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U.S. Department of Transportation

Federal Transit Administration

Effectiveness of External Bus Speaker Systems for Persons With Visual Impairments

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Final Report

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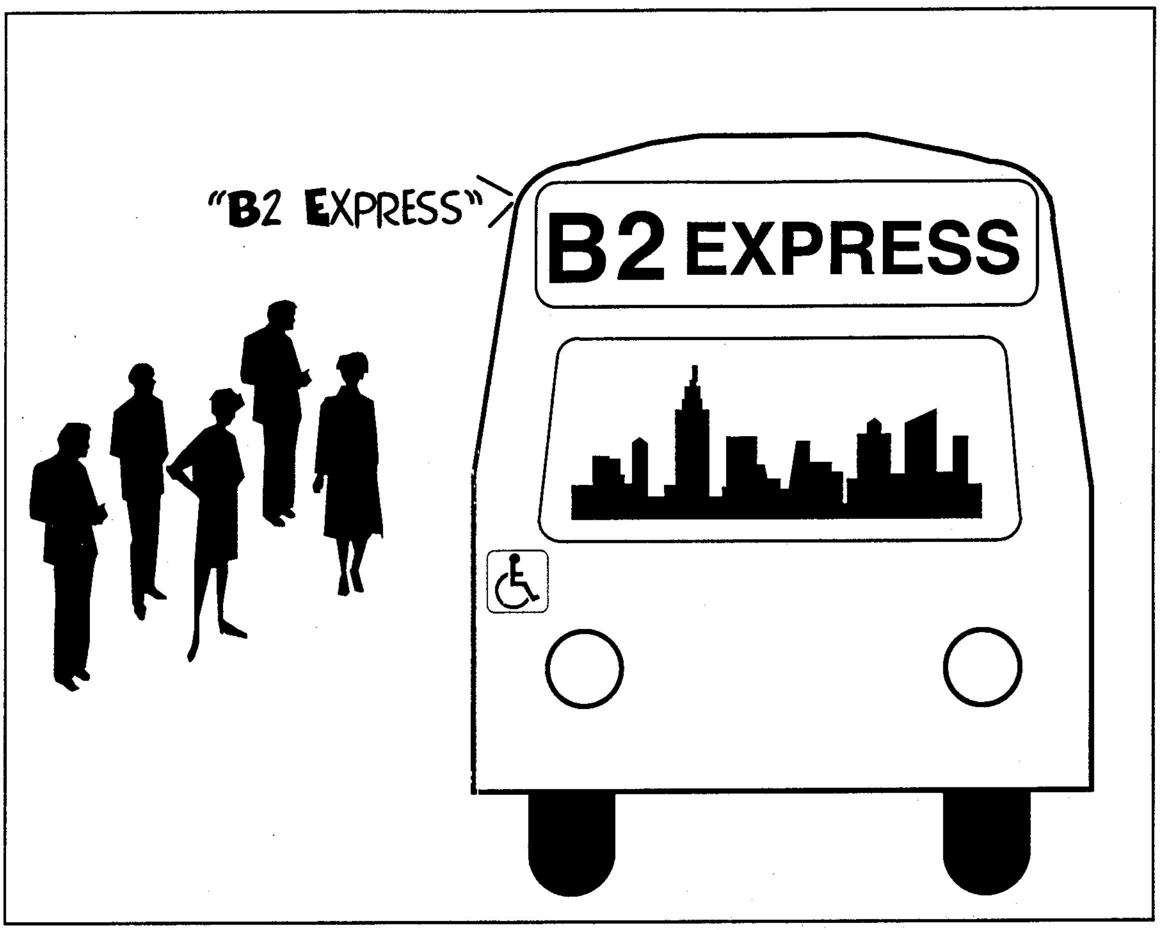

Federal Transit Administration

Office of Research, Demonstration and Innovation

Effectiveness of External Bus Speaker Systems for Persons With Visual Impairments

Final Report
May 1998

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16. Abstract

While speaker systems have been evaluated and modified for use in many environments, no work has been conducted in the United States to study the application of speaker systems for external bus announcements. The purpose of the project was to identify:

- The information needs of bus passengers who are visually impaired as they board the bus
- The extent to which an external bus speaker can deliver this information effectively
- The external bus speaker configurations that would most effectively communicate with visually impaired passengers.

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The "Effectiveness of External Bus Speaker Systems for Persons With Visual Impairments," was prepared by a team of bus experts from Booz·Allen & Hamilton with assistance from scientists and researchers from the Department of Blind Rehabilitation at Western Michigan University and the American Foundation for the Blind. The report identifies the information needs of bus passengers who are visually impaired, the extent to which an external bus speaker system can effectively deliver this information, and the external bus speaker configurations that could most effectively communicate with visually impaired passengers. Booz·Allen & Hamilton would like to specifically acknowledge the assistance of the following individuals:

- Elga Joffee, M.Ed. MPS—American Foundation for the Blind
- Judith Rutberg Kuskin, M.Ed., J.D.—American Foundation for the Blind
- William R. Wiener, Ph.D., Department of Blind Rehabilitation, Western Michigan University.

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Finally, Booz·Allen & Hamilton would like to thank all of the participants in the test and focus groups, and community town meetings whose contributions and feedback were invaluable to the success of the project.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gr)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32) (5/9)]°F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, sq^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)

1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)

1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5)y + 32]°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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FOREWORD

While speaker systems have been evaluated and modified for use in many environments, no work has been conducted in the United States to study the application of speaker systems for external bus announcements. The purpose of the project was to identify:

- The information needs of bus passengers who are visually impaired as they board the bus
- The extent to which an external bus speaker can deliver this information effectively
- The external bus speaker configurations that would most effectively communicate with visually impaired passengers.

NOTICE

EXECUTIVE SUMMARY

Individuals who have full use of their sight are able to use multiple sources of visual information in the transit environment to access and use public transit vehicles. (Although both buses and railcars are considered transit vehicles, this report focuses on transit buses.) These sources include vehicle front and side signs that identify vehicle route numbers and destinations, characteristic outdoor landmarks, and street signs along a vehicle's route that enable passengers to maintain their orientation and identify the stop where they want to disembark.

Persons who are visually impaired face several challenges when trying to travel on transit buses. Often, they are unable to easily recognize that a vehicle approaching a bus stop is actually a bus (as opposed to a vehicle that may sound or look similar); they cannot determine the precise location of a bus at a bus stop; and they often cannot identify the route number and destination of a bus as it approaches the bus stop. At locations where several buses service one particular stop, persons who are visually impaired may have difficulty identifying and boarding a particular bus.

Persons with visual impairments pay attention to those sounds that have the most importance to them. Key environmental sounds are used by visually impaired passengers to assist in orientation. The sound of the bus motor and the sound of the air brakes are used to identify the presence of a vehicle. The sharp compression or hissing air is used to identify the opening of the bus door. While these sounds are useful tools, they are not specific enough to provide all of the information needed to effectively access and board a bus. More specific information is needed to tell a visually impaired person which bus has arrived at a stop. The individual needs to know in which direction the vehicle will be going and its final destination. This information can be presented through external auditory bus announcements. Since environmental noises are constantly changing, speaker systems must be intelligible under varying conditions, must convey the necessary information, and blend into the surrounding soundscape.

PROJECT OBJECTIVES

While speaker systems have been evaluated and modified for use in many environments, no work has been conducted in the United States to study the application of speaker systems for external bus announcements. The FTA funded a research project, with scientists and engineers from the

Department of Blind Rehabilitation, Western Michigan University and the American Foundation for the Blind; and bus technology experts from Booz·Allen & Hamilton. The purpose of the project was to identify:

- The information needs of bus passengers who are visually impaired as they board the bus

- The extent to which an external bus speaker can deliver this information effectively

The external bus speaker configurations that would most effectively communicate with visually impaired passengers.

APPROACH AND METHODOLOGY

The project was carried out in two phases–Phase I took place in Kalamazoo, Michigan and Phase II took place in New York City. Each phase was designed to study the specific information gathering needs of blind and visually impaired passengers; and to determine how, if at all, external speakers can best meet those needs. Kalamazoo, Michigan was selected for Phase I because it is a small city transit environment, characteristic of suburban and small city bus systems. In addition, Kalamazoo provided a transit environment in which external bus speakers were already in use. The transit environment represented in Phase II (New York City) was characteristic of dense, urban conditions where transit vehicles operate.

Two research techniques were used in each phase of the study–focus group research and human performance testing. The focus group research technique probed the experiences, preferences, and needs of persons with visual impairments with respect to travel on buses equipped with external speakers. Human performance testing involved field tests that measured the performance of travelers with visual impairments as they responded to external bus speaker announcements; presented under laboratory-type conditions in Phase I, and actual transit travel conditions in Phase II. Data was gathered on the ability of travelers to perceive and understand the vehicle route numbers and destination information delivered by an external speaker system, and to locate the door of the bus.

The purposes for complementing human performance testing with focus group studies were to learn about the factors that persons with visual impairments believe affect the audibility and usability of external bus speakers in transit environments; to determine the extent to which the preferences of the focus group participants who had experienced audible external bus speakers in transit environments were consistent with human performance experiences; and to explore additional factors that persons with visual impairments believe are related to external bus speakers.

Two community "town-hall" type meetings were conducted - one in Philadelphia, Pennsylvania and one in Dallas, Texas - to identify general community attitudes and concerns about external bus speaker systems. At each meeting, participants were briefed on the objectives of the study and also given the opportunity to hear an example of external bus speaker systems. The meetings were intended to address to key issues:

- Were external bus speaker systems thought to be beneficial? Who might reasonably be expected to receive such benefits? What aspects of external speaker systems were most significant in producing those benefits?

- Were external bus speaker systems thought to pose potential risks and concerns that might serve to diminish any of the potential benefits to users and at the same time generate annoyance among non-users? How might such concerns be alleviated to the greatest advantage of both transit users and the general public?

SUMMARY OF CONCLUSIONS

Based on the results of this study, the following conclusions and recommendations are offered:

- External bus speaker announcements are useful to persons who are visually impaired and are likely to aid the wide range of passengers that use buses. They provide persons who are visually impaired with effective access to the information conveyed by visible bus vehicle signage, assist with the task of locating a desired bus when more than one bus is at a bus stop, and enhance travelers' confidence and independence when they have to locate the bus door.

- External bus speakers should be made available on public bus systems to enhance information access for persons who are visually impaired. The speaker announcements should be delivered through a system that can automatically adjust the volume level of the announcements in the presence of ambient traffic noise.

- The main speaker in an external bus speaker system should be located as close to the front bus door as possible, and if possible above the center of the front bus door.

- The external speaker message should contain the following information in this order - the bus number, whether the bus provides express or local service, the bus direction of travel, and the destination of the bus.

- In order to make the external speaker announcements reliable, they should be automatically activated when the bus door opens, and not have to be activated by the driver each time the bus door opens.

- When bus doors remain open for extended periods of time, the speaker announcements should repeat regularly.

Chapter 1
INTRODUCTION

1.1 BACKGROUND

Individuals who have full use of their sight are able to use multiple sources of visual information in the transit environment to access and use public transit vehicles. (Although both buses and railcars are considered transit vehicles, this report focuses on transit buses.) These sources include vehicle front and side signs that identify vehicle route numbers and destinations, characteristic outdoor landmarks, and street signs along a vehicle's route that enable passengers to maintain their orientation and identify the stop where they want to disembark.

Persons who are visually impaired face several challenges when trying to travel on transit buses. Often, they are unable to easily recognize that a vehicle approaching a bus stop is actually a bus (as opposed to a vehicle that may sound or look similar); they cannot determine the precise location of a bus at a bus stop; and they often cannot identify the route number and destination of a bus as it approaches the bus stop. At locations where several buses service one particular stop, persons who are visually impaired may have difficulty identifying and boarding a particular bus.

Persons who are visually impaired have developed and use a number of approaches for gathering the information they need to identify and board buses. These approaches include asking sighted persons in the vicinity of the bus stop for assistance, or boarding a bus and asking the driver the route number and destination of the bus. The first approach may not work if there is no one in the vicinity and the second approach can be an inconvenience to the visually impaired rider, the driver, and other passengers. If there a number of buses lined up at a stop, a visually impaired rider may have to locate the door of each bus and ask each driver to identify the bus, and in the process may miss the bus. In all situations, passengers who cannot see have to rely on others for information to identify and access the bus and are at risk of receiving incorrect information or no information at all.

Bus transportation is critically important for persons with visual impairments; many consider public transportation as their "lifeline" to employment and community services. In 1990, Public Law 101-336, the Americans With Disabilities Act (ADA), established the framework for making visually displayed information in the environment accessible to persons who are visually impaired. Title II of the ADA specifically addresses the responsibilities of public transit systems to provide accessible transit vehicles, facilities, and services. One of the requirements is that audible information be announced inside a vehicle, but does not require "external" announcements that would identify bus numbers and destinations to passengers waiting at bus stops.

The U.S. Department of Transportation reserved a section of Title II to develop the requirements for external bus announcements, pending further research regarding the effectiveness of these announcements, and the establishment of parameters for external bus speaker systems. Although a rule requiring external speakers was initially proposed, it was deleted following the public comment period. Concerns were raised about whether external bus speaker announcements would be intrusive on the general population in some suburban and residential areas, and whether these speakers would be inaudible in noisy, congested urban environments. The purpose of this study was to examine the most effective approach for using external bus speakers to communicate information to transit passengers with visual impairments, while minimizing the effects of these speakers on noise pollution.

1.2 HOW AUDIBLE INFORMATION CAN BE USED BY TRANSIT RIDERS

Audible information that conveys the same information presented by visible vehicle signage can be useful to both visually impaired and non-visually impaired passengers. For persons who are visually impaired, an external bus speaker systems can provide information about bus routes and destinations, enabling these passengers to accurately identify and locate the bus they wish to use. Similarly, external bus speakers can be useful to persons with normal sight, particularly in situations when visual information is not easily accessible, i.e., when glare or inclement weather obscure vision; when buses cluster closely at a stop, blocking the view of vehicle front destination signs; when buses pull up at a stop angled away from the curb; or when individuals are print impaired for reasons not related to visual impairment.

1.3 REVIEW OF THE CHARACTERISTICS OF SOUND AND HUMAN AUDITION

Sound can be described by two of its most important characteristics - intensity and frequency. Intensity is the level of loudness, measured in decibels (dB), that is created as an energy source vibrates molecules of air. For example, average conversational speech is approximately 60 dB to 70 dB, while the sound of traffic in a downtown area may be 85 dB or more. Horns and sirens may produce intensities in excess of 100 dB. Frequency refers to the number of molecule vibrations that occur within a second. The human ear is sensitive to frequencies between

20 cycles per second (Hertz or Hz) and 20,000 Hz. The frequencies that are most important in speech are between 500 and 4,000 Hz. Within this range, the frequencies between 2,000 and 4,000 Hz provide high frequency emphasis that is most important to identify consonants, and it is consonants that enable people to easily distinguish between words. Therefore, the upper frequencies are most important for word intelligibility.

Traffic sounds and other noises are low in frequency, but often high in intensity (or loudness). Low frequency sounds have a tendency to mask other sounds that are present and many less intense sounds are covered by up louder sounds. Therefore, low frequency noise in the form of traffic sounds are often loud enough to interfere with other important sounds in the environment.

1.4 THE USE OF ENVIRONMENTAL SOUNDS BY PERSONS WITH VISUAL IMPAIRMENTS

Persons with visual impairments pay attention to those sounds that have the most importance to them. Key environmental sounds are used by visually impaired passengers to assist in orientation. The sound of the bus motor and the sound of the air brakes are used to identify the presence of a vehicle. The sharp compression or hissing air is used to identify the opening of the bus door. While these sounds are useful tools, they are not specific enough to provide all of the information needed to effectively access and board a bus. More specific information is needed to tell a visually impaired person which bus has arrived at a stop. The individual needs to know in which direction the vehicle will be going and its final destination. This information can be presented through external auditory bus announcements. Since environmental noises are constantly changing, speaker systems must be intelligible under varying conditions, must convey the necessary information, and blend into the surrounding soundscape.

1.5 REVIEW OF SELECTED EXISTING TECHNOLOGIES TO PROVIDE AUDIBLE BUS INFORMATION

A variety of solutions have been offered to address the difficulties faced by individuals with visual impairments who travel on buses. In the 1980s, research was conducted in England that resulted in the development of a prototype "talking" bus stop, the Electronic Speech Information Equipment (ELSIE). ELSIE made bus transit information accessible to bus travelers through the use of a hand-activated audible speaker system. ELSIE enabled visually impaired passengers to locate a bus stop and operate manual controls to request audible information about bus service and schedules, and the impending arrival of a bus. ELSIE also announced the route number and destination of approaching buses by "reading" the front destination sign with a television camera, or interpreting a broadcast from a radio or infrared transmitter installed on the bus.

Japan provides audible information to its travelers with visual impairments through the use of audio taped messages in stair railings. When the railing is touched, the message is received. Japanese transit systems also provide a uniquely shaped sign post to mark bus stops to facilitate the identification of poles as bus stops; and Japanese drivers are required to undergo training designed specifically to enable bus drivers to accommodate the needs of visually impaired passengers.

In the United States, external bus speaker systems have been proposed as a way of providing bus vehicle information to persons who are visually impaired. One such systems, designed by Digital Recorders, Inc. provides external bus announcements by incorporating an external speaker system with a built-in monitor that continuously listens to ambient noise levels outside the bus. Digital Recorder's DR500C Talking Bus Logic Unit determines the average ambient noise level in the vicinity of the bus the moment the bus door is opened and then plays an external announcement at a correspondingly appropriate loudness level. To maintain the level of clarity, the audible messages are digitized and stored in a computer memory, rather than being recorded on magnetic tape. The Digital system also has the capacity to make announcements inside a vehicle and can be programmed to announce the name of each stop along a vehicle's route. The unit is programmed for internal or external announcements using a keypad installed to the driver's right.

Digital Recorder's external speaker system is powered by 12 to 24 volts of power at 20 watts, has a 40 megabyte capacity, uses flash memory, and provides digital sampling at 11,000 times per second. The system is equipped with an equalizer that allows the messages to be recorded with enhancement of specific frequencies as needed. The Digital system does not specify a fixed location on the bus for the installation of speaker components, thus the position and mounting of the speaker is determined by each individual transit operator. Some systems have placed speakers near the front grille of the bus or beside the rear door, or have used a combination of both configurations.

At the time of this study, several transit systems in the United States had installed Digital Recorder's external speaker system on their bus fleets. Other products that produce audible internal and external information are also commercially available and in service. This project examined Digital Recorder's external bus speaker systems because a Digital system has been in operation for several years on the bus system in Kalamazoo, Michigan and has been widely used by passengers who are visually impaired.

1.6 STUDY OBJECTIVES

While speaker systems have been evaluated and modified for use in many environments, no work has been conducted in the United States to study the application of speaker systems for external bus announcements. The FTA funded a research project, with scientists and engineers from the Department of Blind Rehabilitation, Western Michigan University and the American Foundation for the Blind; and bus technology experts from Booz·Allen & Hamilton. The purpose of the project was to identify:

- The information needs of bus passengers who are visually impaired as they board the bus
- The extent to which an external bus speaker can deliver this information effectively
- The external bus speaker configurations that would most effectively communicate with visually impaired passengers.

Chapter 2
STUDY APPROACH AND METHODOLOGY

2.1 STUDY APPROACH

The study approach utilized the following research questions to frame the purpose of the study:

- To what extent can external bus speakers be heard above the sound of ambient traffic?
- To what extent can the enhancement of the upper frequencies improve the intelligibility of the announcements?
- To what extent can individuals distinguish between simultaneous announcements from two competing buses?
- To what extent can the presence of external speaker announcements improve the visually impaired person's speed and accuracy of locating the bus door?
- To what extent does the placement of the speaker near the door affect the visually impaired person's speed and accuracy of locating the bus door?
- To what extent does the frequency enhancement of the speaker announcement improve the visually impaired person's speed and accuracy of locating the bus door?

The project was carried out in two phases–Phase I took place in Kalamazoo, Michigan and Phase II took place in New York City. Each phase was designed to study the specific information gathering needs of visually impaired passengers; and to determine how, if at all, external speakers can best meet those needs. Kalamazoo, Michigan was selected for Phase I because it is a small city transit environment, characteristic of suburban and small city bus systems. In addition, Kalamazoo provided a transit environment in which external bus speakers were already in use. The transit environment represented in Phase II (New York City) was characteristic of dense, urban conditions where transit vehicles operate.

2.2 METHODOLOGY

Two research techniques were used in each phase of the study–focus group research and human performance testing. The focus group research technique probed the experiences, preferences, and needs of persons with visual impairments with respect to travel on buses equipped with external speakers. Human performance testing involved field tests that measured the performance of travelers with visual impairments as they responded to external bus speaker announcements; presented under laboratory-type conditions in Phase I, and actual transit travel conditions in Phase II. Data was gathered on the ability of travelers to perceive and understand the vehicle route numbers and destination information delivered by an external speaker system, and to locate the door of the bus.

The purposes for complementing human performance testing with focus group studies were to learn about the factors that persons with visual impairments believe affect the audibility and usability of external bus speakers in transit environments; to determine the extent to which the preferences of the focus group participants who had experienced audible external bus speakers in transit environments were consistent with human performance experiences; and to explore additional factors that persons with visual impairments believe are related to external bus speakers.

The project's focus groups were specifically designed to:

- Learn about the previous experiences of the participants who had used buses equipped with external speakers
- Determine the informational needs that could be addressed by external speaker announcements
- Evaluate sample speaker configurations to assist in the selection of speaker specifications for the human performance tests
- Discuss the effectiveness of speaker announcements
- Reconcile test data with the experience of subject participants

- Consider the possible effects that external speaker announcements might have on the environment

- Make recommendations for the future use of external bus speaker announcements.

The project's human performance testing was designed to gather objective data on the ability of persons who are visually impaired to perform the following tasks:

- Correctly identify all parts of messages being announced through external bus speakers

- Locate the door of a bus stopped at a bus stop, with and without the presence of external speaker announcements

- Locate the door of a bus stopped at a bus stop when standard (flat) and frequency enhanced speaker messages were played.

- Locate the door of a bus stopped at a bus stop when external speakers were placed in different positions on the bus

- Identify the correct bus in the presence of competing external speaker announcements.

Chapter 3
TEST PROCEDURES

This section discusses the test procedures that were used in each phase of the study – how participants were recruited, how the focus groups were conducted, the equipment used, and the basic test procedures. Analysis of results from each phase are presented in Chapter 4, Analysis of Results.

3.1 PHASE I - KALAMAZOO, MICHIGAN - TEST SET-UP AND PROCEDURES

3.1.1 Participant Recruitment - Phase I

Eleven adults who routinely use the Kalamzoo bus system were recruited for Phase I. The participants included 5 males and 6 females with severe visual impairments between the ages of 24 to 48, with a mean age of 33 years. Because buses in Kalamazoo are equipped with Digital Recorder external speaker announcements, most of the participants had experience with the speakers during the course of their daily travel.

Participants were recruited through posted recruitment announcements and by contacts with individuals known to the Department of Blind Rehabilitation at Western Michigan University. Priority for inclusion in the study was given to participants who were totally blind or who had no usable travel vision, were weekly or daily bus users, and who rated themselves as "good" travelers. Prospective participants were asked to report if they were aware of having a hearing impairment, since these would be screened out of the study. Participants were also given a hearing screening questionnaire, modified specifically for persons who are visually impaired, immediately prior to their participation in performance testing.

Blindfolds were used to occlude the vision of participants who indicated they had available travel vision to prevent them from using visual clues during testing. All participants were asked to use long white mobility canes and guide dogs were not permitted as travel tools because dog guides are trained to visually locate and guide their masters to an open bus door.

3.1.2 Focus Group Procedures - Phase I

A focus group was conducted first to gather information from visually impaired bus passengers in Kalamazoo about their experiences with external bus speaker announcements, to have them suggest new solutions for providing accessible information, and to identify independent variables that could be used for an objective test of external bus speakers.

First, the focus group discussed the preferences, needs, and recommendations of individuals who are visually impaired and who travel in Kalamazoo using buses equipped with external bus speakers. Following this discussion, participants listened to samples of external bus messages recorded with different levels of frequency enhancement and played through external bus speakers positioned in a variety of locations on a bus. Participants then state a preference for messages with the following combined characteristics:

- Messages that had the greatest frequency enhancement, i.e., were loudest in the upper frequency sounds of the message

- Messages that were produced by speakers located above the front door of the bus.

Based on this focus group feedback, it was determined that the effectiveness of external bus speakers would be tested during the human performance study under the following conditions:

1. No external speaker response

2. An external speaker with a standard flat frequency response

3. A speaker with an enhanced response in the upper frequencies

4. Speakers mounted in the configuration utilized by the Kalamazoo transit agency (one flush-mounted speaker located in the side of the bus behind the rear door at ear level, and one horn-type speaker located in the front of the bus behind the front fender on the side closer to the sidewalk facing down into the street

5. A speaker mounted just above the bus door.

3.1.3 Apparatus and Equipment Set-up - Phase I

In Phase I, Digital Recorder's DR 500B Talking Bus system was used. This model predates the DR 500C (used in Phase II in the New York City urban environment) and does not have the capability of monitoring external sounds and adjusting speaker output accordingly. Instead, it is adjusted manually with a gain control, therefore it lacks the capacity to compensate for temporary sounds of a passing vehicle by increasing the volume of the speaker output.

The DR 500B system has three components - a microphone, an ADC graphic equalizer, and the Talking Bus module. The microphone is fed to a line amplifier connected to the graphic equalizer. The graphic equalizer can be adjusted to enhance the speech signal. The line output of the equalizer is fed to the Talking Bus module. A Windows-based PC is connected to the Talking Bus module to control the recording and playback capability built into the module. The module contains an A/D converter for the recording process and stores the information in its internal Random Access Memory (RAM). The A/D sample rate is 11 kilohertz (kHz) giving an effective recording response to only 5,500 Hz. It contains an anti-alias filter for recording and playback.

Although the DR500B Talking Bus module is capable of playing separate messages both internally and externally at the same time, only the external messages were used during Phase I tests. Two speaker configurations were used. The first configuration was the one currently used by the Kalamazoo Metro transit agency. One flush-mounted speaker is located in the side of the bus behind the rear door at ear level and another speaker (horn-type) is located in the front of the bus behind the front fender on the side closest to the sidewalk and facing down into the street. A second configuration was developed for this study. The speaker in the front of the bus was removed and remounted inside the front door at the top of the doorway. It was located in this position so that holes would not have to be drilled in the outer shell of the bus and to position the speaker so it would not protrude from the roof where it could interfere with bus washing equipment. The rear speaker remained in place in the second configuration.

The sound of an idling bus engine was recorded on a digital audio cassette and played through a special headset worn by test participants. The headset contained headphone cups placed far enough away from the participant's head to allow the sounds from passing cars and the external speaker announcements to enter directly into the participant's ears. This recording of a consistent outdoor auditory traffic situation ruled out the possibility that the participants would use the sounds of an actual idling bus engine for directional clues when traveling to the bus door.

Speaker messages were then recorded to a digital audio tape (DAT) recorder to eliminate speech inflection variances that can occur from one utterance of the same sentence and the next (even with the same person's voice). The DAT recorder was then connected to the line-in of the equalizer in place of the microphone for recording into the Talking Bus system. The first set of speech samples were recorded with a flat equalizer response (i.e., all the frequency controls were adjusted to zero). The second set of speech samples were recorded with the equalizer adjusted to 2 kHz for maximum attenuation or loudness (+12 dB on the panel), which provided approximately 5dB of actual attenuation as measured for this frequency. The third set of speech samples was recorded with the equalizer adjusted with 2 kHz adjusted to +12 dB and 4 kHz to +10 dB (a volume boost for the upper frequency components of the message).

To measure and substantiate the effective boost of the equalizer, a white noise signal was recorded with a flat response (no attenuation, or volume, adjustments with the equalizer) on a DAT recorder. First the 240 Hz band was adjusted to its maximum attenuation and the signal was recorded on the DAT. The 240 Hz band was then set to 9 dB attenuation and the 500 Hz band was adjusted to maximum attenuation and the signal was recorded. The process was repeated for 1 kHz, 2 kHz, 4 kHz, and 8 kHz. The recordings were then fed into a computer with an AD/DA system, using a 44.1 kHz sampling rate with no filter. The results were plotted and each curve was matched against the flat response to determine the actual enhanced attenuation the equalizer provides for each frequency.

3.1.4 Outdoor External Speaker Test Set-up - Phase I

Phase I outdoor testing in Kalamazoo was set up on a main thoroughfare, Michigan Avenue, near the intersection of Michigan Avenue and Rose Street in the downtown area. Michigan Avenue is a one-way street with four lanes of intermittently moving traffic. Rose Street has four lanes of two-way traffic. This small city environment is typical of streets found in small urban and suburban communities in the United States.

The two buses were parked (one in front of the other) on Michigan Avenue near the intersection with Rose Street. The buses remained stationary throughout all test activities, with the engines turned off. One bus had the typical Kalamazoo speaker configuration - one horn speaker mounted in the front grille area and a flush speaker behind the rear door. The other bus had the horn speaker just inside and above the front door and a flush speaker behind the rear door.

3.1.5 Test Procedures - Phase I

Three test conditions were established for each bus speaker configuration:

- Test Condition 1 consisted of a bus door opening without any external speaker announcement

- Test Condition 2 consisted of a bus door opening and an external speaker announcement prerecorded in with a standard (flat) frequency response

- Test Condition 3 consisted of a bus door opening and an external speaker announcement of a message prerecorded with enhancement in the upper frequencies.

Both messages in Test Conditions 2 and 3 announced the bus route number, direction of the bus, and the bus destination.

Test participants were instructed to wear the headphones attached to the DAT tape recording of idling bus engine noise, which was presented at a level calibrated to equal the sound intensity of an idling bus. The purpose of the tape was to duplicate the masking sounds of the bus motor without providing clues as to the location of the bus door, through the location of an idling bus engine.

Next, each test participant was exposed to each test condition 9 times at each bus. Each series of the three test conditions was presented randomly from one of three positions near the front door:

- 15 feet directly in front of the bus door
- 15 feet in front and 5 feet to the right of the bus door
- 15 feet in front and 5 feet to the left of the bus door.

The bus where the participants started testing, as well as the starting position for trials were systematically rotated to prevent order of presentation from affecting the results. At the start of each trial, the bus door was opened and Test Conditions 1, 2, and 3 were presented. The participant was directed to walk to the door of the bus and place one foot on the first step. Participants were signaled to begin finding the door after they heard the word "go." For Test Conditions 2 and 3, participants listened to the message first, before being given the "go" signal.

The participants then moved to another one of the three locations to start another trial. Each participant experience each condition from each position with each bus for a total of 18 trials.

Two observers followed each participant to evaluate their performance with each test condition. When participants made contact with the bus, the observer marked the sidewalk behind the foot closest to the door with a piece of colored chalk so that measurements could be taken later. Different colors of chalk were used for each trial. After the participant had placed one foot on the first step of the bus and if a message had been presented, the participant was asked to identify the bus route number, direction and destination.

Two observers were used to collect data. The primary observer completed a data sheet for each participant; the secondary observer completed a data sheet for one out three test conditions. The procedure, known as establishing inter-rater reliability, was used to establish the reliability of the data that was being recorded by the primary observer. Observers recorded the following:

- The amount of time elapsed between the bus door opening and the participant placing one foot on the bus step

- The distance, in inches, of the participant's foot from the center point of the door after first making contact with the bus

- The participant's accuracy in identifying the bus name, direction, and destination.

After all participants had completed the trials using the headsets, they were exposed to two external speaker announcements that sound simultaneously under natural traffic and bus engine idling conditions. They were asked to identify one bus message from another. Participants were exposed to Test Conditions 2 and 3 (flat frequency and upper frequency enhancement) with the two buses idling their engines. The participants were not required to walk to the doors of the bus, but only to accurately identify one bus from another by listening to the announcements and pointing out the correct bus. Since the participant's ability to locate the bus door was not tested, natural bus sounds could be used without providing audible clues.

At the end of the testing, each participant was asked to complete a debriefing questionnaire to gain subjective information about performance.

3.2 PHASE II - NEW YORK CITY - TEST SET-UP AND PROCEDURES

3.2.1 Participant Recruitment - Phase II

Twenty adults who had no useful travel vision and who routinely used the New York City bus system were recruited for Phase II, which consisted of two focus groups (one held before outdoor testing and one held the day after) and one outdoor test session. Not all participants were included in both focus groups and the outdoor experiment.

	Total Participants	Age Range for All	Males	Females	Age Range for Males	Age Range for Females
Focus Group 1	10	18 - 65	3	7	36 - 50	18 - 65
Focus Group 2	10	18 - 65	3	7	36 - 50	18 - 65
Outdoor Experiment	20	18 - 75	9	11	18 - 50	18 - 75

Notes: All the participants from Focus Groups 1 and 2 participated in the Outdoor Experiment, 7 participants from Focus Group 1 participated in Focus Group 2, and 10 participants from the Outdoor Experiment participated in Focus Group 2.

Because buses in New York City are not equipped with external speakers, most of the participants had not experienced these kinds of speakers during the course of their daily bus travel, although several had encountered external bus speakers in other places. Participants were recruited through recruitment letters sent to the consumer and service organizations for persons with visual impairments in New York City, persons who had participated in other research studies conducted by AFB, through posted announcements, and through e-mail news groups for persons with disabilities. Priority for inclusion in the study was given to participants who were totally blind or who had no usable travel vision, were weekly or daily bus users, and who rated themselves as "good" travelers. Participants who had any remaining usable travel visions, no matter how minimal, were blindfolded during human performance testing activities. Prospective participants were asked to report if they were aware of having a hearing impairment, since these would be screened out of the study. Participants were also given a hearing screening questionnaire, modified specifically for persons who are visually impaired, immediately prior to their participation in human performance testing.

Blindfolds were used to occlude the vision of participants who indicated they had available travel vision to prevent them from using visual clues during testing. All participants were asked to use long white mobility canes and guide dogs were not permitted as travel tools because dog guides are trained to visually locate and guide their masters to an open bus door.

3.2.2 Focus Group Procedures - Phase II

The first focus group in Phase II was held at the National Headquarters of the American Foundation for the Blind and explored the major problems experienced by persons who are visually impaired who travel on buses in a congested urban environment, and the extent to which these problems might be addressed by equipping buses with an external speaker system. The group consisted of 10 individuals who regularly use buses to travel throughout New York City.

Focus group participants stated that their most serious problems using buses were:

- Identifying and locating the correct bus, i.e., the bus they wanted to board
- Knowing when the bus they were on had reached a desired destination
- Gathering reliable information from bus drivers
- Locating bus stop signs at minor bus stops along a bus route.

Based on their understanding of external bus speakers and the limited experience some group members reported with these speakers, group members thought that external bus speakers would be a useful solution to many of their travel needs.

Focus group participants listened to tape recordings of external bus speaker announcements with flat and enhanced high frequency messages. The consensus among the group members was that the enhanced high frequency messages sounded superior to the flat messages. Focus group members were asked to recommend the content and sequence of external bus messages that they believed would be the most helpful to them. They determined that external bus announcement messages should be brief and contain the following information in this order:

1. Bus number
2. Whether the bus is limited (express) or unlimited (local)
3. The direction of travel
4. The bus destination

The group discussed concerns that external bus announcements could be a nuisance to the community. Participants were acutely aware of the potential that external bus speakers have for adding to urban noise pollution, and expressed concern for both bus operators and the general public, but believed that the potential value of external bus speakers might be worth the possible costs to the community.

3.1.3 Apparatus and Equipment Set-up - Phase II

The bus speaker apparatus used in the New York City testing was a DR 500C Talking Bus module, provided by Digital Recorders, Inc. This external bus speaker system was selected for use in New York City because it represents the type of product the New York City Transit Authority (NYCT) believed would be appropriate for its system after reviewing the results of Phase I.

The DR 500C unit differs from the DR 500B unit that was used in Phase I. The key difference is that the DR 500C module has the capacity to monitor ambient sound and automatically adjust speaker intensity output levels accordingly - other speaker features are the same as the DR 500B. The DR 500B relies on manual adjustment of speaker output levels. The monitoring and adjustment capabilities of the DR 500C are particularly important in New York City where great variations occur in the decibel levels of traffic on streets.

The external bus speaker in the New York City outdoor test was mounted on the left of the bus door, rather than directly above the center of the door opening. Although a center mounting would have been optimum, the NYCTA did not want any drilling through the skin of the test buses.

3.2.4 Outdoor External Speaker Test Set-up - Phase II

The New York City outdoor test of external bus speakers took place in Manhattan on 23rd Street, east of the northeast corner of 23rd Street and Seventh Avenue. This street, with two lanes of eastbound traffic and two lanes of westbound traffic is representative of many two-way thoroughfares in Manhattan. During the testing, a steady traffic flow of cars, trucks, buses, and an occasional vehicle with a siren, produced a great deal of ambient noise against which external speaker announcements were presented. Windy and intermittently rainy weather conditions contributed to the soundscape during this phase of the testing. Moderate to heavy pedestrian activity was present on the sidewalk where the tests were conducted.

During the outdoor Phase II testing, one bus equipped with an external speaker system was parked on the north side of 23rd Street, east of the intersection of 23rd Street and Seventh Avenue. The bus remained stationary during all tests. Start lines were drawn on the sidewalk in colored chalk, 10 feet and 15 feet east of the center of the bus door opening, and 5 feet west of the rear of the bus.

3.2.5 Test Procedures - Phase II

The Phase II outdoor tests in New York City were designed to draw on the knowledge gained from Phase I of the study to test external bus speaker messages in the real conditions of an outdoor urban environment. The DR500C external speaker module was used and two enhanced frequency messages (recorded to be consistent in frequency and volume with the messages preferred by the Phase I participants) were used. Two frequently used bus routes in Manhattan were selected for test messages. The messages contained the bus number, the bus direction of travel and the bus destination (express and local designations were not a factor for these routes.

The test procedures in Phase II were different from Phase I since the intent was to have the Phase II participants' experiences more closely resemble actual transit conditions. Instead of asking participants to respond to external bus speakers while listening to tape recorded sounds of idling bus engines through earphones, participants did not wear headsets; and responded to external speaker messages that were activated when the actual bus engine was idling. In addition, participants began their approach to the test bus from a position of more than 100 feet from stop, rather than 15 feet away. Also, instead of responding to the speaker messages from a stationary position 15 from the bus door, participants were in motion when they heard the external messages and as they reached a point that was either 15 feet or 10 feet from the bus. The New York City test measured the time it took participants to locate the bus door. Measures of accuracy were not taken.

Finally, rather than having two buses parked one in front of the other, only one bus was used. In the portion of the test where a second external announcement was needed, the announcement was generated by a speaker held by an observer in a position comparable to where it would have been if two buses were parked one behind the other. A second bus could not be used because another bus could not be removed from revenue service for testing in the heavily used Manhattan bus fleet.

Similar to Phase I, there were several test conditions. The first condition involved asking participants to locate an open bus door with or without the presence of an external speaker message. The second condition required participants to identify a desired bus speaker message when two competing messages were played at the same time. Participants in New York City were screened for hearing loss immediately before the outdoor test and were familiarized with the route between the home base (approximately 100 feet from the bus door) and the place with the test bus was parked on 23rd Street.

After the initial orientation, each participant completed four trials. Each trial involved an independent cane travel trip from the home base tot he open bus door. For two of the trials, the front bus door was opened when the participant crossed a perpendicular line that was 10 feet from the bus door. In the other two trials, the bus door was opened when the participant crossed the 15-foot line. An external speaker placed above and to the left of the front door was activated during one of each of the two 10-foot and 15-foot trials. Thus, on two of the trials a message played simultaneously with the door opening, and on the remaining two trials, no message was played. Trial order was configured to minimize the effects of presentation on results.

A trial was completed when the participant placed a foot on the bottom step of the bus door. The time (in seconds) for each subject to complete the trip from either the 15-foot or the 10-foot line (depending on where the subject was when the bus door opened) to the open bus door was recorded on a data recording form. After each trial, the participant was asked if a message was played by the speaker, and if so to repeat all three elements of the message (bus number, direction, and destination). A response was marked correct only if all three elements were repeated correctly. Following the four bus door trials, each participant was taken to a point 5 feet to the west of the bus, midway between the rear of the bus and a speaker held aloft by an observer. With the bus engine idling, each participant was presented with two simultaneous speaker announcements and was asked to identify the source of one of the two messages. Data for inter-rater reliability was achieved by having a second observer record data for one-third of randomly selected trials. At the completion of all trials, each subject was debriefed and asked to share any reactions that they had concerning the experience.

Chapter 4
STUDY RESULTS

This chapter summarizes the results from Phase I and Phase II testing of external bus speaker systems. The results for each phase address the following issues:

- Audibility and intelligibility of the external speaker announcements
- Identifying the correct bus with two simultaneous, competing messages
- Effects of speaker announcement on the speed and accuracy of locating the bus door
- Effects of speaker position and announcement enhancement on speed and accuracy of locating the bus door.

4.1 PHASE I TEST RESULTS - KALAMAZOO, MICHIGAN

The following sections summarize the results of Phase I testing in Kalamazoo, Michigan.

4.1.1 Audibility and Intelligibility of the External Speaker Announcements - Phase I

An important finding of this study has to do with the participants' overall success identifying and using an audible message presented through external bus speakers, as measured by their objective responses to the speakers. During Phase I testing conditions, participants were able to correctly repeat all three parts of a bus speaker message at least 75% of the time. Although the participants responses to one test condition (enhanced frequency response message) appeared to be more favorable than to the flat frequency response message, the differences in responses under these two conditions was not statistically significant, and thus could not be attributed to enhancement of the bus speaker message in the upper frequencies.

Participants wearing earphones that played the recorded sounds of an idling bus responded to a flat frequency response message by repeating all three parts of the message correctly 50 out of 66 times for a 75% success rate. When the message was delivered with high frequency enhancement, participants correctly identified all three parts of the message 56 out of 66 times for an 84% success rate. Using a McNemar test for the significance of changes, this difference between the flat and the enhanced messages was found not to be significant.

However, participants' subjective responses to the external bus speakers during the debriefings that followed the tests are important to note. During the debriefing, 10 out of 11, or 90% of the participants, stated that they preferred the enhanced frequency response announcement. Participants reported that it took less effort to understand the enhanced messages than the flat messages.

4.1.2 Identifying the Correct Bus with Two Simultaneous, Competing Messages - Phase I

During this portion of the test, where two buses simultaneously sounded an external speaker message, participants correctly identified the bus routes they were asked to listen for on 43 out of 44 trials, for a 98% success rate. Participants reported no difficulty with this task during their debriefing following the tests.

4.1.3 Effects of Speaker Announcement on the Speed and Accuracy of Locating the Bus Door - Phase I

The statistical tool, Analysis of Variance (ANOVA), was used to examine the effects of the two levels of messages - the flat speaker response and the enhanced speaker response - on the participants' speed and accuracy in locating the bus door. This analysis was used to determine if the speed and accuracy with which participants located the bus door under the two test conditions were related to the effect of the different levels of frequency enhancement, or if differences in performance under these two test conditions were a result of chance. Because the experiment design allowed the project to examine the effects of the speaker announcement independent of the position of the speaker, the results reflect only the effects of enhancing the frequency of the speaker message.

The results of this aspect of the study are mixed, and do not clearly indicate which test condition (flat speaker message or enhanced) is more effective in helping individuals who are visually impaired locate the bus door, when speed and accuracy are used as indicators of speaker effectiveness. With respect to speed, participants found the bus door significantly more quickly from 15 feet (less time elapsed) when they responded to a flat speaker message than when they responded to a high frequency enhanced message. On average it took subjects 9.80 seconds to locate the bus door when responding to a flat speaker message, and 11.05 seconds when responding to a high frequency enhanced message. However, with respect to accuracy, participants were significantly more accurate locating the bus door when they responded to high frequency enhanced speaker announcements. Participants' error from the bus door center in inches when responding to a high frequency enhanced message was 23.11 inches, it was 24.98 inches when responding to a flat speaker announcement.

Despite mixed results the data show that the speaker announcement itself, regardless of whether it was flat or enhanced, made a significant difference in improving both the participants' speed and accuracy when compared to the test condition when no speaker announcement was made. Participants' average time in seconds for locating the bus door with both speaker announcements was 9.8 and 11.05 seconds, respectively; significantly faster than the 12.56 second it took when no speaker announcement was made. The average error in inches from the center of the bus door (a measure of accuracy) was significantly greater with no speaker announcement (33.92 inches versus 24.98 inches and 23.11 inches for speaker announcements).

4.1.4 Effects of Speaker Position and Announcement Enhancement on Speed and Accuracy of Locating the Bus Door - Phase I

Analysis of the role of both the external speaker position and the enhancement levels of the message on speed and accuracy of locating the bus door was also performed. It was found that neither the position of the speaker, nor the condition of high frequency enhancement of the announcement had any significant effect on the speed at which the participants located the door. It was found, however, that the position of the speaker did have a significant effect on the accuracy of door location. Participants made their first contact with the bus closer to the door when the speaker was positioned above the door. When the speaker was placed away from the door the average distance of first contact with the bus was 28.9 inches. When the speaker was located above the door the average distance of first contact with the bus was 19.2 inches. Again, the mixed results make it difficult to draw conclusions; however the high frequency enhancement had little effect on locating the door, but the placement of the speaker may improve performance as measured by accuracy. Participants' responses to the debriefing that followed the trials stated that they preferred using bus speaker messages when the speakers were located above the bus door.

4.2 PHASE II TEST RESULTS - NEW YORK CITY

The following sections summarize the results of Phase II testing in New York City.

4.2.1 Audibility and Intelligibility of the External Speaker Announcements - Phase II

Similar to Phase I results, participants in Phase II, New York City testing, were successful in identifying and using audible messages presented through an external bus speaker system. However, in the New York City trials, the number of messages repeated correctly by the participants was 90%. Out of 40 trials performed by 20 subjects, 36 correct responses were scored and 4 responses were listed as incomplete.

4.2.2 Identifying the Correct Bus with Two Simultaneous, Competing Messages - Phase II

During this portion of the New York City testing, where two speaker messages sounded simultaneously, 18 participants correctly identified the bus routes they were asked to list for, while 2 participants gave incorrect responses. This resulted in a successful response rate of 90%.

4.2.3 Effects of Speaker Announcement on the Speed of Locating the Front Bus Door - Phase II

Phase II tests were designed to measure the difference between the effect of having an enhanced external speaker announcement and having no announcement at all. The measure of performance selected as an indicator was the time elapsed in seconds for participants to locate the bus door, one the bus door was opened - an indication of the speed with which participants were able to locate the bus door. A one-way ANOVA was used to compare the time it took participants to locate the bus door both with and without speaker announcements. The analysis showed that although the participants' average time for locating the bus door was shorter when the announcement was present (a mean elapsed time of 11.54 seconds) than when it was when the speaker was absent (a mean elapsed time of 14.76 seconds). The difference between these average elapsed times was not significant, and therefore could not be attributed to the effect of the bus speaker. This finding is not consistent with the finding of Phase I of this study where the participants' speed in locating the bus door was positively affected by the presence of a speaker announcement.

Participants' responses at the debriefing that followed the tests indicated that the participants had very positive impressions about external bus speakers, and believed these speakers made the task of locating a bus door and identifying a bus easier. Some participants indicated that it was difficult to hear the message broadcast by the speaker held aloft by the observer, even though in most cases they heard this message well enough to perform the test activity.

4.3 COMPARISON OF PHASE I AND PHASE II OUTDOOR TESTING

The combined information from the Phase I and Phase II outdoor testing provides valuable insight regarding the effectiveness of external bus speakers. Both outdoor testing trials shown that external speaker announcements can be heard above ambient traffic sounds and can be easily understood by persons who are visually impaired. This appears to be true for messages that are enhanced in the high frequencies as well as for flat frequency messages, although enhanced upper frequency speaker messages tended to be more understandable than the flat frequency speaker messages.

It is important to recognize that the study's Phase I and Phase II tests used artificially stringent criteria for classifying participants' responses as correct, since the participants had to repeat all three message components correctly for a correct response to be counted. Typically, travelers who are visually impaired may be able to identify a bus when only one or two parts of an audible message are understood because they can use partial message information along \with other contextual clues that they have learned to interpret. Therefore, in real world transit conditions it is possible that the "recognition rate" for enhanced upper frequency external speaker messages could be higher than the 84% and 90% measured during Phase I and Phase of this study.

Another important observation is that the participants' ability to repeat correctly the enhanced frequency speaker messages was better in New York City than for Kalamazoo. This may be explained by the difference between the DR 500C external speaker module used in New York City Phase II testing and the DR 500B module used in Kalamazoo Phase I testing. The DR 500C monitors the ambient sound on the street and adjusts the output level of the speaker accordingly, while the DR 500B lacks this capacity. Participants in New York City reported that even when large noisy trucks passed by they were able to hear the speaker announcements because the loudness of the messages increased to compensate for the noise.

One major concern addressed by this study was whether persons who are visually impaired would be able to distinguish between two external bus speaker messages when these announcements play simultaneously, a situation that can occur at a bus stop where more than one bus route passes through. Based on this study, there is strong evidence that persons who are visually impaired are able to distinguish between two competing speaker messages and identify the message for the bus they need. In both Phase I and Phase II, participants consistently selected the message they were asked to identify with an extremely high rate of accuracy (98% in Kalamazoo and 90% in New York City). It is important to recognize that the tasks the participants performed (responding to two speakers sounding simultaneously) was artificially difficult. Under real world transit conditions, it is highly unlikely that two buses will actually start their external speaker announcements at exactly the same time, given passengers the opportunity to hear portions of single messages. Thus, performance in real world situations could be expected to be better than this study observed.

Participants in the New York City study reported that sometimes it was difficult to hear the announcements from the "simulated" rear bus speaker, i.e., from the speaker held aloft by the observer. This can be explained by the testing condition. There was no bus behind this second speaker, therefore the sound it produced was widely scattered rather than reflected forward as it would be by the surface of a bus. Despite this complication, participants were still able to achieve a 90% success rate in identifying a specific speaker message, underscoring the effectiveness of external bus speakers in communicating information to passengers who cannot read vehicle signs.

The study provided mixed results about how well speaker position and frequency enhanced messages increase the speed and accuracy of locating the bus door. The Phase I Kalamazoo test found that flat announcements were effective in improving speed of locating the door, but that the enhanced high frequency announcements resulted in increased accuracy of location. It was also demonstrated that positioning an external bus speaker above the center of the bus door results in more accurate locating of the bus door.

In New York City where two conditions were compared - locating the bus door with and without external bus speakers - speaker effectiveness (measured as a function of the time it took to locate the bus door) was not significantly improved with an external bus speaker. This finding appears to contradict the information participants provided during their debriefing when they clearly and consistently reported that the speaker announcements helped them locate the bus door. To try and resolve this contradiction, a final focus group was conducted after the New York City tests were completed. During this focus group, 10 of the 20 participants in the Phase II outdoor test gathered to review their experiences using external bus speakers.

4.4 RESULTS OF THE NEW YORK CITY DEBRIEFING (SECOND) FOCUS GROUP

The second focus group meeting for the Phase II New York City testing took place at the American Foundation for the Blind's national headquarters in Manhattan, one day following the Phase II outdoor tests. All of the focus group participants were participants in the Phase II tests, and seven had participated in the first Phase II focus group (prior to testing).

The purpose of the second focus group was to debrief the individuals who had participated and to probe the extent to which their experiences with external bus speakers met their expectations. Focus group members were also specifically asked to comment on the discrepancy between the Phase II objective test data, which showed no increment in timed travel using external bus speakers, and the subjective test debriefing data, which indicated that the participants overwhelmingly found the external speakers useful.

Focus group participants agreed that the external bus speakers fulfilled their expectations for making bus vehicle information readily accessible and usable. They were pleased with the audibility and clarity of the messages they heard, and were satisfied that the message content and sequence used for the test messages met their needs. Participants reiterated the importance of including information about express or local service in audible bus messages, when appropriate.

Focus group participants unanimously agreed that external bus speakers ease the task of locating the bus door, and that the speakers would help them locate the bus they needed when two buses were stopped at a bus stop. They observed that if more than two buses were lined up at a stop, external speaker messages might have to be repeated more than once to give them the opportunity to use the speakers effectively. After some discussions, participants determined that when the front bus door is open for more than a brief period of time, the bus speaker messages should be repeated more than once to be effective for passengers who might arrive at a bus stop after the speaker has sounded. Participants were careful to comment that frequent message repetition would not be necessary and could create a nuisance.

Focus group participants reconciled the discrepancy between the objective and subjective test data regarding the helpfulness of external bus speakers. They believed that the tests, which measured the time it took participants to travel to the bus stop, examined the wrong indicator of speaker effectiveness. They strongly believed that their confidence level during travel is the appropriate indicator of speaker effectiveness. Focus group participants, who were all participants in the outdoor test, reported that they felt much more confident locating the bus door when they heard the speaker message sound than when they traveled without the sound of the speaker. The attributed their increased confidence to the confirming cues the speaker provided enroute and at the bus door. According to one participant, "every bit of information helps when you can't see."

Participants were told that during the Phase I tests in Kalamazoo, accuracy in locating the bus door was used in addition to time as a measure of speaker effectiveness. Again, participants stated that their greatest concern is their level of confidence during travel, and thus considered accuracy in locating the bus door to be another inappropriate measure of speaker effectiveness. Participants also observed (almost inadvertently), that as New Yorkers they tend to walk quickly to desired destinations, and would be likely to walk equally quickly to any objective - in this case the hiss of the bus door opening, or the external bus speaker. They were, therefore, not at all surprised that there was no difference in the time it took them to locate the bus door with and without the external speaker.

A final consideration the participants discussed was their feelings about the potential community nuisance that external bus speakers may cause. The focus group moderator probed this concern even though exploring community reactions to external bus speakers was not a formal study requirement. Concern about the possible impact of bus speakers was also a concern of the Phase I participants and the first focus group participants in New York City.

During the first New York City focus group (prior to testing) participants strongly believed that external bus speakers would be helpful to them, but were reluctant to fully endorse the concept because of their concerns for the possible nuisance the speakers might cause to bus drivers and the general public. However, when the New York City group met after the tests, they unanimously endorsed the concept of external bus speaker announcements. Focus group participants expressed the following opinions:

- While the external speaker announcements were loud enough to be heard in the vicinity of the bus, they were not loud enough that they were annoying to others in the surrounding environment

- The external speaker announcements were no more of a community nuisance than the sound of buses pulling up, idling and leaving the bus stop.

- The sounds of the external speakers were not jarring.

- The sounds of the external speakers blended in with other environmental sounds.

The second focus group unanimously believed that any small amount of annoyance that the announcements might create would be offset by their usefulness to all bus passengers, including those who do not have a visual impairment. Several participants observed that bus speaker announcements would be helpful to individuals such as tourists or recent immigrants who do not read English.

Chapter 5
REVIEW OF COMMUNITY "TOWN-HALL" MEETINGS

Two community "town-hall" type meetings were conducted to identify general community attitudes and concerns about external bus speaker systems. The meetings were intended to address to key issues:

- Were external bus speaker systems thought to be beneficial? Who might reasonably be expected to receive such benefits? What aspects of external speaker systems were most significant in producing those benefits?

- Were external bus speaker systems thought to pose potential risks and concerns that might serve to diminish any of the potential benefits to users and at the same time generate annoyance among non-users? How might such concerns be alleviated to the greatest advantage of both transit users and the general public?

This chapter presents a brief review of participants at each community town meeting and then provides a brief discussion of the key issues.

5.1 REVIEW OF PARTICIPANTS

Two "town-hall" type meetings were held, one in Philadelphia, Pennsylvania and one in Dallas, Texas. At each meeting, participants were briefed on the objectives of the study and also given the opportunity to hear an example of external bus speaker systems. Neither Philadelphia nor Dallas provide external bus speaker services so it was anticipated that neither panel would include members with experience on external bus speaker systems. However, two panelists in Philadelphia had lived in cities (Washington, D.C. and Wilmington, Delaware) where external bus speakers were used.

In Philadelphia, 12 individuals participated in the community town meeting. They included representatives of the visually impaired community, both transit users and individuals from agencies involved in assisting visually impaired citizens; a traffic engineer from the City of Philadelphia Streets Department; representatives from the Southeastern Pennsylvania Transit Authority (SEPTA) operations department; and two individuals who served on the Mayor's Commission for People with Disabilities.

In Dallas, 22 individuals participated in the community town meeting. They included representatives of the visually impaired community, both transit users and individuals from agencies involved in assisting visually impaired citizens; an environmental engineer (specializing in noise and sound pollution ordinances) from the City of Dallas; representatives from the Dallas Area Rapid Transit (DART) public relations, ADA compliance, technical support, and paratransit departments; and a major Dallas property management company represented the local business community.

5.2 SUMMARY OF ANTICIPATED BENEFITS OF EXTERNAL BUS SPEAKER SYSTEMS

The community town meetings discussed anticipated benefits of external bus speaker systems from the perspective of the visually impaired ridership and the general ridership.

5.2.1 Anticipated Benefits for Visually Impaired Ridership

The most general and consistently stated benefit of external bus speakers systems was their potential to reduce the level of user stress associated with having to locate the desired bus within a typically short timeframe. Any technology that alleviates that stress was anticipated to be a good thing.

Almost equally important was the potential of external bus speaker systems to contribute to visually impaired transit users' ability to travel independently. Visually impaired riders would not have to be dependent on the advice of (well-meaning, but occasionally misinformed) sighted transit users, or the willingness of drivers to provide information.

Participants also felt that external bus speaker systems would be of greatest benefit in specific locations involving multiple bus routes converging at a single stop; where it is the most difficult for visually impaired riders to identify particular buses without having to seek assistance from drivers or fellow passengers. Participants felt that this would be a benefit for all passengers and would speed up boarding, especially at rush hours.

5.2.2 Anticipated Benefits for General Ridership

External bus speaker systems were projected to be of value to the general ridership as one more means of communicating important information because external speakers could provide backup support in cases where other systems (such as changeable message signs) fail.

Participants stated that since speaker announcements are already familiar to sighted riders at busy train stations, that the addition of external speakers on buses would serve to extend a service already deemed useful to sighted riders in other contexts; and would provide the same potential for lowering stress in locating the right bus at busy stops.

External bus speaker systems would provide benefits to people with cognitive disabilities such as dyslexia; and would be of potential benefit to foreign visitors and tourists who may not read English but can understand spoken English.

5.3 SUMMARY OF CONCERNS PERTAINING TO POTENTIAL SHORTCOMINGS OF EXTERNAL BUS SPEAKER SYSTEMS

In general, community town meeting participants expressed concerns about the potential shortcomings of external bus speaker systems in six general categories - design, environmental issues, information provided, integration, operation, and reliability. Most concerns were related to reliability issues and the fewest concerns were expressed relating to system design and message information provided.

5.3.1 Design Concerns

Since it is essential that information be easily heard by those seeking to locate a particular bus, there was a general consensus that higher-pitched female voices may be more easily heard than lower-pitched male voices.

Since many urban bus stops are extremely busy and accommodate many buses on different routes simultaneously, it may be desirable to design speaker systems to repeat messages in such crowded environments. Also, the speaker system should be designed to avoid being too directional in transmissions at extended curbside stops where there may be long lines of passengers waiting to board the bus.

The most important concern about speaker system design was that local speaker systems should be designed to meet local needs since no two urban cities present identical transit situations.

5.3.2 Environmental Concerns

Since local ordinances frequently establish maximum legal decibel levels as byproducts of particular activities, external speaker systems must account for both ambient environmental noise and local ordinances establishing legal noise levels.

The most frequent environmental concern was that external bus speaker systems might become a potential annoyance to others in the area. Concern was expressed about the possibility of becoming "bad transportation neighbors," especially in residential communities.

5.3.3 Information Provided Concerns

There was general agreement during the community town meetings that any additional information made available to bus riders was going to be helpful; however, the possibility of diminishing returns must be considered - that external bus speaker systems might provide too much information that could not be processed quickly enough by those riders who need it the most.

5.3.4 Integration Concerns

Comments in this category related to the integration of external speakers to other information systems within the bus environment and those that related to the integration of external speakers to other forms of assistance available to visually impaired travelers. Transit representatives in Dallas particularly expressed concern about overall system integration - the need to integrate speakers, doors, accelerator, and driver training to ensure that the bus message is heard at the most advantageous time. Transit representatives in both cities also raised the issue of integration of external speaker systems with internal speaker systems so there would be message consistency and so they would not be competing to be heard.

Some representatives from groups that assist the visually impaired expressed concern about the risk of over-dependence on these types of systems. Although there are clear benefits, the concern was expressed that visually impaired riders might because too dependent on external speakers and would be lost when forced to operate without such systems.

5.3.5 Operational Concerns

There was a wide range of concerns expressed about operational issues. Most comments related to the role of the driver in buses equipped with speaker systems, such as will the system operate itself or is it dependent on the driver to activate and deactivate. Another related issue was what type of back-up systems would be used in case the automated system failed and would they be dependent on the driver making the announcements. Representatives from the transit agencies cited cost of external bus speaker systems as an issue of concern both in terms of the purchase of new buses fully equipped with such systems and the cost of retrofitting older buses.

5.3.6 Reliability Concerns

System and equipment reliability was the greatest concern expressed by all participants in the community town meetings. All participants agreed that the system has no value if it malfunctions. Other reliability concerns were expressed about the effect of cold weather (Philadelphia) and sand and dust (Dallas) on system reliability.

5.4 SUMMARY OF KEY POINTS FROM THE COMMUNITY TOWN MEETINGS

A summary of the key points of consensus that emerged from the community town meetings included:

- External bus speaker systems promise significant benefits to visually impaired and blind riders.

- External bus speaker systems promise comparably significant benefits to the general riding public and these benefits may be expected to help transit agencies increase their general ridership.

- External bus speaker systems seem unlikely to produce any significant annoyance among non-riders in most environments. In many, if not most, of these environments where risk of annoyance seems potentially possible, the use of external bus speaker systems may not be required.

- The major area of concern among community town meeting participants was that of the technical reliability of external bus speaker systems.

- In operational terms, there were concerns about the problem of integrating drivers and bus speaker systems.

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions and recommendations are offered:

- External bus speaker announcements are useful to persons who are visually impaired and are likely to aid the wide range of passengers that use buses. They provide persons who are visually impaired with effective access to the information conveyed by visible bus vehicle signage, assist with the task of locating a desired bus when more than one bus is at a bus stop, and enhance travelers' confidence and independence when they have to locate the bus door.

- External bus speakers should be made available on public bus systems to enhance information access for persons who are visually impaired. The speaker announcements should be delivered through a system that can automatically adjust the volume level of the announcements in the presence of ambient traffic noise.

- The main speaker in an external bus speaker system should be located as close to the front bus door as possible, and if possible above the center of the front bus door.

- The external speaker message should contain the following information in this order - the bus number, whether the bus provides express or local service, the bus direction of travel, and the destination of the bus.

- In order to make the external speaker announcements reliable, they should be automatically activated when the bus door opens, and not have to be activated by the driver each time the bus door opens.

- When bus doors remain open for extended periods of time, the speaker announcements should repeat regularly.

- External speaker announcements should be enhanced in the upper frequencies to make them more intelligible in a noisy environment. For this project, bus speaker announcements were recorded with a boost of 5 dB at 2,000 Hz and a boost of 4 dB at 4,000 Hz.