To the Graduate Council:

I am submitting herewith a thesis written by Eugene J. Baksa, Jr., entitled "A Review and Analysis of the Use of Radio Communications by Rural Transportation Programs in Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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We have read this thesis and recommend its acceptance:

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Accepted for the Council:

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The Graduate School

A REVIEW AND ANALYSIS OF THE USE OF RADIO COMMUNICATIONS BY RURAL TRANSPORTATION PROGRAMS IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Eugene J. Baksa, Jr.

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ABSTRACT

A radio communication system has increasingly become a component of rural transportation programs across the country. However, unlike urban dial-a-ride programs, rural transportation programs typically require that passengers schedule their trips at least 24-hours in advance. The 24-hour advance call-in operating strategy would appear to eliminate the need for a radio communication system.

To this point, questions have arisen as to how radio systems are used in rural transportation programs, what type of radio systems are appropriate, and what are the benefits of these radio systems? In the effort to arrive at answers to these questions, a review of basic radio operation, terminology and types of systems available was performed. This basic information provided the groundwork of understanding for case studies of three rural transportation programs which are utilizing radio communications in Tennessee. Two of these programs use two-way radio equipment and the third used citizens band (CB) radio equipment. In the investigation of these transportaion programs, several different uses of the radio communication systems were documented. Utilizing this information, a detailed analysis of radio use was performed on one of the transportation programs studied. Survey forms were developed that would measure both quantitative and qualitative benefits of the use of the radio system. Data collected over a two week period was expanded to yearly totals and a benefit-cost analysis was performed.

The review of the basics of radio communications and the case studies of the three rural transportation programs utilizing radio systems, indicate that two-way radio equipment is the most appropriate for

rural transportation programs. Citizens band radio equipment was found to be generally inadequate. Of the two-way radio systems available, the mobile relay system was found to be the most appropriate for the multi-county rural transportation programs studied.

Several beneficial functions that result from the use of the radio systems were identified. Among those that could be quantified in terms of miles saved were trip cancellations and additional trips not scheduled the previous day. Qualitative benefits include radio calls involving emergencies, requests for directions and other drivers assistance, and managerial monitoring of the transportation program.

The benefit-cost ratio of 0.90 indicates that the identified quantitative benefits of two-way radio systems do not alone justify their cost. However, the intangible benefits of radio systems noted along with the underlying assumptions made in establishing the quantified benefits must be reviewed before a decision is made regarding the purchase of a radio system. In many cases, these "intangibles" can provide the additional benefits required to justify the use of a two-way radio system in rural transportation.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

As the cost of owning and operating a private automobile has increased recently, so has the interest in and use of the various forms of public transportation. The majority of the effort and money spent on the improvement of the various modes of public transportation has been directed towards urban areas throughout the country. It is in these areas that an improvement in services provided by a public transportation system will affect the greatest number of people. In the past few years though, there has been an increased recognition of the transportation problems faced by those persons residing in rural areas. As state governments increase their efforts to provide a high degree of statewide mobility, numerous rural transportation programs are being initiated. These programs typically operate on a county or regional basis and utilize anywhere from 2 to 20 or more vehicles. Most systems are run on a 24-hour or longer advance passenger call-in basis to provide time for trip scheduling. This requirement is needed to assure that adequate and efficient service is provided in rural areas where long trip distances are typical.

Although most rural transportation systems do not operate on a direct demand-responsive basis, many include some form of communication between drivers and the base or dispatch station. Typically, a two-way radio system is seen as a basic component of the overall transportation program. With the 24-hour advance reservation required by the majority of the rural transportation programs, the question arises: What contribution is made by a communication program? Also, what radio systems are best-suited for rural transportation purposes?

The use of two-way radio systems in urban demand-responsive transportation programs can be justified simply by the nature and scope of their operations. That is, the areas served are relatively small; thus, the trips are shorter, on the average, than in the rural systems. This allows for the dispatching by radio of the vehicles in the system to the persons requesting rides, usually within 20 to 40 minutes of the request. In rural transportation programs, which exhibit longer trip distances and somewhat different operating strategies, it is expected that the communications systems are being utilized in a different fashion.

As more rural transportation programs are initiated, they are increasingly requesting public financing for items such as two-way radio systems. Therefore, it is essential that questions concerning the need for and use of such systems, along with the type of systems that are most appropriate, be addressed.

The objectives of this report are to identify the ways in which radio communication systems are used in the operation of rural transportation programs and to determine what effect the radio has on the efficiency, productivity, cost and management of these programs. This will be accomplished by investigating the operation of various rural public transportation programs within the state of Tennessee. To help facilitate this discussion, a brief review of basic radio operation, terminology and types of systems available is included. This information was gathered by conducting interviews with representatives of the various manufacturers who have set up several of the communication systems for rural transportation in Tennessee. These interviews also help to identify the manufacturer's role in establishing a radio communication system.

Through the assimilation of the knowledge gained from the experiences of those who are currently involved with operating radio communication systems in rural public transportation, it is possible to identify considerations which should be made when establishing such systems. Thus, by fulfilling the objectives, this report provides guidelines for rural transportation program directors who are considering the purchase of a radio system.

CHAPTER II

BASIC TWO-WAY RADIO COMMUNICATION

Introduction

Basic two-way radio communication as covered in this report consists of three distinct communication linkages.[1] These linkages are formed through the interaction of two basic groups found in a rural transportation program: the operators of the mobile units or drivers and the dispatchers. The different linkages that exist as shown in Figure 1 are Mobile-Dispatch, Mobile-Mobile and Dispatch-Dispatch. By far the most important of these is the Mobile-Dispatch linkage because it is the one most likely to affect the operation of the transportation program. Mobile-Dispatch linkages are primarily those which alter a driver's schedule such as additional trip requests, trip cancellations and adjusted pickup times.

Although it is possible to affect the operation of a transportation program by utilizing the Mobile-Dispatch and other communication linkages, the extent of their usefulness depends upon the adequacy of the radio system providing the linkages. Therefore, in order to discuss the various radio systems available and the effect that the communication linkages have on the transportation system, it is useful to review the basics of radio and radio systems operation.

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[1] One-way communication between dispatcher and driver by means of a paging device is not considered practical for rural transportation purposes. The use of these devices requires that the driver call in to the dispatching source to receive instructions. In rural areas, locating a public telephone may result in a great deal of time loss and extra mileage. In addition, there is no way for the dispatcher to know if a transmitted tone is being received until the driver is in a position to respond.

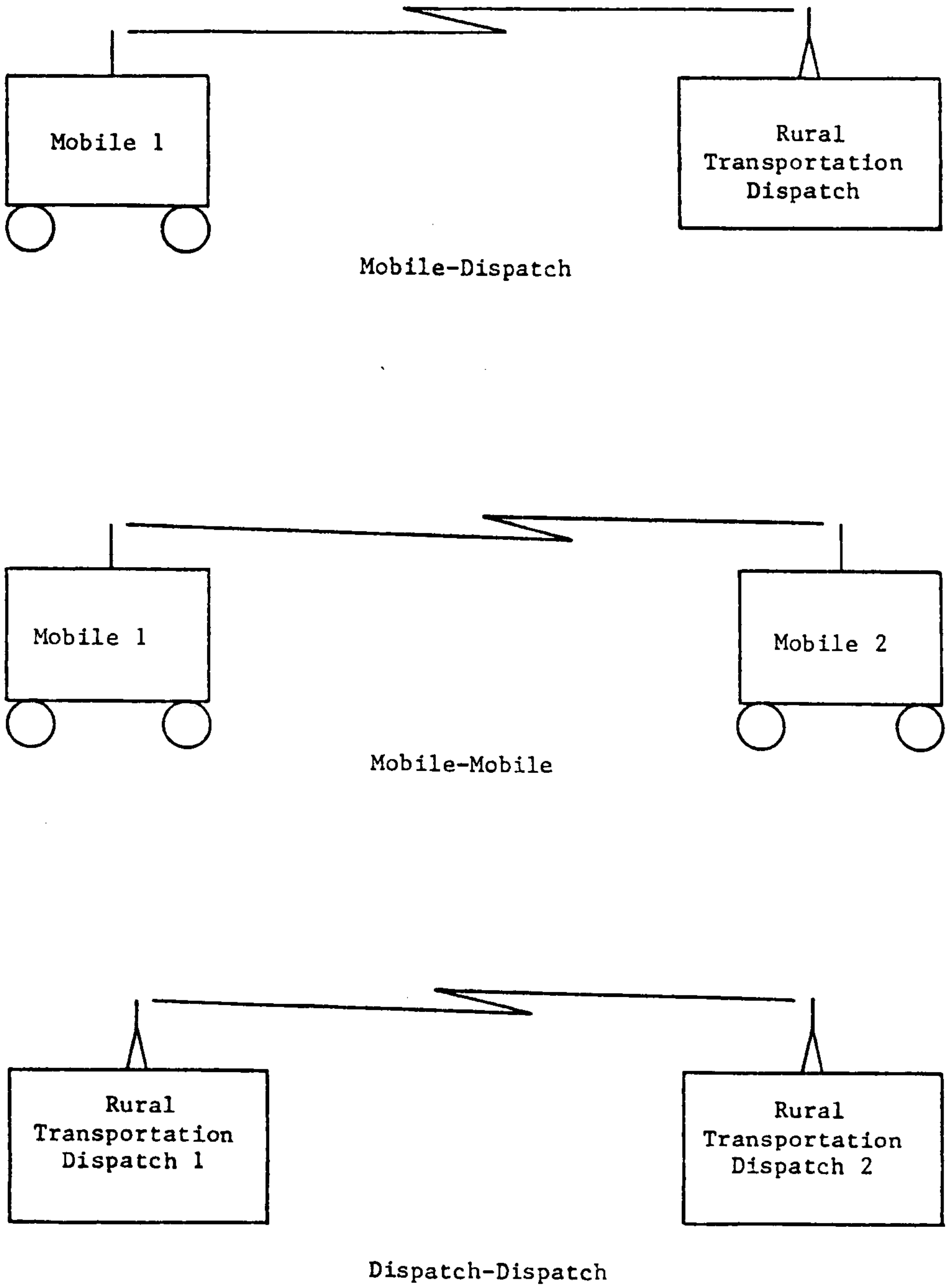

FIGURE 1

RURAL TRANSPORTATION COMMUNICATION LINKAGES

The Carrier Wave

Radio is a means of communication that relies on the use of electromagnetic waves, called carrier waves, which are sent through space at the speed of light. The carrier wave itself does not represent the information to be transmitted (i.e., verbal message), rather it is used as a form of transportation for the message. This "transporter" role is necessary due to the fact that the information to be transmitted by radio usually occurs at fairly low frequencies which are extremely difficult to send over great distances. Therefore, the standard procedure is to combine the signal containing the information (verbal message) with the much higher frequency (and more easily transmitted) carrier wave in a process called modulation. Modulation is simply the process of altering the carrier wave in some fashion so that the alteration can be detected and deciphered by a receiver. The entire radio communication process, then, consists of the modulation of the carrier wave by the information signal, the transmission of the wave, the reception of the desired modulated wave (i.e., rejecting all irrelevant radio waves), the detection of the alterations made to the carrier wave and, finally, the conversion of these alterations into a usable information signal. There are seven basic components in every radio system which carry out this process.

Radio Components

A complete system for two-way radio communication includes: (1) a microphone for converting the information to be transmitted into an electrical signal; (2) a modulator for combining the information- containing signal with a radio-frequency carrier wave; (3) a transmitting antenna for launching the radio wave into space; (4) a receiving antenna for intercepting part of the transmitted wave; (5) a frequency-selective amplifier for screening out all frequencies but that of the transmitted carrier wave and for amplifying that signal; (6) a demodulator or detector for reconverting the information on the transmitted wave to a usable electric signal; and (7) a loudspeaker for converting the electric signal into sound. The process for transmitting a message is illustrated in Figure 2.

In most radio systems the capability to transmit and receive messages is incorporated into each radio, i.e., a single radio is composed of components 1, 2, 5, 6, 7 and is attached to one antenna serving as both components 3 and 4. These radios are often called "tranceivers" as they combine the transmitter an receiver. A typical rural transportation system might utilize three radios an antennas. One radio with antenna would be in a fixed location and would act as the home base or dispatch station. The two remaining radios and antennas would be installed in the vehicles used for transportation and are usually referred to as mobile units.

The life expectancy of the radio units varies. A dispatch unit can be expected to operate without problems for at least 10 years and usually longer. Due to the jarring and jostling experienced during their operation, mobile units typically have a shorter life, ranging up to 10 years.

A prime requirement of a system such as described above is that it provide sufficient coverage with minimum interference in the operation area to complete radio transmissions between the dispatch station and

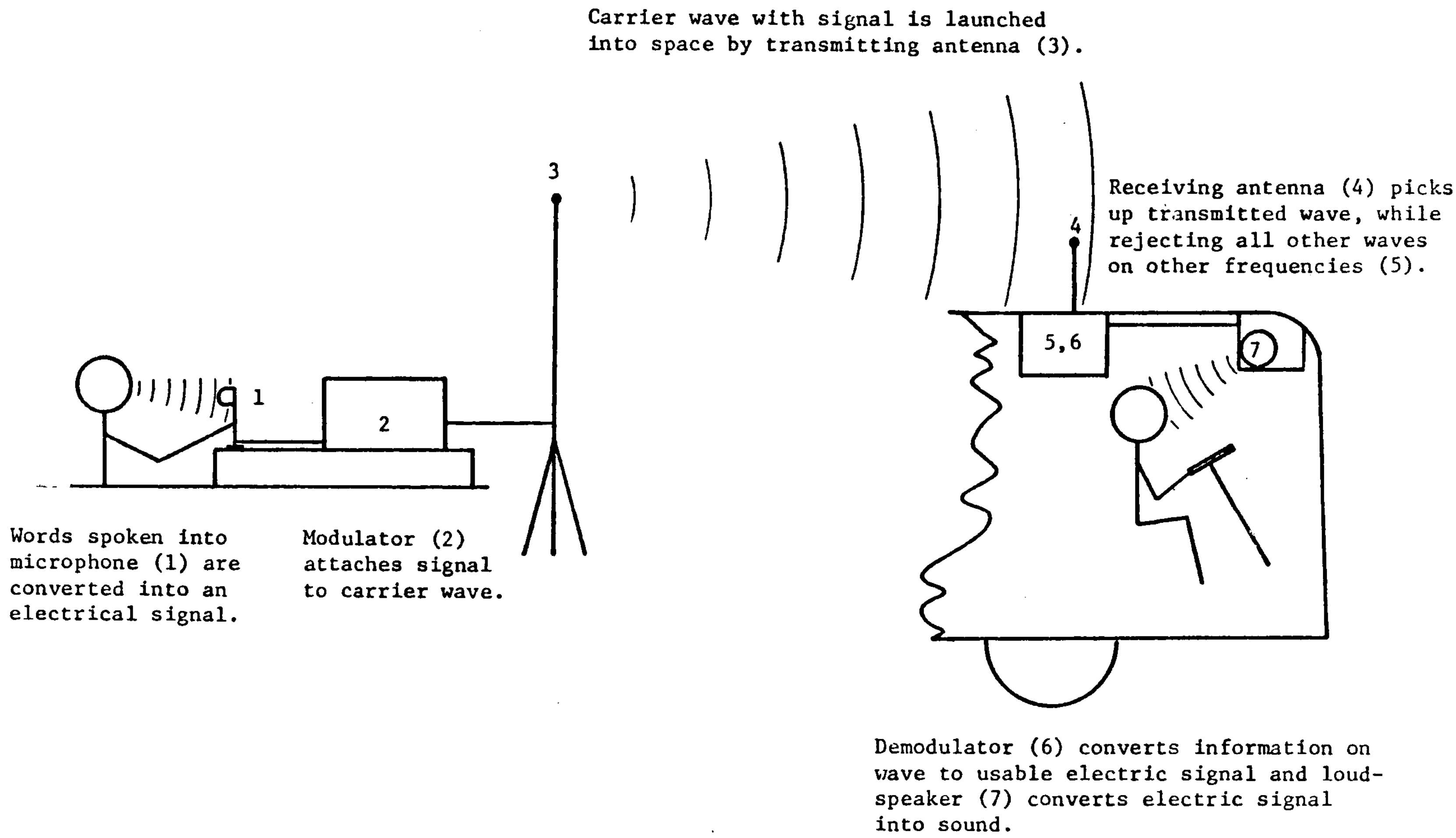

FIGURE 2

BASIC COMPONENTS OF A RADIO SYSTEM

mobile units. Three factors which have a great effect upon coverage and interference are frequency selection, antenna location and power output.

Radio Frequency

There are two major issues to be discussed with respect to radio frequencies. The first involves the selection of the radio frequency band from which is chosen the individual frequency for the system and which is related to the coverage and interference experienced in the system. The second, more of an administrative issue, involves the process of securing the desired frequency and a license to operate from the Federal Communications Commission (FCC).[1] Licensing is discussed in the section regarding the vendor's role.

A radio frequency band is simply a range of frequencies designated for a particular use by the FCC. Rural transportation currently has four bands available from which individual frequencies for radio systems can be selected. These bands are not limited to use by rural transportation alone and are designated as local government bands, available to any local government unit for land mobile radio operation. Each of the four bands has characteristics which result in various operating advantages and disadvantages, particularly in the areas of coverage and interference. The four bands are typically referred to as

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[1]The FCC is an independent agency responsible for the regulation of all civil uses of radio and for all uses of radio by local and state governments. The regulation of radio by the commission includes processing license applications, assigning frequencies and limiting power output. These are the major areas affecting the acquisition of a two-way radio system for rural transportation purposes.

Low Band-Very High Frequency (VHF), High Band-VHF, Ultra-High Frequency (UHF) and 800 MHz.

Low Band-VHF is not used very frequently as its disadvantages outweigh its advantages. The major disadvantages of Low Band-VHF are the extreme difficulty in securing an available frequency and once secured, the frequencies experience a great deal of interference and skip.[1] The band was the principal band used for two-way radio systems in the early days of radio. Hence, over the years it has become very crowded and unused frequencies are hard to obtain. Interference can be caused by electrical storms, large industrial complexes, factories, etc. Skip also may cause a large amount of interference.

The advantage of Low Band-VHF is that it provides the greatest range of the available bands. It is particularly advantageous for mobile-mobile communications because of the limited range provided by the mobile antennas. However, the attribute is limited to the areas with relatively level terrain.

The majority of rural transportation programs in Tennessee utilize frequencies falling in the High Band-VHF. High Band-VHF frequencies provide medium range, are not limited to strictly level terrain and offer less noise and skip interference than Low Band-VHF. These are the band's principal advantages. The major disadvantage is that the

[1] Skip is caused by radio waves bouncing off the ionosphere and traveling great distances. This causes problems when a radio, hundreds of miles away and operating on the same frequency, transmits a signal that travels into a system, inadvertently canceling out any signals being transmitted at the same time.

popularity of the band has caused difficulty in finding a frequency which is not being used in the area.

Frequencies falling in the UHF band have a limited range but experience less noise than the preceding bands and virtually no skip. Most urban transit systems utilize frequencies from the UHF band for these reasons and because UHF frequencies have the ability to "fill in" around large buildings. Radio systems utilizing UHF frequencies require more expensive components than those using the previously mentioned frequency bands because of added sophistication. A major advantage of the UHF band is that it is fairly easy to secure frequencies because of its relative low usage.

A relatively new band allocated by the FCC for local government use, the 800 MHz band, exhibits operating characteristics similar to those of the UHF band. Its major advantage is easily obtainable frequencies because of its newness. The major disadvantage is that sophisticated and expensive equipment is required to operate in this band. It is predicted that, as the other bands become more crowded and radio technology advances, this band will be increasingly utilized.

Antennas

As described earlier, an antenna is designed to launch an electromagnetic wave into space and/or to intercept a fraction of a transmitted wave for reception. The ability to complete the transmission process depends in a large part on the relative locations of the transmitting and receiving antennas. In a land mobile radio system, the most critical antenna location is that of the base or dispatch unit.

For those systems utilizing a remote base antenna or repeater, it is this antenna's location which is most critical. The reason that these locations are so important is that mobile units have no fixed location and, therefore, are dependent on the base antenna to be in position to transmit a signal to the mobile unit's antenna and to receive a signal from the mobile unit, regardless of the mobile unit's location in the system area. A typical location for a base antenna would be at the highest point in or near the system area. This location would prevent the signal from being obstructed by most of the surrounding terrain and would allow the signal to "fill in" behind an obstruction more readily than if the antenna was located in a low area. Most base or remote base antennas are located in such a manner that they provide at least 90 percent coverage. Providing this coverage may require the use of more than one antenna and is achieved by having a complete study of the geography of the area made by the vendor. Those isolated areas without radio coverage, called deadspots, usually are not critical. Rather, they are a nuisance around which the system can, and usually does, adapt.

The relative height of the antenna also has a great effect upon the range of the radio system. As a rule of thumb, the effective radiated power (ERP) of the station and, reciprocally, its ability to receive weak signals are proportional to the square of the antenna height. If the antenna height is doubled the ERP is quadrupled; tripling the antenna height results in an ERP multiplied nine times. Typically, the increase in ERP is designated by the amount of gain provided by an antenna. In most cases, providing an antenna with a high gain is more economical than increasing the power of the unit to achieve the same ERP.

Power Output

The power or wattage of the individual radios in the system can also have an effect on the range. Generally, all other factors being the same, a higher wattage radio will be able to deliver a receivable message at greater distance than a lower wattage radio. However, it is not always advantageous to obtain the highest wattage radio available. Considerations must be made of the frequency band selected, the type and location of antenna utilized and the proximity of any other radio system using the same frequency. This last point is important, as problems with interference can occur which could be avoided if a radio system is not overpowered. Thought must be given so as to obtain an efficient system which will usually cost less and still provide the necessary range and coverage desired.

CHAPTER III

RADIO SYSTEMS AVAILABLE TO RURAL TRANSPORTATION

There are basically three different system designs for land mobile radio which are applicable to rural transportation. Two of these systems are used extensively in rural transportation programs while the other is not. All have some characteristics that may be particularly attractive in a rural transportation system. The systems, which will be discussed in order of increasing sophistication, are One Frequency Simplex, Two Frequency Simplex and Mobile Relay Systems.

One Frequency Simplex System

The one frequency simplex system is the least complicated of the radio systems available. For rural transportation use, the one frequency simplex system is most applicable in those small programs covering one or two counties and operating a limited number of vehicles. The operation of the system is illustrated in Figure 3. Mobile and dispatch units both receive and transmit on the same frequency (F1). Interference problems arise when units attempt to transmit simultaneously. In small systems, this should not pose too many problems as long as simple courtesy is observed.

With this type of system, the location of the base or dispatch station is a critical factor. The location is critical because the base antenna must provide the necessary coverage for the entire area without the benefits of using remote relay devices (repeaters). Therefore, the location of the base antenna, along with the selection of the frequency band, determines the coverage area.

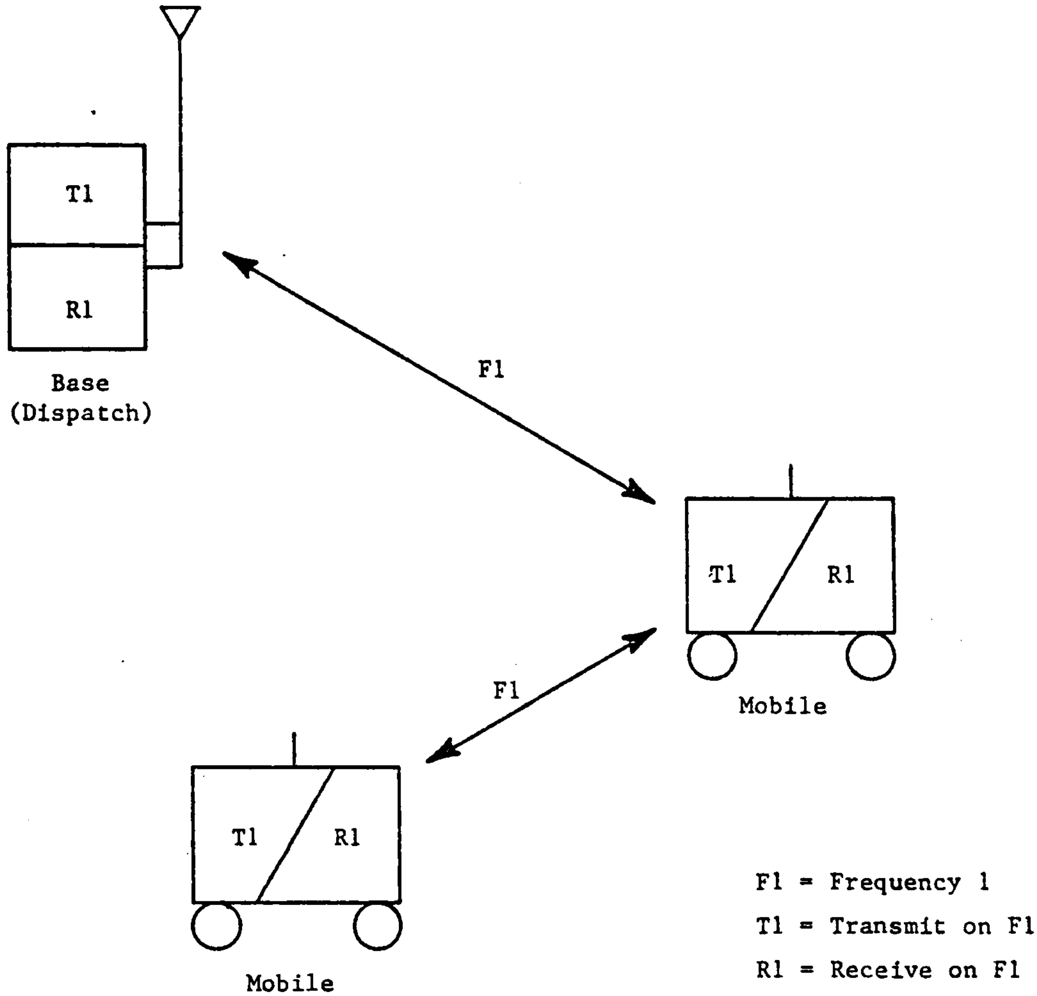


FIGURE 3

ONE FREQUENCY SIMPLEX SYSTEM

There are two means of connecting the base radio unit with the base antenna. One involves locating the antenna in the immediate vicinity of the base station and connecting the two with a short section of coaxial cable. The second method is useful for cases where it is impractical to locate the base station at the optimum site for the antenna. Such a situation would occur where a town (a likely spot for a base station) is located in a county split by a rugged mountain ridge (a likely spot for an antenna, but not a base station). To connect a base station located in the town to an antenna located on the ridge with coaxial cable could prove to be very costly, depending upon the distance. The usual procedure is to lease existing telephone lines at a rate of $6 to $7 per mile per month. A problem with this procedure is that, in addition to the monthly charge, there is a danger of losing access to the telephone lines if the telephone company requires additional capacity to provide service to its customers.

If it is possible to locate the base antenna close to the base station while providing coverage to the desired area, the one frequency simplex system would prove to be the most economical and efficient system to use for rural transportation purposes. With this system, as the name suggests, one frequency is used to both transmit and receive signals. Because every radio in the system receives messages on the same frequency, all transmissions made in the system are heard by all drivers and dispatchers. In a small system (one to five vehicles) utilizing only one dispatcher, this would not cause too many problems with the canceling out of signals caused by simultaneous transmission or with saturation of the channel with calls. However, in a large system (five or more vehicles) with more than one dispatcher, the large number of calls made on the same frequency could result in many cancellations and a possible overload of the system. If this situation occurs, it may be necessary to install an encoder-decoder device to each radio in the system.

An encoder-decoder is a device that emits a tone, usually subaudible, when a transmission is made which corresponds to a particular base or dispatch antenna. Any signal not accompanied by the correct tone is ignored by that receiver. A simple analogy is that of the key and a locked door. If one thinks of the tone as being the key to a door (receiver), then only the correct key (tone) can open the door and, thus, complete the transmission. It is possible, then, to have all vehicles which are assigned to a particular dispatcher "tuned in" to only that dispatcher's antenna, thus reducing the total amount of calls received by any single radio in the system. There is still the possibility that two or more mobile units which are assigned to a particular dispatch station will transmit simultaneously, thus causing interference rendering the transmissions unintelligible. However, because of the fewer number of units utilizing a particular tone, these instances can be greatly reduced. In addition, each mobile unit in the system can be assigned a separate tone which would enable the dispatcher to communicate with an individual driver by selecting the appropriate tone. The driver would hear only those calls directed to him or her, thus eliminating the distractions caused by reception of irrelevant transmissions. The use of encoder-decoder devices also can be useful for managerial purposes where privacy is important, such as communications between manager and driver concerning the driver's performance.

The various encoder-decoder devices available range in price from $120 to $300 per radio unit. Generally, the more expensive the device, the greater the capabilities and sophistication.

The major advantages of the one frequency simplex system are the simplicity of its operation and the ability to use basic low-cost equipment. Mobile units used in the various two-way systems do not differ tremendously in cost, although those used in a one frequency simplex system are somewhat lower in price. Variations in cost are found primarily between "top of the line" equipment versus other models with prices ranging from $600 to $2,000 per unit. The costs for base or dispatch units show greater variations between systems. Typically, dispatch units in a one frequency simplex system are lower in price.

The advantage of low cost is lost when the program requires the use of a large number of dispatch stations. This cost advantage is lost because in the more sophisticated systems, a repeater can take the place of many of the fairly high-cost base antennas required for the simplex system. The price for a dispatch station (radio and antenna) in a simplex system runs about $2,500 to $3,000 while in a mobile relay system the dispatch station may cost approximately $1,500, with an added cost of about $3,000 to $5,000 for each repeater. Therefore, a one frequency simplex system which consists of four dispatch stations costing $2,750 each ($11,000 total) could be replaced by a more economical mobile relay system with four dispatch stations at $1,500 each and one repeater at $4,000 ($10,000 total).

The lack of flexibility in antenna location is the major disadvantage and can lead to additional costs if it is necessary to locate the antenna a great distance away from the base station.

Two Frequency Simplex System

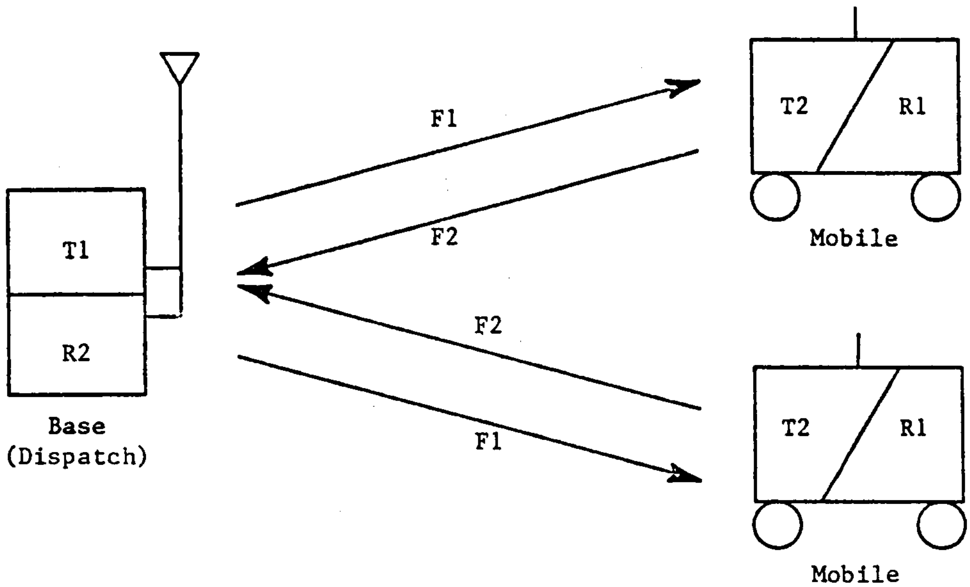
In this system, illustrated in Figure 4, each radio utilizes two separate frequencies, one for transmitting and one for receiving. The base unit transmits information on the frequency on which the mobile units receive information and receives on the frequency on which the mobile units transmit. The use of the separate receiving and transmitting frequencies eliminates the ability of the mobiles to talk to each other and is used almost exclusively by the taxi industry. In many cases for rural transportation, this would be undesirable as the transmissions between mobile units can be useful for transfers of passengers and, in cases of breakdowns or emergencies, when driver-to-driver contact is advantageous.

The cost of a two frequency simplex system is basically the same as that for a one frequency simplex system.

Mobile Relay System

The mobile relay system is the most popular system configuration in use today. The popularity stems from the wide area coverage offered by the system. Mobile ranges of 25 to 100 miles are not uncommon, particularly when the base station is located on a mountaintop.

The system features the use of one or more remote base stations, usually referred to as repeaters, and several control or dispatch stations. The remote base station, or repeater, acts as a relay



Mobile to Base
(Base to Mobile)

F1 = Frequency 1
F2 = Frequency 2
T1 = Transmit on F1
T2 = Transmit on F2
R1 = Receive on F1
R2 = Receive on F2

No direct mobile-to-mobile communication.

FIGURE 4

TWO FREQUENCY SIMPLEX SYSTEM

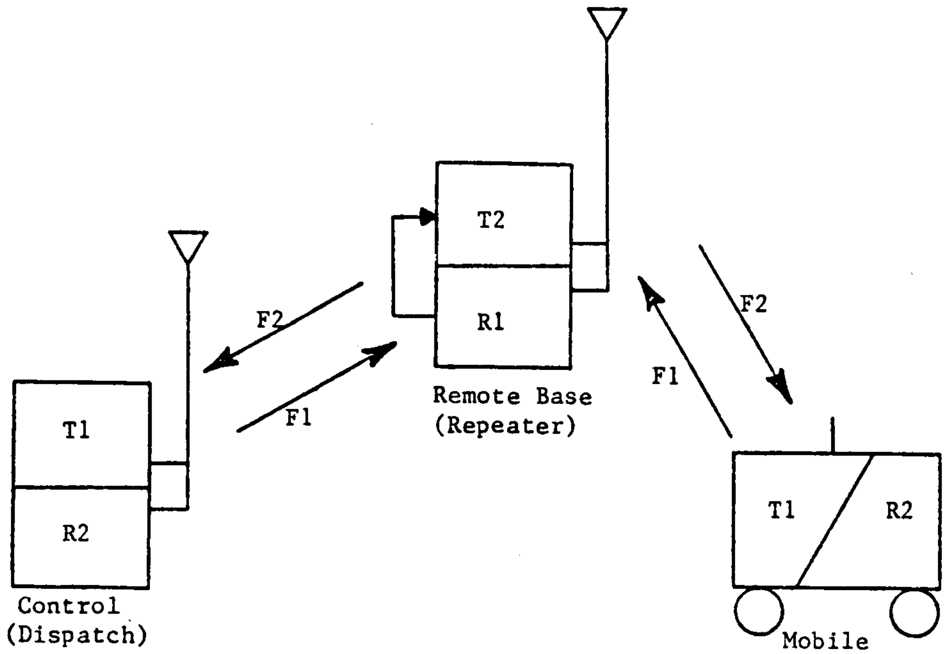
station for radio signals transmitted throughout the system. For this "relay" role to be accomplished, two separate frequencies are required.

As shown in Figure 5, the mobile and dispatch units transmit on frequency 1 (F1) and receive on frequency 2 (F2). The repeater, in turn, receives signals on F1 and retransmits or repeats the signal on F2. It can be seen that all signals transmitted throughout the system must travel through the repeater, illustrating the importance of the role played by the repeater in the mobile relay system.

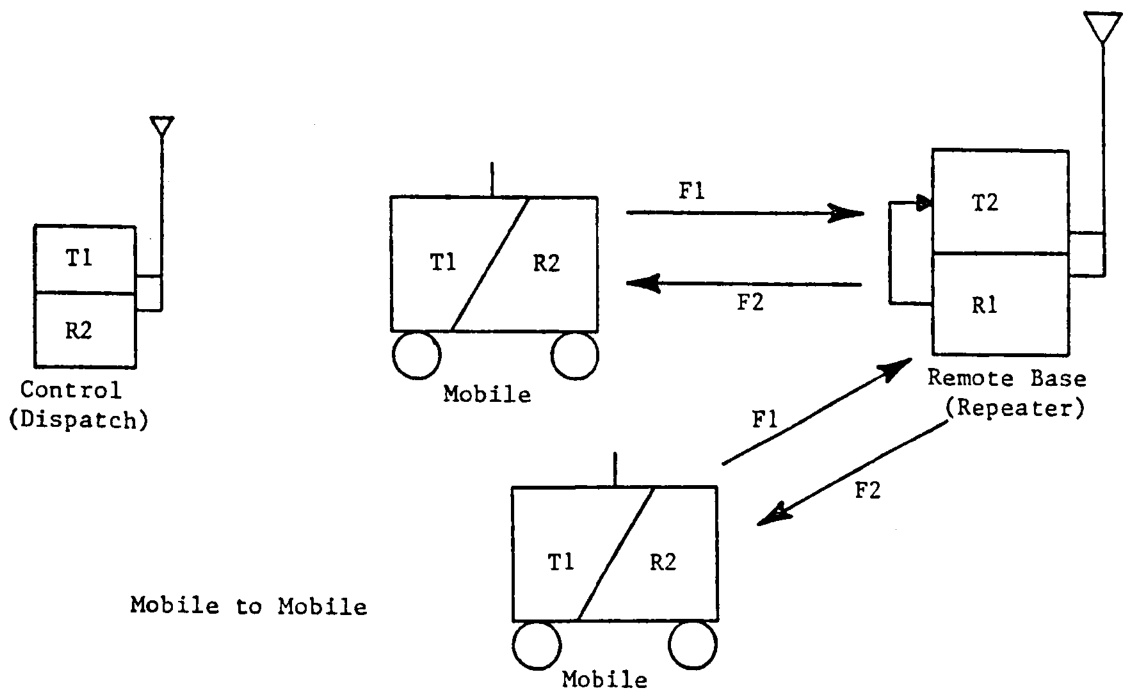
The location of the repeater(s) in a mobile relay system is the major factor affecting the range provided by the system. Because relatively high antenna sites provide a greater coverage area, typical repeater locations are on the tops of mountains and tall buildings.

The use of radio waves to transmit and receive signals between the repeater and dispatch units makes the use of wire lines, as found in the simplex unnecessary. Therefore, the location of the repeater is not dependent upon the location of existing telephone lines. This flexibility in repeater site location aids in providing the desired coverage area for the entire system.

The use of the repeater in mobile relay systems provides tremendous capability for mobile-to-mobile communication. By locating repeaters in strategic locations, it is possible to provide a high percentage of communication linkages between various mobile units regardless of their respective locations. The use of a mobile relay system can eliminate situations where mobile-to-mobile communications may not be possible in less sophisticated systems such as the one frequency simplex system. Figure 6 illustrates such a situation.



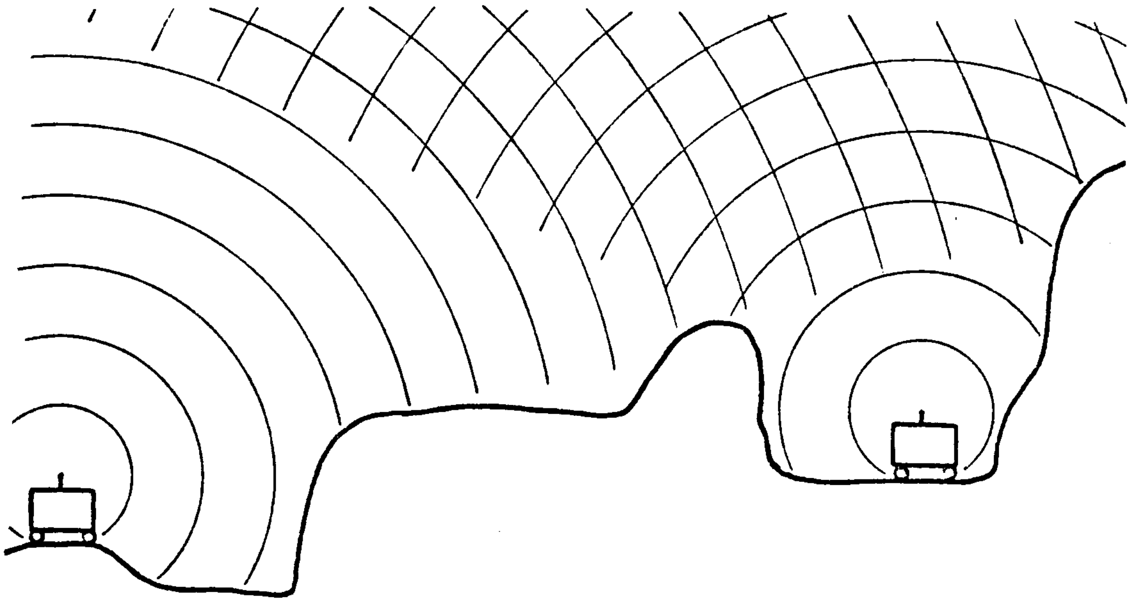
Mobile to Base
(Base to Mobile)



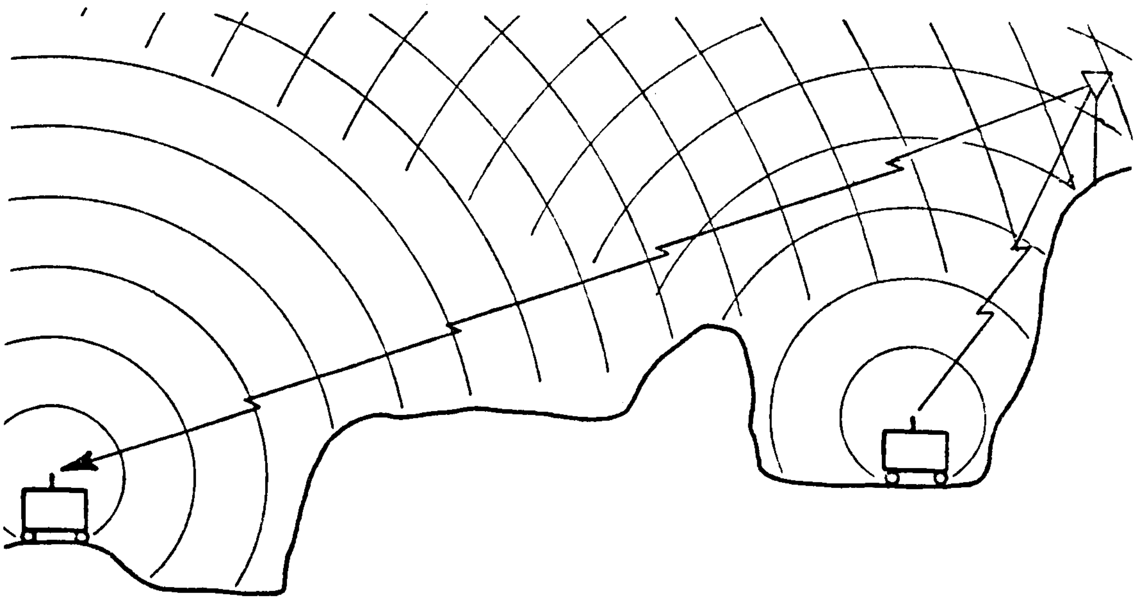
Mobile to Mobile

FIGURE 5

MOBILE RELAY SYSTEM



Simplex System



Mobile Relay System

FIGURE 6

ADVANTAGE OF A MOBILE RELAY SYSTEM

In areas where two or more repeaters are used, in order to provide the desired coverage, it may be necessary to install encoder-decoder device each radio in the system. An example can easily illustrate this situation.

Figure 7 shows the location of two repeaters, two dispatch stations and five mobile units in a single mobile relay system. Both repeaters receive on Frequency 1 (F1) and transmit on F2 (refer to Figure 5). Mobile units A and B can communicate with Dispatcher 1 without problem as can Mobiles D and E to Dispatcher 2. The problem arises with Mobile C's transmission. When Mobile C transmits, it activates both repeaters which in turn retransmit the signals simultaneously and creates interference which effectively cancels the signal. The interference occurs only when signals are transmitted simultaneously and clears up immediately afterwards without resulting in any damage to the equipment. However, it can be seen that a great deal of interference arising from these situations can adversely affect the effectiveness of the communications system. To remedy this problem, encoder-decoder devices, as described in the discussion of the one frequency simplex system, are installed on the radios and repeaters in the system. Now, each mobile unit traveling in the area between the two repeaters will be tuned in only to the repeater serving its respective dispatch station by use of the appropriate tone (see Figure 8). All of the features provided by encoder-decoder devices which were mentioned in the discussion of the one frequency system can also be applied to a mobile relay system. Included would be providing the mobile units with the ability to activate more than one repeater and thus contact dispatch stations serviced by different repeaters.

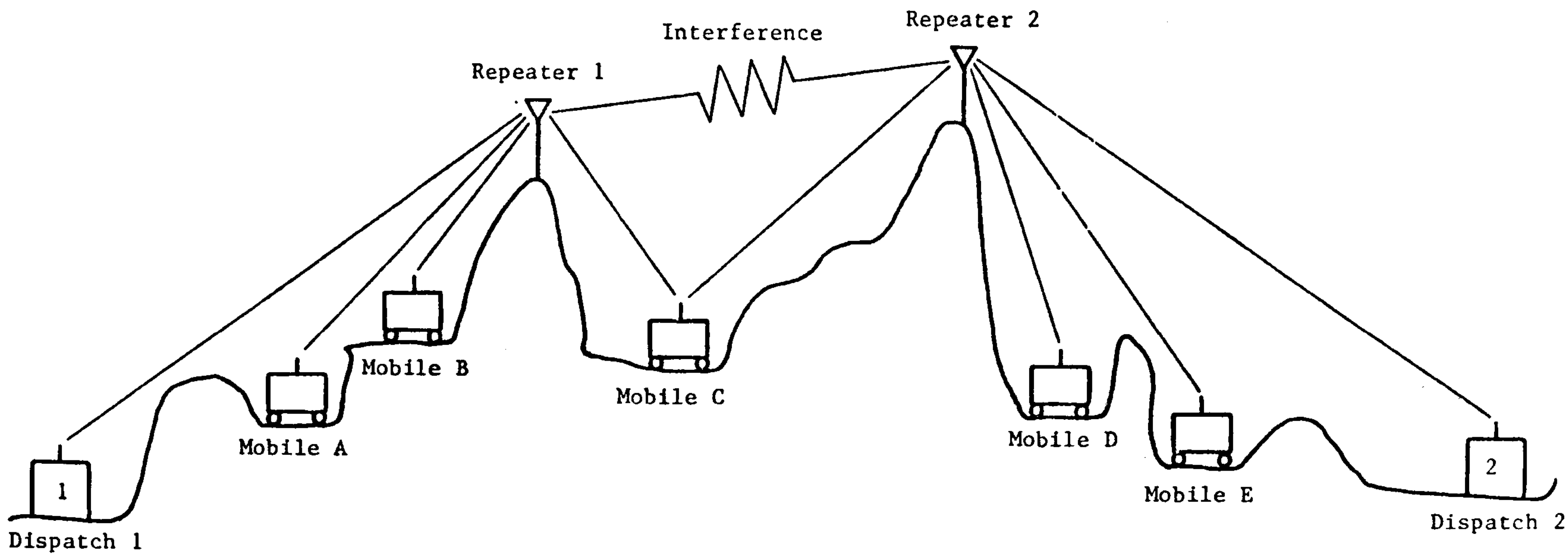


FIGURE 7

MOBILE RELAY SYSTEM WITHOUT ENCODER-DECODER DEVICE

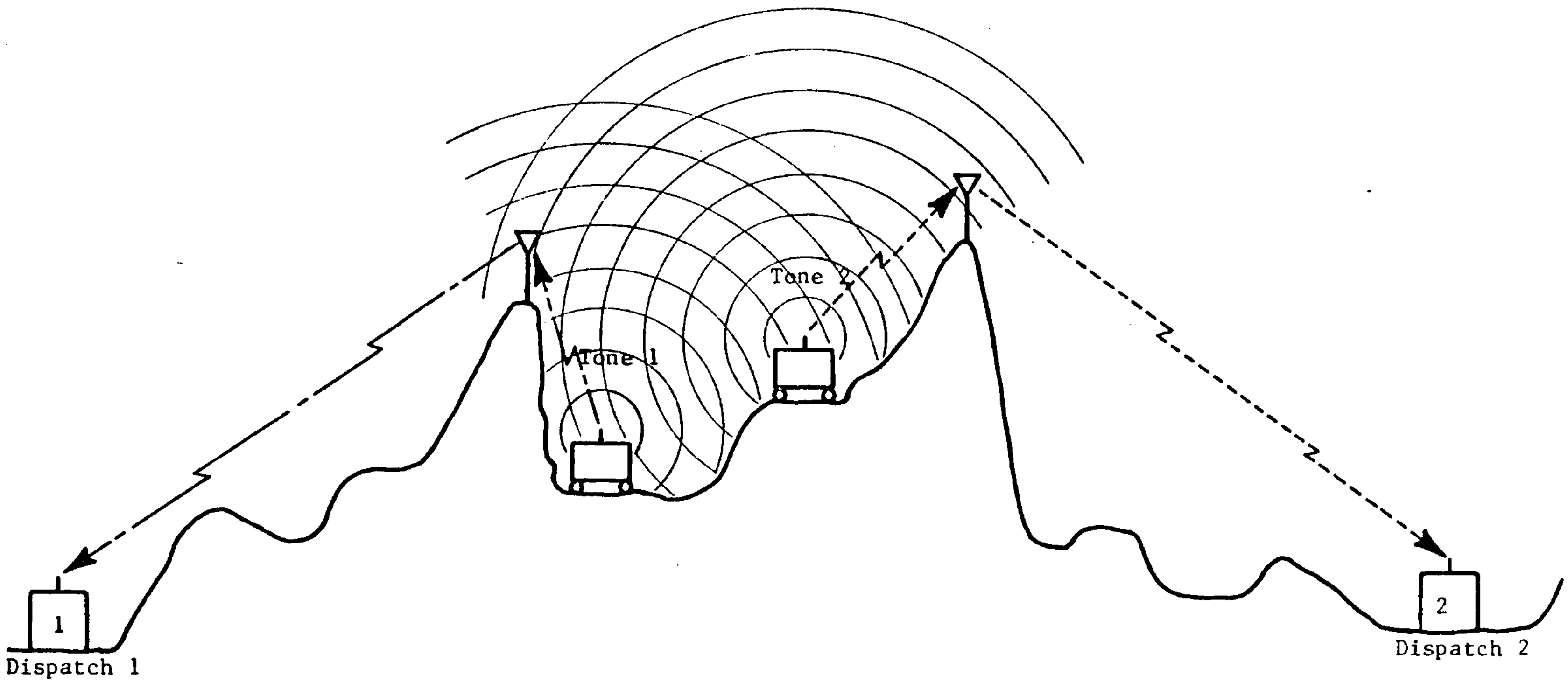
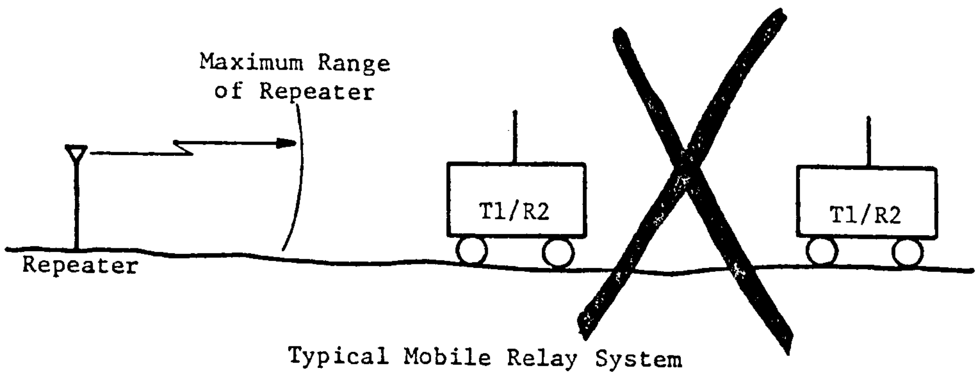


FIGURE 8

MOBILE RELAY SYSTEM WITH ENCODER-DECODER DEVICE

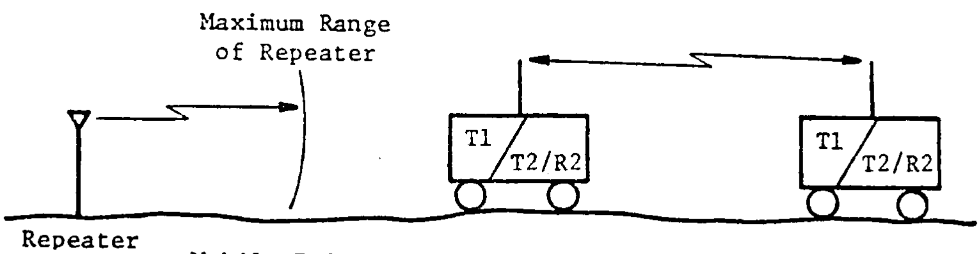
The price for the encoder-decoder devices as noted earlier ranges from $120 to $300 per radio unit. The larger the transportation program, the higher the cost becomes to receive the capabilities provided by these devices. However, it is in the larger programs that the problems which can be alleviated by the encoder-decoders are the greatest. Careful evaluation of the program must be made to ensure that the benefits of encoder-decoder devices exceed their cost. An additional factor to consider is that, as the hardware in a system of any kind becomes more sophisticated, there are more problems that can arise which in some cases results in increased maintenance costs. Currently, there is insufficient data available to verify this observation.

An additional feature available to mobile relay systems is known as "talk-around". The primary purpose of the talk-around feature is to provide radio units in a mobile relay system with the capability to communicate without accessing a repeater. It has been pointed out earlier that all transmission in a mobile relay system must travel through a repeater which can cause problems when two or more mobile units are traveling together outside of the range of their repeater. In this situation the mobile units would be unable to communicate. The talk-around feature solves this problem by providing each mobile unit with the capability to both transmit and receive on one of the two frequencies utilized in the mobile relay system. Communication would be similar to that in the one frequency simplex system and is illustrated in Figure 9. The cost of this feature is approximately $150 per radio unit.



Typical Mobile Relay System

No communication when vehicles are outside of repeater's range.



Mobile Relay System with Talk-Around Feature

Vehicles can communicate on F2 when outside of repeater's range.

FIGURE 9

MOBILE RELAY SYSTEM WITH TALK-AROUND FEATURE

Another application of the talk-around feature is as a backup system to the mobile relay system in the eventuality that a repeater is knocked out of commission. This would necessitate adding the feature to the dispatch stations. However, for the backup system to be effective it would be necessary to increase the power of the dispatch units and to provide them with better antennas. A rough estimate of the cost of this type of backup system is $800 to $900 per dispatch unit in addition to the $150 per dispatch and mobile unit. The backup system would not provide the same coverage as the original system because of terrain and the inadequacy of the dispatch antennae locations which resulted in the choice of the mobile relay system initially. As with the encoder-decoder devices, it is important that the advantages of such a backup system be weighted carefully against the cost of providing them before any purchase.

The principal advantages of the mobile relay system are the excellent mobile-to-mobile communication coverage and the flexibility in locating the repeaters. A cost advantage over the one frequency simplex system is found only in systems with four or more dispatch stations. However, if a smaller system with fewer than four dispatch stations requires a large coverage area or is located in a mountainous region, the operational benefits of a mobile relay system may outweigh the cost benefits of the simplex system. A slight disadvantage of the mobile relay system is that two frequencies are required.

Unfortunately, it is becoming increasingly difficult to obtain frequencies for land mobile radio operation, and the situation is not expected to improve because of the increasing demand for two-way radio communications.

Citizens Band Radio

Among the transportation programs studied in this report, the Caney Fork Development Corporation program utilized citizens band (CB) radio equipment in its communications system. Used primarily by long distance truckers through the 1960s, CB radios gained enormous popularity among average automobile owners by the early to mid 1970s. Today, there are millions of CB radio users licensed by the FCC.

Within the citizens band, 40 separate frequencies or channels are available for public use. However, unlike most two-way radios, nearly all CB radios have the capability to switch frequencies. In fact, most CB radios on the market and in use today have the ability to switch to any of the 40 channels available. This system ensures public access to the citizens band.

CB radios were intended to provide the public with local use of the airwaves for communications purposes and, therefore, have a limited range. Under perfect weather and atmospheric conditions and in relatively flat terrain, a CB radio is capable of transmitting an intelligable message approximately 10 miles.

The radio units are low powered (four watts) and operate in the high frequency band. Radio service in the high frequency band is characterized by a skip zone, but is adequate for local service. The skip zone does cause a good deal of unwanted interference in CB radio operation when atmospheric conditions are poor. This interference further inhibits the effective use of CB radios for reliable everyday service.

CB radios are relatively inexpensive depending upon the manufacturer and model and range in price from $50 to $250. Licensing involves simply filling out the required form and mailing it to the Federal Communication Commission. There is no charge. Life expectancy of the CB again depends upon the manufacturer and model, but generally is between 5 and 10 years.

Sophistication

Throughout the discussion on the technical aspects of two-way radio systems, the term "sophisticated" has been used to help differentiate between the types of systems available. Sophisticated, as it is used in this report, refers to the increase in capabilities provided by a two-way system. This does not necessarily mean that a sophisticated system is any more difficult to operate than a simple system. However, historically as a two-way radio system becomes more sophisticated or provides more capabilities, the cost usually increases. This is where tradeoffs have to be made for rural transportation purposes as these programs usually have limited funding.

Two-way radio technology is experiencing the type of rapid growth that is occurring in most other electronic related industries. Thus, the two-way radio systems discussed in this report cannot possibly include all the capabilities that are now available. It is also very likely that in the future the cost of radio systems may increase reflecting the benefits desired from rapidly advancing technological development. At this point, the concept concerning sophistication may no longer be relevant.

The Vendor's Role

A discussion of two-way radio communications would be incomplete without a look into the role played by the radio manufacturer's representative or vendor.

Typically, a transportation director or manager has limited knowledge about two-way radio communications, although the director is probably familiar with citizens band or CB radios. The operation of CB and two-way radio is basically the same, but the capabilities are quite different. The primary difference lies in the communicating range. CBs are limited to at best 10 miles, while communication between two-way radios 75 miles apart is not uncommon. Therefore, in order to take full advantage of two-way radio capabilities, it is necessary to contact someone knowledgeable in the field, typically the vendor.

The vendor's role begins by discussing the proposed use of the radio system with the transportation manager. The discussion usually covers the physical and operating characteristics of the transportation program along with the expectations the manager has with regards to the communications system. These factors are all critical in determining the type of radio system required and its eventual cost.

The vendor then takes this information to the manufacturer's engineering division which develops a system with the desired capabilities and determines its cost. Usual practice is to guarantee 90 percent coverage for a specific area which encompasses the transportation program area. When the proposed system is selected, the vendor makes the necessary arrangements to secure the license and frequencies from the FCC.

This is usually accomplished with assistance from the state frequency coordinator and can take anywhere from four weeks to six months.

Typically, more than one bid is sought and received on a radio system which provides a little competition among the radio manufacturers. In most cases specifications are written such that the new radio system comes with a guarantee stating that the desired service will be provided before payment is made. This usually ensures that any problem with the system occurring within the first six months to one year will be corrected by the manufacturer with little or no charge. A service contract similar to a preventive maintenance program is also available. The cost of this program depends upon the size of the system and the type of components utilized in it. There are questions concerning the need of such a program given its cost and the relative trouble free operation of radio systems in East Tennessee. It is important that such a program be carefully evaluated before purchase.

To conclude, the vendor's role can be described as being an expert consultant in the field of two-way radio communications. However, it is important to realize that the vendor is primarily a manufacturer's sales representative whose job is to sell radio systems. Therefore, it is essential for the transportation manager to determine the intended use of the radio system and expectations for the system before contacting the vendor. By establishing these criteria the transportation manager will ensure that the system obtained will be acceptable from operational and cost standpoints.

CHAPTER IV

CASE STUDIES ANALYSIS

Several rural transportation programs in Tennessee have been identified by the Tennessee Department of Transportation as having experience with some form of radio communications between the vehicles and dispatch stations. Each program identified was studied so as to determine the type of radio system employed and its contribution to the operation of the program.

East Tennessee Human Resource Agency

A service delivery agency for the East Tennessee Development District (16 counties), the East Tennessee Human Resource Agency (ETHRA) currently provides transportation to seven counties within the district with authority to provide transportation to the remaining nine counties. ETHRA's rural transportation program was funded in May 1977 under Section 147 of the Federal-Aid Highway Act of 1973. The funding was used to acquire the necessary hardware to begin a program which would provide service to five counties (Anderson, Scott, Morgan, Campbell, Union) with a total population of 123,798 persons. Service was expanded in July 1979 to include Claiborne and Grainger counties, increasing the total population in the area served to 157,166 persons.

Currently, 21 vehicles operate in the program area which covers approximately 2,300 square miles. Two of these vehicles are earmarked specifically for senior citizens' use due to restrictions by the funding source (Title III of the Older Americans Act), while the remaining vehicles are available to all persons. Three vehicles are equipped for handicapped passengers. The principle vehicle in use is the 15-passenger van, although one 22-passenger bus also is used.

The ETHRA transportation program is primarily a demand-responsive operation, with the requirement that passengers make reservations 24 hours in advance. This requirement is not binding and, if possible, a passenger will be serviced the day of his or her call. In addition to the demand-responsive service, there is a mixture of fixed-route and subscription service and so called service contracts. The fixed-route consists of regular runs into Knoxville two times per week, which account for nearly 15 percent of the trips for the entire program. The subscription service is a direct result of the fixed-route service as certain passengers make the same trips week after week. Service contracts are agreements made between the transportation provider (ETHRA) and various social service agencies to provide transportation to specific groups at specific times for an agreed-upon price.

As of spring 1979, the ETHRA transportation program operates Monday through Friday and provides approximately 5,000 passenger trips per month (250 pass. trips/month/van).[1] Forty percent of the passengers are elderly, and they account for nearly 60 percent of the passenger trips.

The Communications System. ETHRA utilizes a two-way mobile relay radio system as a means of communication between the mobile and base units. The system is composed of (18) 100-watt mobile units and eight 65-watt base stations. The cost of these radios and two repeaters in

[1]These figures are based on data collected from the original five counties operating 20 vehicles.

terms of 1977 dollars was approximately $40,000 as compared to an operating budget of $350,000 per year and a minimal yearly maintenance cost. A base station is located in each county served by the program, and one is located at the office of ETHRA's director of transportation.

Operating Characteristics. ETHRA presently utilizes dispatchers in each county with each dispatcher responsible for the operation of the program in that county. The people of the primarily rural counties were reluctant to phone in requests to a central dispatcher, despite the fact that the number was toll free. It was also found that prospective passengers were more comfortable scheduling trips with someone from their own county and that having a person who was intimate with the geography of the county aided in the dispatching process.

The dispatchers are responsible for receiving the requests for rides and for organizing these into a schedule which meets the requests in the most efficient manner under the constraints imposed upon the system. If requests for same-day service are received, it is the responsibility of the dispatcher to determine whether the ride can be fit into the schedule for that day. This situation would necessitate the use of the radio system to advise the driver of the new trip request. Approximately 5 to 15 new requests per county are processed in the ETHRA program per week. Other common situations that involve dispatcher/driver use of the radio are the cancellation of a previously scheduled trip, a call advising a driver that a passenger is ready to be picked up earlier than scheduled, driver check-in or out of the system, the coordination of transfer trips between vans operating in adjacent counties and the reporting of any emergency involving or spotted by a driver. An example of this latter use of the radio in the ETHRA program occurred when a vehicle was shot at in Campbell County. The driver was traveling along a particularly isolated road when a bullet shattered the back windo glass of the van. Unable to decide what to do and nearly hysterical, the driver immediately radioed Transportation Director, Ken Faulkner, who was able to calm her down and discern what happened. After being advised that the driver was not hurt and there were no passengers, Faulkner instructed the driver to find the closest phone and call the sheriff which she proceeded to do. This situation illustrates an important use of the two-way radio system.

System Characteristics. The type of two-way system employed by ETHRA is the mobile relay system. The basis of this system lies around the use of one or more repeaters which aid the transmission of signals between the various radio units. (The features of this type of system are discussed in Chapter III.) The ETHRA system has one repeater, although a second is currently being installed to provide better coverage The repeaters cost approximately $3,000 each.[1] The existing repeater tower is owned by the Anderson County sheriff's office and is located on land owned by Motorola Communications and Electronics, Inc. A $50/month rental fee is paid to Motorola for use of the land. There is no fee charged by the sheriff's office for use of the tower. No arrangements have been made for the new repeater as of now.

The ETHRA radio system operates and shares its frequencies with the Progress for People system in lower East Tennessee. The sharing of

[1]1979 dollars.

the common frequency was required due to the lack of available frequencies in the area that do not interfere with other operating frequencies. In East Tennessee, this problem is accentuated by the close proximity of four states which border Tennessee (Kentucky, Virginia, North Carolina, Georgia), which leads to difficulties in obtaining a clear frequency.

The overall operation of the ETHRA two-way radio system has been relatively trouble free. The system was set up by the Motorola radio company and utilizes Motorola equipment. In addition, ETHRA has contracted with Motorola to provide service on the radio system similar to a preventive maintenance program for a fee of $2,000 per year.

The use of a single repeater in the ETHRA system has both disadvantages and advantages. The major disadvantage is that in the mountainous region of East Tennessee it is nearly impossible to provide complete radio coverage with a single repeater. The presence of numerous "hills and hollows" results in areas where the signal from the repeater cannot reach the mobile unit or vice versa. The ETHRA system has one of these so-called "dead spots" in a narrow 15-mile stretch between Lake City and Caryville in Campbell County. The dispatcher in Campbell County deals with this situation by requiring the drivers to advise her before they enter the zone and to give an estimate of the length of time they will be out of radio contact. This procedure will no longer be necessary after the new repeater becomes operational and eliminates the dead spot.

As the operation of a transportation program such as ETHRA expands into adjoining counties, it is usually necessary to make adjustments to the radio system. Thus, the single repeater which is adequate for the initial program area may not provide enough coverage to encompass the expanded program area. In the case of the ETHRA program, the combination of the two situations--that of the "dead spot" and the addition of two counties to the system--reinforced the decision to obtain an additional repeater.

The advantages of using a single repeater are the low cost and simplicity when compared to a system with two or more repeaters. The cost of a repeater can reach $5,000 and, in many cases, may include a monthly rental fee for the site of $40 to $150. As noted in the discussion on basic radio, the proximity of repeaters to each other can affect the ability to transmit signals throughout the system and can require the addition of sophisticated equipment known as encoders and decoders. The addition of encoder-decoder devices was required in the ETHRA system when the additional repeater was installed. The encoders-decoders which were installed on each radio (26) in the ETHRA system cost approximately $120 per radio.

Summary. Although no previous data has been collected supporting the fact, Transportation Director Ken Faulkner believes that the use of the two-way radio communications system has increased the efficiency of the entire rural transportation program. To support his argument, Faulkner cites a decrease in deadhead mileage and in time used by driver and vehicle per trip as the primary benefit. This occurs as changes in a driver's schedule are made and subsequently transmitted by radio, thus preventing an unnecessary trip or allowing the consolidation of unscheduled trips. In addition, Faulkner utilizes the radio system that cannot be handled by the dispatchers. Particularly with new drivers, mostly CETA employees without extensive experience, the radio provides monitoring capabilities and support to the drivers in instances where assistance is required.

The expenditure of approximately $43,000 for the entire system including radios, antennas, repeaters and encoder-decoder devices is thought to be worth the investment for the flexibility in management and operation it provides. Operating costs are minimal, limited to approximately $2,600 per year for the maintenance program contracted from Motorola and the repeater site rental. There is no insurance on the radios because the cost of it is more than the replacement cost for a radio. To this date no radios have been stolen or vandalized. The equipment used in the ETHRA system is not as sophisticated as some available but provides the desired capabilities. Those additional capabilities that could be provided by more sophisticated equipment are not thought to be needed especially given the additional cost. To conclude, the two-way communications system employed by the ETHRA transportation program provides welcomed flexibility in management and operation. The feeling of those involved in the ETHRA program is that the radio system is an integral and essential part of their rural transportation program.

Progress For People Human Resource Agency

The Progress for People Human Resource Agency (HRA)[1] provides transportation to the elderly, the handicapped, the poor and the

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[1]An excellent description of the HRA rural transportation program can be found in Report No. DOT-TST-77-42, Evaluating Rural Public Transportation, February 1977.

general public of a 10 county region in southeastern Tennessee. The program was initiated in 1974 on a limited basis and received a demonstration grant under Section 147 of the Federal Highway Act in June 1976. Currently, 3888vvehicles operate in the 10 counties (Bledsoe, Bradley, Grundy, Hamilton, Marion, McMinn, Meigs, Polk, Sequatchie) which have a total population of 420,000 persons and cover approximately 3,700 square miles.

HRA offers a variety of services including demand-responsive, fixed route and commuter services. Some service contracts are used. The principal vehicles used for rural transportation are 12- and 15-passenger vans. The program currently operates five days per week and transports 6,300 persons per month. Approximately 20,000 services per month are provided by the program.[1]

Communications System. The two-way radio system employed by HRA was installed in December 1976 at a cost of $53,000. As a comparison, the total operating cost for the first 12 months of the demonstration, during which the radios were bought, was approximately $442,000.

The system consists of nine 60-watt dispatch units, 33 60-watt mobile units and two 100-watt repeaters. A dispatch unit is located in each county serviced by the program.

Operating Characteristics. The HRA communications system exhibits many of the same operating characteristics as in the ETHRA system. The

[1]A service is defined as being any stop for a particular purpose made during a trip. Therefore a person who stops at the drug store and grocery store on the way home from the doctor has been provided three services (drug store, grocery store and home).

similarities exist because the experiences of the HRA system were utilized in the development of the ETHRA system. HRA utilizes dispatchers in each county, thus providing local identity to the system which aids in the dispatching process.

As in the ETHRA system, the dispatcher's main duty is to receive ride requests and to schedule those requests into a workable trip log. Any requests for same-day service are accepted if the trip can fit into a driver's schedule. The principal means to advise a driver of a new request is to contact him or her on the two-way radio. The HRA system serves approximately 15-20 new trip requests per week per county. Other dispatcher/driver uses of the radio are described in the section covering the ETHRA program.

System Characteristics. HRA employs a mobile relay system to provide communications for the transportation program. The system shares its radio frequencies with the ETHRA communications system. The sharing of the common frequencies poses the problem of interference between the systems, a problem both systems try to avoid.

The HRA system was set up by the General Electric Company and utilizes G.E. MASTR II radios. The individual units range in price from $1,000 to $1,300.[1] Repeater costs were minimized by utilizing existing towers. The MASTR II radios were the top of the line radio offered by G.E. at the time of purchase. The mobile units are sophisticated and utilize a telephone-like head for communicating. The use of this type of head provides quiet communications between the

[1]1976 dollars. Current (1979) prices are approximately $2,000 per unit.

dispatchers and drivers because the only speaker is located in the telephone earpiece. Each mobile unit can be assigned a particular coded tone so that individual drivers can be contacted. When the dispatcher dials a van's number, a light goes on in the van alerting the driver of the call. This light will stay on until the driver picks up the head. Therefore, the driver will know contact has been attempted if the driver was away from the van at the time of the call.

The telephone head feature also eliminates most direct driver-to-driver contact. The mobile units do not have the necessary hardware to dial up a particular van due to price constraints.[1] Therefore, if a driver wishes to contact another driver, the driver must first contact the dispatcher who either can relay the message or can dial up the other driver and patch the two together. The drivers can make direct contact if they are both listening into the telephone earpiece at the same time, although this is unlikely unless previously planned.

The mobile units also have the ability to switch to five different transmitting tones, although in this system only two are used currently. Each of the two repeaters which provide coverage for the entire program area is activated by a particular tone. This is done to avoid both repeaters being activated simultaneously and cancelling out a signal. Therefore, when a driver is out of range of one repeater, the driver simply pushes a selection button to switch to the tone of the other repeater. The ability to switch tones also allows vehicles to be moved throughout the system without having to switch radio units.

[1]The encoders which would provide this capability cost approximately \$200 to \$300 per radio.

Currently, the system is operated without the use of the individual van dial-up capabilities. With the addition of the ETHRA system on the same frequency, it became difficult to dial a vehicle without the signal being interrupted. Typically, the dispatcher dialed a four-digit number which activated the tone of the desired mobile unit and alerted the driver to pick up the telephone head. However, during the time the dispatcher was dialing the appropriate code, another unit in the system would frequently transmit and cancel out the code. The dispatcher had no way of knowing that the code was not completed and might have assumed that the friver was out of the vehicle. This situation caused long unnecessary delays and considerable confusion. The additional calls from the ETHRA program compounded this problem. To remedy the problem, the decoding devices were disconnected and a low price external speaker was installed on each of the mobile units. Now the system operates in the same manner as the ETHRA system with the drivers able to hear all transmissions made on the frequency. The mobile units still have the capability to activate the various repeaters in the system.

Summary. The HRA communications system has been cited as having a positive effect upon the efficiency and productivy of the transportation program. The use of the two-way radio system coincided with a marked increase in services provided. In 1976, when eleven 12-passenger vans were obtained through the demonstration grant, the agency was handling 7,000 requests per month. After the first radios were HRA's response improved dramatically. The number of rides jumped to 8,000 in January 1977; 12,000 in February 1978; 20,000 in March 1978; and 25,000 in April 1978. The total increase in ridership from January 1977 to April 1978 represents approximately 90 additional services met per day per county. Part of this increase can be attributed to increased publicity resulting from the demonstration grant; however, those involved with the program are convinced that the new communications system played an important role.

The radio system provides management with the ability to monitor the operation of the transportation program. Specifically, it is possible to keep track of the drivers and to receive any information concerning delays. Without the radio system it was difficult to determine whether a driver was goofing off or was experiencing an unavoidable delay. The HRA radio system also has been used to hold impromptu staff meetings or to inform employees of a scheduled meeting time and place.

The present feeling about the type of radio system employed and its components is that it is too sophisticated for rural transportation purposes. Executive Director and Transportation Manager, Don Denton, feels that the advantages provided by the sophisticated system do not warrant the high cost involved in its purchase. As noted earlier, the major feature of the HRA system, quiet communications, has been dismantled. Although passengers can now overhear the radio transmission, Denton believes that this does not create enough problems to warrant the cost of the quiet communications.

HRA initially purchased a maintenance agreement from G.E. but did not renew the contract after the first year due to its excessive cost. The radios in the system have operated for the past three years without any significant problems. Recently one radio was knocked out of commission when the van operator got the unit wet while washing the vehicle. One mobile radio was stolen, although theft does not seem to be a major problem.

Caney Fork Development Corporation

The Caney Fork Development Corporation (CFDC) is a private non-profit organization which provides transportation to elderly, handicapped and low income persons living in a four county region in middle Tennessee. The present transportation program was initiated in October 1971 when four vehicles were obtained. Funding was provided by Office of Economic Opportunity, currently called Community Services Administration. Presently, 12 vehicles operate in the four counties (Cannon, Dekalb, Van Buren, Warren) serving a total population of 50,348 persons.

The CFDC transportation program operates demand-responsive, fixed-route, subscription and contract services. The demand-responsive service requires that reservations be made 24 hours in advance, although same-day demands are met if possible. Currently, the transportation program provides approximately 4,000 passenger trips per month.

Communications System. The CFDC communications system is interesting in that it does not utilize two-way radios. Rather, CFDC utilizes citizens band (CB) radios which provide an entirely different level of service and associated cost than a two-way system. The system currently consists of three base units (located in Warren, DeKalb, and Van Buren counties) and five mobile units. In 1976, when the radio system was introduced, Cannon County was equipped with a base station. This unit was stolen in 1978. The nature of the service in Cannon County (primarily scheduled service) was such that the loss of the radio had little effect; therefore, the radio was never replaced. Several different radio brands are used in the system including Claricon, Royce and RCA. Prices for the units, including antennas, average about $125[1] each while maintenance has averaged less than $50[1] per year for the entire system.

Operating Characteristics. As mentioned above, the level of service offered by a CB radio system is quite different from that of a two-way radio system. The major problems associated with a CB system are limited communications range, skip, and interference. In addition, the difficulty in finding a clear channel or frequency in the citizens band initially was a problem. The CFDC radio system experiences all of these problems which tend to limit the extent in which the operation of the transportation program is affected.

The problem of finding a clear channel on which to operate has been solved in the CFDC radio system. Cooperation has been obtained from the various CB radio operators in the region so that Channel 1 of the 40 channel citizens band is left clear for rural transportation communications. It should be noted that the vehicles operate in a relatively low density area.

Although there are base units in three counties of the CFDC program, no full-time dispatchers are utilized. Warren County comes closest to having a full-time dispatcher with Transportation Director

[1]1979 dollars.

Kenneth Kirby, taking trip requests and dispatching vehicles in addition to his daily managerial routine. In Dekalb and Van Buren Counties, any driver in the office acts as the dispatcher.

The interference problems associated with the low wattage and relative simplicity of the CB units limit the range of communication to five miles at best in the CFDC system. Therefore, dispatch-to-dispatch communication is impossible. The five-mile limit also affects the extent to which dispatch-to-mobile communication can be accomplished. Typically, these communication linkages are completed on a hit-or-miss basis. With this system it is virtually impossible to monitor the location of a mobile unit, so the dispatcher can only guess at its location and hope that the transmitted message is received. This procedure works best in Warren County due to a high concentration of trip requests within the five-mile range of the dispatch unit.[1] In Warren County, an average of 12 dispatch-mobile linkages are made each day which affect the transportation service. Examples of these are additional trip requests, trip cancellations and revised pickup times. It is estimated that there are approximately three unmet trip demands per week in Warren County due to the lack of adequate dispatch-mobile communications. Figures for Dekalb and Van Buren Counties are unavailable, but it is expected that the number of dispatch-mobile linkages are lower and the number of unmet demands are the same or higher.

Summary. The CB radio system employed by the CFDC program is barely adequate in providing communication for rural transportation

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[1]The Warren County dispatch unit is located in McMinnville, population 10,662.

purposes. The radio system is unable to provide communication coverage to the entire program area due to the range limitations. Those communication linkages which are completed do have a positive effect upon the transportation program in that they enable additional trip demands to be met and they inform drivers of trip cancellations and adjusted pick-up times, all which can decrease deadhead mileage.

The low cost of providing such a system is the principal advantage. The price tag for the entire CFDC system was under $1,500, with a maintenance cost of less than $50 per year.

The radios also provide a sense of security to the vehicle operators and have been used on occasion for emergency purposes. In an emergency situation, the range limitations of the CB would not necessarily be critical because of the CB radio's channel selection ability which would allow the driver to search the various channels to receive assistance.

Although the CB radio system does not provide many communication capabilities, the small amount of assistance it does provide to the operation of the transportation program and the security it provides to the drivers makes it a fairly useful tool. If there is a decision to be made between having no communications system and having a CB system, the merits of the CB system along with its relatively low cost may justify its selection.

CHAPTER V

DETAILED RADIO USE ANALYSIS

Introduction

To help further evaluate the benefits of two way radio systems in rural transportation programs, a detailed analysis of radio use was performed on the East Tennessee Human Resource Agency (ETHRA) system. The ETHRA system, as described in Chapter IV, operated in seven counties in 1979; five of which utilized radio communications. The five counties (Anderson, Scott, Morgan, Campbell, and Union) were the focus of a data collection effort which was designed to measure the utilization of radio communications during normal operating conditions. Due to personnel changes during the survey period, data from Union County was not compiled. Data from the remaining four counties was analyzed and an effort was made to quantify costs and benefits.

Data Collection

At the outset of the data collection effort, interviews with ETHRA Director of Transportation Ken Faulkner and Chief Dispatcher Gayle Cheetwood, indicated four basic functions that radio communications had in the operation of the rural transportation system. The four functions typically involved dispatcher-driver communication in the following areas:

1. Additional (Unscheduled) Trips. This would involved the dispatcher contacting the driver, by radio, of an unscheduled trip request for the same day that was phoned in after the driver had picked up their schedule for the day.

2. Trip Cancellation. This would involve the dispatcher contacting the driver, by radio, of a cancellation of a previously scheduled trip.

3. Adjusted Pick-Up Time. This would involve the dispatcher contacting the driver, by radio, of an adjustment in a scheduled passenger's scheduled pick-up time.

4. Emergencies or Drivers Assistance. This would usually involve drivers contacting the dispatcher by radio, to get assistance at an accident, at a breakdown, or for directions.

It was determined that the best technique for measuring the impact of these functions was to have the dispatchers in the various counties complete a survey form during regular operating hours. The survey forms would have to be designed to provide as much information regarding the identified functions as possible yet be relatively simple to fill out and understand. In designing the forms each of the functions were analyzed along with the operation of the system so that the data gathered would lend itself to an analysis that would reveal quantifiable benefits of the radio system. Indications were that three functions, Additional (Unscheduled) Trips, Trip Cancellations and Adjusted Pick-Up Time could lead to quantifiable benefits where Emergencies or Drivers Assistance would lead to more qualitative benefits.

A series of trial survey forms were field tested in the Anderson County dispatcher office in Clinton, Tennessee. With each trial run, the forms were modified either to simplify them for the dispatcher's benefit or to gather the required information more efficiently. Two factors became apparent during the trial runs--the forms would have to be extremely simple to fill out and should be designed such that the dispatcher could enter the required information while or immediately after the radio transmission was being made. If even a small amount of time passed after the radio transmission was made before the dispatcher could enter the required information the information would most likely not be entered at all.

In analyzing the completed trial forms, the Adjusted Pick-Up Time function was found not to be significant in affecting the operation of the rural transportation system. In fact of four different forms tested over a months time, each with a slightly different presentation of the Adjusted Pick-Up Time function only three entries documenting a driver being notified of an adjusted pick-up time by radio were recorded. Discussions with the Transportation Director and the Chief Dispatcher concerning these results indicated that they were surprised that the Adjusted Pick-Up Time function was apparently not significant; however, they had no data available to support their initial feelings that it was. Based on these discussions the Adjusted Pick-Up Time function was dropped from the final survey form to reduce confusion for the system dispatchers. A sample of the final survey format along with instructions which accompanied the forms to the five counties are illustrated in Appendix A.

Data Results

As noted in the Introduction to this Chapter, due to personnel changes in Union County during the time of the survey, results from this county are not available. Data was gathered in the remaining four counties during the first two weeks of January 1980. The forms were distributed in December and contact was made with each dispatcher to offer any further explanations needed. In general, cooperation of the dispatchers was good, although some grumblings of "more work" were noted. Each of the dispatchers were also contacted by the Transportation Director who requested that they cooperate in the data collection effort.

The preliminary results of the survey forms appeared to be reasonable based on previous indications of the various functions given by the Transportation Director. However, the number of additional trips surveyed in Scott County appeared high. Forty-one additional trips serviced were logged by the Scott County dispatcher while the remaining three counties logged an average of twelve each. Because this number is much larger than those recorded in the remaining counties, an investigation was undertaken to determine the reason why. Discussions with the Scott County dispatcher and Chief Dispatcher Cheetwood revealed that the high numbers of additional trip requests were caused by an operating strategy particular to Scott County. In Scott County the dispatcher works only Mondays, Wednesdays and Fridays. The operating strategy is generally that the drivers will service a different defined area of the county on each of the three days. This fixed-scheduled operating strategy is followed week after week. With no dispatcher in the office on Tuesdays and Thursdays, it becomes very difficult for passengers to call 24 hours in advance as the standard ETHRA operating procedure requires. Therefore, knowing what area the driver will be travelling in any of these three days, the passengers regularly call early on the day they want their ride and are confident that they can be fit into the schedule.

In order to prevent the survey data to be skewed by the unusual operating strategy of Scott County, an adjusted number of additional trip requests was computed to be used in the analysis. The number was arrived at by averaging the remaining three counties Additional Trip Data. Chief Dispatcher Cheetwood agreed that the new number would better reflect the additional quantitative benefits of the radio system but also pointed out that by having the radios ETHRA is able to provide a more convenient service to Scott Countians.

A total of 47 additional trips were noted for the four counties over the two week period. This translates to approximately 6 additional trips per week per county. As noted in Chapter IV, ETHRA's Transportation Director estimated that between 5 and 15 new trip request per county were processed in the ETHRA program per week. The average additional trip requests per week ranged from 2.5 in Campbell County to 8.5 in Anderson County.

There were a total of 21 trip cancellations noted in the radio survey for the four counties over the two week period. This is an average of approximately 3 trip cancellations per week per county. The average number of trip cancellations per week ranged from 0.5 in Campbell County to 4 in Morgan and Scott Counties. Of the trip cancellations noted, 13, or 59%, were recorded as involving distance saved. The average distance saved per cancelled trip counting all 21 cancellations noted was 4.6 miles per trip. Counting only the 13 cancellations which resulted in distance saved yields an average distance saved of 7.75 miles per trip. The recorded distances saved ranged from 0 miles to 34 miles per cancelled trip.

There were a total of 26 radio calls by the drivers for assistance or to notify the dispatcher of emergencies noted in the four counties over the two week period. This is an average of approximately 3 calls per week per county. The average number of Emergency or Assistance radio calls per week ranged from 1 in Morgan County to 6.5 in Campbell County. Some of the common responses recorded include: calls for dispatcher to phone a scheduled passenger that the driver was waiting outside, calls to notify the dispatcher that the driver was going home for the day, calls to get someone from the county to come turn on gas pumps for drivers, calls for directions, and calls to notify the dispatcher that the van had broken down.

To augment the data collected from the radio survey forms, January Daily Vehicle Reports from each county which are normally compiled were reviewed. The reports include information on passengers, trip purposes, pick-up and drop-off times and odometer readings. In addition, at the end of each day the driver notes the total mileage driven and the total number of miles driven without passengers in the van or dead-head miles. An example of a daily vehicle report is shown in Figure 10. Table 1 summarizes the radio survey results and information taken from the January daily vehicle reports.

For use in the following analysis it was necessary to expand the two week survey data to average annual data. This was accomplished by doubling the survey data collected to reach a monthly figure then applying a ratio that related January trip totals to average monthly trip totals. The resulting expanded average monthly survey data was then multiplied by twelve to reach an average yearly estimate of the

VEHICLE NUMBER 09
DATE 1-3-80
DRIVER Julia Chitwood
DEPARTURE TIME 8:00
BEGINNING ODM 64445-3

ENDING ODM 64571-4
ENDING TIME 11.00
TOTAL MILEAGE 126
TOTAL D/H MILES 39

$3.00

PASSENGER/	AMOUNT & TYPE PAYMENT	FROM	TO: TRIP PURPOSE: MEDICAL	WORK	NUTRITION	SOC/REC	SHOPPING (OTHER)	EDUCATION	SHOPPING (GROCERY)	HOME	WELFARE	SR. CITIZEN CENTERS	TRANSFERS	OTHER	PASSENGER CLASS: HANDICAP	ELDERLY (OVER 60)	P/U TIME	D/O TIME	P/U ODM	D/O ODM
R Carter	DARC	And CO	A✓												A✓		8:00	9:04	453	477
F Moren	50	AND co					A✓									A✓	8:09	8:58	458	476
I Bass	RA	AND CO					A✓								A✓		8:09	8:58	458	476
R Boone	RA	AND CO	A✓												A✓		8:19	8:58	460	476
B Ballis	DARC	AND CO	A✓												A✓		8:33	9:04	467	477
B King	50	AND CO		A✓											A—		8:35	8:40	468	469
C White	[illegible]	AND CO											A✓			A✓	8:43	9:04	470	477
P Burchfield	[illegible]	And CO	A✓												A✓		8:52	9:04	474	477
A Andrews	DARC	AND CO	A✓												A✓		8:52	9:04	474	477
B Vanhuss	RA	AND CO								A✓					A✓		9:19	9:55	480	491
Ray Vanhuss	RA	AND CO								A✓							9:19	9:55	480	491
S. Martin	RA	AND Co.												A✓			10:20	10:40	498	509
A. Martin	RA	AND. Co.												A✓			10:20	10:40	498	509
F Moren	50	AND CO					A✓									A✓	10:45	11:05	509	515
I Bass	RA	AND CO					A✓								A✓		10:45	11:05	509	515
R Boone	RA	And Co					A✓								A✓		10:45	11:05	509	515
[illegible] Tribble	COA	And CO			A✓											A✓	10:50	11:10	510	516
F Evans	COA	And CO			A✓											A✓	10:55	11:10	512	516
E Flora	COA	And CO			A✓											A✓	10:55	11:10	512	516
E Smith	COA	And CO			A✓											A✓	10:55	11:10	512	516

FIGURE 10

DAILY VEHICLE REPORTS

TABLE 1

RADIO SURVEY RESULTS

FOR 2-WEEK PERIOD IN JANUARY 1980

County	Trip Cancellations No	Trip Cancellations Average Distance Saved	Additional Trips	Emergencies or Drivers Assistance	Trips (a)	Miles (a)	Deadhead Miles (a)
Anderson	5	4.2	17	3	702	3591	873
Campbell	1	5	5	13	467	3378	1230
Morgan	8	6.8	13	1	248	2746	862
Scott	8	3.2	41/12 (b)	9	586	4887	1076
TOTALS	22	4.6	78/47 (b)	26	2003	14602	4041

(a) This information was taken from Daily Vehicle Reports completed by the drivers over the survey period.

(b) Forty-one is the actual number of additional trips recorded in Scott County. Twelve is the adjusted number of additional trips used in the following analysis. For further explanation see discussion on Page 53.

surveyed functions. Unfortunately, complete monthly trip data from the ETHRA program in 1980 is unavailable, either lost or inadvertantly thrown out during a clean-up effort when records were moved to rented storage space. Since the required ratio essentially measures seasonal fluctuations of trip making it was reasoned that ratio's developed from different years could be utilized without affecting the results. This assumption was discussed with the Chief Dispatcher who agreed that the monthly trip patterns did not appear to differ significantly over the years. Monthly trip data for the 1983 fiscal year, shown in Table 2, was utilized to arrive at the required ratio. The ratio was developed using the total monthly trips in January and the total average monthly trips over the year for the four counties surveyed. This ratio was 0.90, indicating that trip making in January is only 90 percent of the average monthly trip making throughout the year. The surveyed data was divided by 0.90 to reach average monthly data then multiplied by twelve to give the average yearly estimate of the surveyed functions. The results of the expanded survey effort are shown in Table 3.

TABLE 2

DAILY VEHICLE REPORT SUMMARY FOR FISCAL YEAR 1983

County	Total Trips	Average Monthly Trips	Total Miles	Average Monthly Miles	Total Deadhead Miles	Average Monthly Deadhead Miles
Anderson	11,248	937	73,977	6,165	19,807	1651
Campbell	11,698	975	61,063	5,089	23,026	1919
Morgan	3,006	250	25,436	2,120	6,534	544
Scott	10,092	841	59,579	4,965	15,697	1300
TOTAL	36,044	3003	220,055	18,339	65,064	5422

TABLE 3

EXPANDED RADIO SURVEY RESULTS

ESTIMATED TOTAL FOR 1980

County	Trip Cancellation		Additional Trips	Emergencies Or Drivers Assistance
	Number	Miles Saved @ 4.6 Miles/Trip		
Anderson	133	612	453	80
Campbell	27	124	133	347
Morgan	213	980	347	27
Scott	213	980	320	240
TOTALS	586	2696	1253	694

Analysis

An effort will be made in this section to quantify the benefits of utilizing a two way radio system in a rural transportation program so that they can be compared with the radio systems cost. Of the three functions of radio use surveyed, Trip Cancellations and Additional Trips have been identified as having quantifiable benefits. These benefits are in terms of cost savings based on miles saved due to the use of the radio system. The Emergency or Drivers Assistance function of radio use surveyed results in benefits that are more intangible or qualitative. In addition, a qualitative benefit of Additional Trips is that there is an increased utilization of the rural transportation system.

Trip Cancellations. The Trip Cancellation data was collected such that miles saved could be determined directly from the survey forms. Discussions with the Transportation Director and the Chief Dispatcher indicated that most scheduled passengers who cancel a trip the day it is scheduled, do so within an hour of their scheduled pick-up time. Chief Dispatcher Cheetwood estimates that "at least 85 percent" of the trip cancellations processed by radio would not be processed under a transportation system running without the two-way radios. By processed it is meant that drivers have been notified of a trip cancellation before they make their way to the cancelled passengers scheduled pick-up point. In a no-radio scenerio, the driver would have to contact the dispatcher either by phoning from an outlying area or stopping at the dispatch office. Since the majority of the cancellations occur within one hour of the scheduled pick-up time, the opportunities for the drivers to contact the dispatchers are very limited and thus the 85 percent figure appears reasonable.

Applying the 85 percent figure to the expanded radio survey results indicates that in the ETHRA transportation program, approximately 498 trip cancellations each averaging approximately 4.6 miles saved per cancellation occur every year due to the use of the two-way radio system. This represents a total savings in distance per year of approximately 2291 miles. Transportation Director Faulkner indicated that the total operating costs per mile driven systemwide including equipment and personnel costs were approximately $0.85 per mile and rising as the cost of gasoline rose. The application of this figure to the total miles saved, yields annual cost savings due to the use of the two-way radio system for trip cancellations of approximately $1950.00.

Additional (Unscheduled) Trips. Unlike trip cancellations, Additional Trip data was not collected in a form that could easily reveal distance saved. In the first survey forms tested, an effort was made to collect information that would allow the distances saved to be easily determined by reviewing the entries in a similar fashion as in the Trip Cancellation data. However, it became apparent early on that quantifying the Additional Trip function would be much more difficult.

The difficulty in quantifying this function lies in the development of a reasonable scenerio in which the transportation program would run without the radio system. After discussing several possible scenerios with Chief Dispatcher Cheetwood, the following was developed as the most reasonable:

A. Drivers would phone the dispatching office from convenient predetermined locations throughout the county when thy are near these.

B. Drivers would not call the dispatcher between 7:30 a.m. and 9:30 a.m. nor between 2:00 p.m. and 4:00 p.m. These are the busiest times of operation for the transportation system with opportunities for the driver to phone the dispatcher being limited.

C. Drivers would stop at the dispatch office when they were in the immediate vicinity.

D. All additional trips surveyed would be forced to occur under a no-radio system and the additional miles required, if any, over what actually occured using the radio is the resulting benefit of having radios.

Utilizing these criteria, a detailed analysis of the Additional Trips recorded in Anderson County was perfomed. Anderson County was selected for the detailed analysis for several reasons. It is approximately the average size in area of all the counties in the ETHRA program. It has a combination of rural and urban tripmaking characteristics. It has a relatively large population. The Anderson County Dispatcher was the most familiar with the survey forms due to the earlier testing and the data collected there is expected to be the most accurate and reliable. Discussions with Chief Dispatcher Cheetwood indicated that the results from the detailed analysis could be applied to the remaining counties without an appreciable amount of error.

The detailed analysis of Additional Trips in Anderson County involved reviewing each additional trip request surveyed along with the driver's daily vehicle report with Chief Dispatcher Cheetwood. By noting times, locations and vehicle odometer readings, it was possible to track the vehicle to determine when and where the driver could phone the dispatcher given the criteria noted above. Of the 17 Additional Trip requests surveyed, nine, or 53 percent, involved miles saved. The distances saved per additional trip request ranged from 0 miles to 18 miles with the average distance saved being 4 miles. This final figure was applied to the average yearly estimated Additional Trip data for the four counties surveyed shown in Table 3. The resulting estimated total miles saved annually for the four counties is 5012 miles, yields an estimated annual cost savings due to the use of the two-way radio system of $4260.00.

Emergency or Drivers Assistance. As noted in the beginning of this Section, the Emergency or Drivers Assistance function does not lend itself to a quantifiable analysis. Therefore, the results of this function along with the other qualitative benefits noted will be shown as the intangibles attributed to the radio system.

Annual Cost Savings. The results of the quantifiable benefits of the radio system in the four counties surveyed are shown below:

Annual Cost Savings due to Trip Cancellations	=	$1,950.00
Annual Cost Savings due to Additional Trips	=	$4,260.00
Total Cost Savings due to use of Radio System	=	$6,210.00

In order to compare these annual savings due to the use of the radio system to the cost of the radio system, a present worth analysis was performed. This analysis utilizes the annual savings minus the annual costs to determine the present worth of the savings at the time the initial investment was made given the life of the equipment and the interest rate at which the savings could have been invested. If the present worth of the savings is larger than the cost of the radio system, then the quantified benefits outweigh the costs and the radio system is justified. If the costs are greater, then the qualitative benefits would come into play in deciding whether or not the radio system is justifiable.

As noted in Chapter IV, the estimate cost of the ETHRA radio system as of spring 1979 was approximately $40,000 in terms of 1977 dollars. This includes the cost of 18 mobile units, 8 base stations and two repeaters. However, since the survey encompassed only 4 counties, the cost of the radio system to be used in the analysis will be based on only the equipment required to operate in these counties. The radio equipment required is as follows:

One mobile unit for each van in the four counties and one mobile unit for the Transportation Director for a total of 12 mobile units.

One base station in each county plus one base station at the Transportation Directors office for a total of 5 base stations.

One repeater.

The cost for this equipment in terms of 1977 dollars is approximately \$24,700.[1]

Also noted in Chapter IV was the annual maintenance and repeater site rental costs which total approximately \$2600 annually. The discussion in Chapter II indicates that the two-way radios have an expected useful life of 10 years. It will be assumed for the present worth analysis that there is no salvage value of the radios after the 10 year period.

Present Worth Analysis of Benefits. The following information taken from the discussion above is required for the present worth analysis.

Cost of Radio System	=	\$24,700
Annual Costs	=	\$ 2,600
Annual Savings	=	\$ 6,210
Life of the Radio System	=	10 years

An interest rate of 10 percent will be used in the analysis.

The equation which solves for the equivalent present worth is:

$$P = A \frac{(1+i)^N - 1}{i\ (1+i)^N}$$

where,

P = equivalent present worth

A = net annual savings

i = interest rate

N = life of the radios

---

[1]This figure was arrived at by using the \$28,000 (1977 dollars) cost of the initial ETHRA radio system which was comprised of 15 mobile units, 6 base stations and one repeater used in the five original counties which included the four counties surveyed. The cost includes an additional \$120 per mobile unit for the encoder-decoder devices added in 1979.

Applying the data yields,

$$P = (6210 - 2600)\,\frac{(1 + 0.10)^{10} - 1}{0.10(1 + 0.10)^{10}}$$

$$= (3610)(6.1446)$$

$$= \$22,288.00$$

The analysis reveals that the benefits of the radio system come very close to equaling the costs of the system. The benefit-cost ratio is:

$$\frac{22,182}{24,700} = 0.90$$

Although this analysis indicates that the quantified benefits do not alone justify the acquisition of a two-way radio system for rural transportation, the addition of the intangible qualitative benefits noted may help provide the additional justification needed.

Summary. The results of the present worth analysis would seem to indicate that the purchase of two-way radio equipment for use in rural transportation programs is not justified. However, because the benefit-cost ratio is so close to the break-even point it would be improper to base a decision on purchasing radio equipment on this ratio alone. It is important to review the intangible benefits of radio systems noted along with the underlying assumptions made in establishing the quantified benefits. Among the latter, the following assumptions are brought forth as a few which if made differently could have resulted in a different benefit-cost ratio.

1. The number of radio assisted trip functions is directly related to the number of trips made during a given month at a rate that is the same for all months of the year. It is

possible that radio assisted trip functions may be made at a different rate during the summer months than in winter.

2. The radio equipment has a life of 10 years with no salvage value. It is possible for the equipment to operate over 10 years if properly cared for and a moderate salvage value could be expected.

3. The 10 percent interest rate may be high or low.

Several intangible benefits of radio use in rural transportation programs were noted. Among these several could result in cost savings such as in the use of the radios to communicate information regarding van breakdowns, the use of county gas pumps and directions.

Other intangible benefits that should not be discounted are the use of the radios for managerial functions as noted by several transportation directors in Chapter IV, the additional utilization of equipment, the ability to offer a more immediate demand responsive system and the security provided to the drivers travelling the rural counties.

CHAPTER VI

CONCLUSION

Advantages of Radio Use

The use of the communication capabilities provided by a two-way radio communications system can have a positive effect upon the operation of a rural transportation program. The principal advantages of radio use are:

1. Efficiency can be increased. Wasted driver and vehicle time can be avoided by utilizing the radio to inform drivers of additional trip requests, trip cancellations or adjusted pickup times instead of requiring them to stop and check in or allowing them to make an unnecessary trip.
2. Productivity can be increased. Additional people can be transported when they want, i.e., same-day service.
3. The operation of the transportation program can be monitored. The manager or dispatcher can keep close tabs on the drivers so that intentionally wasted time is kept at a minimum. Also, drivers can inform the dispatcher of an unavoidable delay which can be relayed to the clients.
4. Radios help in emergency situations. Drivers have the ability to contact the dispatcher without searching for a telephone and leaving the vehicle in the event of an emergency.

The benefit-cost analysis performed on the ETHRA transportation program indicates that those benefits that can be quantified do not alone justify the acquisition of a two-way radio system. However, the 0.90 benefit-cost ratio indicates that the quantified benefits do come very close to matching the costs. Given the wide ranging qualitative benefits of radio systems in rural transportation noted in this study, it would be improper to base a decision regarding the acquisition of a radio system on the benefit-cost ratio alone. The rural transportation system's Director along with the agency involved with funding the radio system must weigh the additional qualitative benefits demonstrated very carefully in their decision. In many cases, these "intangibles" can provide enough additional benefits to justify the use of a two-way radio system in rural transportation programs.

Equipment

For large, multi-county transportation programs, the two-way radio mobile relay system is the most appropriate of the communications systems available. It is this type of system that provides maximum coverage per dollar of equipment investment. For smaller programs covering only one or two counties, the one frequency simplex system usually can provide the desired communication capabilities at a lower cost than the mobile relay system. However, as the transportation program size increases, the mobile relay system becomes the most cost effective.

CB radios are inadequate for rural transportation communications purposes. Although very inexpensive in relation to two-way radio systems, a CB system provides extremely limited communications capabilities. These capabilities result in a very slight operational improvement over a program utilizing no radios at all.

The initial equipment cost for a two-way radio system has been approximately 12 percent of the total operating budget for the year that the equipment was purchased. Operating costs for the radio systems (including fulltime dispatchers, equipment maintenance, replacement, etc.) is approximately 14 percent of the total operating costs, of which 12 percent is for the fulltime dispatchers. However, the transportation managers interviewed have stated that the dispatchers would be required regardless of whether a radio system was utilized or not, at least on a half-time basis and most likely on a full-time basis.

The major factor which determines the eventual cost of a radio system is the degree of sophistication that is obtained. Increased sophistication typically results in increased communication capabilities. However, much of the increase in communication capabilities is in the form of added convenience and does not appreciably affect the operation of a rural transportation program. An example of this can be found in the transportation program of the Progress for People Human Resource Agency (HRA). The initial radio system included a feature which allowed individual vehicles to be contacted by a dispatcher, thus eliminating the constant chatter that would be heard if the vehicles received all transmissions. Currently this feature, which costs between $250 to $300 per radio, is not being utilized because its operational advantages have been outweighed by difficulties which arose as the system expanded. Conversely, in the East Tennessee Human

Resource Agency (ETHRA) program, the initial system had no sophisticated features. As the system expanded, difficulties arose which warranted increased sophistication of the initial equipment. However, the cost for the additional equipment was only $120 per radio. Thus, it can be seen that it is prudent to begin with a basic low-cost system that can become increasingly sophisticated by adding new equipment when warranted.

Two-way radio equipment typically is not insured even though it is relatively expensive ($800-$2,000 per radio). The high cost of insuring the equipment and the lack of problems with theft and vandalism have been cited as the major reasons for not obtaining insurance. The cost of the insurance is such that it is usually less expensive to replace a radio.

Two-way radio equipment is relatively durable with lifespans ranging up 10 years. Dispatch units, by virtue of their fixed position, can be expected to operate without major difficulties for over 10 years. Maintenance agreements with the manufacturers are available, although their worth is disputed. Given the trouble free operation of the equipment thus far, maintenance agreements may be questionable investments. The radios are under warranty for one year, and the system typically is guaranteed to operate to the manager's satisfaction before payment is made. Thus, the maintenance agreement does not seem to provide advantages in the early years of a system. As the system grows older, a maintenance agreement may be appropriate to Protect against breakdowns due to old age.

State Role

The role of the manufacturer's representative or vendor was discussed in this report. It was found that there is a conflict of interest of sorts in that the vendor is typically a consultant to the transportation manager along with being a salesperson. It is in this area that existing state and local governmental agencies which utilized two-way radio equipment can be of great assistance. These agencies may include state and local police departments, county sheriff offices, emergency medical services, state forestry or wildlife conservation agencies and local transportation services. These agencies should be encouraged to share their experiences with those in rural transportation who are interested in obtaining a two-way communications system. In addition, those in rural transportation should be made aware of these excellent sources of information concerning two-way communications and should be encouraged to tap this well of knowledge.

Tennessee currently employs a state frequency coordinator who has the job of assisting in the process of locating and securing a frequency for communications use. This position is limited to an advisory role and acts as an intermediatary between the applicant for a frequency and the FCC which holds power over all radio communications.

Finally, there has been much discussion of a statewide communication network for rural transportation utilizing either one or two sets of frequencies. Such a network would provide a unifying force that would help coordinate the efforts of those across Tennessee who provide transportation to rural areas. This is a desirable idea. However, the problems experienced by the HRA and ETHRA programs in East Tennessee which utilize the same frequency should rule out the option of one statewide frequency for rural transportation. Rather, the use of two sets of frequencies statewide is recommended. This scheme would incorporate geographical boundaries to help minimize the interference between systems having the same frequency by alternating the two frequencies region by region. Those vehicles which are expected to travel in two adjacent regions would be provided with capabilities to use both frequencies.

Guidelines For The Transportation Manager

The rural transportation manager typically has little or no knowledge about radio communication systems. Barring any state involvement in providing a radio consultant, the transportation manager must rely on the vendor as a consultant. Therefore, in order to assist both the manager (so that the program receives the desired communication capabilities) and the vendor (so that the vendor can provide the desired capabilities), the following guidelines are offered to the transportation manager.

1. Keep in mind the eventual use of the communications system in a rural transportation context. Although it is impossible to know what radio system is appropriate, it is possible to know how that system is to be used. Is it important for mobile units to hear only calls directed to them or is it acceptable for them to hear all calls? Is it necessary to have the ability to substitute vehicles throughout the system which requires that all radios have the same power output or can a few vehicles be designated as rovers so that variable powered radios can be used?

2. Contact several vendors. Although it may be convenient to deal with one manufacturer, getting more than one proposal will ensure a good price.
3. Require system specifications which are specific enough to gain the desired capabilities yet general enough so that several manufacturers can submit proposals. Beware of the vendor that offers to write the specifications so that all others out are written of the bidding.
4. Remember, the vendor is a sales representative. The vendor is probably the only expert on the subject that will be contacted, so it is important to recognize that the vendor is also a salesperson.

REFERENCES

REFERENCES

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APPENDIX A

SURVEY FORMAT

RADIO USE SURVEY

DATE ________ COUNTY________

ADDITIONAL (UNSCHEDULED) TRIPS

Bus Number ________ New Passenger's Initials ________ COMMENTS

- At what time was the new trip request phoned in? ________
- At what time was the driver notified of the new trip request? ________
- Did the passenger have an appointment or request a specific time to be at their destination? Yes No
- If yes, what was that time? ________

Bus Number ________ New Passenger's Initials ________ COMMENTS

- At what time was the new trip request phoned in? ________
- At what time was the driver notified of the new trip request? ________
- Did the passenger have an appointment or request a specific time to be at their destination? Yes No
- If yes, what was that time? ________

Bus Number ________ New Passenger's Initials ________ COMMENTS

- At what time was the new trip request phoned in?
- At what time was the driver notified of the new trip request? ________
- Did the passenger have an appointment or request a specific time to be at their destination? Yes No
- If yes, what was that time? ________

Bus Number ________ New Passenger's Initials ________ COMMENTS

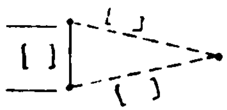
- At what time was the new trip request phoned in?
- At what time was the driver notified of the new trip request? ________
- Did the passenger have an appointment or request a specific time to be at their destination? Yes No
- If yes, what was that time? ________

TRIP CANCELLATION

Bus Number ________ COMMENTS

List the following passengers initials as listed on the drivers schedule and write in the distances between their pick-up or drop-off locations.

Passenger Before Cancelled Passenger ________



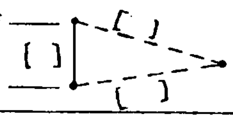
Cancelled Passenger

Passenger After Cancelled Passenger ________

Bus Number ________ COMMENTS

List the following passengers initials as listed on the drivers schedule and write in the distances between their pick-up or drop-off locations.

Passenger Before Cancelled Passenger ________



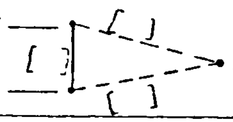
Cancelled Passenger

Passenger After Cancelled Passenger ________

Bus Number ________ COMMENTS

List the following passengers initials as listed on the drivers schedule and write in the distances between their pick-up or drop-off locations.

Passenger Before Cancelled Passenger ________



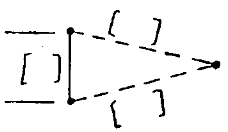
Cancelled Passenger

Passenger After Cancelled Passenger ________

Bus Number ________ COMMENTS

List the following passengers initials as listed on the drivers schedule and write in the distances between their pick-up or drop-off locations.

Passenger Before Cancelled Passenger ________



Cancelled Passenger

Passenger After Cancelled Passenger ________

RADIO USE SURVEY

DATE ________________ COUNTY ____________

	EMERGENCIES OR DRIVER ASSISTANCE
BUS NUMBER	BRIEF DESCRIPTION OF SITUATION

TRIP CANCELLATION FORM

Use the TRIP CANCELLATION form when you notify a driver, by radio, of the cancellation of a previously scheduled trip. The purpose of the form is to identify those cases in which the use of the radio saves the driver an unnecessary trip. The assumption made here is that without a radio the driver would travel to the person's house only to find that the person doesn't need or want the scheduled ride. By filling in the distances shown on the form it will be possible to determine the number of miles that are saved.

The following is an example showing how the form is used and includes a sample drivers schedule:

	Pick-up Time	Passenger	
This is the schedule for	9:00	Sue Best	
the driver of Van #5	9:15	Mary Jean Hill	15 Miles
	9:40	Tim Smith	10 Miles
	9:50	Ruth Ann Baker	5 Miles
	10:15	Mabel Reid	

The dispatcher notifies the driver by radio that Tim Smith has cancelled his trip and fills out the form as follows:

TRIP CANCELLATION

Bus Number 05

List the following passengers initials as listed on the drivers schedule and write in the distances between their pick-up or drop-off locations.

Passenger Before Cancelled Passenger MJH (15)

(10) TS Cancelled Passenger

Passenger After Cancelled Passenger RAB (5)

ADDITIONAL (UNSCHEDULED) TRIPS FORM

Use the ADDITIONAL (unscheduled) TRIP form when you notify a driver, by radio, of an unscheduled trip request that was called in after the driver has picked up his or her schedule for the day. The purpose of the form is to identify those cases in which the use of the radio allows the addition of new trips to a drivers schedule without the driver having to check-in physically or by telephone. Here the assumption is that without the radio a large number of new trip requests for same day service would not be able to met. By filling in the information required on the form it will be possible to determine those new trips that are serviced due to the use of the radio.

The following is an example showing how the form is used:

> Jim Dandy called into the dispatch office at 9:30 AM requesting a ride for later in the morning. Jim has a doctors appointment at 11:30 AM. The dispatcher tells Jim that a driver will be by to pick him up around 10:45 AM. The dispatcher then radios the driver of Vehicle # 10 at 9:40 AM and informs her about the new trip. The following is what the form should look like.

ADDITIONAL (UNSCHEDULED) TRIPS

Bus Number 10 New Passenger's Initials J.D. COMMENTS

- At what time was the new trip request phoned in? 9:30 AM
- At what time was the driver notified of the new trip request? 9:40 AM
- Did the passenger have an appointment or request a specific time to be at their destination? Yes No
- If yes, what was that time? 11:30 AM

EMERGENCIES OR DRIVERS ASSISTANCE FORM

The EMERGENCIES OR DRIVERS ASSISTANCE form is to be used whenever the radio is utilized to help provide assistance to a driver. This would include situations where the driver calls the dispatcher for assistance at an accident, at a breakdown, or for directions. Any situation that seems to provide assistance to a driver over the radio should be noted. If there is any question jot the instance down and make a note that you are not sure and we'll check it over. The purpose of the form is to identify the number and types of situations in which the radio is used to help provide assistance to a driver.

The following is an example of how the form is used:

EMERGENCIES OR DRIVER ASSISTANCE	
BUS NUMBER	BRIEF DESCRIPTION OF SITUATION
#10	Van Break-down in Lake City. Driver called dispatcher on radio to get help
#6	Driver asked for directions while in Knoxville
# 3	Driver calls dispatcher to inform her about an accident on I-75. Dispatcher informs police

APPENDIX B

RADIO TERMINOLOGY

APPENDIX B

RADIO TERMINOLOGY

Most of the following information was taken from Rules and Regulations, Volume V, Part 90, Private Land Mobile Radio Services, Federal Communications Commission, March 1979.

Antenna. Device used to transmit and receive radio signals.

Assigned frequency. Center of a frequency band assigned to a station.

Assigned frequency band. The frequency band the center of which coincides with the frequency assigned to the station and the width of which equals the necessary bandwidth plus twice the absolute value of the frequency tolerance.

Average terrain. The average elevation of terrain between two and ten miles from the antenna site.

Bandwidth. The range of frequencies identified by lower and upper frequencies and designated by the FCC for specific uses.

Base unit. A radio unit at a specified site authorized to communicate with mobile units.

Carrier wave. An easily transmitted high frequency radio wave which is utilized to transport or "carry", by means of modulation, electronic signals representing verbal messages.

Channel chatter. A large amount of transmissions or "talking" on a particular frequency which makes it difficult to receive or "hear" incoming messages.

Channel guard. Manufacturers' term for the capabilities provided by encoder-decoder devices.

Channel loading. The number of mobile transmitters authorized to operate on a particular channel within the same service area.

Control point. Any place from which a transmitter's functions may be controlled.

Control station. An Operational Fixed Station, the transmissions of which are used to control automatically the emissions or operation of another radio station at a specified location.

Deadspot. An area in which signals transmitted from the control or base station cannot reach a mobile unit because of the terrain.

Decoder. A device used in conjunction with an encoder which allows selective reception of radio signals by accepting only those signals which are accompanied by a particular subaudible frequency or tone.

Dispatch unit. A base unit used for the dispatching of a transportation service vehicle.

Effective radiated power (ERP). The power supplied to an antenna multiplied by the relative gain of the antenna in a given direction. The ERP is a measure of the transmitting capabilities of an antenna and, reciprocally, of its ability to receive weak signals.

Encoder. A device used in conjunction with a decoder which attaches a particular subaudible frequency to a transmitted signal so that the signal can be selectively received.

Frequency advisor or coordinator. An individual or entity that has been recognized by the FCC for the purpose of coordinating the assignment of frequencies, by recommending to applicants, upon request, appropriate frequencies for which to apply.

Gain antenna. An antenna which concentrates the radiation pattern of signals in a direction other than the spherical pattern exhibited by a normal antenna, in order to provide greater range or specific directivity.

Interference. Any emission, radiation, or induction which degrades, obstructs, or interrupts the reception of transmitted signals, typically the result of simultaneous transmission occurring on the same frequency within close proximity of a central station.

Mobile relay station or repeater. A remote base or control station which automatically retransmits signals which it receives from mobile or dispatch stations.

Mobile service. A service of radio communication between mobile and base units or between mobile units.

Mobile unit. A radio unit in the mobile service intended to be used while in motion or during halts at specific points.

Modulate. The process of altering the carrier wave in such a fashion so that the alteration can be detected and deciphered by a receiver.

Operational fixed station. A fixed station, not open to public correspondence, operated by, and for the sole use of those agencies operating their own radio communication facilities in the Public Safety, Industrial, and Transportation, Marine or Aviation Radio Services.

Private line. See channel guard.

Receiver. A device which is capable of responding to a wanted signal and rejecting unwanted signal and which amplifies that signal and extracts from the modulated wave the intelligence which was impressed upon it at the transmitter.

Repeater. See mobile relay station.

Skip. A type of interference caused by radio waves bouncing off the ionosphere and traveling great distances.

Talk-around. Trade name for feature which allows radio units in a mobile relay system to communicate without accessing a repeater.

Transceiver. A radio unit which has the ability to both transmit and receive signals, typically known as a two-way radio.

Transmitter. A device which is capable of impressing upon a carrier wave a desired message by means of modulation and launching the signal into space.

Tone-coded squelch. See channel guard.

Vendor. The name used for the radio manufacturers' representative or salesperson.

VITA

Eugene J. Baksa, Jr., was born in Trenton, Michigan on May 18, 1955. He attended elementary schools in Trenton and graduated from Trenton High School in June, 1973. The following September he entered Michigan State University and in June 1977 he received a Bachelor of Science degree in Civil Engineering. That June, he accepted a position with the Michigan Department of Transportation as a Road Design Engineer.

In September, 1978, he accepted a teaching assistantship at The University of Tennessee, Knoxville and began study towards a Master's degree. He accepted a research assistantship in June, 1979, which resulted in a report prepared for the Bureau of Mass Transit, Tennessee Department of Transportation entitled The Use of Radio Communications in Rural Transportation. This report which was reprinted by the U. S. Department of Transportation Technology Sharing Program was the basis of this thesis.

In February, 1980, he accepted a position with the Knoxville/Knox County Metropolitan Planning Commission as a Transportation Planning Engineer until September, 1981, when he took his present position with Allen & Hoshall Engineers, Inc., as a Transportation/Civil Design Engineer.

The author is a registered P.E. and is an associate member of the Institute of Transportation Engineers.