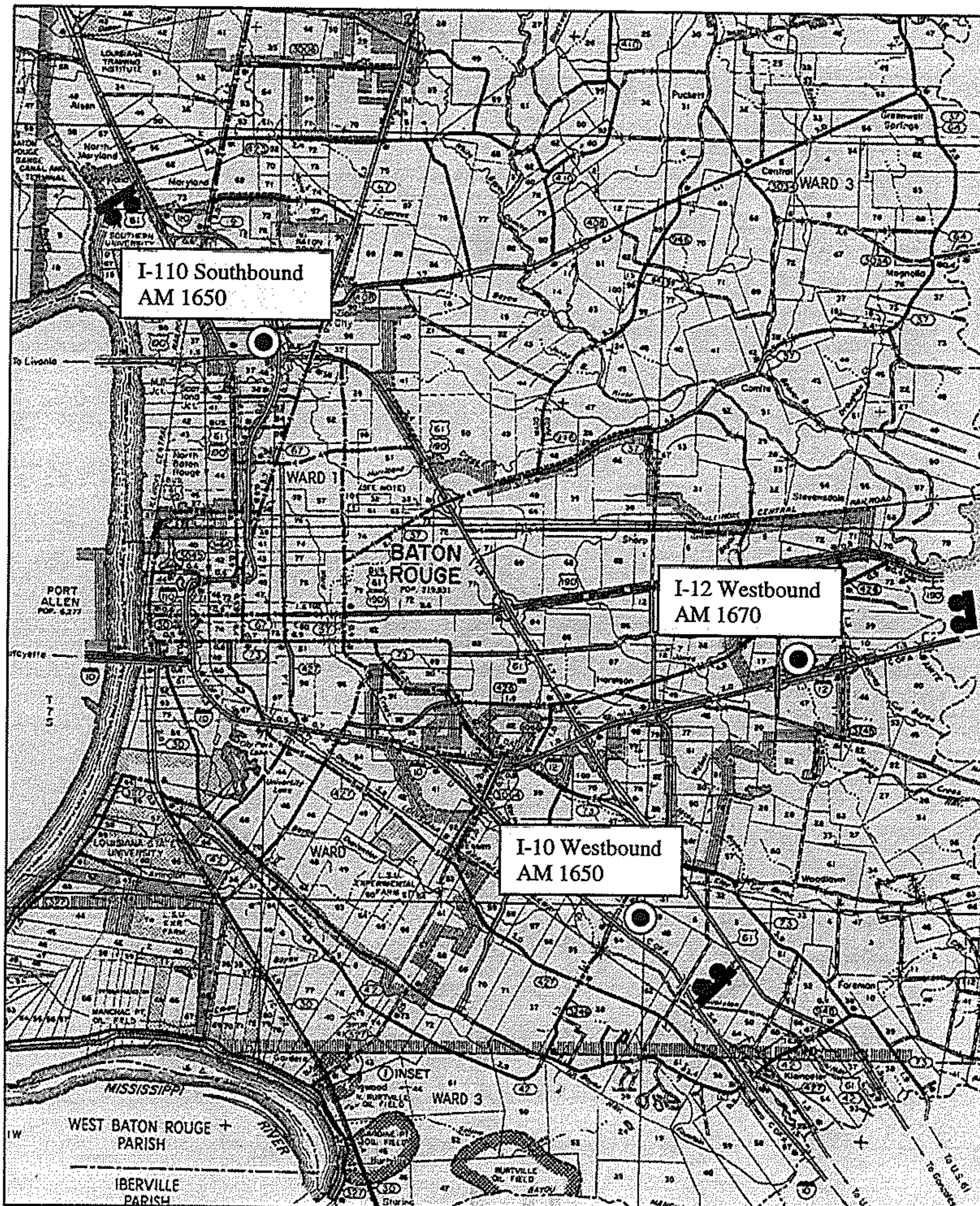

Figure 11
East Baton Rouge HAR project map

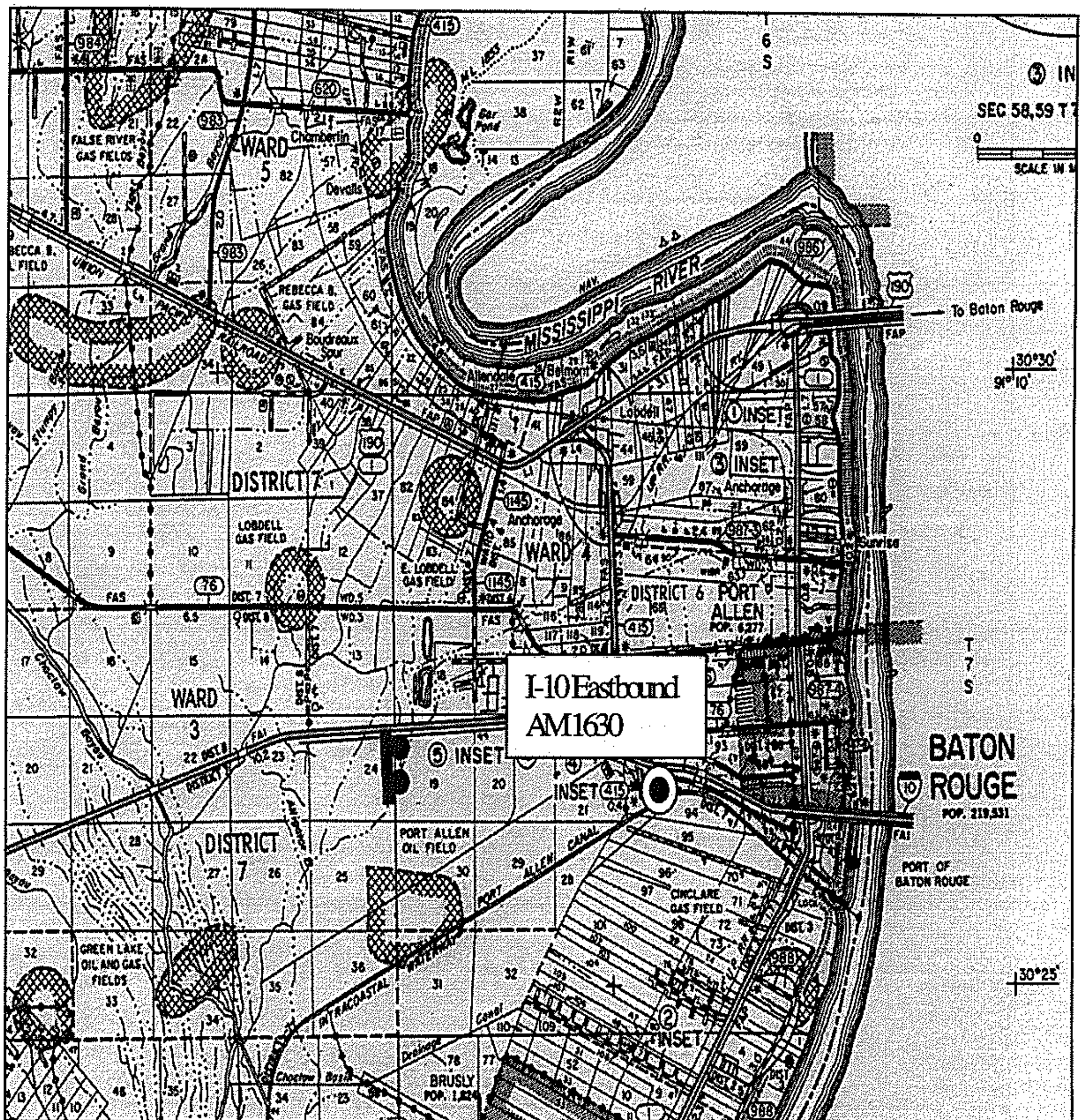

Figure 12
West Baton Rouge HAR project map

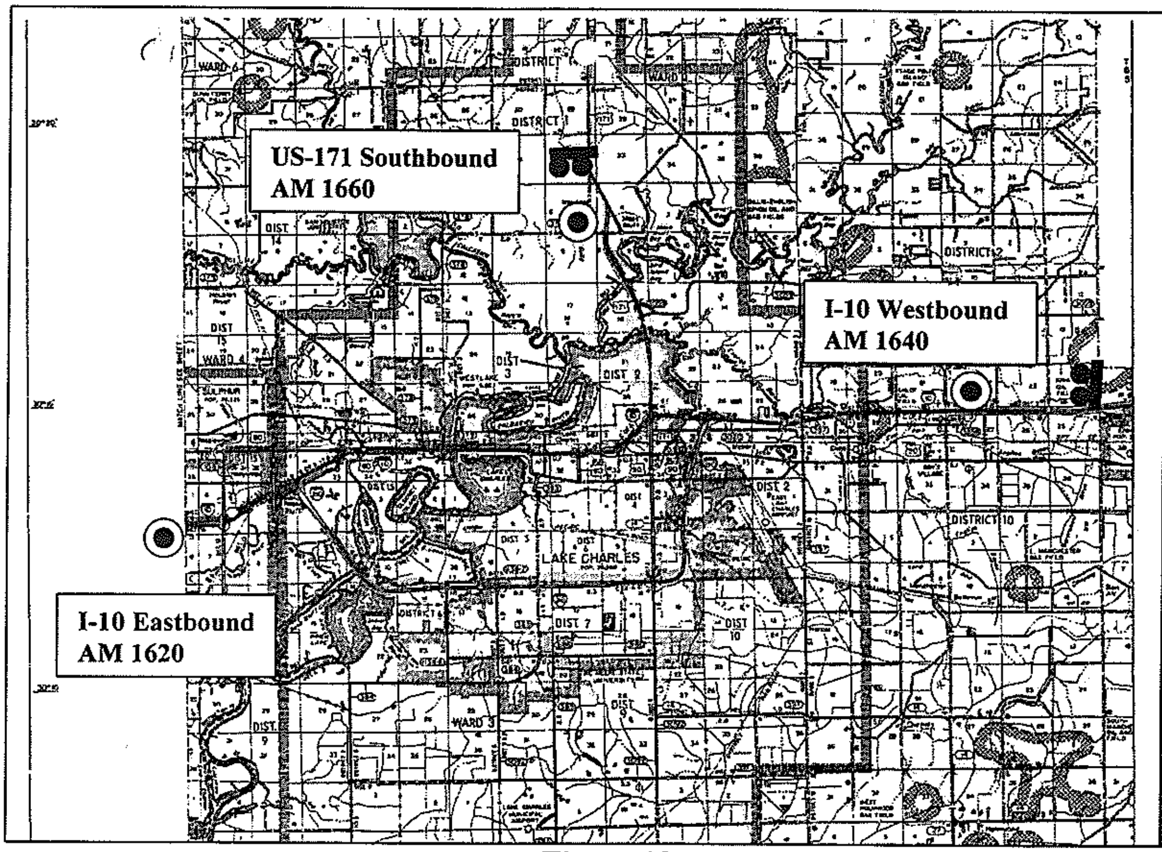

Figure 13
Lake Charles HAR project map

Installation Phase. The installation time and effort for any specific HAR system depends on a number of factors including the number of transmitters and the complexity of the system. Like most construction projects, an HAR installation (if it includes more than a single transmitter) takes place in a series of steps arranged to maximize labor efficiency. Most HAR installations also require the efforts of a local electrical contractor and utility service providers, in addition to DOTD and equipment supplier. Each of the critical steps is summarized below.

After temporary broadcast authority is granted by the FCC and the equipment is fabricated, assembled and shipped by the manufacturer, the installation process begins. As part of the equipment purchase, Highway Information Systems Dispatches an installation team to coordinate and complete the system installation. Prior to their arrival on-site, HIS technical staff coordinate the installation of a power pole and (if necessary) utility service connections.

The installation crew is composed of a one or two-man team. The supplier installation crew is responsible for guiding the installation of the grounding system (shown earlier in Figure 2) and the placement of a transmitter pole. To reduce costs, the pole and grounding system installation are sub-contracted to local contractors or (when possible) completed by highway department crews. Installation of HAR advance signs (shown earlier in Figure 4) and support posts is commonly sub-contracted or installed by highway department sign crews. Supplier crews typically install the flash activation system. Under special circumstances, an owner may wish to purchase and install the system on his own.

After these items are installed, the supplier crews complete all of the hardware installation and power connections. As shown in Figures 8 and 9, all transmitter hardware is enclosed in an environmentally sealed traffic controller cabinet. Hardware installation includes the mounting and configuration of the recorder/player, power source, audio and telephone connections, as well as the connection of these systems to external electrical (solar or AC) sources, surge suppressors, and telephone (cellular or land line) sources. Since most of the hardware is pre-assembled at the factory, the installation process is usually completed in a matter of hours for each transmitter station.

Post-Installation Phase. Once all hardware is assembled, mounted in the cabinet, and power connections are made, the transmitter is broadcast capable. However, prior to gaining full operational capability, several critical tasks remain which must also be completed. The accelerated project development schedule used for the Lake Charles installation, shown earlier in Table 2, lists the critical tasks of the post installation process. These begin with the testing of the transmitter and flash activators, continued through system training, and conclude with message recording and loading. As in the previous two phases, the post-installation phase also requires participation from both the equipment manufacturer and the owner (DOTD).

To speed up the project development schedule, many of the training and message development tasks can be completed prior to the post-installation phase. Table 2 illustrates a typical installation chronology similar to the one followed in Baton Rouge. However, based on the lessons learned in Baton Rouge, it was found that the post-installation tasks of message development and some training could be completed prior to installation. Specifically, the development of messages, selection of a reader, and recording of the messages can take place in advance of system activation. This pre-emptive work allows the stations to be "broadcast-ready" immediately after installation and was effective in Lake Charles. Using the Baton Rouge equipment, DOTD personnel from the Lake Charles District office were also trained on HAR system operation and maintenance months in advance of the Lake Charles installation.

Many post-installation tasks can not be completed until the transmitters are operational. These activities involve system testing and adjustment. The broadcast strength of HAR is limited (by the FCC) to a field strength of ten miliVolts per meter at one kilometer. As such, field strength measurements must be taken to verify this fact and letters of confirmation filed with the FCC. As in the cases of both Baton Rouge and Lake Charles, these items are typically completed by the HAR supplier. An additional item of testing after installation is the testing of the advance sign flash activation system.

Additional items in the post-installation list are tasks required for the integration of a computerized HAR control system. The computerized control system permits automated message scheduling and broadcast from a remote location without the need to dial the transmitter stations directly with a telephone. The computer control center can also be installed and partially configured prior to the installation of the system. However, all of the dial-up and message transfer protocols must be set after the transmitters are installed. It is anticipated that, in the future, Baton Rouge HAR computer control capabilities will reside at the traffic management center. Ultimately, control capability in Lake Charles is expected to wrest with the Calcasieu Parish Police Jury.

Equipment Issues

While HAR is a mature technology, the technology associated with many commercial HAR systems is evolving rapidly. As a result of this rapid and continuing and development, there remain a number of subtle system issues that must be dealt with during the installation of any new system. The HAR installation in Baton Rouge was an illustration of this case.

In Baton Rouge, DOTD was the beneficiary of new developments in HAR technology. The HAR equipment supplier, Highway Information System, Inc., had recently completed the development and testing for a new, more sophisticated, HAR system. The Black Max system (described in Section 4.3.2) featured significant improvements over prior transmitter stations. These included expanded memory storage, computer control capability, and a simplified rack mounted design for faster maintenance. As a good "public relations" and marketing gesture, HIS Inc. substituted their new system for the original equipment specified in the bid documents.

The Black Max offered a number of enhanced features over the base configuration. However, as with any a new technology, there were some technical issues that had to be worked out prior to smooth operation. While some of these technical issues appeared to be connected to the new Black Max system, several others were not. The following paragraphs detail some of the technical issues that had to be resolved before the Baton Rouge system could operate operating effectively. Among several positive outcomes resulting from the resolution of the technical difficulties in Baton Rouge, one was that none of these problems were encountered in the installation of the Lake Charles system.

One of the initial problems encountered involved power supply difficulties. These power supply problems were initially traced to the solar power panels. A field evaluation after installation showed that the installation of a single solar panel at each site was insufficient to fully charge and operate the system during certain weather conditions. To resolve this situation, the supplier installed a second solar collector panel at each of the four Baton Rouge transmitter stations. The dual panel solar collection system is illustrated in Figure 6 and, in increased detail, in Figure 14.

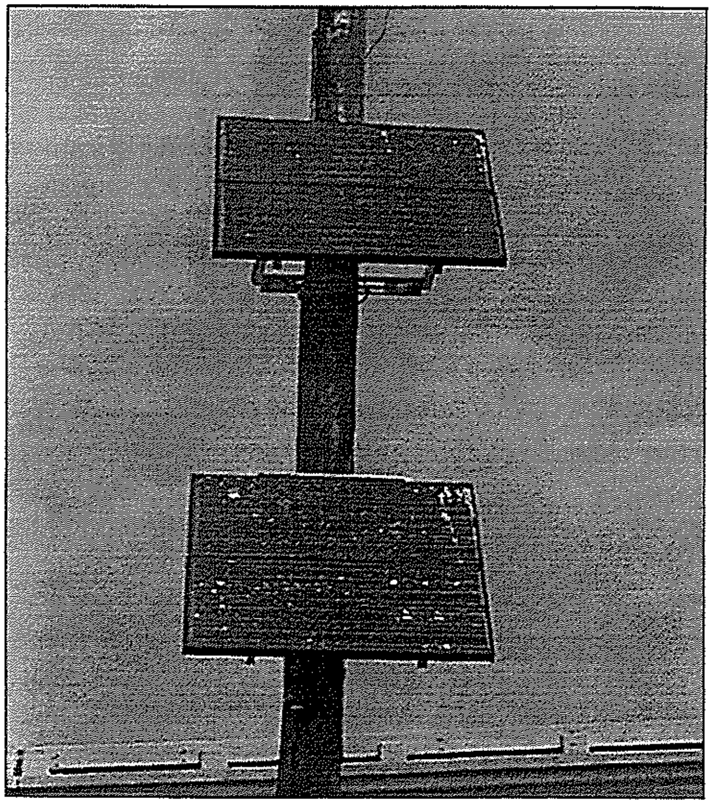

Figure 14
Double Solar Panels

After the installation of an additional solar power panel on each of the transmitters, three of the four stations began normal operation. However, difficulties were encountered at the 1620 AM (Airport) site during nighttime and limited sun operating periods. Initially, it was thought that these difficulties were related to power switching systems within the power supply circuit. After numerous field tests, it was decided that the battery vault would be excavated to inspect it for damage. Upon excavation, it was found that the battery chamber was flooded by groundwater infiltration into the "sealed" enclosure. The flooded conditions at the excavation scene are illustrated by the photograph in Figure 15. This particular battery vault, while designed to be environmentally sealed, was not properly assembled in the field. Given the common high ground water conditions frequently encountered in south Louisiana, it was concluded that future underground battery installations will need to be monitored closely to insure proper chamber seals.

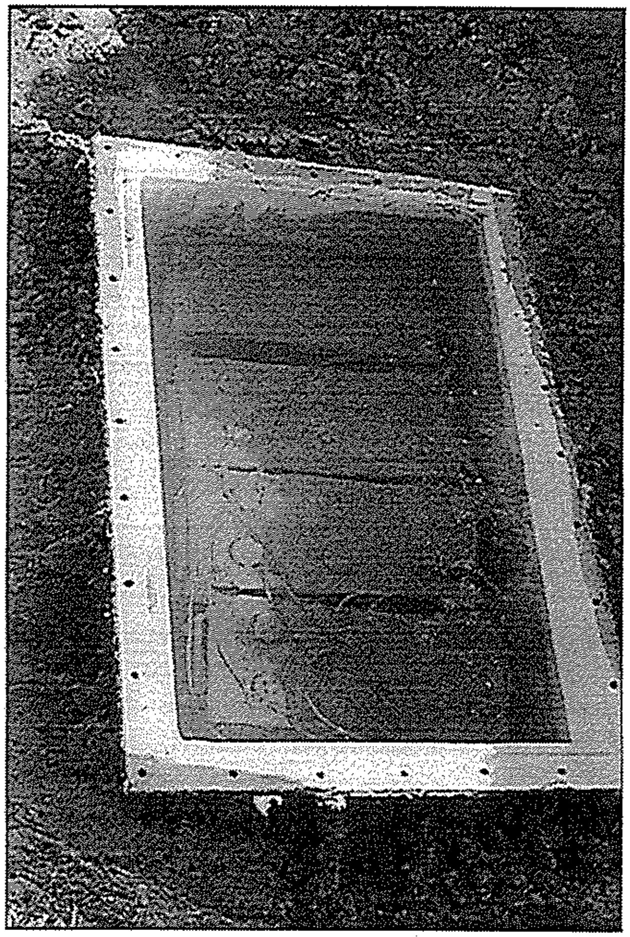

Figure 15
Flooded Battery Vault

Another operational difficulty that was encountered in Baton Rouge was associated with the telephone communication circuitry within the stations. While the process to resolve these problems was lengthy, and has not been fully resolved, the exact source of the problems and methods to address them have been identified. The specific problem surrounding the telephone operation of the equipment was traced to the "star" button on the phone.

Each key on a touch-tone telephone emits a specific set of tone frequencies. These tonal frequencies are used to identify the specific button that was pressed by the user. After exhaustive testing, it was determined that the tones generated by the star button on many cellular telephones is not always "pure." The digital nature of the HAR operating system requires the phone touch-tones to operate within a small range of variation.

The simplest way to eliminate these tonal problems is to use land-based wire telephone communication exclusively. Land lines assure tonal quality within the system. Since this was not an option in Baton Rouge, two solutions were suggested. The first suggestion, though not necessarily the most practical, was the use of tone generating devices. These devices are able to reliably produce pure telephone tones for use in operating the transmitters. Tonal generators are relatively inexpensive (approximately $4.00) and are pocket sized. The other option was to limit telephone operation to the use of higher quality cellular or hard wire telephones. It was also suggested that these phones be used with speaker phone options deactivated.

Two other minor technical situations were also encountered during the test phase of the Baton Rouge system. The first was a situation involving broadcast "bleed through" between the transmitter and the player/recorder. At times new, messages would pick–up background interference from the broadcast resulting in a degraded audio quality of the new messages. To temporarily resolve this problem, the transmitter was deactivated during the loading of new messages. However, this situation has now been permanently resolved through a reconfiguration of the system hardware by the manufacturer.

The final minor problem encountered in Baton Rouge was a fire inside the transmitter enclosure cabinet. The exact source of the fire has not been determined. However, most of the fire damage occurred to the cellular telephone system. Two possible scenarios have been suggested, although none have been confirmed. The first, and most likely, is a water leak and subsequent short circuit of electrical components. The enclosure cabinets are environmentally sealed against water leakage. However, an improper sealing of the cabinet door may have resulted in some leakage. The other possibility involves a lightening strike. It is unlikely that the fire was initiated by a lighting strike because there were no obvious signs of external or internal damage to the system components consistent with a strike. To address this problem, and reduce the likelihood of future similar occurrences, the telephone was replaced, the enclosure double checked and sealant added for additional waterproofing. Also, an in-line fuse was added to the phone circuit for additional surge protection.

Communications and Public Relations Issues

As a communication toll, one of the primary roles of HAR is to become a familiar and useful tool to the driving public. To most effectively serve motorists, the system must be promoted and accessible to as many people as possible. Its precise role and capabilities must also be realized so that unreasonable expectations are not placed on the system. The system in Baton Rouge, because of its novelty, proved to be a valuable learning tool to DOTD in of gaining knowledge on many of these important communications and public relations issues.

The initial reaction to the Baton Rouge HAR system from the public appeared to be positive. The system received considerable advanced publicity from local radio, television, and newspaper services, and the public appeared to support DOTD effort to provide traveler information to drivers in the vicinity of the I-10/I-12 construction zone. However, some of these opinions changed as misperceptions about the system's capabilities and DOTD's intentions spread.

The first public information about the Baton Rouge HAR system was spread through a front page article in the Sunday Advocate on September 28, 1997. The article (included as appendix B of this report) described the project and summarized the operational aspects, goals, and plans of the project. The article also included comments from Peter Allain of DOTD, John Spain of the CVB, and Brian Wolshon of LSU. Overall, the article was regarded as an accurate, positive, and helpful portrayal of the system and it objectives.

This initial Advocate article was followed, one week later, by an editorial article in the October 5, 1997 Sunday Advocate. The editorial was critical of DOTD, East Baton Rouge City/Parish DPW, and LSU and ability of each of these entities to maintain roads and reduce traffic congestion. The author of the article seemed to question the logic of installing highway-specific communication devices when, in his view, higher priority projects should be addressed.

This second, more critical article, lead to an increased level of misunderstanding and misinformation of the system. In the following week, the Baton Rouge HAR system became a topic of conversation on local radio talk shows. It was apparent that at least one commercial traffic reporting agency felt that it was not the place of a governmental agency to compete against private enterprises. To publicize these feelings, an open meeting was called in October 1997 to discuss issues related to the Baton Rouge HAR system.

While no representatives of DOTD, City/Parish, nor LSU attended the meeting, Mr. John Spain of the CVB spoke on behalf of those agencies. Mr. Spain attempted to address the concerns of the broadcasting groups. Based on the greatly reduced level of controversy following the meeting, it appeared that his efforts were successful.

Another instance of public relations/communication difficulty resulted from the active operation of the system during the initial installation and testing phase of the project. At several times during the early stages of the project, traffic was heavily congested within the construction zone. During these periods, the HAR broadcast did not include any timely traffic information. In one instance, a television news station reported on the lack of information. Thus, the system was portrayed as not able to provide timely and accurate traveler information to motorists in the vicinity of the I-10/I-12 construction zone.

The lack of information during this period was due to the lack of use protocol and training during the early phases of the project. It has since been recognized that HAR systems in Louisiana should not be promoted to the public (through advance information signs nor media) until the system is fully operational and all necessary personnel are trained in its use. If an HAR system must operate during the test phase, a temporary operating protocol must be established between its owners. Key issues that must be resolved to address short-term operation include broadcast responsibilities, training in the basic operation of the system, and a schedule for the completion of the installation/test phase.

In the case of Baton Rouge, training was provided to DOTD personnel from traffic services, construction, and communications. Responsibility for the broadcast of DOTD information, including that related to the construction, would belong to the DOTD Office of Communications during normal business hours. The recording and broadcast of construction-zone-specific information would be provided through the office of the construction engineer.

Based on the experience gained from these events in Baton Rouge, it is strongly recommended that DOTD appoint a project "champion" in all future HAR projects. This person would coordinate all installation and training activities and would be in charge of disseminating accurate information about the systems objectives and capabilities to the public. It is expected that the level of controversy will be reduced and level of public understanding increased with increased information.

System Operation

The operation of both the Baton Rouge and Lake Charles HAR systems has been limited during the experimental phases of the project. While they have not been used to their full capability, the systems have been able to offer useful information to drivers approaching the freeway construction zones. Furthermore, the experimental use period of the two systems has allowed the development of use protocols, message content guidelines, and allowed the joint operating agreements for the operation of HAR in Louisiana. The following sections describe DOTD's multi-jurisdictional operating philosophies and summarize the basic operational and broadcast message aspects system. They also summarize the development these use strategies and the important issues that lead to the development of these guidelines and operating agreements.

Operational Issues. The operation of a HAR involves a number of important issues that are critical to the effective operation of the system. Earlier it was stated that the three key criteria for messages, accuracy, timeliness, and usefulness must be met for effective and credible HAR broadcasts. To meet these three criteria, a system of information gathering/data collection, message development, and operational management must be in place. At the present time, the HAR systems in both Baton Rouge and Lake Charles lack these several or all of these critical elements.

During the experimental phase of operation, both systems are operating in a repeated static mode. No real-time or periodically updated information is being broadcast to drivers. The messages in Lake Charles are providing useful information to drivers approaching the I-10 construction zone from the north, east, and west. The scripts of the Lake Charles messages are included as appendix C of this report. However, these messages have been in a repeating mode since initial activation and will likely remain in this mode through the end of construction. The broadcasts in Baton Rouge are providing information primarily from the Baton Rouge Convention and Visitor's Bureau. The scripts of the Baton Rouge messages are included as appendix D of this report.

While both of these systems provide drivers with accurate and relatively useful information, the current state of operation does not permit timely broadcasts, nor does it provide traffic oriented information. The lack of effective up-to-date traffic information stems primarily from a lack of accurate information about the current traffic conditions. It is apparent that to resolve this situation a great deal more data collection and communication infrastructure is required.

A review of existing HAR systems around the country showed that the collection and analysis of up-to-date traffic information is a critical issue in the use HAR broadcasts for real-time traffic conditions. To broadcast current traffic information, traffic data collection infrastructure is vital. Based on the literature, traffic flow information is primarily collected through pavement loop detection and closed circuit television camera systems. These systems are usually linked to a traffic management center where traffic systems engineers and technicians are dedicated to the task of traffic management disseminate information through HAR broadcasts. While this type architecture does not presently exist in Louisiana, it is expected to be available after the construction of the Baton Rouge traffic management center.

Joint-Use Agreements. The joint operating agreements in the Louisiana HAR projects involved the participation of several local agencies with DOTD. The basic structure of the joint operating agreement in both Baton Rouge and Lake Charles stated that DOTD had primary responsibility of the purchase and installation of the systems. While freeway construction was in progress, DOTD would use the systems for the broadcast of construction-related traffic information. These routine traffic information messages would also incorporate special-attention information when required by special circumstances. Routine traffic information could also be pre-empted by local emergency broadcasts providing information on natural or man-made emergencies.

In Baton Rouge, the joint arrangement for the operation of the HAR system was created primarily between DOTD and the Baton Rouge Convention and Visitors Bureau (CVB). The CVB is a quasi-governmental agency in Baton Rouge and is funded primarily by Chamber of Commerce funds with the goal of attracting tourist visitors to the metropolitan area. The obvious interest in HAR is the attraction of pass-through tourist trade travelling to and from Texas, Florida, and the City of New Orleans. The CVB has close ties to the City of Baton

Rouge/Parish of East Baton Rouge government agencies, including the Department of Public Works, Office of Emergency Preparedness, and City Police and Fire Departments. An additional participant in the joint-operating agreement was the regional State Police post.

This joint-operating arrangement allowed DOTD to purchase three of the four transmitter stations with DOTD funds and a fourth to be purchased using CVB funds. DOTD took the responsibility of system implementation, including: utility coordination, site selection, sign fabrication, and broadcast operation. The arrangement was structured to allow broadcast priority to wrest with DOTD for purpose of construction information. Routine or non-emergency broadcast messages were composed primarily of tourist information accompanied by construction announcements for the Interstate reconstruction project. At the conclusion of the reconstruction project, the joint use agreement turns over the responsibility of the system to the City/Parish and CVB. While the transmitter stations will remain in DOTD right-of-way, responsibility for the message content, maintenance and operation will wrest with the local agencies.

In Lake Charles, a similar arrangement was created between DOTD and Calcasieu Parish. Like the Baton Rouge system, primary operating responsibility during the reconstruction of the interstate highways remained with DOTD. DOTD was also responsible for the purchase of all three transmitters, as well as the utility coordination, site selection, sign fabrication, and broadcast operation. However, in contrast to Baton Rouge, one of the three Lake Charles transmitters was located outside of DOTD right-of-way. This transmitter provided broadcast coverage to the north side of the metropolitan area. Due to inference from overhead electrical lines on DOTD right-of-way, the transmitter was installed on a Calcasieu Parish library site.

The Calcasieu Parish interest in HAR evolved from their need to alert residents and highway motorists to the occurrence of hazardous chemical discharges. As home to a large petrochemical industry, the Lake Charles area is subject to occasional chemical spills and vapor leaks that have the potential to create serious health risk. The Calcasieu Parish Police Jury and emergency preparedness personnel looked to HAR as an effective method for communicating these and weather related situations to drivers on I-10. The Parish authorities also have the long-term goal of installing a Parish wide communications network that will provide emergency weather and chemical spill broadcasts to the Parish residents. The DOTD HAR system is the first phase of this objective.

Officials from the Parish Police Jury will have right of access to broadcast emergency information when necessitated by emergency situations. However, the DOTD construction information will take precedence at all other times. Unlike Baton Rouge, no plans to include local tourism information have been made, although this may change in the future.

Integration of HAR and ITS Technologies

One of the long-term goals of HAR in Louisiana is to integrate it with advanced traffic management systems. The combined use of HAR with various traffic data collection, processing, and analysis systems will allow DOTD to assess traffic conditions and communicate important information to drivers. Ultimately, it is hoped that such analysis and communication activities can be accomplished in real-time and without the need for operator inference.

In addition to exploring promising avenues for the integration of HAR with existing or emerging ITS technologies for the purpose of real-time traffic data collection and analysis, this study also included an investigation of these systems. The investigation of data collection systems explored the development of collection technologies and the applicability of these types of system in Louisiana. This section also includes the framework of a real-time, automated system of integrated traffic data collection, analysis, and communication based on the existing Louisiana HAR systems.

ITS Traffic Data Collection Systems and Technologies

A number of vehicle detector technologies are available for traffic data collection. Each has its own strengths and weaknesses that make it more or less suited to a specific application. The selection of a specific detector technology depends upon a number of factors including, the nature of data to be collected, accuracy needed, number of lanes to be monitored, detector installation and maintenance costs involved. In addition to these factors, the detector must also be compatible with current and future traffic management infrastructure. Though nearly all of the available technologies reviewed satisfy basic traffic detection requirements, they must also be monitored because all technologies evolve with the needs of a particular site change.

Many existing vehicle detection systems provide information beyond the simple presence or non-presence of a vehicle. The ordering, placement, and combined use of detection systems can yield information on a variety of traffic parameters, such as vehicle counts, travel times, speeds, lane occupancy, etc.

Nearly all vehicle detection systems can be classified in to three broad categories. The categories are based on their placement with respect to road surface. They are: “overhead” detectors, “surface” detectors, and “subsurface” detectors. Overhead detection systems include systems mounted above the surface of the road. These typically include video and ultrasonic detectors mounted on signal mast arms and strain poles or on bridge structures. Surface detectors include systems that are placed directly on the roadway surface. These systems include traditional pneumatic tube counters and more advanced electronic strip detectors. Subsurface detection is accomplished through the placement of equipment under the roadway surface. Common subsurface detection technologies include inductive wire loops and magnetic micro-loops sensors. The following sections describe specific systems within each of the three traffic detection system categories. The report also provides specific details about the positive and negative characteristics of each.

Inductive Loop Detection. Inductive loop detectors are the most common subsurface traffic detection system in the United States. As a subsurface system, loop detectors are installed in road pavement and vehicle presence is identified by a change in inductance of the coils forming the loops. When properly installed, loop detectors are very durable and often last as long as the pavement in which they are placed. They are also commonly used in locations where it is not possible to place detectors over the surface.

The data measured by inductive loop detectors are vehicle passage, count and occupancy. The size of the detector is generally six feet by six feet and can detect vehicle presence in an area of nine feet by nine feet. The principle components of an inductive loop detector are one or more turns of insulated wire buried in a shallow cutout in the roadway. A lead-in cable connects the loops to a roadside pull box, then to the controller unit typically located in a traffic signal controller cabinet.

When a vehicle stops on or passes over the loop, its inductance is decreased. This inductance change sends a pulse signal to the controller, indicating the presence or passage of a vehicle. Improvements in digital signal processing have increased the accuracy of the measurements. The reliability of loops can be improved through careful installation. In some advanced detector processing systems, vehicle classification and fault detection can be performed by digitizing the detector output and feeding it to the microprocessor containing embedded signal processing algorithms. The response time of this detectors is as low as one millisecond.

One disadvantage in these types systems is their inability to directly measure speed. However, loop detectors can measure vehicle speed indirectly. Vehicle speed is calculated by assuming a common vehicle length and the resulting vehicle density.

Video Image Processor Detection. A video image processor (VIP) is a combination of software and hardware components that extract information from the output of an imaging sensor, usually a conventional TV camera or an infrared camera. The combination of imaging hardware, processor, and software form a VIP detector. The images obtained from the cameras are digitized using computers. The digitized images are studied for information about vehicle passage, presence, speed, length and lane change by passing them through a series of algorithms which detect the changes in the image background by comparing the contrast level of the pixels that make up the image.

Most current VIP's analyze imagery transmitted to them at full frame rates of 30 frames per second. VIP's tolerate an oblique view of the highway if the mounting height is about 45 to

50 feet (ft). For lower heights in the vicinity of 18 to 25 feet, a mounting location centered over the area of interest may be required. However, the lower the camera, the greater the error when making speed measurements since the measurement error is proportional to the vehicle height divided by the camera mounting height. VIP's are also sensitive to motion and may be adversely effected by strong winds.

Current VIP's sense motorcycles, subcompact cars and larger motorized vehicles and can provide collection capability over three or more lanes. VIP detectors are capable of measuring speeds between zero and 160 miles per hour (mph). Vehicle counts are generally accurate to within more or less five percent. Their detection range is eight meters to 20 meters for applications requiring traffic data close to the mounting location, and a minimum of 92 meters (300 feet.) for adaptive, real time signal control at city intersections, as well as for freeway incident detection and traffic management. VIP detector functions without operator adjustments during setup or normal operations to account for day-night transitions, shadows, reflections from vehicle or pavement during rain and weather changes. Operations, such as initialization, repositioning of field of view and resetting the vehicle detection zone, require human intervention. A single VIP can replace several in-ground inductive loops. This provides area-wide detection of vehicles and the promise of lower maintenance costs. Table 4 presents the different aspects of upstream and downstream viewing.

Table 4
Characteristics in Upstream and Downstream Viewing

Upstream Viewing	Downstream Viewing
• Headlight blooming and glare from wet pavement.	• Camera concealed from drivers.
• More blockage from tall trucks.	• More information from tail lights available for breaking indication, vehicle classification and turning movement identification.
• With infrared imagery, there is no difference in information obtained from headlights or taillights when a tracking algorithm is used.	• With visible imagery, more information is available to a tracking algorithm from tail light viewing.

Combined results of clear and inclement weather show vehicle volume, speed and occupancy measurement accuracy in excess of 95 percent using a single detection zone.

Ultrasonic Detection. Ultrasonic detectors sense the presence of vehicular traffic through the use of pulsed ultrasonic energy. In addition to vehicle presence, these detectors are also able to measure traffic volume and speed. Vehicle speeds are measured using the time taken for the pulse to leave the detector, reflect from a surface and return to the detector. from the object. The range from detector to the road surface is reduced when a vehicle enters the field of view. This reduction of range produces a vehicle detection signal. Typically, these devices are installed at signalized intersections.

Ultrasonic detectors are typically unsuitable for long-range surveillance applications that are commonly required for freeway detection. The advantages of ultrasonic detectors are relative compactness in size, easy installation and their high economical value when used to measure range in order to provide vehicle passage and presence data. However, they are also sensitive to temperature, and air turbulence can reduce the accuracy of the data collected.

Presence-only and speed-measuring ultrasonic detectors are currently available commercially. They enable direct measurements of vehicle presence, occupancy and speed, depending on the detector type. The preferred viewing configurations for range measuring (presence) ultrasonic detectors are downward and side viewing. Speed-measuring ultrasonic detectors are forward-looking, facing approaching traffic. These detectors can detect subcompact and large vehicles. Presence-measuring ultrasonic detectors transmit a pulse waveform, while speed-measuring ones uses continuous wave. The frequencies transmitted are between 25 kHz and 50 kHz. Beam-width are designed to detect vehicles in single lane. Typical beam-widths establish patterns on the road surface that are four feet wide at the specified mounting height. These detectors will detect two separate vehicles when they are 1.5 to 10 meters apart, depending upon detector design and vehicle speeds, as well as the detection range is eight to twenty meters for vehicle counting, occupancy and speed measurements. Speed measuring detectors currently respond to vehicles travelling between 2.5 and 75mph.

Microwave Radar Detection. Two types of microwave radar are used for traffic surveillance applications. The first uses the Doppler principle to measure the speed of vehicles by transmitting electromagnetic energy at a constant frequency. The difference in frequency between transmitted and received signals is proportional to the speed of the vehicle. Since the frequency difference does not change for a stopped vehicle, this type of detector is not suitable for determining vehicular presence.

The second type of microwave radar is called frequency modulated continuous wave (FMCW). This form of radar detection can sense also stopped vehicles. This type of detector uses an electromagnetic frequency that is changed continuously with time. When vehicles pass between two internal markers of known distances from radar, the time taken by vehicle to travel such distance is stored and then used to calculate the vehicular speed.

The microwave wavelength is typically between one and 30 centimeters, corresponding to a frequency range of 1GHz to 30GHz. Microwave radar transmits energy towards an area of roadway from an antenna, mounted overhead, and illuminates approaching or departing traffic, or in a side looking configuration that views traffic across several lanes. When a vehicle passes through the beam, a portion of the transmitted energy is reflected back to the antenna. The energy then enters a receiver, where the detection is made. By appropriate processing of the information in the received energy, direct measurements of vehicle presence, occupancy and speed can be obtained.

Microwave detectors can sense subcompact cars and larger motorized vehicles. The antenna pattern may be designed to illuminate single or multiple traffic lanes. Some multiple lane applications such as vehicle counting require signal processing to differentiate between vehicles detected in the different lanes. The incidence angle of these detectors can be adjusted in both the azimuth and elevation planes. The response time of current models is less than 0.3 seconds. The upper limit may be unacceptable for counting high-speed vehicles in high-density traffic. The minimum vehicle speed measured is approximately three miles per hour for Doppler detectors, and the maximum is 65mph to greater than 85mph, depending on the model. Microwave Doppler detectors measure speed within approximately two to three miles per hour. Presence microwave detectors can detect stopped vehicles too, and its speed measurement accuracy is approximately ten percent.

Presence-measuring radar can also be used to control left-turn signals and monitor traffic queues. Radar that detects moving vehicles from the Doppler frequency can be used to measure vehicular speed on both arterial streets and freeways.

Infrared Detection. Infrared detection (IR) devices are constructed in both active and passive models. Active infrared detectors transmit a beam of light and detect the portion that is reflected back to the detector by the objects in the field of view. They provide presence, speed, count and occupancy data in day and night operations. When a laser diode is used as the transmitting energy source, the detector can also provide vehicle profile and shape data, and hence, be used for vehicle classification.

Active infrared detectors are operational within ten seconds after application of power. The response time of laser diode type IR detectors is approximately ten milliseconds when a vehicle enters or leaves the field of regard. Currently available detectors measure speeds between 0 to more than 80mph. The calculated accuracy for vehicle speed measurement is ±1mph up to 70mph. These detectors can be designed with different fields of view when required for stop-line and for presence in intersection approach. The units accommodate mounting heights between 15 and 30 feet.

Passive IR detectors sense objects through the energy that they emit. Commercially available passive detection systems have a single detector element that provides signals giving vehicle presence, occupancy and count. Response time for these detectors is 500 milliseconds.

State-of-art passive IR detectors detect stopped vehicles and those travelling at freeway speeds. An operator-controlled sensitivity adjustment may be required to give adequate dynamic range to detect vehicles under the anticipated weather conditions. Passive IR detectors have a detection range between 6.4 to 15 meters.

IR detection systems also have several disadvantages that could significantly impact their effectiveness in certain types of weather conditions. Atmospheric conditions may scatter the transmitted beam and received energy. Glint from sunlight may cause unwanted and confusing signals. The amount of energy reaching the focal plane is also sensitive to water from fog, haze, rain, and snow as well as smoke, and dust. These airborne particles cause scattering and often absorb energy that would otherwise be detected.

Passive Acoustic Detection. Passive acoustic detection systems detect vehicles through the sounds produced by vehicles. The sound energy produced by the vehicles is converted to a vehicular presence signal.

Vehicular traffic produces acoustic energy or audible sounds from a variety of sources within each vehicle and from the interaction of the vehicle's tires with the road. The radiated sound acts as a beacon signal containing information that can be extracted by roadside acoustic energy detectors. Arrays of passive acoustic microphones provide a spatial detection zone from which sounds are continuously detected and processed from a specific location along the highway. Sounds from other locations are rejected. Presence acoustic arrays can replace magnetic induction loops by providing vehicle presence outputs in the form of contact closures. Using this output, a traffic signal controller can calculate various traffic flow measures, such as volume, occupancy and average speed.

Magnetic Detection. Magnetic detectors indicate the presence of a metallic object by the disruption it causes in an induced or natural magnetic field. These detectors may be active devices (magnetometers) or passive devices (magnetic detectors). Magnetometers are generally buried about one to 1.5 feet below the road surface. Some magnetic detectors are subsurface mounted and others are mounted flush with the roadway. The primary use of these detectors is to supplement or enhance the data from other types of traffic detectors, although they are sometimes used in stand-alone applications.

Magnetometers are devices exited with an electrical current in windings around a magnetic core material. They measure the passage of a vehicle and give continuous output as long as the vehicle occupies the zone of detection. They are used where the point or small-area location of a vehicle is required, such as on bridge decks and viaducts where inductive loops are disrupted by the steel support structure or can weaken the existing structure. The Self-Powered Vehicle Detector (SPVD) is a magnetometer detector with a self-contained battery and transmitter that broadcasts passage or presence information to a receiver that can be located remotely in a controller cabinet. The current SPVD model fits into a cylindrical hole six inches in diameter and 22 inches deep. Their suitability for permanent installation is a function of traffic volume and battery type.

Passive magnetic detectors sense perturbations in the earth's magnetic flux that are produced when a vehicle passes over the detection zone. They require some minimum vehicle speed for detection, usually three to five miles per hour, and hence, cannot be used as presence detector. The two types of passive detectors differ only in their installation and size. The first type is two inches in diameter and 20 inches long. The second type is three by five by twenty inches in dimension and is encased in aluminum housing and flush mounted with roadway. Passive magnetic detectors are responsive to flux changes over a large area, covering up-to three lanes. If the lanes are considerably wider than 12 feet, several detectors may be used to get response from small vehicles and motorcycles.

A Framework for the Real-Time Collection, Analysis, and Communication of Traffic Information

One of the stated long-term goals of the HAR experimentation project was to examine systems and procedures to integrate HAR with other ITS technologies for automated collection, processing, and communication of traffic information. Based on the knowledge gained during the completion of this project, a framework has been developed. The system, if and when completed, could be housed at a traffic operations/management center (such as the one under development in Baton Rouge) where it could be further integrated with other systems such as dynamic message signing.

The primary objectives of the system would be to design, construct, test and implement a system that would collect traffic flow information, analyze this information, create a traffic advisory message based on these conditions, and broadcast the message to motorists. The system would also be designed so that the collection, analysis, and communication functions will be accomplished in real-time, independent of the need for operator intervention.

To limit the development and testing effort, the proposed system would employ proven, "off-the-shelf," commercially available technology whenever possible. Many of the key elements of the proposed system, such as advanced traffic detectors and highway advisory radio (HAR), are currently in use by highway agencies throughout the United States. The proposed project will combine these existing technologies with the new systems developed for this project that will link and enhance the utility of each of these separate elements. The system would also be designed to be compatible with future DOTD system and hardware and would reside within the urban traffic management centers planned for the major urban centers of Louisiana.

The development of hardware interfaces and analysis software to link the various traffic detection and communication components is the critical link of the proposed system. The system would be based on plan described below.

Traffic flow information would be collected using one or more of the detection technologies described previously. Multiple data feeds would be used to receive simultaneous video detector input from multiple locations. It is anticipated that the input detection information would include constantly updated traffic speed, flow, and volume information.

Pertinent features of the traffic flow data would be analyzed by an external, computer-based analysis program that will analyze the traffic data to identify critical levels of speed and flow. The program will be configured to query the traffic flow data files on a constant basis, searching for values that exceed predetermined threshold values of speed and flow. For example, traffic conditions could be assumed to be "congested" when the program identifies average operating speeds of five miles per hour or less for more than three consecutive one-minute intervals. When the threshold value is exceeded, a call to the congestion notification message library would be invoked.

Once it has been determined that a traffic advisory broadcast is warranted, operation of the system would move to an automated message assembly and retrieval system. A library of pre-recorded traffic advisory messages and message segments would be created in digital format and stored in the memory of a standard personal computer (PC). The messages will contain standard notification language in a "fill-in-the-blank" format for the insertion of time, location, and event specific information. A complete message would be assembled from these pre-recorded message segments and stored as a single computer file.

For example, if the control program detected reduced operating speeds at a select location, the program could be configured to retrieve the following message segments:

1. A time/date stamp (ex. <u>Wednesday, June 28th</u> at <u>4:05p.m.</u>)
2. The nature of the situation (ex. Operating speeds of <u>8 mph</u> on <u>E.B. I-10</u> at <u>College Drive</u>)
3. A suggested action (ex. Be prepared to slow down or watch for back-ups)

Note: The underlined information would be inserted into the message "blanks."

Along with its capability to analyze data, store, retrieve, and assemble messages, the analysis software would also have the ability to transfer traffic advisory messages to a highway advisory radio transmitter. The information transfer system would be designed to determine which transmitter location is applicable to the message, to dial the appropriate transmitter phone number, and access code tones, as well as to input the traffic advisory message and initiate the broadcast. The entire process would be machine-based and independent of operator interference, unless manually overridden. Advisory broadcasts would continue until a change in traffic conditions warrant termination of the broadcast or the creation of a new message based on different traffic conditions.

The system could also be configured to dial and activate the roadside HAR sign beacons and dynamic message signs. The dial-up system will incorporate the capability to determine which sign is associated with a particular transmitter and dial the flash activator for that sign. The beacon setting (flash or shut-down mode) would be implemented based on the prevailing traffic conditions. Dynamic traffic sign messages would also be invoked using a pre-designated message data-base configured to be consistent with the current HAR broadcast message.

CONCLUSIONS

Literature Review

The review of highway advisory radio literature has shown that HAR is a relatively mature technology with an extensive record of past trials. Implementation projects have taken place throughout the United States spanning the past 50 years. The results of prior HAR test projects have been varied. Some agencies have rejected the use of HAR as an effective means of traffic communication because of the need to dedicate personnel for the collection, analysis, and dissemination of information. Other agencies have felt that the FCC restrictions placed on the HAR systems do not allow them to communicate in a useful way to motorists.

The extensive use of HAR has lead to the development of a set of procedures for the operation of such systems. The general procedures have evolved based on the experiences of individual highway agencies and are not the result of any coordinated effort on the part of a national group to suggest protocols or operating standards for such systems. Each state or local highway agency has adapted some aspects of prior tests to fit a particular need.

Another result of the continuing development in highway advisory radio systems has been development of specific-use commercial HAR systems. Currently, two manufacturers of radio system specifically marketed to HAR systems are available. While the broadcast capabilities of the two competing systems are comparable (due in part to the FFC rules governing HAR), the technical features of the system vary significantly. Each manufacturer offers a range of options and technical capabilities that can be added to a particular system. These options include features like computer message control and synchronized broadcasting from multiple transmitter stations.

With the potential for large-scale implementation of HAR systems in many of major metropolitan areas of the country, many operators of commercial radio stations have the perception that public owned and operated radio stations could pose a threat to their commercial ventures. Given this feeling, and the need to more uniformly govern HAR in the United States, the Federal Communications Commission has adopted many rules and regulations to govern the technical and operational elements of HAR. These include limitations placed on the broadcast power of the stations and guidelines for composition of information presented over the broadcasts. The literature review also showed how HAR has the potential to be useful when combined with other ITS systems.

Louisiana Projects

The HAR implementation project was very valuable to DOTD in many respects. It represented the department's first attempt to deploy a radio communications system dedicated solely to highway traveler information in the state of Louisiana. As such, a considerable amount of valuable information was gained. One of the most important pieces of information gained was regarding the implementation process for HAR (licensing, installation, power supply, hardware, signal propagation, and-on features (computer control, cell phone), cost,). Another was the insight gained into the many pitfalls associated with the technology (solar vs. electrical, signal interference, intra-agency cooperation, unit installation (flooded battery vault, low power solar collectors).

One of the main problems associated with HAR is collecting and disseminating accurate and pertinent travel information to be broadcast. During the test phase of the HAR implementation in Baton Rouge, the system was never used to disseminate any real-time or near real-time information to drivers. This was primarily due to the lack of a data collection infrastructure used to generate travel time information. Emerging technologies, such as wide area traffic surveillance and data collection, must be incorporated to give timely and accurate travel information.

The installation of a highway advisory radio system in Baton Rouge was limited by the ability of DOTD to collect real-time traffic flow information. A highway advisory radio system does not function at its best unless it is integrated into a real-time traffic data collection, analysis, and communication system. Highway advisory radio is the last piece of this data collection and information dissemination system. The utility of a highway advisory radio system is directly influenced by how well the "front-end" elements of the system operate.

RECOMMENDATIONS

Many of the questions associated with the purchase, installation, and operation of HAR in Louisiana were answered through the course of this project. However, many critical questions and issues remain. Using the knowledge and experience gained from the installation of two separate HAR projects, several recommendations regarding the short and long-term use of HAR operation are made in the this section. Specifically, these recommendations involve the creation of operational protocols to (from DOTD's perspective) best use the system.

Many of the operational issues involved in the project were resolved through verbal agreements between the joint-use partners (discussed in Section 3.5.1) and through the creation of a Joint-Use Agreement Memorandum of Understanding (shown in appendix E). This document provided the documentation that permitted a coordinated multi-jurisdictional use of the Baton Rouge and Lake Charles systems. However, this document, on its own may not be sufficient to address all potential situations. As such, several recommendations regarding the formal and in-formal operating procedures have been offered to manage the operation of the system.

The following paragraphs address these critical operational questions:

- **Who should have access to the HAR system?**

The Memorandum of Understanding gave the primary responsibility for system operation and programming to the Baton Rouge Convention and Visitor's Bureau. The CVB takes the lead role for all HAR scheduling and broadcasting modifications during regular business hours. During non-business hours (i.e., nights, weekends, and holidays), the primary responsibility for HAR operation resides with the Baton Rouge Police Department Communications Center. Such an arrangement allows the system to be attended on a 24 hour per day, seven day per week basis. DOTD also has access to the system on a continuous basis to alert drivers of urgent traffic information. Ultimately, the control of Baton Rouge HAR should be integrated in to the Baton Rouge traffic management center. The Lake Charles joint-use arrangement allows DOTD to maintain full control over the system until the reconstruction of I-10 through Lake Charles is completed in 2001.

- **Who should be responsible for the collection and processing of traffic/construction information for the system?**

Prior to beginning the project, it was concluded that the system would not be able to incorporate real-time or near real-time traffic congestion information to drivers. As such, the goal of the system was to provide construction traffic information to pass-through drivers in the vicinity both construction zones. With the reduced role of the system, the need to collect and analyze traffic flow information was eliminated. However, the need to provide construction zone traffic detour and lane shift/closure information remains. In Baton Rouge, construction information should be provided by the district construction engineer.

In Lake Charles the operational aspects of the system were somewhat different. It appears that construction information was coordinated through the combined efforts of the construction project engineer and the district traffic engineer in an effective manner. Based on verbal agreements with local agencies, it has been agreed that emergency information not related to construction project (i.e., industrial spills, weather alerts, etc.) would be coordinated through the police (or police jury) dispatch centers. Additional participation during major civil emergencies, such as hurricane evacuations, would come from local Offices of Emergency Preparedness.

- **How should messages be prioritized and organized within the broadcast rotation?**

Through informal verbal operating agreements, it has been decided that message prioritization should be accommodated on a case-by-case basis. It was recognized by all project participants that emergency information of vital importance shall always receive the highest priority and will play until the situation is resolved. Such was the case during Hurricane George in October 1998. During this period, the HAR transmitter at I-10 and Siegen Lane in Baton Rouge was sent to broadcast freeway closure information for three days as the New Orleans metropolitan area was evacuated further inland.

The prioritization on non-emergency messages differed between Baton Rouge and Lake Charles. In Lake Charles, DOTD maintained exclusive control of all non-emergency broadcasts. While some traveler amenity information was given, the predominant message content involved construction information. In Baton Rouge, the content of messages was predominantly visitor information. Due to the increased level of monetary and personnel participation from the CVB in Baton Rouge, the content issue was less clearly defined. Therefore, discussions of issues pertaining to the amount of traffic and construction information versus tourist/visitor information have taken place. Due to the infrequency and lack of significant traffic flow pattern changes, it was agreed that the message content of the existing messages was acceptable to DOTD.

The organization of the message play lists and storage of pre-recorded messages within the transmitter memory has been formally allocated to the system users. It is expected that the memory space allocation will reduce the potential for inadvertent erasing of existing messages and the scheduling of incorrect message play lists. The message numbers have been reserved in blocks for use by DOTD, police department, CVB, and OEP. The space allocation scheme the recorder/player memory is shown in Table 5.

Table 5
Recorder/Player Message and Play List Designations

User	Message/Play List Numbers	Message Numbers
Department of Transportation & Development	1 – 4	1 - 40
Convention and Visitors Bureau	5 – 8	41 – 60
Baton Rouge Police Department	9 –12	61 – 80
Office of Emergency Preparedness	13 – 16	81 – 99
Reserved (Flash Activation Codes)	---	100, 101
Unreserved (Open Use)	17 – 19	102 – 221, 223 - 256
Reserved (Open Emergency Use)	20	222

The Department of Transportation and Development have reserved message numbers one through 40 for use. Currently, pre-recorded messages reside in message numbers one through eight. Message list numbers five through 16 and message numbers 41 through 99 have been reserved for the various participating agencies. Message list numbers 17 through 19 and message numbers 102 through 221 and 223 through 256 are unreserved and are open to use by any of the user groups. Since these allocation spaces are open and are subject to inadvertent erasing and overwriting, it is recommended that they be used for temporary operation.

Table 5 also shows all of the reserved message and list numbers. Message numbers 100 and 101 have been reserved for the DTMF codes to activate and deactivate the advance sign flashers. Message number 20 and message number 222 have been reserved for emergency use. These numbers are designated for "broadcast immediately" messages. Unlike messages 100 and 101, these numbers are open to any user and are expected to be overwritten and erased as needed.

- **Who should schedule and record messages for broadcast?**

As in the case of the message prioritization process, the scheduling of messages should be accommodated on a case-by-case basis. While no formal agreements have been made by the participating agencies, it has been verbally agreed that emergency information has the highest scheduling priority. Such messages will be scheduled to play on an immediate basis and will play until the situation is resolved. During non-emergency periods, it is expected that an agency wishing to air information will contact the other participants and discuss the nature and length of need for a particular broadcast.

The recording of specific messages, emergency or non-emergency, is the responsibility of each agency. For long term non-emergency messages, it is suggested that the participating agencies utilize a "professional", or dedicated, voice to maintain consistency and credibility throughout all broadcasts.

- **How long should messages play?**

The length of broadcast for non-emergency messages should also be determined on a case-by-case basis. No formal agreements regarding the duration of message broadcast project participants have been made. As in the prior cases, however, emergency information has the highest priority and these messages were to be scheduled to broadcast exclusively, until the emergency has been resolved.
Issues of broadcast duration during non-emergency periods should be addressed through direct contact between all interested parties. Two of the four agencies (OEP and Baton Rouge P.D.) are likely to broadcast on an emergency basis only. Therefore, they are not anticipated to require agreement between the project partners. DOTD and CVB currently have verbal agreements that allow a combination of traffic and tourist-oriented information to be broadcast during non-critical construction periods. However, in the case of long-term (several days to a week) periods of disruptive construction activity, the DOTD information will take broadcast precedence and will dominate the transmissions.

- **How long should a message or play-list be?**

All users should assume that the broadcast range of the two Louisiana HAR systems is limited to approximately four miles. In reality, this range is considerably greater during most operating conditions. It is recommended that messages be heard twice, in their entirety, so drivers are able to comprehend the full content of the broadcast. If it is assumed that vehicles will be traveling at approximately the posted speed limit (60 mph), we can also assume that, under low range broadcast conditions, drivers will be able to hear the HAR broadcast for about four minutes.

Based on these assumptions, it is recommended that message play lists be limited to a maximum of two minutes in length. At this length, drivers will be able hear two complete cycles of a broadcast.

- **What type of information should a message contain?**

The exact type of information that a broadcast message should contain depends on the nature (emergency or non-emergency) of environment within the broadcast vicinity. Section 3.5.2 of this report addresses the specific elements of both types of messages, as well the other key elements of special condition messages. The accompanying manufacturer-supplied reference guides and bibliographical references to this study also identify other key message elements for special situations.

ACRONYMS, ABBREVIATIONS, & SYMBOLS

AC:	Alternating Current
AM:	Amplitude Modulation
CVB:	Convention and Visitors Bureau
DC:	Direct Current
DMS:	Dynamic Message Sign
DOT:	Department of Transportation
DOTD:	Louisiana Department of Transportation and Development
DPW:	Department of Public Works
DSRC:	Dedicated Short Range Communications
DTMF:	Dual Tone Multiple Frequency
E.B.:	East Bound
FCC:	Federal Communications Commission
FDOT:	Florida Department of Transportation
FHWA:	Federal Highway Administration
FM:	Frequency Modulation
FMCW:	Frequency modulated continuous wave
ft:	foot (1 ft = 0.3048m)
GHz:	Giga-Hertz
HAR:	Highway Advisory Radio
HIS:	Highway Information Systems Dispatches
IDOT:	Illinois Department of Transportation
IR:	Infrared
ITS:	Intelligent Transportation Systems
kHz:	kilo-Hertz
km:	kilometer (1km = 0.6215 mph)
LA:	Louisiana
LSU:	Louisiana State University
LTRC:	Louisiana Transportation Research Center
MDOT:	Michigan Department of Transportation
MnDOT:	Minnesota Department of Transportation
NCDOT	North Carolina Department of Transportation
mi:	mile (1 mi = 1.609 km)
mph:	miles per hour (1 mph = 1.609 km/h)
mV/meter	miliVolt/meter
NWS:	US National Weather Channel
OEP:	Office of Emergency Preparedness
PC:	Personal computer
PD:	Police Department
RC:	Remote Control
S.B.:	South Bound
SPVD:	Self-Power Vehicle Detector

TIS:	Travelers Information Stations
TV:	Television
VDOT:	Virginia Department of Transportation
VIP:	Video image processor
VMS:	Variable Message Sign

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