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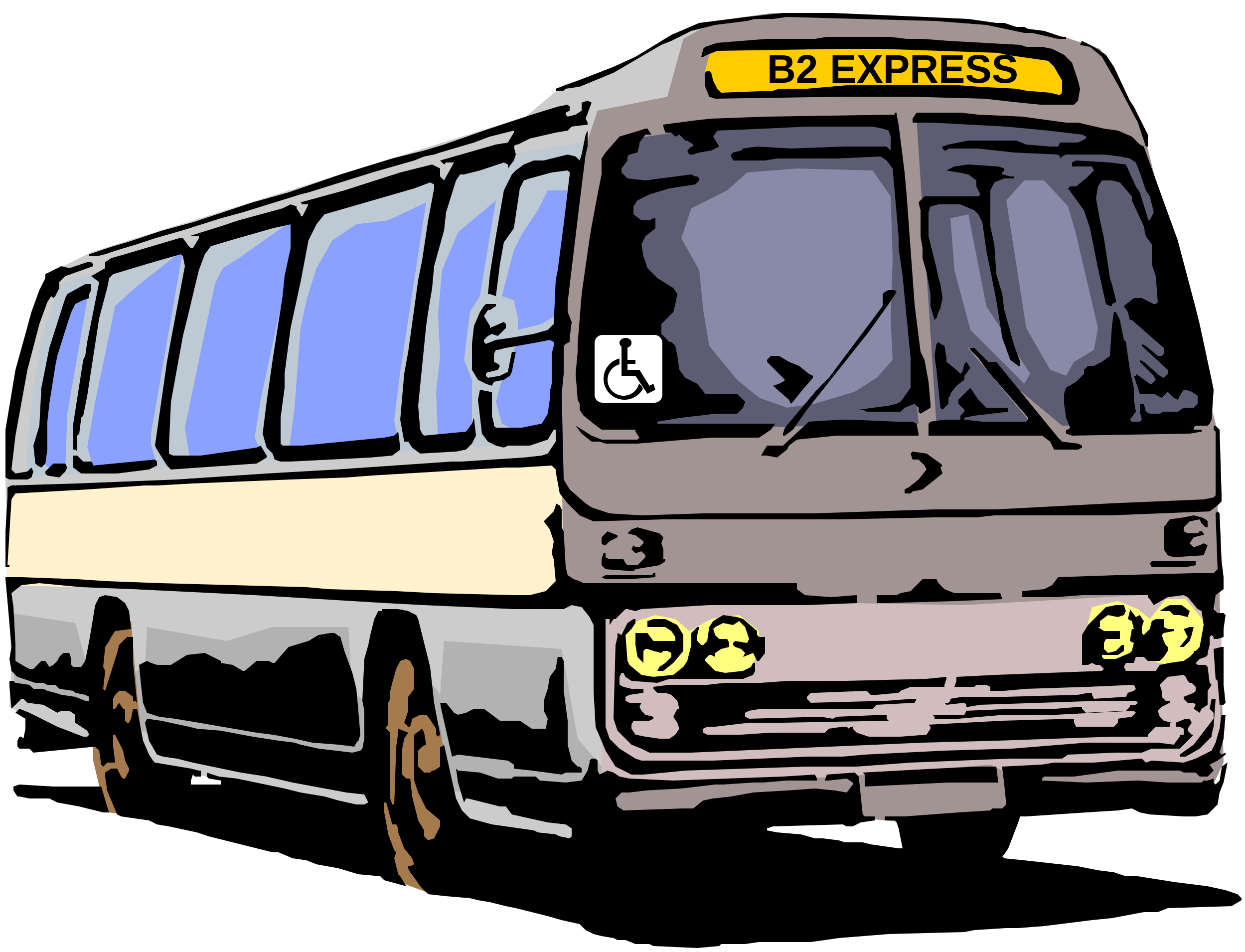
Gap Analysis

Bus Signage Guidelines For Persons With Visual Impairments: Electronic Signs.

September 2001



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6. AUTHOR(S)
David F. Wourms Paul H. Cunningham Dale A. Self Sara J Johnson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Booz Allen Hamilton
Suite 131
4141 Colonel Glenn Highway
Dayton OH 45431

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This report focuses on the adequacy of Americans with Disabilities Act (ADA) destination signage guidelines for visual technologies used to improve the dissemination of public transit information to the visually impaired. Specifically, this document is concerned with the use of light emitting diode (LED) and liquid crystal display (LCD) signs in and on the transit vehicle to present destination and route information. The content is derived from relevant standards, guidelines, and research literature identified during extensive government and commercial database searches, as well as a comprehensive search of world wide web resources. To the extent available, input from subject-matter experts and industry points-of-contact is also included.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC		METRIC TO ENGLISH	
LENGTH (APPROXIMATE)		**LENGTH (APPROXIMATE)**	
1 inch (in)	= 2.5 centimeters (cm)	1 millimeter (mm)	= 0.04 inch (in)
1 foot (ft)	= 30 centimeters (cm)	1 centimeter (cm)	= 0.4 inch (in)
1 yard (yd)	= 0.9 meter (m)	1 meter (m)	= 3.3 feet (ft)
1 mile (mi)	= 1.6 kilometers (km)	1 meter (m)	= 1.1 yards (yd)
		1 kilometer (km)	= 0.6 mile (mi)
AREA (APPROXIMATE)		**AREA (APPROXIMATE)**	
1 square inch (sq in, in^2)	= 6.5 square centimeters (cm^2)	1 square centimeter (cm^2)	= 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2)	= 0.09 square meter (m^2)	1 square meter (m^2)	= 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2)	= 0.8 square meter (m^2)	1 square kilometer (km^2)	= 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2)	= 2.6 square kilometers (km^2)	10,000 square meters (m^2)	= 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he)	= 4,000 square meters (m^2)		
MASS - WEIGHT (APPROXIMATE)		**MASS - WEIGHT (APPROXIMATE)**	
1 ounce (oz)	= 28 grams (gm)	1 gram (gm)	= 0.036 ounce (oz)
1 pound (lb)	= 0.45 kilogram (kg)	1 kilogram (kg)	= 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)	1 tonne (t)	= 1,000 kilograms (kg)
			= 1.1 short tons
VOLUME (APPROXIMATE)		**VOLUME (APPROXIMATE)**	
1 teaspoon (tsp)	= 5 milliliters (ml)	1 milliliter (ml)	= 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp)	= 15 milliliters (ml)	1 liter (l)	= 2.1 pints (pt)
1 fluid ounce (fl oz)	= 30 milliliters (ml)	1 liter (l)	= 1.06 quarts (qt)
1 cup (c)	= 0.24 liter (l)	1 liter (l)	= 0.26 gallon (gal)
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 meter (m^3)	= 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	= 0.76 cubic meter (m^3)	1 cubic meter (m^3)	= 1.3 cubic yards (cu yd, yd^3)
TEMPERATURE (EXACT)		**TEMPERATURE (EXACT)**	
[(x-32)(5/9)] °F	= y °C	[(9/5) y + 32] °C	= x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0		1			2			3		4			5
Centimeters	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT - CELSIUS 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 NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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ACRONYMS

ADA	Americans with Disabilities Act
ADAAG	ADA Accessibility Guidelines
AMLCD	active matrix liquid crystal display
APTA	American Public Transit Association
DOT	Department of Transportation
DTIC	Defense Technical Information Center
FTA	Federal Transit Administration
HSIAC	Human Systems Information Analysis Center
ISTEA	Intermodal Surface Transportation Efficiency Act
LCD	Liquid Crystal Display
LED	Light Emitting Diode
NTIS	National Technical Information Service
POCs	points of contact
SBPG	Standard Bus Procurement Guidelines
SME	Subject-Matter Expert
TCRP	Transit Cooperative Research Program
TNLCD	twisted nematic liquid crystal display
TRIS	Transportation Research Information Service

EXECUTIVE SUMMARY

Transit signage specifications developed by the Architectural and Transportation Barriers Compliance Board (Access Board) and issued in the ADAAG do not appear to fully address the range of issues that interest FTA researchers or that might prove important for LED/LCD signage readability.

The user population for transportation systems is perhaps broader and more complex than the user population for any other system. Public transit systems are especially important to people who are visually challenged, since their reduced visual capabilities may make driving impossible. Unfortunately, a person with a visual impairment may have difficulties deciphering printed or electronic destination signage provided both on and in the transit vehicle. Not having access to this information can make the experience of public transportation difficult, and in some instances dangerous, for a person with a visual impairment.

This report focuses on the adequacy of Americans with Disabilities Act (ADA) destination signage guidelines for visual technologies used to improve the dissemination of public transit information to the visually impaired. Specifically, this document is concerned with the use of light emitting diode (LED) and liquid crystal display (LCD) signs in and on the transit vehicle to present destination and route information. The content is derived from relevant standards, guidelines, and research literature identified during extensive government and commercial database searches, as well as a comprehensive search of world wide web resources. To the extent available, input from subject-matter experts (SMEs) and industry points-of-contact (POCs) is also included.

ADA guidelines are limited to specifying minimum requirements for sign placement, character height, character width-to-height ratio, stroke width-to-height ratio, and intercharacter spacing. Recent research on flip dot/split flap and roller curtain sign design parameters has made recommendations for larger font sizes and greater intercharacter spacing than is currently indicated by the ADAAG. Other items of interest to the Federal Transit Administration (FTA), such as glare, contrast, viewing under different lighting conditions, streaming capability and rate, and motion (vehicle moving-user stationary/user moving-vehicle stationary) are not adequately addressed.

More relevant to the current effort, research has been undertaken to determine optimum characteristics to promote legibility of in-vehicle LED next stop message signs by persons with varying visual acuities. Unfortunately, this research did not capture data for on-vehicle signage or for sign characteristics influencing readability under varying illumination. Presumably the LED/LCD sign technologies could provide greater readability during daytime, twilight and nighttime conditions. The ADA regulations, however, along with information identified in many other accessibility guideline documents, do not provide quantitative guidance for "adequate" illumination levels to accommodate the visually impaired.

Contact with subject-matter experts in the transit vehicle and sign manufacturing community offered little additional guidance. LED/LCD sign manufacturers indicated their designs were often driven by the space allotted on the vehicle, and in all U.S. cases they indicated that their signs could be programmed to meet minimum ADA requirements.

The results of this gap analysis effort lead to the following conclusions regarding the existing electronic signage design guidance, and recommendations for filling the identified gaps and promoting additional research efforts in transit sign design to accommodate the visually impaired.

It appears adequate research and guidance is available to indicate the following:

- On-vehicle electronic transit destination information should be located on the front of the vehicle (above the driver's field of view), on the side of the vehicle near the entry, and that at least a route number should be displayed on the rear of the vehicle.
- While not extensively documented with empirical research, the current guidelines for flip dot/split flap technologies are consistent with a number of documented best practices and provide sufficient guidance regarding character height, width-to-height ratios, stroke width-to-height and intercharacter spacing for LED/LCD applications.

The results of this gap analysis have generated the following recommendations:

- Conduct research activities to address questions identified as important to FTA researchers in Section 4, SYNTHESIS, but found as gaps in the body of guideline and research literature.
  - Lack of definitive guidance on LED/LCD sign readability under varying illumination (i.e., daytime, twilight, nighttime).
  - Lack of definitive guidance on streaming/paging style and rate for on-vehicle signs.
  - Lack of definitive guidance for the use of color in LED/LCD transit destination displays. This would include determination of adequate contrast ratios between letter or symbol color(s) and background under all anticipated lighting conditions.
- Conduct additional research activities to address issues of importance to the FTA but not directly identified in Section 4, SYNTHESIS.
  - Research the influence of motion (vehicle moving-user stationary; user moving-vehicle stationary) on the legibility of LED/LCD destination and route displays. This would include determination of adequate viewing angles for all on-vehicle signage locations.
  - Research the influence of glare on LED/LCD sign legibility.

A follow-on "Needs Analysis" effort (the second phase of this project) capturing input from transit agencies, transit system users and advocacy groups for the visually impaired will allow the FTA to prioritize future research efforts and address the most important user needs in a cost-effective manner.

It appears a noticeable amount of work remains to be done by researchers and engineers both in the human factors and manufacturing domains to prove and provide the benefits that might be gained by implementing LED/LCD technologies for transit vehicle destination signs. Achieving a meaningful and intelligent implementation of these technologies will require a synergistic effort involving the FTA, disability advocacy groups, research labs, system manufacturers, and equipment makers.

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CHAPTER 1
INTRODUCTION

1.1 Government and Legal Environment Background

The Americans with Disabilities Act (ADA) was passed on July 16, 1990. The act is designed to encourage integration and to eliminate discrimination against persons with disabilities in areas such as employment, public services, telecommunications, and transportation. The ADA defines disability as:

> **Section 222 of the ADA states, "It shall be considered discrimination for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C 794) for a public entity which operates a fixed route system to purchase or lease a new bus, a new rapid rail vehicle, a new light rail vehicle, or any other new vehicle to be used on such system, if such bus, rail vehicle, or other vehicle is not readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs."**

- Physical or mental impairment that substantially limits one or more of the major life activities of such individuals,
- A record of such an impairment, or
- Being regarded as having such an impairment.

Since the passage of this law, transit agencies have been undertaking significant initiatives to comply with legislation and improve access to public transportation for persons with disabilities.

1.2 Purpose

Public transit systems are especially important to people who are visually challenged, since their reduced visual capabilities may make driving impossible. For many who are visually challenged, public transportation provides a lifeline that allows them to interact with the community and maintain gainful employment. One major obstacle to accessible public transportation is transit signs that are difficult, if not impossible, to read.

> **This project is part of the Federal Transit Administration (FTA) Strategic Plan, Strategic Goal #2: Mobility and Accessibility to ensure a transportation system that offers choices, and is accessible, integrated, and efficient, for all Americans. This effort continues research that was first documented in *FTA's Bus Signage Guidelines for Persons with Visual Impairments* (1998).**

Public transit vehicles use signage on the outside of the vehicle to indicate important information, such as route number and final destination. Signs may be placed on the front, side and/or rear of the transit vehicle. If route and destination information is not legible or readable to the visually challenged, then many other modifications to enhance accessibility will be ineffective.

While the ADA and its amendments provide guidance about transit signage, the available research has primarily focused on static destination (i.e., roller curtain) or traveler information signs rather than the new dynamic, electronic (light emitting diode

(LED), liquid crystal display (LCD)) signs that are being used more often to indicate transit destination information. LED/LCD displays have characteristics that are unique, and if not correctly designed and engineered, may be very hard to read under day, night, and low light conditions by those who are visually challenged.

1.3 Scope

Travelers with visual impairments must be considered when designing on- and in-vehicle electronic destination signs. Further, appropriate attention to information presentation format and content can improve the travel experience for all persons, including first time users of the system, persons whose first language is not English, and seniors. The scope of this report is to:

- Conduct a literature search and review to identify gaps in current practice, guidelines, standards and research for on- and in-vehicle electronic destination signage. Questions of specific interest to Federal Transit Administration (FTA) researchers include:

    - Do the ADA specifications for electronic destination signs adequately address the needs of people who are visually challenged under different lighting conditions–daylight, low light, and nighttime?
    - Are minimum character heights of one inch and two inches for side and front electronic destination signs respectively, sufficient for people who are visually challenged under various lighting conditions–daylight, low light, and nighttime? If these sizes are not adequate, what character size is readable as well as appropriate for vehicle placement? For a given character size, what is the optimum distance of such a sign for readability?
    - Are electronic destination signs that provide multiple messages with alternating text readable by people who are visually challenged under day, night, and low light conditions?
    - What color combinations provide the best levels of contrast under day, night, and low light conditions?
    - Are people who are visually challenged better able to read mixed upper and lower case letters as they form a word, or are all capitals preferable, under day, night, and low light conditions?
    - Does a wider character width improve readability for people who are visually challenged under day, night, and low light conditions?

- Facilitate subsequent transit authority and user survey efforts and make recommendations for additional human factors research to fill the identified gaps with comprehensive guidelines for electronic destination signage.

A significant number of reports and studies have been produced on various signage technologies and their application by transit agencies. This report is derived from the literature produced on the specific issue of improving on- and in-vehicle

LED/LCD destination signage readability and legibility for persons with vision limitations. To the extent available, input from subject-matter experts (SMEs) and industry points-of-contact (POCs) is also included.

1.4 Report Organization

This report is presented in six sections, with supporting bibliographic material and appendices. Section 1, INTRODUCTION, describes the project background and scope of this gap analysis task. Section 2, METHOD, briefly describes the process and procedures used to identify current industry practices, major design issues, innovations, standards, guidelines, and human factors research in transit vehicle signage. Section 3, REVIEW OF RESEARCH RESULTS, captures and documents the relevant standards, guidelines, and best practices identified from the literature review and subject-matter expert contact. Section 4, SYNTHESIS, uses the literature review results to address each of the FTA's research questions and provide a clearer picture of the design guidance gaps that exist for implementing electronic signage. Section 5, CONCLUSIONS AND RECOMMENDATIONS, concludes the body of the report by providing pointers for future human factors research to fill the identified gaps and produce comprehensive design guidance for in- and on-vehicle destination signage. REFERENCES, Section 6, comprises the full bibliographic material for items cited in the body of the report.

Appendix A contains the literature search strategy used for searching government and commercial database resources. Appendix B contains copyrighted literature search results from commercial database resources. Appendices C and D contain POC matrices developed while contacting SMEs in the transit and vehicle signage industries and orientation and mobility advocacy groups.

1.5 Limitations

Many technologies for presenting transit-related information to the visually impaired traveler are discussed in the literature, including roller curtain and flip dot/split flap signs as well as auditory and tactile displays. By necessity and direction of the FTA, this report focuses on newer LED/LCD technologies designed to present in- and on-vehicle route and destination information for the visually impaired traveler. While documented in the literature and mentioned briefly in this report, auditory, tactile and Braille displays, as well as information regarding other sensory, cognitive, or mobility related disabilities are not specifically addressed.

CHAPTER 2
METHOD

2.1 Literature Database Search

A keyword list and search strategy (Appendix A) was developed, and a search of both government and commercial literature databases was conducted to identify relevant information. The search strategy was employed by professional database researchers using the following in-house, government and commercial databases:

- Defense Technical Information Center (DTIC) Technical Reports,
- Dissertation Abstracts,
- Ei Compendex (1980-Present),
- Human Systems Information Analysis Center (HSIAC) Document Database,
- INSPEC,
- National Technical Information Service (NTIS),
- PsycINFO,
- Science Citations Index,
- Standards & Specifications, and
- Transportation Research Information Service (TRIS)

Search results produced over 700 citations and abstracts. The abstracts were reviewed to identify the most pertinent and the results are compiled in Appendix B of this report. Selected documents were identified and acquired to use as source material in report preparation.

An internet search was also conducted to identify and retrieve current industry practices, major issues, innovations, standards, guidelines, and human factors research in transit vehicle signage not yet published in the traditional open literature sources.

2.2 Subject-Matter Expert Search

A search was conducted to identify key organizations and SMEs that (1) train, assist, or support the visually impaired population with orientation and mobility related skills and (2) design, manufacture or procure transit vehicle signage. The following sections describe the specific methods of identification and contact.

2.2.1 Orientation, Mobility, Ageing, and Disability Organizations

The literature database search and in-house knowledge of service providers was a starting point for identifying organizations that could assist with the project. Agencies and advocacy groups working directly with the visually impaired were included, as were research and health service organizations. These agencies provided not only a clinical perspective to the issues surrounding visual impairments but also insight into how advocacy and assistance programs incorporate the use of buses and trains to help their clients and how visual impairments affect sign readability.

Examination of organization web-sites produced potential contacts and links to other related organization sites. Initial contact was established either by telephone or email, depending on whether a phone number or email address was obtained. Direct telephone contact was preferred since this results in a more immediate identification of who in an organization is appropriate to provide assistance and if they are willing. A short description of the project was given to each person contacted and their potential role described. Roles include providing expert knowledge, reviewing results, data and materials produced in the project, and helping to coordinate the inclusion of other relevant contributors. Those who agreed to provide assistance were asked if they could provide the contact information for additional SMEs.

A summary of the contacts providing relevant content for this gap analysis is found in Section 3.4.1, and a complete listing of the contacted organizations is in Appendix C.

2.2.2 Transit Sign and Vehicle Manufacturers

Again, the literature database search and in-house knowledge of service providers was a starting point for identifying SMEs that could assist with the project. Transit vehicle and sign manufacturers were identified and contacted to obtain information concerning sign specifications or requirements they might use that exceeded the existing ADA requirements.

A summary of the contacts providing relevant content for this gap analysis is found in Section 3.4.2, and a complete listing of the identified organizations, web sites and available POCs is found in Appendix D.

CHAPTER 3
REVIEW OF SEARCH RESULTS

The following sections briefly identify the needs of visually impaired travelers and summarize the major design issues identified from the literature review, including technology descriptions, standards, guidelines, and best practices for current signage methods and electronic signage technologies designed to better communicate with the visually impaired.

3.1 Visual Impairment Defined

Visual impairment represents a continuum, from people with very poor visual acuity[1], to people who can see light but no shapes, to people who have no perception of light at all. For general discussion, however, it is useful to think of this population as representing two broad groups, those with low vision and those who are legally blind.

A person is termed *legally blind* when their visual acuity (sharpness of vision) is 20/200 (Snellen scale) or worse *after correction*, or when their field of vision is less than 20 degrees in the best eye after correction. Those who are legally blind may still retain some perception of shape and contrast or of light versus dark (the ability to locate a light source), or they may be totally blind (having no awareness of environmental light).

Low vision includes problems (after correction) such as dimness of vision, haziness, film over the eye, foggy vision, extreme near- or farsightedness, distortion of vision, spots before the eyes, color distortions, visual field defects, tunnel vision, no peripheral vision, abnormal sensitivity to light or glare, and night blindness.

Because many people with low vision still have some visual capability, many of them can read with the assistance of magnifiers, bright lighting and glare reducers. Many such people with low vision are helped immensely by use of larger lettering, sans-serif typefaces, and high contrast coloring.

Diseases causing severe visual impairments (glaucoma, cataracts, macular degeneration, and diabetic retinopathy) are common among the ageing population as well. With current demographic trends toward a larger proportion of elderly, the incidence of visual impairments will certainly increase.

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[1] For purposes of this report, diminished visual acuity is defined as having a best corrected acuity in the range of 20/70 to 20/400 on the Snellen scale. The Snellen scale tests distance visual acuity (distance vision) and is only one of the tests done to assess eyesight. A chart is usually made up of capital letters, numbers, symbols or pictures which are larger at the top and smaller at the bottom of the chart. This measure of distance vision compares ones distance visual acuity to a **normal** patient. Most surgeons are careful to describe 20/20 as normal, not perfect. Contrast sensitivity, glare, halos, and other measures of visual function are not assessed with Snellen acuity.

3.2 Destination Sign Technology

The transit destination sign market is currently dominated by two technologies, printed roller curtain signs and electromagnetic flip dot/split flap signs. Each technology offers distinct advantages and disadvantages that are discussed in some detail in a May 1998 FTA Report, *Bus Signage Guidelines for Persons with Visual Impairments* (FTA-MD-26-0001-98-1). Sections 3.2.1 and 3.2.2 below briefly summarize the material contained in that report. The remainder of Section 3.2 is devoted to a description of the newer LED/LCD technologies and their respective advantages and disadvantages.

3.2.1 Roller Curtain Print Signs

Figure 3-1. Roller Curtain Sign

The traditional roller curtain print signs have been used successfully for many years in a wide variety of transit applications. This technology offers substantially lower acquisition costs and is able to utilize a wide variety of colors and graphics to present transit information. However, this technology is limited in the number of destinations that can be accommodated within the diameter of the roll that fits the overhead compartment provided in most transit vehicles. In addition, much effort (and potentially cost) can be expended in updating the signs with new routes or destinations; a process that involves "splicing" in new text or replacing the entire curtain roll.

3.2.2 Electromagnetic Flip Dot/Split Flap Signs

This sign technology consists of matrices of dots or split flaps with an electromagnet behind each dot that reverses polarity on a signal from a driver controlled central processor. A change in polarity causes the dot to flip over or the split flap to open, thereby exposing either the painted (typically reflective yellow, though other colors are available) or the black side.

Figure 3-2. Flip Dot Sign

Recent advances in flip dot/split flap signs include the introduction of LED or fiber optic illumination of the individual painted surfaces. This technique provides additional "brightness" for both nighttime and bright sunlight viewing.

An extensive treatment of flip dot/split flap sign design guidelines is provided in *Bus Signage Guidelines for Persons with Visual Impairments* (FTA-MD-26-0001-98-1, 1998).

3.2.3 Electronic Signs[2]

Technological advances have generated an emerging interest in electronic information systems utilizing LED and LCD technologies to present both in- and on-vehicle transit destination information.[3] LEDs and LCDs are readerboards using either single or multicolored lettering. They can provide a two-dimensional array of display letters, numbers, or symbols and allow some animation depending on the system capabilities. Implemented correctly, systems that use LED/LCD technology may provide a significant benefit to all passengers and a specific benefit to those individuals with auditory or visual impairments.

The following sections provide additional detail on each of the technologies. These new technologies present their own set of advantages and disadvantages, and while mentioned briefly in the 1998 FTA guideline document, they are the primary focus of this report.

3.2.3.1 Light Emitting Diode (LED)

Figure 3-3. LED Sign

An LED is a semiconductor device. A small current is passed through the semiconductor material which causes electrons in the material to be temporarily excited (raised in energy) such that they move to a higher level energy band than their normal position. When the electrons return to their normal energy band, photons (specific quantities of light energy) are emitted. The type of semiconductor material in the LED determines the color of the light emitted.

Advancements in LED technology include the development of brighter devices that emit a broad range of colors including green, orange, and yellow. Currently, only red LEDs are bright enough for outdoor use.

Modern LED displays do not use separate LEDs placed into holes to make the display matrix. Instead the display is made up of component blocks. Each block is a square matrix with flat top cavities for each individual dot of semiconductor material. The result is that the luminous elements are right on the display surface, providing the widest possible viewing angle.[4]

Advantages of LED displays, compared to other transit system display technologies include the following:

[2] Material in Section 3.2.3 describing LED/LCD technologies and their respective advantages and disadvantages is drawn primarily from the Transit Cooperative Research Program ((TCRP), Transportation Research Board, 1996) Report 12, *Guidelines for Transit Facility Signing and Graphics*.

[3] In a survey conducted by Transit Cooperative Research Program ((TCRP), Transportation Research Board, 2001) transit agencies were asked to identify and rank the effectiveness of their current methods of communicating with persons with disabilities; LED destination signs were one of the technologies identified as "very effective."

[4] The viewing angle referred to here is the angle between a line that is perpendicular to the display surface and a line drawn from the display to the viewer.

- LED display panels can display text in a wide range of character heights (including ADA compliant),
- Lower cost than LCDs,
- Solid state design resists vibration (making LEDs suitable for on-vehicle use),
- Flat configuration suitable for use in limited space situations, and
- Animation capability (thus more suitable for advertising).

Disadvantages of LED displays, compared to other transit system display technologies include the following:

- They are more subject to glare than some types of LCD displays (thus they are not as suitable as an outdoor display), and
- Their readability is distorted when viewed at an angle.

In summary, LED displays are most suitable for on-vehicle or vehicle stop displays where space limitations, vibration, and the desire for advertising revenue exist.

3.2.3.2 Liquid Crystal Display (LCD)

LCDs use the property of certain crystals to change their orientation and their effect on light when an electric current is applied. An LCD display is formed by shaping the liquid crystal elements to form characters or symbols when the display is manufactured. The temperature change caused by a small amount of electrical current abruptly changes the light transmission properties, electrically activating proper elements to form the desired image.

The two most common types of LCDs are the active matrix liquid crystal displays (AMLCD) used in lap-top computers and the twisted nematic liquid crystal displays (TNLCD) used for watch faces, calculators, and in transit system applications.

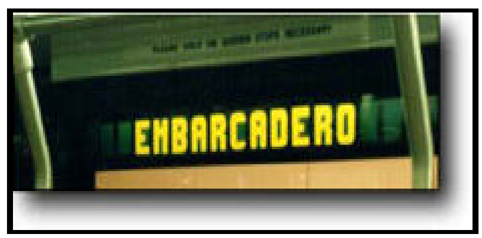

Figure 3-4. LCD Sign

Depending on the characteristics of the materials behind the liquid crystal elements, the TNLCD is available in three types, reflective, transmissive, and transflective. The reflective display is very clear when the surrounding illumination level is high, but it must be illuminated from the front of the display in low lighting conditions. The transmissive display must be back lighted, usually by a fluorescent element. It is very clear in low lighting conditions, but it is not suitable for daytime outdoor use because of poor visibility in high levels of illumination. The transflective display is suitable for high and low illumination levels because it has both reflective and transmissive properties with back lighting. A TNLCD that is transflective is the best LCD type for transit system use where illumination levels vary (TCRP, 1996).

Characters may be formed on a TNLCD by either a segmented or mosaic tile liquid crystal element layout. Watch faces and calculators are examples of a segmented display. A more complex approach, necessary for a more readable display, is the use of specially developed elements of varying shapes to form clearer characters. The elements are called mosaic tiles. Mosaic tile displays provide the clarity needed by people with visual impairments. The associated disadvantage is higher cost than segmented displays.

Advantages of TNLCD display, compared to other transit system display technologies include the following:

- Reflective TNLCDs perform equally well in bright, outdoor conditions as well as in indoor conditions,
- Transflective TNLCDs perform very well in bright, outdoor conditions, and with low illumination,
- Solid state design resists vibration (making TNLCDs suitable for on-vehicle use),
- Flat configuration is suitable for use in limited space situations,
- Viewing from an angle is much better than with LEDs, which distort at even a slight angle, and
- Mosaic tile TNLCDs present a very readable character, even for those with visual impairments.

Disadvantages of TNLCD displays, compared to other transit system display technologies, are as follows:

- They are more expensive,
- They have no animation/streaming capability (making them less suitable than LEDs for advertising), and
- TNLCDs cannot be used for time varying colors, although they are capable of displaying images in various fixed colors.

In summary, TNLCD displays are most suitable for on-vehicle or vehicle stop displays where space limitations, vibration, and the ambient illumination levels range from bright daylight to low-level nighttime conditions.

3.3 Standards, Guidelines and Research

The same basic design principles apply to electronic destination signs as for all information systems for public transport – clarity, legibility, readability, relevance and accessibility. The following sections contain excerpts from relevant research and guideline documents identified during the literature search portion of this project. Not every standard or guideline document covers all aspects of designing electronic signs for the visually impaired. Further, information not directly related to transit vehicle signage, but still relevant to text readability for the visually impaired, is included when appropriate. Finally, not all documents identified contained quantitative guidelines or standards that could be implemented directly in the engineering or design process. In many cases the information was presented in qualitative terms (e.g., display should be bright) or as *best practices* for the implementation of electronic signage systems to accommodate the visually impaired.

3.3.1 Current ADA Transit Signage Regulations

The current regulations for in- and on-vehicle transit destination signage were developed by the Architectural and Transportation Barriers Compliance Board (Access Board) and first issued in the ADA Accessibility Guidelines (ADAAG), Section 4.30.2, in July 1991. After a period of public comment, these regulations were adopted by the U.S. Department of Transportation and were published in the *Federal Register*, Volume 55, Number 173, pp. 45757-45760, dated Friday, September 6, 1991.

Transit signage regulations are referenced in *Title 49, Code of Federal Regulations; Part 38 Americans With Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles; Subpart B-Buses, Vans and Systems; Section 38.39, Destination and Route Signs*. The text of the regulation citation is as follows (emphasis added):

> § 38.39 **Destination and route signs**.
>
> (a) Where destination or route information is displayed on the exterior of a vehicle, each vehicle shall have *illuminated signs on the front and boarding side of the vehicle*.
>
> (b) Characters on signs required by paragraph (a) of this section shall have a *width-to-height ratio between 3:5 and 1:1* and a *stroke width-to-height ratio between 1:5 and 1:10*, with a *minimum character height* (using an upper case "X") *of 1 inch for signs on the boarding side* and a *minimum character height of 2 inches for front "head signs,"* with "wide" spacing (generally, the *space between letters shall be 1/16 the height* of upper case letters), and *shall contrast with the background*, either dark-on-light or light-on-dark.

The Access Board also issued a Technical Assistance Manual in October 1992, entitled "Buses, Vans, and Systems" which recommended that signage characters contrast with the background by 70 percent. The manual provided the following formula for determining contrast percentages:

Contrast = $[(B_1-B_2)/B_1] \times 100$

where B_1 = light reflectance value of light area
and
B_2 = light reflectance value of dark area

3.3.2 American Public Transit Association (APTA) Guidelines

The Standard Bus Procurement Guidelines (SBPG) issued by APTA are a model for solicitation of offers and contracts for the supply of transit buses. They are intended to be a starting point for a transit agency assembling a solicitation of offers and to assist in a cost-effective procurement. SBPG *Part 5: Technical Specifications* defines requirements for a heavy duty transit bus which, by the selection of specifically identified alternative configurations, may be used for both suburban express service and general service on urban arterial streets. It is intended for the widest possible spectrum of passengers, including children, adults, the elderly, and persons with disabilities. The destination sign design guidelines offered within Part 5 of the SBPG document are as follows (emphasis added):

- An automatic electronic destination sign system shall be *furnished on the front*, *on the right side near the front door,* and *on the rear of the vehicle*. Display areas of destination signs *shall be clearly visible in direct sunlight and/or at night*. The sign system shall provide optimum visibility of the message display units for passengers and *shall meet applicable ADA requirements defined in 49 CFR, Part 38.39*.
- The *front destination sign* shall have no less than 1,689 octagonal dot pixels, 16 rows by 105 columns, with a *message display area of not less than 9.8 inches high by not less than 63 inches wide*.
- The *side destination sign* shall have no less than 672 octagonal dot pixels, having at least 8 rows and 84 columns with a *message display area of not less than 3.15 inches high by not less than 30 inches wide*.
- The *rear route number sign* display area shall have no less than 448 octagonal dot pixels, having at least 8 rows and 28 columns with a *message display area of not less than 6.1 inches high by not less than 11 inches wide*.
- Sign displays shall have alternating message capability with programmable blanking time between message lines as may be required. *Variable blanking times shall be* programmable *between 0.5 to 25 seconds in duration*.

3.3.3 Best Practice Manual for the Publication and Display of Public Transport Information

The Ageing and Disability Department, in association with the Royal Blind Society of New South Wales, produced this manual in recognition that many older people and people with disabilities have difficulty with information about the public transport system. The stated aim of the manual is to assist the operators of public transport services to develop clear and understandable information which meets the diverse needs of their passengers.

3.3.3.1 Route numbers

Route numbers should be displayed on the front, side and rear of vehicles. Often the layout of terminals or the placement of bus stops means that passengers may approach the vehicle from the rear. Numbers at the side where boarding occurs make it easy for passengers to confirm they are boarding the correct service. Failure to do this may result in unnecessary confusion and delay.

The size and legibility of route numbers is particularly important on vehicles for the following reasons.

- Some people may have difficulty reading information which is moving.
- It is necessary to be able to identify a route number from a considerable distance in order to hail the vehicle in time for it to stop safely.
- It may be necessary to identify a route number in a crowded street or interchange.

In Canada it is recommended that *route numbers outside the front and rear of buses be a minimum of 200mm high* (Hunter-Zaworski & Watts, 1994).

3.3.3.2 Destination boards

Regular bus users may need only the route number to identify the service they want but other passengers will require more detailed information. This is generally provided by the destination boards displayed at the front of the bus.

As a rule of thumb the final destination should be shown along with major points along the route. This is particularly important if there is no obvious route or if the service deviates from what seems to be a direct route. Scrolling destination signs are an option, but *the scroll rate should be slow enough to allow people the time to read the information*.

As with other text, a *high contrast with the background is necessary*. *Yellow characters on a black background is a good choice* (Marner, 1991).

3.3.3.3 Traveler Information Systems

The following guidelines were presented for use with electronic traveler information systems. While not directly related to the transit vehicle application of primary interest in this report, there is value in presenting the information as best practice to increase readability of electronically presented text.

- According to Woodson (1981), the ratio of character width to height should be 3:5 to 4:5.
- According to Saunders and McCormick (1993) the ratio of stroke width to character height should be 1:8 to 1:6.

- The horizontal spacing between characters should be 25 percent to 50 percent of characters within a word and 75 percent to 100 percent between words (Woodson, 1981).
- The height of a character should equal the distance between viewer and screen divided by 137.5. For example, if the viewing distance is 2 meters then the character height would equal 14.5mm. This is derived from the work of Saunders and McCormick (1993) who suggest that the height of alphanumeric characters should be such that a character subtends not less than 25 minutes of visual angle.

This can be expressed in the equation:

H =*VAxD = 25xD = D*

Where:
H = the height of the character
D = the viewing distance in the same units as used for the character (usually mm)
VA = the angle between the top and bottom of the character measured from the position of the viewer's eye.

For example:
If the viewing distance is 2 meters then the equation would read:

2000 ¸ 137.5 = which would equal 14.5 mm character height
(Hunter-Zaworski & Watts 1994 p26).

- If the display is not commonly repeated, *upper case can provide a readable display*. However, if the information is commonly repeated and therefore likely to have a recognition pattern to the letters which make up the words, then sentence case will facilitate comprehension by people with visual impairments.
- *Yellow characters on a black background has been highly recommended* by the Royal National Institute for the Blind in the U.K. (Marner, 1991). However, Schofield and Flute (1997) state that *recent research has suggested that white on deep navy blue is the preferred combination for people with visual impairments.* Either could be used.
- Scrolling information is very difficult for a person who is visually impaired to read, therefore *text should be displayed in a fixed manner if possible* (Gill, 1997). *If scrolling is used* information should be left on the screen for at least twice the normal reading time (Harris & Whitney, 1993). A fixed time of about 10 seconds is likely to avoid confusion (Barham, Oxley, & Shaw 1994) so *a display time of 10 to 20 seconds should be used*.

3.3.4 Transportation Research Board, Transit Cooperative Research Program (TCRP)

The TCRP, proposed by the U. S. Department of Transportation (DOT), authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and established under FTA sponsorship in July 1992, serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet the demands of upgrading transit systems, expanding service areas, increasing service frequency, and improving transit system efficiency.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems and support and complement other ongoing transit research and training programs. The next sections provide excerpts from two TCRP reports containing relevant transit signage guidelines and recommendations.

3.3.4.1 Guidelines for Transit Facility Signing and Graphics—TCRP Report 12

This report was designed to assist transit operators in the use of appropriate signs and symbols for their facilities. These guidelines describe the use of signs and symbols that provide for the safe and efficient movement of passengers to and through transit facilities. These guidelines also assist transit operators in providing passenger information systems that encourage the use of transit by new users, infrequent riders, and individuals with disabilities.

While not specific to destination signage, a section of the report devoted to electronic visual information displays describes the characteristics of LED displays (LED size, dot pitch, character formation, and display luminance) that affect their performance as follows (emphasis added):

- **LED Size**—The diameter (or width if the display is a matrix of square LED elements) of one LED is referred to as the "dot size" of the display. *The prevalent dot size for transit system displays is currently 5 mm (0.197 in.)*.
- **Dot Pitch**—*The dot pitch, or distance between dot centers, which is currently prevalent in transit system displays is 6 mm* (.236 in.). Greater spacing between dots produces a reduction in readability. This is due to the loss of a cumulative effect whereby adjacent LEDs act together to form an image, rather than as individual dots.
- **Character Formation**—To form a character, *a minimum dot matrix of 7 x 9 is preferred. Characters must be double stroke* (made up of two adjacent rows of dots).
- **Display Luminance**—The display *must be capable of enough brightness to be visible in the intended environment*. If lighting conditions are variable, this would make the display too bright for the lower illumination levels. Therefore, *dimming controls or sensors should be used for*

displays with varied ambient conditions. Current indoor, semi-outdoor, and ultra bright versions of LED blocks for different illumination levels are available. Their ratings are given below, in Table 3-1.

TABLE 3-1. LED Ratings for Different Illumination Levels

Use*	Color	Display Luminance (cd/m^2)
Indoor (V&P)	Red-green-amber	100
Outdoor (V)	Red-green-amber	500
Outdoor (P)	Gradient control red (ultra bright)	1000

*V=Vehicles P=Platforms

3.3.4.2 Passenger Information Services: A Guidebook for Transit Systems—TCRP Report 45

The objective of this report is to produce a clear and practical guidebook to assist transit professionals in making transit information more accessible and user friendly for transit systems of varying complexity. The guidelines include a compilation of principles for the design and format details that are part of all passenger information aids. This research did not develop a high-technology, paperless approach to passenger information. Rather, it focused on traditional media for presentation of information, such as schedules, maps, and signage. Therefore, this section first offers recommendations specific to traditional bus header/identifications signs. It then presents general recommendations and guidelines to help make transit information systems easier to read and understand.

- A *bus header/identification sign is mounted on the bus front* (at least; rear and sides if possible) in static or electronic form, to identify the route number and name (if any) and, if applicable, the direction in which the bus is traveling. The sign should be visible to passengers waiting at the bus stop.
- Route number *must be legible to persons with low vision* (20/200), in daylight conditions, *at 30 feet* (*i.e., six inch high characters and/or symbols, preferably larger*).
- *Placement* should be *high on the bus body, above the window lin*e.
- Display may be by changeable message sign. Back illumination or flood illumination should be provided for nighttime operations.

For general application to transit industry information systems, the following suggestions apply:

- *Use all capital letters* (upper case) *for stop designations*, terminals, and other short labels.
- Use capital and lower case letters for long legends and instructions.
- Given that viewing distances for signs will vary according to where they are placed in relation to the intended reader, this guidebook specifies most sign character sizes in terms of visual angle. This is expressed either in

degrees or in radians. The visual angle is the angle that the letter or other object makes up in the visual field of the reader. A person with "normal" vision (20/20) will just be able to make out letters that are 1/12 degrees (0.00145 radian) of arc. ADA requirements call for the major route designators and other essential information to be visible from 30 feet away by individuals with low vision. This translates into a requirement for approximately 1 degree letters (0.017 radian). Some sample 1 degree and 1/4 degree (15 min) character sizes are shown in Table 3-2.

TABLE 3-2. Sample 1 Degree and ¼ Degree Character Sizes for Given Viewing Distance

Viewing Distance	One-Degree Character Height	15-Minute Character Height	Viewing Distance	One-Degree Character Height	15-Minute Character Height
3 feet	0.6 inches	0.2 inches	30 feet	6.1 inches	1.5 inches
6	1.2	0.3	40	8.2	2.0
9	1.8	0.5	50	10.2	2.6
12 feet	2.4 inches	0.6 inches	60 feet	12.2 inches	3.0 inches
15	3.0	0.8	70	14.3	3.6
18	3.7	0.9	80	16.3	4.1
21 feet	4.3 inches	1.0 inches	90 feet	18.4 inches	4.6 inches
24	4.9	1.2	100	20.4	5.1
27	5.5	1.4			

- For signs and printed materials that are not black-on-white (especially for bus stop signs, which may be a unique color for visibility against other street signs), a contrast formula can help determine how well text or other elements will stand out against a background. The defining formula is provided as follows.

Contrast (%) = $L_c - L_b/L_b$

Where:
L_c = Luminance (brightness) of characters
L_b = Luminance (brightness) of background

"Luminance" is measured in ft-lamberts or in candela/meter^2

NOTE: If the reflectances (in percent) of the characters and the sign background are known, these values can be substituted for the L_c and L_b in the equation above to find the contrast. Black type has a reflectance of 10%, and white paint has a reflectance of 90%. Substituting in the equation above, the contrast would be

Contrast = ((10-90)/90) x 100 = -88.9%

This formula produces "negative" contrast for signs and publications when the letters are dark against a light background, and "positive" contrast otherwise. Contrast for all signs, schedules, and publications should be at least 70 percent.

3.3.5 The Public Service Vehicle Accessibility Regulations 2000

This United Kingdom document is intended to provide guidance for those in the manufacturing and operating industries. The Public Service Vehicles Accessibility Regulations 2000 prescribe the **minimum** acceptable to meet the needs of disabled people. The guidance explains the intention of the regulatory requirements and provides advice on **best practice** that should be followed, recognizing that there may be circumstances in which design or operational constraints apply.

A regulated public service vehicle shall be fitted with a route number display and a destination display in the following positions:

- On the front of the vehicle, as close as practicable to the part of the windscreen which is within the driver's field of vision; and
- On the near-side of the vehicle adjacent to the entrance which is closest to the front of the vehicle at a height of not less than 1.2 meters to the lower edge of the display characters and not more than 2.5 meters to the upper edge of the display characters measured from the ground and, if fitted with a kneeling system, with the vehicle in the normal condition for vehicle travel.
- The front display may be fitted above the windscreen or, as low as practicable within the windscreen area, but above the driver's field of view. It must not be placed in any position that may obscure the driver's field of view.
- A regulated public service vehicle shall be fitted with a route number display on the rear of the vehicle.

Any **route number display** shall be capable of displaying the following:

- Characters of not less than 200mm in height on the front and rear of the vehicle and not less than 70mm in height on the side of the vehicle,
- Characters that contrast with the display background,
- Characters that are provided with a means of illumination, and
- Not less than three characters.

Any **destination display** shall be capable of displaying the following:

- Characters of not less than 125mm in height when fitted to the front of a vehicle and not less than 70mm in height when fitted to the side of a vehicle,
- Characters that contrast with the display background,
- Characters that are provided with a means of illumination,

- Not less than fifteen characters, and
- White or bright yellow lettering on a black background is most clearly visible.
- LED/LCD or other electronically generated characters should only be used if they can offer the same clarity, both night and day, as a conventional roller blind display.
- Destination information shall not be written in capital letters only. The use of both upper and lower case text helps ensure that words that are not completely clear and legible to people with a degree of vision impairment or learning disability, are still identifiable through shape recognition of the word.

3.3.6 Generally Accepted Human Factors Guidelines

Many generally accepted human factors guidelines are noted and incorporated in the information presented in the previous sections. Additional best practices are presented in this section.

3.3.6.1 Woodson, Tillman, & Tillman (1992)

- Any bus that will be used by the public should be configured so that handicapped persons and the elderly are not excluded from its use and/or put under stress because of the difficulties imposed.
- The principal external feature of concern to the passenger is bus identification. Signs should be located both on the front and on the sides of the bus. The front sign should be positioned so that sun reflection will not obscure the information. All signs should have illumination so that they can be read at night.

3.3.6.2 Vanderheiden (1997)

- Make letters and symbols on visual output as large as possible/practical,
- Use upper and lowercase type to maximize readability,
- Make sure that…
  - leading (space between the letters of a word),
  - the space between lines, and
  - the distance between messages

  is sufficient that the letters and messages stand out distinctly from each other,
- Use high contrast between text or graphics and background,
- Keep letters and symbols on visual output as simple as possible,
- Use only black and white or use colors that vary in intensity so that the color itself carries no information (for people with colorblindness),
- Minimize glare (e.g., by employing filtering devices on display screens and/or avoiding shiny surfaces and finishes),
- Provide the best possible lighting for displays,

- Provide adjustable speed for dynamic displays, and
- Avoid the color blue to convey important information.

3.3.7 Transit Vehicle Signage for Persons Who Are Blind or Visually Impaired

The Research Note, *Transit Vehicle Signage for Persons Who Are Blind or Visually Impaired*, by Joffee (September--October 1995 issue) describes, in part, the results of human-factors research that was completed under a subcontract to the American Foundation for the Blind (Bentzen, Easton, Nolin, & Mitchell, 1994). The results of this FTA funded research were used to develop the recommendations found in the 1998 FTA document, *Bus Signage Guidelines for Persons with Visual Impairments* (FTA-MD-26-0001-98-1).

As described elsewhere in this report, these guidelines were focused on flip dot/split flap and roller curtain signage technology. Recognizing that there may be important differences in the design guidelines recommended for LED/LCD technologies, additional research (Bentzen & Easton, 1996) was undertaken and is described in the following section.

3.3.8 Specifications for Transit Vehicle Next Stop Messages

This project was undertaken to determine optimum characteristics to promote legibility of **in-vehicle** LED next stop message signs by persons with varying visual acuities, including persons having no visual impairments as well as persons who are legally blind. Characteristics of LED next stop message signs considered relevant to this report were color, letter characteristics, intercharacter spacing, streaming versus paging[5], and change rate.

The project obtained both objective data on legibility of messages displayed as 84 participants were riding buses and subjective data on legibility of messages displayed to three focus groups who were seated in a room. The following items summarize the relevant results of that research effort:

- **Color**. One word green messages were significantly more legible than red messages at the fast streaming rate, and there was a strong preference for green next stop message signs. Participants in both postexperimental focus groups suggested that advertising messages and next stop messages should be different in color.
- **Letter Characteristics**. Both objective measures of legibility and subjective judgments indicate that the 5:7 character width-to-height ratio is more legible than the 6:7 character width-to-height ratio. The results of this research indicate that there are very real differences in legibility of LED letters having different proportions. The more legible 5:7 ratio is

[5] Streaming text is characterized by the lettering appearing to "travel" across the display area from left-to-right or right-to-left. Paging text appears to fill the display area, is static for a period of time, and then is replaced with entirely new text material.

slightly wider than the minimum 3:5 width-to-height permitted by ADAAG; the less legible 6:7 ratio is somewhat narrower than the maximum 1:1 width-to-height permitted by ADAAG. This suggests that, at least for dynamic in-vehicle LED signs to be read at distances of 3-33 feet, letters having width-to-height ratios equal to or wider than 6:7 should not be permitted.

- **Intercharacter spacing**. The preexperimental focus group of persons who are visually impaired found messages having intercharacter spacing of two-stroke widths (that is, 2:7) to be subjectively easier to read than messages having intercharacter spacing of just one stroke width (1:7). This is consistent with the findings of research on flip dot signs. This is a much wider intercharacter width than currently suggested by ADAAG. The results of this research indicate that for in-vehicle changeable message LED signs to be read at distances of 3-33 feet, an intercharacter spacing of 1:16 (as suggested by ADAAG) would definitely not result in optimal legibility for persons having visual impairments.
- **Streaming versus Paging**. Static signs are more legible than streaming signs. The objective measure of legibility for streaming versus paging signs showed highly significant differences favoring streaming signs over paging signs. One of the two post-experimental focus groups, however, tended to prefer paging signs.
- **Change Rate**. There was an objective effect of rate on legibility, which interacted with placement. The best legibility for two word messages was achieved for messages which changed at the slower rate (2.74 seconds per frame dwell time).

Relevant recommendations from this report are as follows:

- LED next stop message signs should use a character which is 5x7 (character proportion 5:7), having all capital characters with a one pixel wide stroke width (1:7).
- LED next stop messages should have an intercharacter distance of two stroke widths (2:7).
- Where message length is short enough to fit within the length of an LED sign, the message should be static (that is, it should not stream or page).
- Where message length is too long to fit within the length of an LED sign, the message should stream with a dwell time of 2.74 seconds.
- Paging motion should not be used for next stop messages.
- Advertising messages and next stop messages should be different in color.

3.4 Subject-Matter Expert (SME) Guidance

3.4.1 Orientation, Mobility, Ageing, and Disability Organizations

Twenty-five SMEs working in the field of low vision have agreed to provide assistance at various levels to this project. Their contributions have come in a variety of forms including identifying technical data, providing expert knowledge, and helping to identify and coordinate or otherwise include the help of others. The entire list is included in this report as Appendix C. Of the people and organizations contacted, three have provided technical reports relating to signage readability for persons with visual impairments. The following summarizes the results of those contacts:

Contact Information: Ms. Ana Ramirez
Miami Valley Regional Planning Commission
(937) 223-6323

Ms. Ramirez is an engineer for the Miami Valley Regional Planning Commission and agreed to look for information regarding specifications for signage for the visually impaired used on buses and trains. She provided the internet address for the article titled "Improving Bus Accessibility Systems for Persons with Sensory and Cognitive Impairments."

Contact Information: Billie L. Bentzen, Ph.D.
Mcguinn Hall 346
140 Commonwealth Avenue
Chestnut Hill, MA 02467
Phone: (617) 552-4112 or Dept. 4100
Email: billie.bentzen.1@bc.edu

Dr. Bentzen works for Boston College and Accessible Design for the Blind. She provided two research papers. One paper titled, "Transit Vehicle Signage for Persons who are Blind or Visually Impaired" appeared in the Journal of Visual Impairment and Blindness. The other paper titled "Specifications for Transit Vehicle Next Stop Messages" is an internal research document for Sunrise Systems Inc. Content from both papers is summarized in this report.

Contact Information: Lighthouse International
Research Department
Phone: (212) 821-9537

Lighthouse International provided their information on recommendations for signage readability for people with visual impairments. The documents were titled, "Effective Color Contrast," "Low Vision Defined," and "Making Text Legible."

3.4.2 Transit Agency, Sign, and Vehicle Manufacturers

Fifteen sign manufacturers and 24 bus manufacturers were identified and contacted. They were questioned concerning guidelines used to design, manufacture, or procure electronic destination signage. Of those 39 contacts, seven returned e-mails or phone calls with information relevant to this gap analysis effort. The following summarizes the results of those contacts:

Contact Information: David L. Turney CEO
Digital Recorders
4018 Patriot Dr., Ste. 100,
Durham, NC 27703
Phone: 919-361-2155
Fax: 919-361-9847
mailto:davet@digrec.com

Mr. Turney from Digital Recorders stated that his company does provide signage for transit buses, but they do not manufacture the signs themselves. The only specifications that they had for the interior signs were that they were 16 and 20 character red and yellow LED signs.

Contact Information: Dan Kelleher
Luminator
1200 East Plano Parkway,
Plano, TX 75074
Phone: 972-516-3073
Fax: 972 578-9528
mailto:dkelleher@luminatorusa.com

Mr. Kelleher and an engineer, Mr. John Gunther, sat down for a teleconference with Booz Allen personnel to discuss guidelines for making signs. They stated that the industry was quickly heading toward electronic signs and thought that the switch would be complete in about two years. However, despite this increase in growth, there are still only the ADA guidelines that are required for the manufacturers. Luminator follows the Standard Bus Procurement Guidelines (SBPG) from APTA, which describes the minimal bus requirements that would meet government standards.

Contact Information: Marco Olmi
Area Manager
Solari di Udine SpA
Phone: +39.0432.497262
Fax: +39.0432.480160
mailto: molmi@solari.it

Mr. Olmi stated that there were no specifications for font size, width, spacing, etc. Therefore, Solari di Udine applies the use of full graphic LED signs, especially for the track indicators. This option leaves it up to the user to decide the details for the message. The company also commonly integrates an audio system with their signs.

Contact Information: Carol M. Walle
Collins Bus Corporation
P.O. Box 2946
Hutchinson, KS 67504-2946
Phone: (800) 533-1850
mailto:carol.walle@collinsbus.com

Ms. Walle stated that World Trans Inc. purchases sings from Trans Sign, Luminator and Twin Vision. Collins accepts the standards the sign manufacturers provide, and they only put limitations on the physical size of the sign.

Contact Information: Mark Osborne
Mayflower House,
London Road,
Loudwater,
High Wycombe, Bucks.
HP10 9RF
Phone: +44 1723 581500
Fax:+44 1723 581479
mailto:M.Osborne@plaxton.co.uk

Mr. Osborne stated that the United Kingdom has a relatively new piece of legislation "The Public Service Vehicle Accessibility Regulations 2000" that gives specifications for destination signs. The relevant guidelines are documented elsewhere in this report.

Contact Information: Allan Haggai
Thomas Built Buses, Inc.
1408 Courtesy Road
High Point, NC 27260
Phone: 336-889-4871
Fax: 336-889-2589
mailto:allan.haggai@thomasbus.com

At Thomas Built Buses Inc. buses are equipped with signs that are specified by the customer, and built by another company. They only install the unit, and make sure that it works properly. The company sets no restrictions on the sign manufacture, and it is up to the manufacturer to make sure that the signs are ADA compliant.

Contact Information: Joseph R. Gibson
Nova BUS
1301 Hillside Ave.
Schenectady, NY 12309
Tel: 817-379-3744
Fax: 817-337-5242

Nova BUS provides several electronic sign offerings for the front, side and rear destination signs. They do not manufacture the signs in-house, but get them from Luminator, Twin Vision, and Bailios. These signs are designed to meet the ADA requirements for visibility, size (character height and width), color, as well as locations required on the bus. The signs also have the capability to interface with voice systems and Global Positioning Systems.

The consensus among transit vehicle and sign manufacturers indicates that ADA guidelines are the primary standard used (within the U.S.) when designing, manufacturing or acquiring electronic destination signage. In addition, the use of the Standard Bus Procurement Guidelines (SBPG) appears to be a driving force in the design of front, side, and rear electronic displays as these guidelines specify the minimum space allocated for destination and route number signs. The United Kingdom does have the Public Service Vehicle Accessibility Regulations, and at least one sign provider had internal specifications for color and number of characters presented.

In summary, the bus manufacturers generally leave it up to the sign manufacturers when it comes to the details of the sign, only putting restrictions on the physical size of the sign to meet the minimum space requirements indicated in the SBPG. The sign companies, in turn, are producing LED/LCD signs that the customer (e.g., transit agency) can program to meet their own operational requirements, including meeting the ADA standard minimums.

CHAPTER 4
SYNTHESIS

While the ADA and its amendments provide guidance about on-vehicle transit signage, this information has primarily focused on static signs. Today, transit authorities are installing the new dynamic, LED/LCD signs on their transit vehicles to indicate destination information, as well as to disseminate other important information. These displays have characteristics that are unique, and if not correctly designed and engineered, they may be very hard to read under day, night, and low light conditions by those who are visually challenged.

To assist the FTA in addressing this issue, a gap analysis was performed to determine if sufficient guidance is currently available for contrast, motion, character height, upper case versus lower or mixed case, on LED/LCD destination signs for visually impaired individuals. The gap analysis indicates that the current human systems and transit standards/guidelines literature is inadequate or incomplete in a number of the areas researched. To facilitate summary and discussion of the gap analysis results, this section is organized by the relevant questions FTA researchers are attempting to address.

4.1 Do the ADA specifications for electronic destination signs adequately address the needs of people who are visually challenged under different lighting conditions: daylight, low light, and nighttime?

While not specifying application to the newer LED and LCD technologies, transit signage specifications developed by the Architectural and Transportation Barriers Compliance Board (Access Board) and issued in the ADAAG do not appear to fully address the range of issues that interest FTA researchers or that might prove important for LED/LCD signage legibility. The guidelines are limited to specifying minimum requirements for sign placement, character height, character width-to-height ratio, stroke width-to-height ratio, and intercharacter spacing. Other items of interest to the FTA such as glare, contrast, viewing under different lighting conditions, and streaming capability and rate, are not adequately addressed.

Recent research efforts have looked at flip dot/split flap and roller curtain sign design parameters that influence readability for the visually impaired. This research has concluded that ADA guidance is often viewed as the minimum requirement and has made recommendations for larger font sizes and greater intercharacter spacing than is currently indicated by the ADAAG. Results of this research were used to develop the 1998 FTA guidance document mentioned previously. However, there is a concern that LED/LCD sign technology presents issues that are not covered by the research on flip dot/split flap and roller curtain technologies (e.g., streaming capability/rate).

More relevant to the current gap analysis effort, research has been undertaken to determine optimum characteristics to promote legibility of **in-vehicle** LED next stop message signs by persons with varying visual acuities, including persons having no visual impairments as well as persons who are legally blind. Characteristics of LED next stop message signs investigated in this research and considered relevant to the FTA are color, font size, intercharacter spacing, streaming versus paging, and change rate. Specific recommendations coming from that research are documented in Section 3.3.8. Unfortunately, this research did not capture data for on-vehicle signage or for sign characteristics influencing readability under varying illumination.

Presumably the LED/LCD sign technologies identified in this report could provide greater readability during daytime, twilight and nighttime conditions. Unfortunately, the ADA regulations, along with information identified in many other accessibility guideline documents, do not provided quantitative guidance for "adequate" illumination levels to accommodate the visually impaired.

Finally, and possibly most important, the ADA guidelines do not present empirical evidence for the values that are designated, and therefore they can not be fully evaluated regarding their adequacy in addressing the needs of the visually impaired.

4.2 Are minimum character heights of one inch and two inches for side and front electronic destination signs respectively, sufficient for people who are visually challenged under various lighting conditions–daylight, low light, and nighttime? If these sizes are not adequate, what character size is readable as well as appropriate for vehicle placement? For a given character size, what is the optimum distance of such a sign for readability?

ADA character height/size specifications appear to have been accepted–largely without question–as the **minimum** requirements to meet the needs of the visually impaired. Again, while not specifying application to the newer LED and LCD technologies, the regulations require a minimum character height of one inch for boarding-side signs and two inches for front signs.

Little empirical research is available for review that supports the ADA specifications for minimum character heights as being adequate for electronic destination signage. The research conducted to support 1998 FTA guideline development indicates/advocates larger sized lettering for both the front (minimum six inches) and side (minimum two inches). However, as noted earlier, this research was focused on the flip dot/split flap and roller curtain sign technologies and did not address in any quantitative fashion the issue of readability under varying lighting conditions.

Various other guideline and research documents identified during this project reveal a range of character size recommendations. In all cases the sizes recommended have been larger than those found in the ADAAG; ranging from approximately three inches high for on-vehicle side destination signs to approximately nine inches high for on-vehicle front destination signs. Character size recommendations for rear destination/route signs generally fell somewhere between these two values (six to eight inches). In many cases, the guidance provided was qualitative in nature only (e.g., must be large enough to be seen by those with visual impairments, make as large as possible/practical).

Results of contact with SMEs in the transit vehicle and sign manufacturing community offered little additional guidance. LED/LCD sign manufacturers indicated their designs were often driven by the space allotted on the vehicle and in all U.S. cases they indicated that their signs could be programmed to meet ADA requirements.

There appears to be general consensus regarding the placement of signage on the outside of the vehicle. In all cases where a recommendation, guideline, or standard addressed the issue, they called for presentation of destination information on the front (generally above the drivers field of view to prevent obstruction) and on the side of the vehicle next to the door. It was also recommended that at least the route number be presented on the rear of the vehicle.

In-vehicle placement was briefly addressed and indicated only that the sign be separated from other signs presenting nontransit related information (e.g., advertising) and that placement consideration be made for viewing the sign when people might be standing in the center aisle of a bus.

ADA requirements call for the major route designators and other essential information to be visible from 30 feet away by individuals with low vision. Given that viewing distances for signs will vary according to where they are placed in relation to the intended reader, many guideline documents specified or provided formulas for calculating sign character sizes in terms of visual angle, primarily under daylight conditions only. For example, a person with "normal" vision (20/20) will just be able to make out letters that are 1/12 degrees (0.00145 radian) of arc. This translates into a requirement for approximately one degree letters (0.017 radian; six inch high characters and/or symbols, preferably larger) to accommodate readability from 30 feet away for individuals with low vision. Table 3-2 in Section 3.3.4.2 presents a full range of character sizes and the distance from which they can be read.

There are other formulas to calculate character size based on visual angle presented in this report. However, this information is based on readability guidelines for conventional transit information technologies and may not be valid for use with the LED/LCD technologies that are the focus of this effort.

4.3 Are electronic destination signs that provide multiple messages with alternating text readable by people who are visually challenged under day, night, and low light conditions?

Some new dimensions to meeting basic human factors principles of clarity, legibility, readability, relevance and accessibility apply with electronic information systems. For example, the temptation to provide too much information can be hard to resist. LED technology has as one of its stated benefits the ability to stream or page information across the screen. This enables the inclusion of advertising or other nontransit related information to be presented in the same space/location as destination information. Avoiding this temptation is noted as a best practice in a number of guidance documents reviewed.

The guidance is less clear regarding the distinction between streaming or paging text, and at what rate. In general, static signs are more legible than those that stream or page. When motion is used, however, there appears to be a quantitative advantage to streaming versus paging signs for in-vehicle next stop messages. Where alternating text is presented, many of the guidelines regarding rate are qualitative in nature (e.g., scroll rate should be slow enough to allow people time to read the information) or suggest making provision for speed adjustment. When quantitative guidelines are provided, the range of display time is from 2.74 seconds per frame for in-vehicle next stop information up to 20 to 25 seconds for more complex transit information.

Again, none of the guidelines, research documents, or standards reviewed for this effort commented on the readability of streaming or paging information under day, night, or low light conditions.

4.4 What color combinations provide the best levels of contrast under day, night, and low light conditions?

Contrast refers to the brightness difference between letters or symbols and their background. In general, the greater the contrast, the easier it will be to see and to read text on printed materials and on signs.

The Access Board issued a Technical Assistance Manual in October 1992, entitled *Buses, Vans, and Systems*, which recommended that signage characters contrast with the background by 70 percent[6]. Many of the other documents reviewed indicated the use of yellow characters on a black background as a good choice. In at least one case the research suggested that white on deep navy blue is the preferred combination for people with visual impairments.

LED/LCD technology, however, is not yet advanced enough to present a full range of colors that can be seen under all lighting conditions of interest. Currently only red LEDs are bright enough to be seen outside in full sunlight. Other colors (yellow, green, blue) are available and in use for inside (vehicle or terminal) or low ambient lighting conditions. At least one study indicated a strong preference for the use of green LEDs to present in-vehicle next stop information, and basic human factors guidelines suggest avoiding the color blue to convey important information.

4.5 Are people who are visually challenged better able to read mixed upper and lower case letters as they form a word, or is all capitals preferable, under day, night, and low light conditions?

The general guidance found in the literature regarding the use of upper or lower case lettering for destination signage is as follows:

[6] The manual provided a formula, found on page 10 of this report, for determining contrast percentage.

- Use all capital letters (upper case) for stop designations, terminals, and other short labels.
- Use capital and lower case letters for long legends and instructions.

This guidance appears repeatedly, with one exception, throughout the literature for both transit destination signage and other transit related information systems. The rationale behind this guidance states that if the display information is not commonly repeated, upper case can provide a readable display. However, if the information is commonly repeated and, therefore, likely to have a recognition pattern to the letters which make up the words, then sentence case will facilitate comprehension by people with visual impairments.

None of the studies, guidelines, or standards indicated a difference in the guidance based on ambient illumination levels.

4.6 Does a wider character width improve readability for people who are visually challenged under day, night, and low light conditions?

ADAAG calls for a character width-to-height ratio between 3:5 and 1:1 and stroke width-to-height ratio between 1:5 and 1:10, with "wide" spacing between characters– generally 1/16th the height of upper case letters.

As with many of the other guidelines and standards identified, there is some general (but not complete) agreement on values in and around this range for application to text readability. For example, basic human factors guidelines call for the ratio of stroke width to character height to be in the range of 1:8 to 1:6.

Only one study identified in this report looked at both objective measures of legibility and subjective judgments indicating that a 5:7 font is more legible than a 6:7 font with in-vehicle next stop signs. The results of this research indicates that there are very real differences in legibility of LED fonts having different proportions. The more legible 5:7 font is slightly wider than the minimum 3:5 width-to-height permitted by ADAAG; the less legible 6:7 font is somewhat narrower than the maximum 1:1 width-to-height permitted by ADAAG. This suggests that, at least for dynamic in-vehicle LED signs to be read at distances of 3-33 feet, fonts having width-to-height ratios equal to or wider than 6:7 should not be permitted.

Here again there was no research identified that examined this issue with varying illumination levels.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The results of this gap analysis effort lead to the following conclusions regarding the existing electronic signage design guidance, and recommendations for filling the identified gaps and promoting additional research efforts in transit sign design to accommodate the visually impaired.

It appears adequate research and guidance is available to indicate the following:

- On-vehicle electronic transit destination information should be located on the front of the vehicle (above the driver's field of view), on the side of the vehicle near the entry, and that at least a route number should be displayed on the rear of the vehicle.
- While not extensively documented with empirical research, the current guidelines for flip dot/split flap technologies are consistent with a number of documented best practices and provide sufficient guidance regarding character height, width-to-height ratios, stroke width-to-height and intercharacter spacing for LED/LCD applications.

The results of this gap analysis have generated the following recommendations:

- Conduct research activities to address questions identified as important to FTA researchers in Section 4, SYNTHESIS, but found as gaps in the body of guideline and research literature.
  - Lack of definitive guidance on LED/LCD sign readability under varying illumination (i.e., daytime, twilight, nighttime).
  - Lack of definitive guidance on streaming/paging style and rate for on-vehicle signs.
  - Lack of definitive guidance for the use of color in LED/LCD transit destination displays. This would include determination of adequate contrast ratios between letter or symbol color(s) and background under all anticipated lighting conditions.
- Conduct additional research activities to address issues of importance to the FTA but not directly identified in Section 4, SYNTHESIS.
  - Research the influence of motion (vehicle moving-user stationary; user moving-vehicle stationary) on the legibility of LED/LCD destination and route displays. This would include determination of adequate viewing angles for all on-vehicle signage locations.
  - Research the influence of glare on LED/LCD sign legibility.

A follow-on "Needs Analysis" effort (the second phase of this project) capturing input from transit agencies, transit system users and advocacy groups for the visually impaired will allow the FTA to prioritize future research efforts and address the most important user needs in a cost-effective manner.

It appears a noticeable amount of work remains to be done to prove and provide the benefits that might be gained by implementing LED/LCD technologies for transit vehicle destination signs. Achieving a meaningful and intelligent implementation of these technologies will require a synergistic effort involving the FTA, disability advocacy groups, research labs, system manufacturers, and equipment makers.

CHAPTER 6
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APPENDIX A

Search Strategy Statement

Search Strategy Statement
for
Literature Review Support to the Department of Transportation (DOT) Federal Transit Administration (FTA)

Traveler Information Systems Americans with Disabilities Act (ADA) Guidebook "Bus Signage Guidelines for Persons with Visual Impairments: Electronic Signs"

PURPOSE

The purpose of this project is to develop recommended design and implementation guidelines for electronic destination signs on bus and rail vehicles that are more responsive to people who are visually challenged. This project is part of the Federal Transit Administration's Strategic Plan, Strategic Goal #2: Mobility and Accessibility. This goal is to ensure a transportation system that offers choices, and is accessible, integrated, and efficient, for all Americans.

BACKGROUND

While the ADA and its amendments provide guidance about "on-vehicle" transit signage, this information has primarily focused on static signs. Today, transit authorities are installing the new dynamic, electronic signs on their transit vehicles to indicate destination information as well as to disseminate other important information. Electronic displays have characteristics that are unique, and if not correctly designed and engineered, they may be very hard to read under day, night, and low light conditions by those who are visually challenged.

TASK

Human Systems Information Analysis Center (HSIAC) will conduct a comprehensive literature search on the research topic limited to documents that have been published ***within the last ten years***. The literature and source search will cover, at a minimum, the following:

- FTA Report "Bus Signage Guidelines for Persons with Visual Impairments,"
- The Access Board publication listing,
- Transit Cooperative Research Program (TCRP) Report #45 – Passenger Information Services: A Guidebook for Transit Systems,
- TCPR Synthesis #17 - Customer Information at Bus Stops,
- TCPR Project 20-A - Strategies for Improved Traveler Information Systems (Draft Report),
- FTA Electronic Document Guidelines,
- Scientific and Technical literature for information and standards on electronic signage visibility under low light, nighttime, and bright lighting conditions; as

well as information and standards on contrast, and the affect motion speed and direction has on the readability of electronic signs; and

- American Public Transportation Association (APTA) resources for current practices and issues.

HSIAC will perform a “Gap Analysis” to determine if sufficient guidance is currently available for contrast, motion, character height, upper case versus upper or mixed case, on electronic destination signs for visually challenged individuals. HSIAC will prepare a white paper summarizing the ADA regulations pertaining to transit signage, human factors research findings and other relevant information. If HSIAC finds that current literature is inadequate or incomplete in any of the areas researched, recommendations will be made as to which factors should be tested under laboratory conditions. Relevant questions to be answered include, but are not limited to, the following:

- Do the ADA specifications for electronic destination signs adequately address the needs of people who are visually challenged under different lighting conditions–daylight, low light, and nighttime?
- Are minimum character heights of one inch and two inches for side and front electronic destination signs respectively, sufficient for people who are visually challenged under various lighting conditions–daylight, low light, and nighttime? If these sizes are not adequate, what character size is readable as well as appropriate for vehicle placement? For a given character size, what is the optimum distance of such a sign for readability?
- Are electronic destination signs that provide multiple messages with alternating text readable by people who are visually challenged under day, night, and low light conditions?
- What color combinations provide the best levels of contrast under day, night, and low light conditions?
- Are people who are visually challenged better able to read mixed upper and lower case letters as they form a word, or is all capitals preferable, under day, night, and low light conditions?
- Does a wider character width improve readability for people who are visually challenged under day, night, and low light conditions?

SUGGESTED SEARCH TERMS/STRATEGY

- transportation
  - ground vehicles
  - surface/land transportation system(s)
    - bus(es)
    - rail (light, commuter)
    - paratransit
- transit systems—public
- transit accessibility
- advanced public transportation systems (APTS)
- advanced technology transit applications

and

- display(s)
  - visual
  - alphanumeric
  - sign(s); signage—electronic
    - readability
    - legibility
    - mounting (location, height)
  - variable message signs (vms)
- human factors (engineering)
- human (visual) performance
- information/information technology

transit information system
traveler information
transit communication system

vision
- visual perception
  - acuity
  - contrast
  - discrimination
  - threshold(s)
- disorder(s)

visually handicapped (challenged)
sensorially handicapped (challenged)
partially sighted
disability/accessibility
- laws/civil rights

SUGGESTED DATABASES

- Applied Social Sciences Index and Abstracts
- Dissertation Abstracts
- EiCompendex
- Global Mobility Database
- IHS International Standards and Specifications
- INSPEC
- National Technical Information Service (NTIS)
- PsycINFO
- SciSearch
- Transportation Research Information Services (TRIS)
- Wilson Applied Science & Technology Abstracts

SOME AUTHORS/RESEARCHERS/SOURCES OF NOTE

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- Thorn, F.
- Thorn, S.

APPENDIX B

COPYRIGHTED LITERATURE SEARCH RESULTS
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APPENDIX C

SUBJECT-MATTER EXPERT CONTACT LIST

Contributing Organizations and Professionals

The following is a list of organizations and professionals who volunteered to contribute to this project. Their contributions have come in a variety of forms including identifying technical data, providing expert knowledge, and helping to identify and coordinate or otherwise include the help of others.

Private Industry Service Providers

Clovernook Center

Contact Information:

Keith Tackett
Clovernook Center
115 West Monument, Apt. 402
Dayton, OH 45402
Phone: (937) 223-2059

Goodwill Industries of the Miami Valley/Easter Seals

Contact Information:

Kim Carr
Goodwill/Easter Seals
1511 Kuntz Rd.
Dayton, OH 45404-1297
Phone: (937) 461-4800 ext. 572
Email: k.carr@goodwilldayton.org

Contact Information:

Jennie Adae
Goodwill/Easter Seals
1151 Kuntz Rd.
Dayton, OH 45404-1297
Phone: (937) 461-4800 ext. 339

Lighthouse International

Contact Information:

Kent Higgins Ph.d.
Lighthouse International
111 E. 59th St.
New York, NY 10022-1202
Phone: (212) 821-9200
Email: khiggins@lighthouse.org

Smith-Kettlewell Institute for the Visual Sciences

Contact Information: John Brabyn
Email: brabyn@ski.org

Contact Information: Bill Crandall, Ph.D.
Smith-Kettlewell
Rehabilitation Engineering Research Center
San Francisco
Phone: (415) 345-2111
Fax: (415) 345-8455

Universities

Wright State University

Contact Information: Jeff Vernooy
Director, WSU Office of Disability Services
3640 Colonel Glenn Hwy.
E186 Student Union
Phone: (937) 775-5680
Email: Jeffrey.vernooy@wright.edu

Contact Information: Jerry Hensley
Desktop Software Specialist
3640 Colonel Glenn Hwy.
Dayton, OH 45435-0001
Phone: (937) 775-2349
Fax: (937) 775-4049
Email: Jerry.Hensley@wright.edu

Contact Information: Chuck Taylor
Phone: (937) 775-3063
Email: charles.taylor@wright.edu

Contact Information: Ann C. Wendt, Ph.D.
1448 Sanzon Drive
Fairborn, OH 45324
Phone: (937) 427-8090

Fax: (937) 427-3499
Email: Ann.wendt@wright.edu

Contact Information: Mark Willis
Phone: (937) 775-3814
Email: Mark.willis@wright.edu

Boston College

Contact Information: Billie L. Bentzen, Ph.D.
Mcguinn Hall 346
140 Commonwealth Avenue
Chestnut Hill, MA 02467
Phone: (617) 552-4112 or Dept. 4100
Email: billie.bentzen.1@bc.edu

Texas Transportation Institute at Texas A & M

Contact Information: Sue Chrysler Ph.D.
Texas Transportation Institute
Texas A & M University
3135 TAMU
College Station TX 77843-3135
Email: sue_Chrysler@hotmail.com

Western Michigan University, Department of Blind Rehabilitation

Contact Information: Dr. Richard Long
1903 West Michigan Av.
Kalamazoo, MI. 49008-5318
Phone: (616) 387-3451
Email: richard.long@wmich.edu

University of Iowa

Contact Information: Daniel V. McGehee, Ph.D.
University of Iowa
227 South Quad
Iowa City, Iowa 52242-1192
Phone: (319).335-6819

Fax: (319).335-6801
Email: mailto:daniel-mcgehee@uiowa.edu

Contact Information:

Tom Schnell, Ph.D.
Department of Industrial Engineering
2135 Seamans Center
The University of Iowa
Iowa City, Iowa 52242-1527
Phone: (319) 384 0811
Email: thomas-schnell@uiowa.edu

Contact Information:

Mark E. Wilkinson, OD
Associate Professor (Clinical)
Director, Low Vision Rehabilitation Service
UIHC Ophthalmology and Visual Sciences
200 Hawkins Drive, 11290 PFP
Iowa City, IA 52242
Email: wilkinsm@horus.ophth.uiowa.edu

University of Minnesota

Contact Information:

Gordon E. Legge
University of Minnesota
Department of Psychology
Email: legge@eye.psych.umn.edu

Government Organizations

Bureau of Vocational Rehabilitation (BVR)

Contact Information:

Susan Chrumbacher
Vocational Councilor
Bureau of Vocational Rehabilitation
1147 Bellbrook Av.
Xenia, OH 45385
Phone: (937) 426-1475

Bureau of Services for the Visually Impaired (BSVI)

Contact Information: Paula Shew
Supervisor
Bureau of Services for the Visually Impaired
111 West First Street, Suite 303
Dayton, OH 45402
Phone: (937) 285-6370

Green County Coordinated Agency Transit System (Green CATS)

Contact Information: Rick Schultz
601 Ledbetter Rd., Suite A
Xenia, OH 45385
Phone: (877) 227-2287

Miami Valley Regional Planning Commission

Contact Information: Ana Ramirez
Engineer
Miami Valley Regional Planning Commission
Phone: (937) 223-6323

Miami Valley Regional Transit Authority

Contact Information: Don Brubaker
Operations Project Manager
600 Longworth St.
P.O. Box 1301
Dayton, OH 45401
Phone: (937) 443-3033
Fax: (937) 443-3124
Email: DBRUBAKER@MVRTA.ORG

Contact Information: Mary Ellen Pfeil
Disability Specialist
4 South Main Street
P.O. Box 1301
Dayton OH 45401

Phone: (937) 425-8357
Fax: (937) 425-8418
Email: MPFEIL@MVRTA.ORG

Contact Information: William E. Snyder
Planning Supervisor
4 South Main Street
P.O. Box 1301
Dayton OH 45401
Phone: (937) 425-8351
Fax: (937) 425-8418
Email: BSNYDER@MVRTA.ORG

Project Mobility

Contact Information: Rodney Behrens
Chair, Appeals Board for Project Mobility
2523 Auburn Av.
Dayton, OH 45406
Phone: (937) 901-3763
Email: behrensr@national-citymortgage.com

APPENDIX D

TRANSIT SIGN AND VEHICLE MANUFACTURERS CONTACT LIST

TRANSIT SIGN AND VEHICLE MANUFACTURERS CONTACT LIST

Company	Description	Point of Contact
TwinVision Inc.	Messages produced by LED/flip-dot displays are readable from a great distance, and TwinVision's direct-view design concentrates the maximum LED energy directly toward the viewer. All passengers - particularly the visually challenged appreciate readability. The TwinVision LeDot Destination Sign System is designed with the Americans with Disabilities Act in mind by providing more readable signs for transit passengers. TwinVision also complies with all Buy-America regulations. http://www.twinvisionna.com/advantage.html (Retrieved on July 11, 2001)	Jerry Sheehan VP, Sales & Marketing Research Triangle Park, NC 800-222-9583 or 919-313-3080 Fax: (919) 361-9635 jerrys@digrec.com
Trans-Industries	Trans-Industries makes signs, displays, and lighting systems, primarily for the mass transit industry. Trans-Industries' displays are installed in airports, rail terminals, bus stations, and car rental facilities to provide travel times and safety and directional information. The company's products are also used in mass transit vehicles and highway systems. Subsidiaries makes dust capture systems for manufacturers, vehicle interior lighting, and bus glass. Bus maker Gillig accounts for 11% of sales. Chairman and president Dale Coenen owns about 20% of the company; director Duncan Miller owns about 15%. http://www.transindustries.com/ (Retrieved on July 11, 2001)	2637 S. Adams Rd, Rochester Hills, MI 48309 248-852-1990 248-852-1211 inquiries@transindustries.com
Digital Recorders	The company's electronic destination signs display transit information for buses. Digital Recorders, which outsources most of its manufacturing, sells to vehicle makers, transit operators, and law enforcement agencies. Taiwanese light-emitting diode maker Lite Vision owns 12% of the company.	David L. Turney CEO 4018 Patriot Dr., Ste. 100, Durham, NC 27703 919-361-2155 Fax: 919-361-9847 davet@digrec.com
Luminator	Electronic destination sign specialist…The Max3000 Series with LED illumination for outstanding nighttime readability has: Uniform lighting with each individual pixel illuminated by its own long life LED, Incorporates the best of two Technolgies,-industry proven Electomagnetic flip dots, and LEDs, Designed to interface with other Electroni Equipment. Also produces products for rail systems. http://www.luminatorusa.com/bus/index.htm (Retrieved on August 3, 2001)	Dan Kelleher 1200 East Plano Parkway, Plano, TX 75074 972-516-3073 Fax: 972 578-9528 dkelleher@luminatorusa.com

Company	Description	Point of Contact
Display Technologies Inc	Looking for a sign? Display Technologies (formerly La-Man) has several subsidiaries (Ad Art, Don Bell Industries, J.M. Stewart Industries) that make and service electronic video displays, message centers, schools. The company also services signs, parking lot lighting and other exterior lighting installed by other vendors. Its aggressive acquisition streak and a need to restate the value of inventories (which erased several quarters of earnings) weakened the company's financial position in 2000. Director Lou Papais, the founder of Ad Art's Predecessor, owns 9% of Display Technologies. http://www.dteksigns.com	5029 Edgewater Dr. Orlando, FL 32810 407-521-7477 Fax: 407-521-8767
Pocatec Systems	Pocatec designs, manufactures, and supplies advanced information and entertainment system for the public transit industry. The company is ISO 9001 certified and the sole manufacturer of integrated audio and visual systems. It boasts a solid reputation for both its products and its service. Products at the cutting-edge of technology and innovation. Outstanding solutions to meet your requirements. Versatile and highly flexible with very fast turnaround. Reliable, JIT delivery. http://www.pocatec.com./en/qui/qui.htm (Retrieved on July 11, 2001)	Engineering 53 rue Bel-Air Lévis, Québec, Canada G6V 6K9 T (418) 838-0724 F (418) 856-5978 pocatec@pocatec.com
Southport Engineering (AUST.) PTY. LTD.	Southport Engineering a new name with proven technology. Technology that was enhanced with acquisitions from Amphenol Australia and Alcatel Components, the latter a company with a record of supplying electronic destination signs for over 16 years, and with thousands of systems operating throughout Australia. The Southport Engineering system provides many features and benefits such as graphic displays variable message scrolling, large message bank capacity and excellent visibility for both day and night applications. Windows based programming software enables operators to construct messages and download efficiently to the sign controller by means of a robust PCMCIA card. Southport Engineering design, manufacture and write supporting software for your individual needs. Southport Engineering are accredited to ISO9001, contact us by clicking on the 'Contact Us' button above for the economical solutions and further technical information for your specific applications. http://www.southporteng.com.au/electron.htm (Retrieved on July 11, 2001)	ISO 9201 Lic 2625 Standards, Australia 03-9793-3663 Fax: 03-9791-1559 info@southporteng.com.au

Company	Description	Point of Contact
Trans-Lite, Inc.	Trans-Lite, Inc. was founded in 1959, taking over the lighting and air distributor division of the Safety Car Heating and Lighting Company. Our product line includes standard products and products custom engineered to customer specifications. Our product selection includes Interior Lighting, Exterior Lighting, Locomotive Lighting, Destination Signs and Communication Systems. Trans-Lite has concentrated its efforts on the lighting and destination sign systems of transit vehicles and locomotives. We can provide anything from roller curtain signs to full graphic LCD, LED and Vacuum Fluorescent sign systems with computer and advanced train control interfaces. The backbone of our systems is LONWORKS, a communications protocol that is becoming better known in the transit industry every day. All of our inter sign communications are based upon the Neuron chip, a processor which handles the sign control and communications functions. We have found the communications to be extremely reliable and the micro controller very flexible. This has been a great benefit to us especially in the noisy (electrically) train environment and where customer's specifications can change for every project. We have required shielded twisted pair wiring on all new contracts, however, for retrofit and other special circumstances there are other choices. http://www.trans-liteinc.com/index.htm (Retrieved on July 11, 2001)	Joe McClurken, Sign Prod. 120 Wampus La. Milford, Ct. 06460 203 878-8567 Fax: 203 877-2630 jmcclurken@trans-liteinc.com
Digital Optics Inc	Digital Optics, Inc. produces an extensive range of highly visible destination signs for the transportation industry. We have been manufacturing destination signs since 1987. These signs can be found in school buses and transit buses throughout the United States and Canada. http://www.digopt.com/index.htm (Retrieved on 7-11-01)	William Costa CEO 7421 Railroad Street, Gilroy CA 95020 1-800-211-3434 BCosta@digopt.com
Transign	Transign Inc., established in 1959, a division of Trans-Industries, is the leading manufacturer of original equipment destination sign mechanisms and printed curtains in North America. Transign products are standard equipment on all North American transit buses using mechanical or scroll type destination signs. We offer a complete line of front, side and rear destination signs as well as stop requested signs and run number boxes. http://www.transindustries.com/tsign_CP.htm (Retrieved on August 3, 2001)	3777 Airport Road, Waterford Michigan 48329 248-623-6400 Fax: 248-623-2930 Transign@aol.com

Company	Description	Point of Contact
Vultron, Inc.	Vultron, Inc. was established in 1966 to provide electronic products to the transportation industry. The initial product line of reflective disk changeable message signs utilized digi-dot technology and were installed as destination signs in transit buses. Through on-going product development to meet ADA (Americans with Disabilities Act) standards, Vultron destination signs continue to have a strong presence in the market and are in use in over 20,000 transit vehicles worldwide today. Vultron became a wholly owned subsidiary of Trans Industries, Inc. in 1970, combining technical know-how and resources for continued growth in the electronic display arena. Customer demand for variable message displays in other transportation related applications allowed Vultron to penetrate many new markets. Those markets include the airport, commuter rail, and highway information systems markets. In addition, our signs have many commercial applications, such as sports arenas, theaters and schools. In-house capabilities include sheet metal fabrication, environmental and optical testing, and software development for full system integration. http://www.vultron.com/ (Retrieved on July 11, 2001)	Paul Kiley City Park Industrial Estate, Unit 2, Gelderd Road Leeds LS12 6DR England 44- 113-263-323 Fax: 44- 113-279-4127
Visual Communication Network Telecite Inc	Visual Communication Network (VCN) is a robust and comprehensive wide area network based passenger information system capable of fulfilling the information display needs of any mode of public mass transportation. VCN offers the power of ultra flexible applications - from monochrome text-only applications to fully animated multimedia graphics using LED, LCD and Plasma display technologies, wireless data communication via high speed multi-point and wide area networks, and an open architecture that brings Internet media to your passengers. http://www.telecite.com/en/products/products_en.htm (Retrieved on August 3, 2001)	296 Avenue D., Suite #20 Williston, Vermont 05495 Phone: (514) 333-0888 Fax: (514) 333-0496 Email : sales@telecite.com
Infocite Group Inc.	Manufacturers LED signs, 100% solid-state Variable Message Sign containing clusters of amber LEDs employing AlInGaP technology (Aluminum Indium Gallium Phosphide).	4050 Charleroi Montreal, Quebec H1H 1S6 (514) 322-1113 Fax: (514) 326-4636

Company	Description	Point of Contact
HiTech Electronic Sign Company	We manufacture LED signs since 1984 and have over 15,000 installations worldwide. Hi*Tech Products & Services: Indoor LED Signs: Accelerator - Single color, indoor or outdoor LED sign. Communicator - Single color or multicolor LED sign. Photo*Comm - New! Indoor Multicolor - 1,024 colors. Gas Plasma - Full-color indoor video screen. 8 color Sun*Blazer - New! Blue, green, red, amber, magenta, cyan, white & black. Outdoor LED Signs: Sun*Blazer - Single, Multi and Full Color LED Displays. 8 color Sun*Blazer - New! Bright and colorful LED sign. Photo*Blazer - New! Alternative to Video Displays for Advertising. LED VDO - Full Color LED Video Displays for advertising and special events. ChannelLights - New! Affordable alternative to NEON. Channel Letters & Logos - New! Structure populated with individual led pixels. Time & Temp - Single color, time & temperature LED display. Display Structure - Single color Hi*Tech LED Display. Services: Animations - Custom graphics, logos & animations. Options & Accessories - Computer options for LED displays. Software - Software to run Hi*Tech LED Diplays. http://www.hitechled.com/contact.htm (Retrieved August 3, 2001)	13900 US HWY 19 N, Clearwater, Fl 33764 sales@hitechled.com
Solari di Udine	Regarding our signs, we have already experienced the request to be ADA compliant; in particular, we are supplier of the Long Island Rail Road for the Information Display System, including the track signs, that must comply with such regulations.	Marco Olmi Area Manager Solari di Udine SpA tel. +39.0432.497262 fax +39.0432.480160 e-mail: molmi@solari.it
Blue Bird	Whether it's tour & charter, commuter, shuttle, transit, or specialty transportation you seek, Blue Bird has the commercial vehicle to fit your needs. Every coach in our diverse line features a rugged steel chassis and high-quality steel body construction, and all have passed the rigorous 350,000 mile, ten-year simulated life testing at the Altoona Federal testing facility. http://www.blue-bird.com/ (Retrieved on July 18, 2001)	Blue Bird Corporation 402 Blue Bird Blvd. PO Box 937 Fort Valley, GA 31030 info@blue-bird.com
Collins Bus Corporation	For 30 years, we've concentrated our efforts on one product line. It has made us the small school bus company. And our customers benefit from those years of focused development with vehicles that are the industry's safest, most reliable, and economical solutions to their tranportation needs. http://www.collinsbus.com/home.html (Retrieved on August 3, 2001)	Collins Bus Corporation P.O. Box 2946 Hutchinson, KS 67504-2946 (800) 533-1850 info@collinsbus.com

Company	Description	Point of Contact
Complete Coach Works	Complete Coach Works is experienced and qualified to bid and accomplish any retrofit, repair, or modification involving transit buses, highway coaches, or support vehicles. Complete Coach Works has performed every type of retro-enhancement from air-conditioning to complete bus remanufacturing. Complete Coach Works has a full team of experts with mechanical, electrical, structural, and body repair experience. Our mechanics receive extensive training and education on buses, demand response and private passenger vehicles. http://www.completecoach.com/ (Retrieved on July 18, 2001)	Dale E. Carson, President Riverside, CA (909) 684-9585 Fax: (909) 684-2088 dale@completecoach.com
Dennis Bus & Coach	Dennis Bus leads the market with innovative economical low floor products that provide easy access for all, while Dennis Coach are capturing increasing market share with the uniquely fuel efficient Javelin, providing more for you and your passengers. http://www.dennisbus.com/ (Retrieved on August 3, 2001)	Dennis Way, Guildford, Surrey GU1 1AF +44 (0) 1483 571271 Fax:+44 (0) 1483 301697 sales@dennisbus.com
ElDorado National	Currently Thor has twelve subsidiaries in two different industries. They are the second largest recreational vehicle (RV) manufacturer and the largest commercial bus manufacturer in North America. With three manufacturing locations, current annual production averages approximately 2,600 vehicles. Consisting of 10 different models, our products range from 20' to 37' in length with a capacity range of 10 to 37 passengers. http://www.enconline.com/ (Retrieved on July 18, 2001)	13900 Sycamore Way Chino, CA 91710 304 Ave. B Salina, KS 67401 (800)362-1287 or (800)850-1287 Fax: (909)591-5285 or (785)827-0965
Electric Bus - Daktari Engineering	Electric Transit is the trading name owned by DAKTARI ENGINEERING PTY LTD. DAKTARI ENGINEERING PTY LTD is a technologically advanced company that has embarked on an ambitious Electric Vehicle manufacturing program. The Company has always been at the forefront of technical innovations and has recognized the requirements for a range of continuously operating transport / commercial/ industrial vehicles. http://members.ozemail.com.au/~daktari/index.htm (Retrieved on July 18, 2001)	daktari@ozemail.com.au

Company	Description	Point of Contact
Girardin	Since 1966, Girardin has specialized in designing, manufacturing, and marketing a wide variety of sophisticated small school buses and commercial buses with the exceptional service and reliability that our customers have come to expect. With our background being in the school bus industry, safety and quality are a priority. Our unitized steel roof bow construction acts as a safety cage, with all joints precision welded and coated for exceptional durability. Aluminium side and roof skins, along with heavy gauge steel side impact barriers also enhance occupant safety. The quality of our products is a direct reflection of our experienced personnel, state of the art twin assembly line manufacturing facility, and premium quality materials. In a relentless pursuit of perfection, we are constantly improving our products and services. http://www.girardin.com/main.htm (Retrieved from August 3, 2001)	Transcanada Highway Drummondville (Quebec) Canada, J2B 6V4 (819) 477-8222 Fax: (819) 475-9633 minibussales@girardin.com
Goshen coach	Goshen Coach is a quality manufacturer of price-conscious small to medium-sized transit buses. Whether you need to carry the church's octet, or a 37 member football team, we will custom design a floor plan to provide your passengers with the utmost in comfort and safety. We use the largest windows in the industry for a picturesque view of the passing scenery. All buses are insulated so all passengers can enjoy maximum comfort. Goshen Coach specializes in designing floor plans to accommodate the physically challenged passenger. http://www.goshencoach.com/ (Retrieved on July 18, 2001)	1110 D.I. Drive Elkhart, IN 46514 (219) 264-7511 Fax: (219) 266-5866 engineer@goshencoach.com
International	With nearly 1,000 dealer locations in North America, International is committed to delivering the most comprehensive, customer driven support packages. http://www.navistar.com/school_bus/default.asp (Retrieved on July 18,2001)	International Truck and Engine Corporation 4201 Winfield RD. P.O. Box 1488 Warrenville, IL 60555 (630)753-5700
MCI	MCI specializes in the motor coach industry. We design, build, sell, service, and finance MOTOR COACHES. We can even put you in touch with someone to customize your conversion shell! And if that isn't enough, we also sell parts to keep all your coaches running smoothly (even if they're not MCI or Dina!) We are your one-stop shopping center for motor coaches. Because in today's business world, it's the relationship that makes the difference! http://www.mcicoach.com/ (Retrieved on July 18, 2001)	Tom Sorrells, Chief Operating Officer 1700 East Golf Road Schaumburg, IL 60173 USA (800) RIDEMCI (743-3624) Fax: (847) 285-2013 marketing@mcicoach.net

Company	Description	Point of Contact
Mid bus	Mid Bus is a U.S. manufacturer of Type A-I & A-II school buses, from 10 to 48 passengers. Wide selection. Sales and service. We are a subsidiary of Collins Industries, the leader in specialty vehicles and emergency vehicle manufacturing. Featuring the Mid Bus Guide Dual Wheel (4, 5 and 6 row seating arrangements with seating capacities from 10 to 31 passengers), the Mid Bus Guide Single Wheel (4 and 5 rows [body sections] of seating which will allow for a maximum capacity of 20 passengers), the Mid Bus School Coach (comfortable seating for 10 to 48 passengers), and the Mid Bus Single Wheel Activity Bus (available in 4 and 5 rows [body sections] of seating, with floor plans for 14, 16 or 20 passengers). http://www.midbus.com/ (Retrieved on July 18, 2001)	Mid Bus 505 East Jefferson Street Bluffton, OH 45817 (877) 358-6055 Fax: (419) 358-2400 sbsales@midbus.com
National Refurbishing	National Refurbishing Incorporated is a division of the Tokmakjian Group, a multi-faceted corporation involved in all facets of the transit and motorcoach industry serving the Canadian/American and global markets. http://www.natrefurb.com/ (Retrieved on July 18, 2001)	811 Steeles Ave East, Milton Ontario L9T-5B9 1-905- 878-3909 Fax: 1-905- 878-9231 nri@mail.interlog.com
Neoplan	NEOPLAN USA is pleased to present this multimedia presentation on our company. NEOPLAN USA has the largest product line ever offered by any U.S. bus manufacturer. It includes all sizes of standard and low floor transit buses, articulated units and suburban models, as well as a full line of luxury coaches... including doubledeckers. We are proud to be a 100% American owned company. Each and every bus in our product line is entirely built in the United States. http://www.neoplanusa.com/index.html (Retrieved on July 18, 2001)	700 Gottlob Auwaerter Drive Lamar, CO 81052 (719) 336-3256 ext: 308 Fax: (719) 336-4201 sales@neoplanusa.com
New Flyer	New Flyer is the largest transit bus manufacturer in North America. We have a wide range of models to choose from. New Flyer's innovative business style has been evident since our beginnings in 1930 as Western Auto and truck Body Works Limited with the production of truck and bus bodies.	Paul Smith, V.P. Sales & Marketing 711 Kernaghan Avenue Winnipeg,Manitoba CANADA, R2C 3T4 (204) 224-1251 Fax:(204) 224-4214 buses@newflyer.com

Company	Description	Point of Contact
Nova Bus	Nova BUS Corporation's mission is to excel in the design, production and marketing of urban transit buses and related products and services in North America. To succeed, it must understand and meet the short-, medium-, and long-term expectations of its customers. http://www.novabuses.com/index.htm (Retrieved on July 18, 2001)	1301 Hillside Ave. Schenectady, NY 12309 http://www.novabuses.com/english/contact/plant.htm (July 18, 2001..other locations) (518) 382-1692 Fax: (518) 372-8416 marketing@novabuses.com
Orion Bus	Orion bus Industries manufactures custom-crafted, heavy-duty transit buses that meet the divers and demanding needs of the transit industry in North America. Orion products include tough, reliable urban transit buses, versatile low-floor buses, and efficient, economical shuttle buses. Orion offers a leader in enviornmentally friendly alternative fuel technology. More than 230 North American cities and 20 European centers deploy transit vehicles from Orion Bus Industries. http://www.freightliner.com/products/orion.html (Retrived on August 3, 2001)	Olga Kupycz Orion Bus Industries 350 Hazelhurst Road Mississauga, Ontario, Canada L5J 4T8 Phone: (905) 403-7286 Toll Free (800) 220-9934 x7286 Fax: (905) 403-8800
Transbus International (Plaxton, Alexander, and Dennis)	Transbus International is Britain's leading manufacturer of next generation buses and coaches. It brings together three famous names in bus building- Alexander, Plaxton, and Dennis. It is Europe's largest bus and coach bodybuilder. TransBus is a global pioneer in low floor, easy access vehicles based on lightweight aluminum structures and is also a leader in technologies such as coach ventilation and glazing. It dominates the European midi bus sctor and is the world's leading producer of double deck buses. TransBus offers a full range of chassia dn bodywork options; fully integrated buses and coaches; and kits for assembly in facilities around the world. http://www.transbusint.com/intro.htm (Retrieved on July 18, 2001)	Eastfield Scarborough YO11 3BY 01723 581500 Fax: 01723 581479 sales@plaxton.com
Prevost	Much has changed since that day in 1924, when cabinet-maker Eugene Prevost was commissioned to create his first wooden coach body and mount it on a brand new REO truck chassis. Nearly three-quarters of a century later, PREVOST CAR, now jointly owned by Volvo Bus Corporation and Britain's Henly's Group PLC, stands as one of the North American manufacturers of premium intercity touring coaches and the undisputed world-leader in the production of coach shells for high-end motorhome and specialty conversion. http://www.prevostcar.com/eng/default.htm (Retrieved on August 3, 2001)	2580 Northwest Parkway Elgin, Illinois 60123 http://www.prevostcar.com/eng/default.htm (other locations, Retrieved on July 18, 2001) (800) 799-9938 Fax: (847) 844-7682

Company	Description	Point of Contact
Setra	Accommodating up to 51 or 59 passengers, the Setra S 215 and S217 HDH represent the finest motorcoaches on the road today...engineered in Germany for the utmost in reliability, with an American drive train for ease of maintenance. In our ongoing dedication to innovation, advanced technology is standard equipment on today's Setra coaches — from ABS, traction control and independent suspension for a safer, smoother ride...to the patented Setra mirror system that offers a superior view of the front and sides of the coach. http://www.setrausa.com/ (Retrieved on July 18, 2001)	6012B High Point Rd. Greensboro, NC 27407 336-878-5400 Fax: 336-878-5410 sentrausa@sentrausa.com
Thomas Built Buses	Since the 1930s, Thomas Built Buses has provided a variety of specialized vehicles to meet the needs of commercial and governmental customers. Among the specialty vehicles currently available: Thomas Custom Show Buses, Thomas Correctional Transport Vehicle, Thomas Poultry Transport Vehicle, Thomas Police/Fire/Rescue Command Center, Thomas Mobile Medical Center. http://www.thomasbus.com/ (Retrieved on July 18, 2001)	Thomas Built Buses, Inc. 1408 Courtesy Road High Point, NC 27260 336-889-4871 Fax: 336-889-2589 allan.haggai@thomasbus.com
Evobus	Tradition and progress. International presence and close co-operation with local customers. The best know-how and the best service: Travel safely and comfortably with Mercedes-Benz and Setra. We offer comprehensive services covering every aspect of buses and coaches. Our customers are the focus of everything we do. EvoBus – We are moving people. http://www.evobus.com/evobus_e (Retrieved on August 3, 2001)	EvoBus GmbH Vaihinger Strasse 131 70567 Stuttgart
Champion	Part of Thor Industries, which is the largest mid-size bus manufacturer in North America. Champion has seven different types of buses, all ranging in different size. http://www.thorindustries.com/scripts/ThorFramework.exe/ModelsView?Manufacturer=Champion+Bus (Retrieved on July 18, 2001)	331 Graham Road PO Box 158 Imlay City, MI 48444 800-776-4943 Fax: 810-724-1844 cbiups@tir.com
National Bus Sales & Leasing, Inc.	National Bus Sales stocks a wide variety of commercial buses from manufacturers such as Goshen Coach, Blue Bird Body Company, and Krystal Koach. These vehicles are custom built to suit the needs of various churches, retirement facilities, transit authorities, universities, rental car companies, parking lot shuttles, hotels, hospitals and many more. http://www.nationalbussales.com/commercial.htm#InfoRequest_Commercial (Retrieved on July 11, 2001)	P.O. Box 6549, Marietta, GA 30065-0549 800-282-7981 Fax: (770) 422-9007

Company	Description	Point of Contact
North American Bus Insustries Inc.	We are committed designers and manufacturers of quality buses, first and foremost meeting the requirements of operators and their patrons. We are dedicated to assisting our employees in continuously improving themselves. We are long-term, stable and competitive partners in our business relationships, including those with our customers and our suppliers. We place a high priority upon excellent customer service environmental responsibility and upon developing the most technically innovative solutions to assure our long-term success. http://www.nabiusa.com/ (Retrieved on August 3, 2001)	North American Bus Industries, Inc. Sales & Marketing Office 20350 Ventura Blvd., Suite 205 Woodland Hills, CA 91364 USA Tel: (818) 610-0330 Fax: (818) 610-0335 bussales@nabiusa.com