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16. Abstract


Modern fully retroreflective sign legends can create a blooming effect that reduces legibility. This research project evaluated three alphabets to determine if performance of a white high intensity legend on a green high intensity background could be improved by reducing the blooming effect. The three alphabets were: Series E(Modified), Clearview™, and British Transport Medium. Overhead and ground-mounted sign positions were evaluated in both daytime and nighttime conditions. There was no sign illumination for the nighttime conditions other than vehicle headlights. Both legibility (unknown word) and recognition (known word) distances were measured.

A total of 54 subjects participated in both daytime and nighttime trials. There was significant variability in the results of the various experimental conditions. In general, the results indicated that Clearview™ was slightly more legible than Series E(Modified) in the overhead position in both daytime and nighttime conditions. The extent of improvement was generally in the range of two to eight percent over Series E(Modified). The greatest improvement was achieved for older drivers. Clearview™ ground-mounted signs were less legible than Series E(Modified) in daytime conditions. In nighttime conditions, the ground-mounted Clearview™ did not demonstrate a consistently better performance than Series E(Modified). A greater degree of improvement was realized in the recognition of Clearview™ in the overhead position for both day and night conditions. British Transport Medium was generally less legible than Series E(Modified).


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# LEGIBILITY COMPARISON OF THREE FREEWAY GUIDE SIGN ALPHABETS

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of Legend Used on Large Freeway Guide Signs

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The successful completion of this research project was achieved only because of a significant degree of assistance from a large number of individuals.

At the initiation of this project, the Texas Department of Transportation (TxDOT) formed a panel of Project Advisors to provide guidance in the development and conduct of the research activities and review project deliverables. The Project Advisors were able to provide the researchers with valuable insights related to the manner in which guide signs are used on Texas freeways. They also served as a valuable resource for obtaining information related to the research activities. The research team met with the Project Advisors on several occasions, and the assistance and comments received from them were instrumental in conducting the project activities. The researchers would like to acknowledge the following Project Advisors for their time, efforts, and contributions:

**Project Director**

- Greg Brinkmeyer, Traffic Operations Division, Texas Department of Transportation

**Project Advisors**

- Art Barrow, Materials and Test Division, Texas Department of Transportation
- Robert Cates, Wichita Falls District, Texas Department of Transportation
- Pete Martinez, Tyler District, Texas Department of Transportation
- Dian Nauman, Traffic Operations Division, Texas Department of Transportation
- Lewis Rhodes, Traffic Operations Division, Texas Department of Transportation
- Dee Smith, San Antonio District, Texas Department of Transportation

In particular, the researchers would like to recognize the contributions of Dee Smith and the staff of the San Antonio sign shop. They provided the large sign panels used as the background for the words, cut the letters for two of the alphabets evaluated in the research, and provided extra sheeting for experiment development. Travis Brundick of the Brownwood sign shop also assisted the project by cutting the letters for the third alphabet.

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# IMPLEMENTATION RECOMMENDATIONS

Freeway guide signs are a vital element of the freeway system because they provide drivers with directional information and indicate where to exit the freeway. The basic design parameters for freeway guide signs were established in the 1950s. Although there have been numerous advancements in sign materials and sign fabrication procedures since then, there have not been any changes in the alphabet used in freeway signs. The use of a 40-year old alphabet design with modern materials can create a halo, or blooming, effect for some drivers which can have a negative impact on legibility. This research project evaluated whether legibility and recognition of freeway signs could be improved by using an alternative alphabet that reduces the halo effect.

The research results indicate that some degree of improvement can be achieved by using Clearview™ instead of Series E(Modified) in overhead signs, but the extent of the improvement is in the range of 2 to 8 percent, and the improvement is not statistically significant. There is little or no benefit to using Clearview™ in ground-mounted signs. There does not appear to be any widespread benefit to using British Transport Medium over Series E(Modified).

Based on the findings of the evaluations described in this report, the researchers offer the following recommendations regarding the use of legends in freeway guide signs:

1. Clearview™ and British Transport should not be implemented on a widespread basis.
2. Because of the small, but consistent, improvement over Series E(Modified) in overhead signs, limited field experiments of Clearview™ are appropriate.
   a. Field experiments should be limited to overhead signs only.
   b. Permission to experiment should be requested from the Federal Highway Administration. The request should indicate that the Clearview™ legend will remain on the signs throughout their service life.
   c. Experimental use of Clearview™ should be limited to specific locations.
   d. Factors to be considered in evaluating the experimental use of Clearview™ should be the visual appearance of the signs and input (positive or negative) from the driving public.
   e. If the results of the evaluations are positive, then Clearview™ may be implemented statewide after letter spacing, stroke width, and material effects issues are investigated (see recommendations for future research).
3. If implemented on a statewide basis, use of Clearview™ should include the following conditions:
   a. Clearview™ should be an option for overhead freeway signs legends only. It should not eliminate the ability to use Series E(Modified).
   b. If used on an overhead freeway, white on green sign panels using the Clearview™ alphabet should not be mixed on the same overhead sign bridge as white on green sign panels using Series E(Modified).
4. Consideration should be given to using different design parameters for overhead and ground-mounted signs to account for the different performance characteristics of each. Series E(Modified) should continue to be used for all ground-mounted signs.

5. Clearview™ is a developing alphabet. This research represents the second evaluation of the alphabet. As such, there are several aspects of the Clearview™ alphabet that have not been evaluated or need refinement. These include:
   a. Uppercase letters - The two evaluations of Clearview™ used very limited samples of uppercase letters. As such, many of the uppercase Clearview™ letters have not been observed in full-scale real-world signing applications.
   b. Numbers - There have not been any evaluations of the numbers in the Clearview™ alphabet.
   c. Letter spacing - The letter spacing for Clearview™ has not been evaluated in a scientific manner.
   d. Stroke width - The difference in performance between overhead and ground-mounted signs indicate the need to evaluate other height-to-stroke width ratios of Clearview™ to determine the optimal balance between the two sign positions or the individual stroke widths that should be used with each type of sign.
   e. Colors - To date, the only evaluations of Clearview™ have been for white letters on a green background. The effectiveness of white letters on other color backgrounds should be assessed before using these color combinations.
   f. Material effects - As the survey of state practices found, many different combinations of sign materials are used on freeway guide signs. The performance of sign legends as a function of materials should be evaluated so that the selection of an alphabet will reflect the performance characteristics of the materials it will be fabricated from.
   g. The Clearview™ alphabet that will be available for fabricating signs is slightly different from the Clearview™ evaluated in this research. Some limited comparisons of the old and new Clearview™ should be conducted to ensure that the refinements have not reduced the performance of the alphabet.

# SUMMARY

In the 1950s, national signing standards introduced the use of white on green guide signs for freeways. These signs used a lowercase alphabet (Series E(Modified)) for destination names, which was the first use of lowercase letters on U.S. highway signs. This lowercase alphabet has remained the same since it was introduced in the 1950s. The only change has been in the manner in which the letters are fabricated. The original generation of freeway sign legend used button copy letters, in which retroreflector buttons were placed in an aluminum letter. Modern legends are cut-out letters, in which the letters are cut directly from retroreflective sheeting. When these fully retroreflective letters are combined with the use of brighter sheeting materials, a phenomenon known as blooming (also known as halation, overglow, or irradiation) can occur for some drivers. Individual features of some letters are washed out, causing a reduction in their legibility.

This research project was conducted to determine if the legibility of freeway guide signs could be increased by optimizing the performance of specific sign design parameters. The focus of the research was the comparison of three lowercase alphabets: Series E(Modified), Clearview™, and British Transport Medium. Series E(Modified) is the current U.S. standard lowercase alphabet and has been for over 40 years. Clearview™ is a new alphabet that was recently developed by Meeker & Associates and the Pennsylvania Transportation Institute to overcome the blooming effects of high brightness materials in guide signs. Transport Medium is the alphabet used in Britain for overhead guide signs with positive contrast (white legend on a dark background). All three alphabets were fully retroreflective letters fabricated from white high intensity sheeting. The sign background was fabricated from green high intensity sheeting.

In addition to the three alphabets, researchers evaluated two other independent variables, including sign position (overhead and ground-mounted) and lighting condition (day and night with no sign illumination). Both legibility (unknown word) and recognition (known word) distances were measured.

In the experimental procedure, test subjects in the test vehicle would start at a distance where the signs were not legible. There were three words on the sign panel, with all three words in the same alphabet. The experimenter would indicate one word that test subjects would identify the position of on the sign (recognition task). They were to read the other two words (legibility task) and identify their position on the sign. A total of 54 subjects participated in both daytime and nighttime trials. There were 7 young drivers (<35 years old), 18 young-old drivers (55-64 years old), and 29 old-old drivers (65+ years old).

There was significant variability in the results of the various experimental conditions. In general, the results indicated that Clearview™ was slightly more legible than Series E(Modified) in the overhead position in both daytime and nighttime conditions. The extent of improvement was generally in the range of two to eight percent over Series E(Modified). This improvement was not statistically significant. The greatest improvement was achieved for older drivers. Clearview™ ground-mounted signs were less legible than Series E(Modified) in daytime

conditions. In nighttime conditions, the ground-mounted Clearview™ did not demonstrate a consistently better performance than Series E(Modified). A greater degree of improvement was realized in the recognition of Clearview™ in the overhead position for both day and night conditions. British Transport Medium was generally less legible than Series E(Modified).

The results of the legibility evaluations found that, for older drivers, the legibility index for Series E(Modified) is significantly lower than the 0.66 m/mm (55 ft/in) value traditionally used for sign design. The 85th percentile daytime legibility index for young-old drivers was about 0.48 m/mm (40 ft/in) and, for old-old drivers, about 0.36 m/mm (30 ft/in). At night, the 85th percentile legibility indexes for the older driver groups were about 60-70 percent of the daytime legibility. Even the mean legibility indices of the older driver groups were lower than the traditional values.

The research results indicate the Clearview™ should not be implemented on a widespread basis. However, the presence of a small, but consistent improvement for overhead signs indicates that there may be some value in conducting limited field experiments of Clearview™ for overhead signs. Permission to experiment should be obtained from the Federal Highway Administration and the experimentation should be limited to a small number of sites. If the experimentation is successful and future research indicates a benefit to using Clearview™, then Clearview™ may be implemented on a statewide basis on overhead guide signs. Clearview™ should be an alternate to Series E(Modified) and should not replace Series E(Modified). All signs on a single overhead sign structure should use the same alphabet (either Series E(Modified) or Clearview™). Ground-mounted signs should continue to use only the Series E(Modified) alphabet. Finally, there are many aspects of Clearview™ which have not yet been evaluated. Additional research should be conducted on these issues before Clearview™ is widely implemented.

## CHAPTER 1
# INTRODUCTION

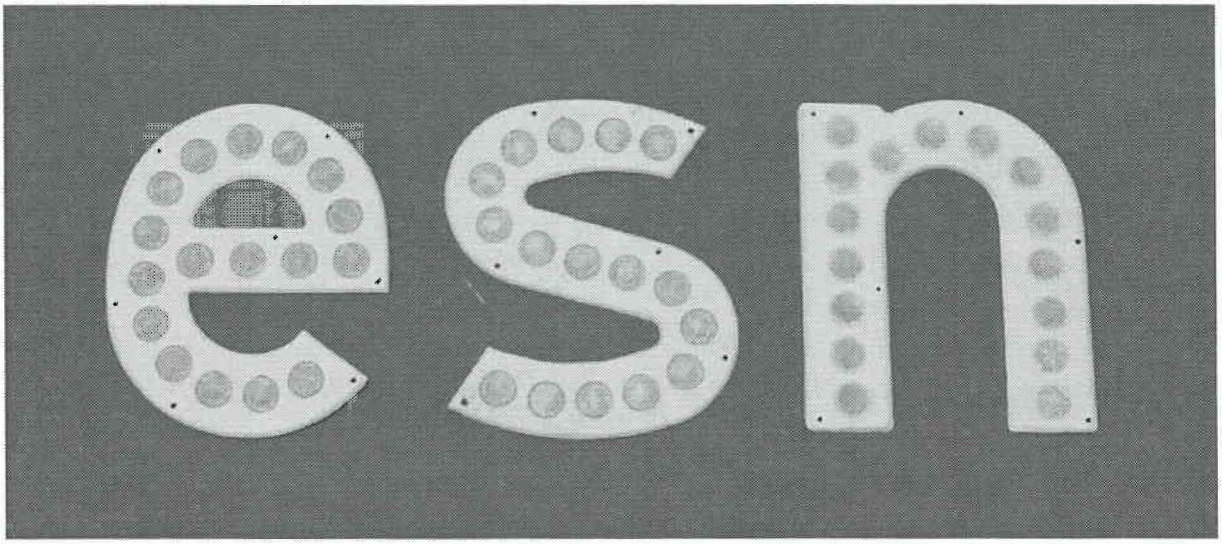
Freeways, or controlled access highways, are a vital part of the surface transportation system. Although urban freeways make up only 2.7 percent of the national urban highway mileage, they carry 33.1 percent of vehicle-miles of urban travel (1). Because they are controlled access facilities, virtually all travel on freeways is at 90-115 km/h (55-70 mph). Therefore, the guide signing on these facilities requires different design characteristics than guide signing on conventional highways. Freeway guide signing has several characteristics that distinguish it from guide signing for conventional highways. They include:

- larger signs and larger letters,
- lowercase alphabet (also referred to as a font or typeface) for destinations,
- both overhead and ground-mounted signs,
- overhead signs may be illuminated,
- information may be spread over multiple signs (redundancy),
- destination names are emphasized ("control city" concept), and
- the road system has high speeds and controlled access.

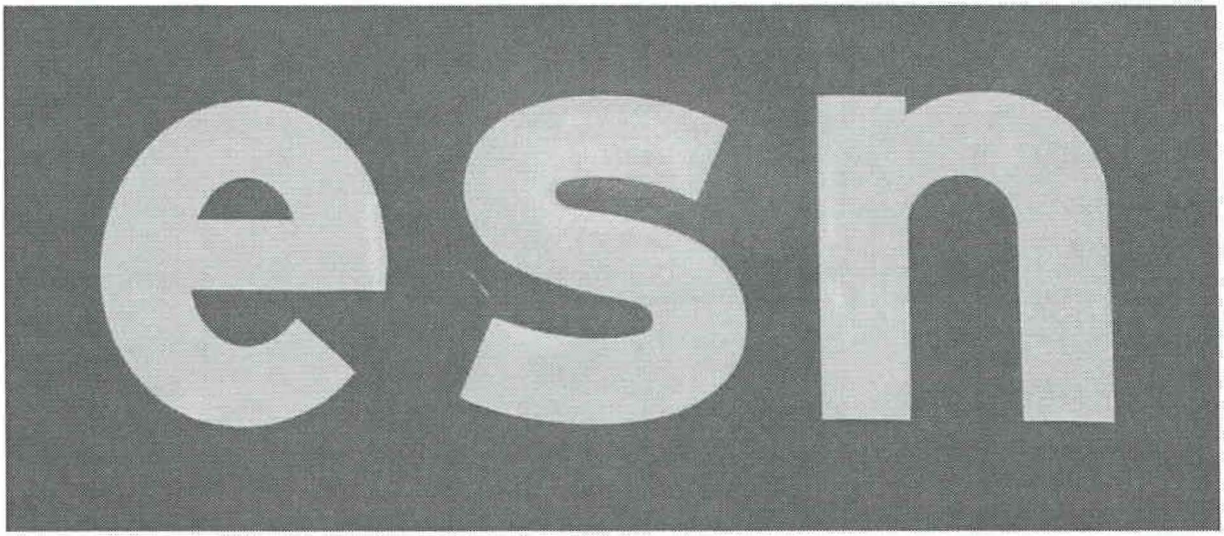
Freeway signing was first described on a national basis in the 1958 American Association of State Highway Officials (AASHO) *Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways* (2). This document introduced the use of white on green signs and the lowercase alphabet for use in freeway guide signs. The green background color was selected on the basis of sign tests conducted by the Bureau of Public Roads (BPR, predecessor to the Federal Highway Administration, FHWA) and documented in an unpublished report (3). The lowercase alphabet that was introduced in this document was the Series E(Modified) alphabet, although it was not referred to by this name until later. This alphabet was developed by the California Division of Highways and evaluated in a California-sponsored research study (4).

The early freeway signs used removable, or button, copy letters on a non-retroreflectorized background with independent sign illumination. Button copy letters are made from aluminum and have prismatic retroreflector buttons arranged on the centerline of the stroke. Figure 1a is a photo of button copy letters. Button copy letters were used initially because they provided the most cost-effective method of fabricating signs. Today, advances in the sign fabrication process have permitted freeway letters to be cut directly from retroreflective sheeting, resulting in a fully-retroreflectorized letter, as shown in Figure 1b. Figure 2 compares the retroreflective performance characteristics of button copy and fully retroreflectorized cut-out letters for a 400 mm (16 in) uppercase "R." As can be seen from Figure 2, although the two letters have the same overall letter area, the cut-out letter has a much larger retroreflective area. This is due to the fact that the entire area of the cut-out letter is retroreflectorized, while only the reflector units in the button copy are retroreflective. Despite the fact that button copy and cut-out letters have different levels of retroreflective performance, the same general alphabet is used for both types. (It is worth noting that the button copy alphabet is not an exact representation of the Series

E(Modified) alphabet, as can be see by comparing the two “s” letters in Figure 1.) The larger retroreflective area of cut-out letters can create a blooming effect at night, in which elements of a letter tend to wash out, making the letter harder to read. This effect is also referred to as halation, overglow, or irradiation. Figure 3 illustrates this blooming effect. Blooming is a particular problem for light colored legends on a darker background (positive contrast signs) and for drivers with cataracts and other vision deficiencies. In this situation, the light returned by the brighter and lighter legend tends to wash out the features of the individual letters, causing the letters to appear as a blur, thereby reducing legibility. The blooming effect can be compounded by the use of sheeting materials with higher levels of retroreflectivity. The blooming phenomena may indicate the need to redesign the freeway sign alphabet to accommodate modern sign fabrication processes and the brighter sign materials.

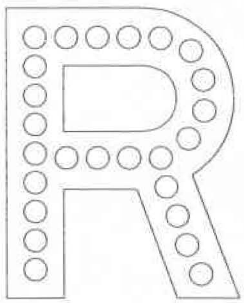



a. Button Copy




b. Cut-Out Legend

**Figure 1. Types of Letters**



**Button Copy Letter**

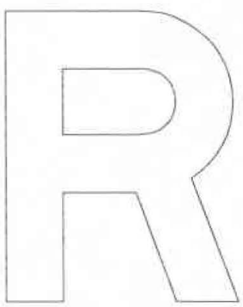
**Letter Height**
400 mm (16 in)

**Total Area of Letter**
0.087 m$^2$ (134 sq in)

**Means of Retroreflection**
25 reflector buttons

**Width of Retroreflective Stroke**
button diameter – 32 mm (1¼ in)

**Retroreflective Area**
0.02 m$^2$ (31 sq in)



**Cut-Out Letter**

**Letter Height**
400 mm (16 in)

**Total Area of Letter**
0.087 m$^2$ (134 sq in)

**Means of Retroreflection**
Sheeting

**Width of Retroreflective Stroke**
letter width – 3 mm (3⅛ in)

**Retroreflective Area**
0.087 m$^2$ (134 sq in)

**Figure 2. Comparison of Letter Types**

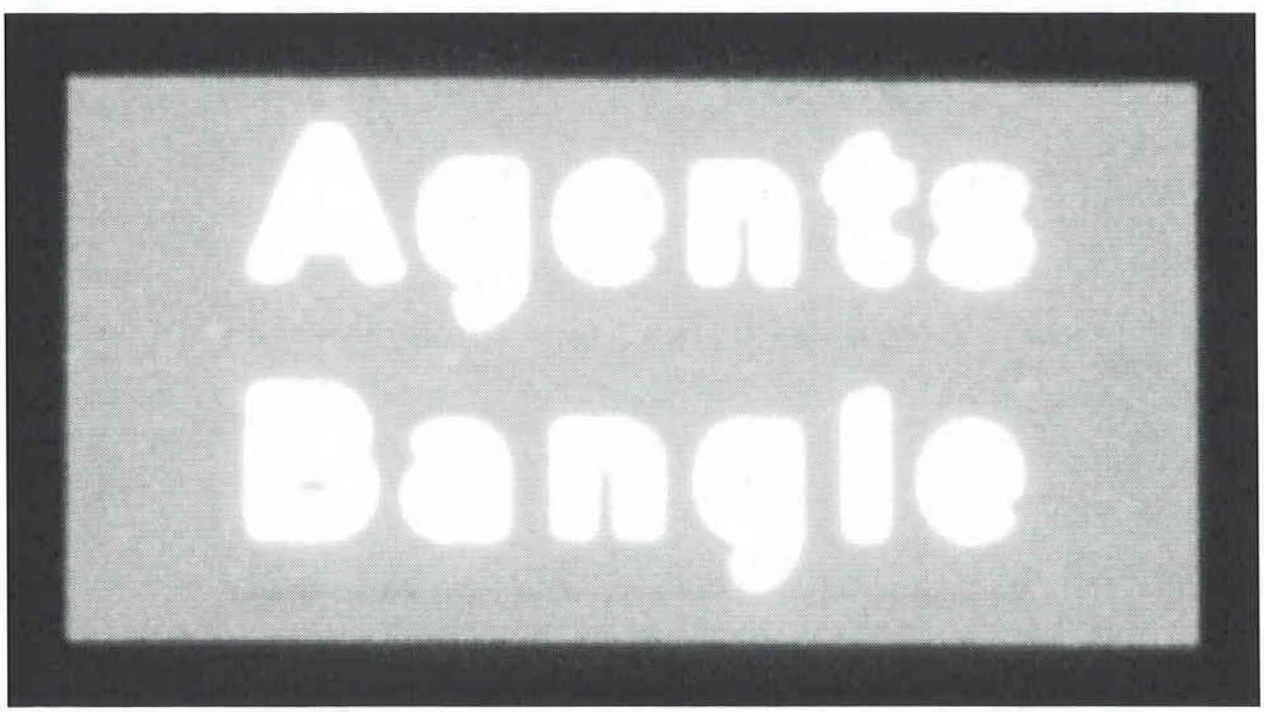



**Figure 3. Blooming Effect**

In addition to changes in the retroreflectivity of freeway letters, sign backgrounds have also evolved over time. The earliest freeway signs used a green non-retroreflective sign background. In daytime conditions, the green color was visible. However, at night the background appeared black to drivers unless the sign was illuminated, which was a common practice. Non-reflective background signs were eventually replaced by signs with engineering grade sheeting. These signs appeared green to the driver during both day and night conditions, with or without sign illumination. More recently, transportation agencies have begun using high intensity sheeting for the background with a fully retroreflective high intensity letter. Texas followed this trend, when in September 1993, the Texas Department of Transportation (TxDOT) specified in a memorandum to District Engineers that freeway guide signs would use high intensity cut-out letters on high intensity backgrounds. Combined with this change to a high intensity cut-out letter on a high intensity background, many state transportation agencies have reduced the use of sign illumination on overhead freeway signs made from the brighter sheeting materials (5). TxDOT is one of these agencies, as the September 1993 memorandum indicated that overhead sign lights are not required for the high intensity on high intensity signs except in areas where sign sight distance or geometric conditions warrant the use of sign lighting.

An obvious conclusion that can be drawn from the preceding brief description of the evolution of freeway signing materials is that, although materials and characteristics for freeway letters and backgrounds have changed dramatically over the last 40 years, the alphabet itself is the same today as the alphabet developed in the early 1950s. The alphabet has remained the same despite the fact that it is used with different materials than those for which it was developed. The deficiencies of the Series E(Modified) alphabet were identified almost 30 years ago in research sponsored by the BPR (6). This report indicated the need to improve the U.S. highway sign alphabets (including the lowercase alphabet) and provide better specifications for their use. More recently, research sponsored by the FHWA indicated that the nighttime legibility of a white high intensity legend on a green high intensity background could be improved by reducing the stroke width of the letters (7). The concept of improving legibility of high intensity freeway signs by reducing the stroke width of the letters was also confirmed by unpublished, in-house evaluations performed by TxDOT's Traffic Operations Division. However, none of these studies were comprehensive enough to evaluate all the factors associated with the legibility of large freeway guide signs. In addition to researchers, graphic designers have also been critical of the U.S. highway alphabets. In particular, one author stated that the U.S. alphabets "*have inherently ill-considered design characteristics which are contrary to normal or appropriate legibility standards. The letters and their display on road signs contradict many fundamental legibility concerns*" (8). Both this author and the 1968 BPR research indicated that the British Transport alphabets possessed more desirable characteristics than the U.S. alphabets.

## RESEARCH APPROACH

As a direct result of their in-house evaluation of high intensity sign legibility, TxDOT identified the need to conduct research to determine whether the legibility of freeway signs could be improved, with particular emphasis on the need to improve the Series E(Modified) lowercase alphabet. The research project was awarded to the Texas Transportation Institute (TTI) with the following goal and objectives:

- **Research Goal:**
  - Determine the most effective legend design elements that will optimize the legibility of large freeway guide signs, in both daytime and nighttime conditions.
- **Research Objectives:**
  - Identify available information on the legibility of large freeway guide signs.
  - Determine the most effective procedures for evaluating both the daytime and nighttime legibility of freeway guide signs.
  - Develop an experimental plan for evaluating legibility that accounts for the factors of greatest concern to TxDOT.
  - Measure the legibility of current freeway guide sign design standards for both overhead and ground-mounted signs.
  - Evaluate the impact of stroke width on the legibility of both overhead and ground-mounted freeway guide signs.
  - Evaluate the effects of new alphabet designs on the legibility of both overhead and ground-mounted freeway guide signs.
  - Evaluate the effect of increased letter spacing on the legibility of both overhead and ground-mounted freeway guide signs.
  - Evaluate the effect of illumination (vehicle or sign) on the legibility of both overhead and ground-mounted freeway guide signs.
  - Determine the differences in legibility for younger and older drivers.
  - Develop guidelines that will optimize both the daytime and nighttime legibility of overhead and ground-mounted freeway guide signs.

## RESEARCH ACTIVITIES

The research project conducted by TTI was a two-year effort that consisted of two basic phases. The first phase, which took about 16 months, consisted of information gathering and preparation for conducting the legibility evaluations. The second phase was the actual conduct of the legibility evaluations and the analysis of the results. The activities that took place during each phase are described below.

- **First Panel Meeting** - The initial meeting between the researchers and TxDOT Project Advisors took place on October 3, 1995, approximately one month after the project started. In this meeting, the group discussed:
  - the project objectives and the general plan for meeting the objectives,
  - the key findings from previous research,
  - TxDOT's concerns and experiences,
  - activities in which the researchers would require TxDOT assistance, and
  - issues and/or factors that needed to be addressed in the research, including type of alphabets, letter size, letter spacing, letter and background materials, sign illumination, and others.

  During the course of the meeting, the group made the following decisions regarding the development of an experimental plan:
  - The letters should be 400 mm (16 in) uppercase letters with appropriately sized lowercase letters.

- The legibility data collection should be conducted using U.S. units of measure.
- Series E(Modified) should be one of the alphabets evaluated and Clearview™ should be another.
- Sign materials should be high intensity legend on high intensity background. Only sheeting from a single manufacturer should be used throughout the experiment.
- Button copy letters should not be evaluated.
- Sign lighting should not be used.
- Evaluations should not consider the impacts of varied spacing between letters or lines of text.
- The driver sample should place a heavy emphasis on older drivers.

- **Literature Review** - The research team reviewed a wide body of previous research to assess the state-of-the-art in sign legibility and to identify experimental procedures that might have application to the TTI research. Chapter 2 describes the results of the literature review.
- **State Practices Survey** - One of the initial efforts of the project was a survey of state practices regarding freeway guide signs. Chapter 2 describes the survey and survey results.
- **Alphabet Selection** - The task of selecting two of the alphabets for evaluation was simple. The selection of the third alphabet required greater consideration. The alphabet selection process is described in Chapter 3.
- **Experimental Plan** - To maintain manageable control of the data collection and analysis effort, the researchers needed to develop an experimental plan that carefully balanced the project resources with the variables needing evaluation. The development of the experimental plan is described in Chapter 3.
- **Second Panel Meeting** - The second panel meeting was held on April 11, 1996. In this meeting, the researchers presented the experimental plan for conducting the evaluations.
- **Experiment Infrastructure** - The preparation of the experimental infrastructure was a time-consuming and complicated process. The various aspects of the infrastructure are described in Chapter 3.
- **Preliminary Clearview™ Investigation** - Because the Clearview™ development was still underway at the time of this research project, it was necessary to have a preliminary investigation of Clearview™ to establish certain experimental parameters for its use in the research. This investigation is described in Chapter 3.
- **Subject Recruitment** - Before beginning the data collection process, researchers had to recruit test subjects from the local area. A newspaper advertisement was used to recruit subjects, with an emphasis on older drivers. The recruiting process is described in Chapter 3 and Appendix C.
- **Data Collection** - The actual data collection effort began in January 1997 and was concluded in June 1997.
- **Data Analysis** - After the data collection was completed, the data were analyzed to assess the relative performance of the three alphabets selected for evaluation. Chapter 4 describes the results of the analysis.
- **Final Panel Meeting** - Following the data analysis, the researchers and TxDOT Project Advisors met on August 28, 1997, for the final panel meeting. In this meeting, the researchers presented the results of the evaluations, conducted daytime and nighttime demonstrations of the alphabets evaluated, and demonstrated the experimental procedure.

# CHAPTER 2
# BACKGROUND INFORMATION

Sign legend legibility has been the subject of numerous research studies since the early days of traffic signs. Before developing an experimental plan for evaluating freeway sign legibility, the researchers established past and current practices and reviewed the results of previous research.

## HIGHWAY SIGN ALPHABETS

Within the traffic engineering profession, the style of letters used in signs has been referred to as the alphabet. Other terms that are commonly used are font and typeface. The design of the alphabets used in highway signs is a critical element, as it has a major impact on the legibility of signs. The U.S. alphabets consist of six series of letters that have existed for over 40 years. The U.S. alphabets are also used in many other countries around the world. However, some countries have developed other alphabets, some of which accommodate the difference in performance between positive and negative contrast signs. More recently, researchers in the U.S. developed a new alphabet (Clearview™) designed to overcome some of the perceived deficiencies of the U.S. lowercase alphabet (9).

### U.S. Highway Alphabets

Both the federal and Texas *Manual on Uniform Traffic Control Devices* (MUTCD) (10, 11) indicate that all letters used in traffic signs shall use the alphabets approved by FHWA. There are six series of alphabets: B, C, D, E, E(Modified), and F. Series E(Modified) is the only alphabet with lowercase letters. The other five are capital letters only. The Series E(Modified) alphabet has the same width and height dimensions as the Series E alphabet, but the stroke width has been increased. The loop height of a lowercase letter in the Series E(Modified) alphabet is three-fourths the height of the uppercase letter. Table 1 summarizes the height/stroke width ratios for the six alphabets. These alphabets are contained in the *Standard Alphabets for Highway Signs* publication, which has both a U.S. (12) and a metric (13) unit version. The U.S. and metric unit alphabets are not proportionally the same. The metric alphabet was created by reducing the height of the U.S. alphabet by 1.6 percent, while keeping the letter widths, spacing, and stroke widths the same. Also, as mentioned in the previous chapter, the alphabet used with button copy letters is not an exact replication of the Series E(Modified) alphabet. There are also slight differences between the alphabets in the computer programs used to design and fabricate freeway signs. As a result of these factors, the concept of a standard Series E(Modified) alphabet is a myth. Figure 4 illustrates a few typical letters from each Series of the U.S. alphabets. Appendix B presents all the letters of the Series E(Modified) alphabet.

There is very little documentation on the origin and development of the U.S. highway alphabets. The original alphabet developed by AASHO in the 1920s for the first national signing manual (15) used a block letter alphabet. This type of alphabet had a squared-off appearance. It was used because it simplified the process of making signs from embossing dies. In 1945, the

U.S. Public Roads Administration (previously and later the BPR) issued the first *Standard Alphabets for Highway Signs* publication (16). The document contained Series A, B, C, D, E, and F alphabets. These alphabets were intended to replace the AASHO block letter alphabets developed 20 years earlier. The new alphabets used a rounded style which was considered to have "*a more pleasing appearance than the old [alphabet], and extensive tests have shown it to be considerably more legible*" (16). The legibility research is not identified or described in the publication. The 1945 alphabet publication was reprinted in 1961.

**Table 1. Summary of Alphabet Stroke Widths and Legibility Indices**

| Series | Height/Stroke Width Ratio | | Daylight Legibility Index | | Source of Legibility Index |
|---|---|---|---|---|---|
| | U.S. units | Metric units | ft/in | m/mm | |
| B | 8.00/1 | 8.00/1 | 33 | 0.40 | (14) |
| C | 7.11/1 | 7.02/1 | 42.5 | 0.51 | Average of Series B and D |
| D | 6.41/1 | 6.25/1 | 50 | 0.60 | (14) |
| E | 5.83/1 | 5.71/1 | 55 | 0.66 | Assumed |
| E(Modified) | 5.00/1 | 5.00/1 | 55 | 0.66 | (4) |
| F | 5.33/1 | 5.26/1 | 60 | 0.72 | Assumed |

In 1958, the BPR issued the Series E(Modified) lowercase alphabet for use on freeway guide signs (17). The introduction of this document indicated that the lowercase alphabet was prepared by BPR for AASHO and is basically the same alphabet developed by the California Division of Highways after extensive research. Again, the research is not identified, but it is assumed to be Forbes et al. 1951 research on a lowercase alphabet (4). That research is described later in this chapter. However, Forbes' research simply indicated that it used the alphabet developed by California without describing how the alphabet was developed.

### Alphabets in Other Countries

The Series E(Modified) alphabet appears to be the grandfather lowercase alphabet for the world. The available documentation indicated that it is used in the countries listed below. It may also be used in other countries, but documentation was not found.

- Canada - Uses the alphabets in the same manner as the U.S.
- Australia - Uses the Series A alphabet and adds a narrow and medium spacing.
- Netherlands - In addition to using the standard U.S. Series E(Modified) alphabet, they use a lowercase alphabet with a narrower stroke width that is based on the Series E(Modified) alphabet.
- South Africa - Uses the alphabets in the same manner as the U.S.

Although the U.S. alphabet is widely used throughout the world, other alphabets are also used in various countries. The most common different alphabets are those used in Europe, with Great Britain being the only country with English language alphabet standards.


**Figure 4. U.S. Alphabets**

The MUTCD equivalent in Britain is *The Traffic Signs Regulations and General Directions* document (18). This document identifies two primary alphabets for highways signs, one for positive contrast signs (light legend on a dark background) and one for negative contrast signs (dark legend on a light background). A separate document refers to these alphabets as the Transport Medium alphabet for positive contrast signs and the Transport Bold alphabet for negative contrast signs. There are also two other alphabets that are used on a more limited basis: Motorway White for white legend on a blue background and Motorway Black for black legend on a yellow background. Both of these alphabets consist of numbers and a limited number of letters (mostly compass directions). Figure 5 illustrates a few letters of the two Transport alphabets. Appendix B presents all the letters of the Transport Medium alphabet.

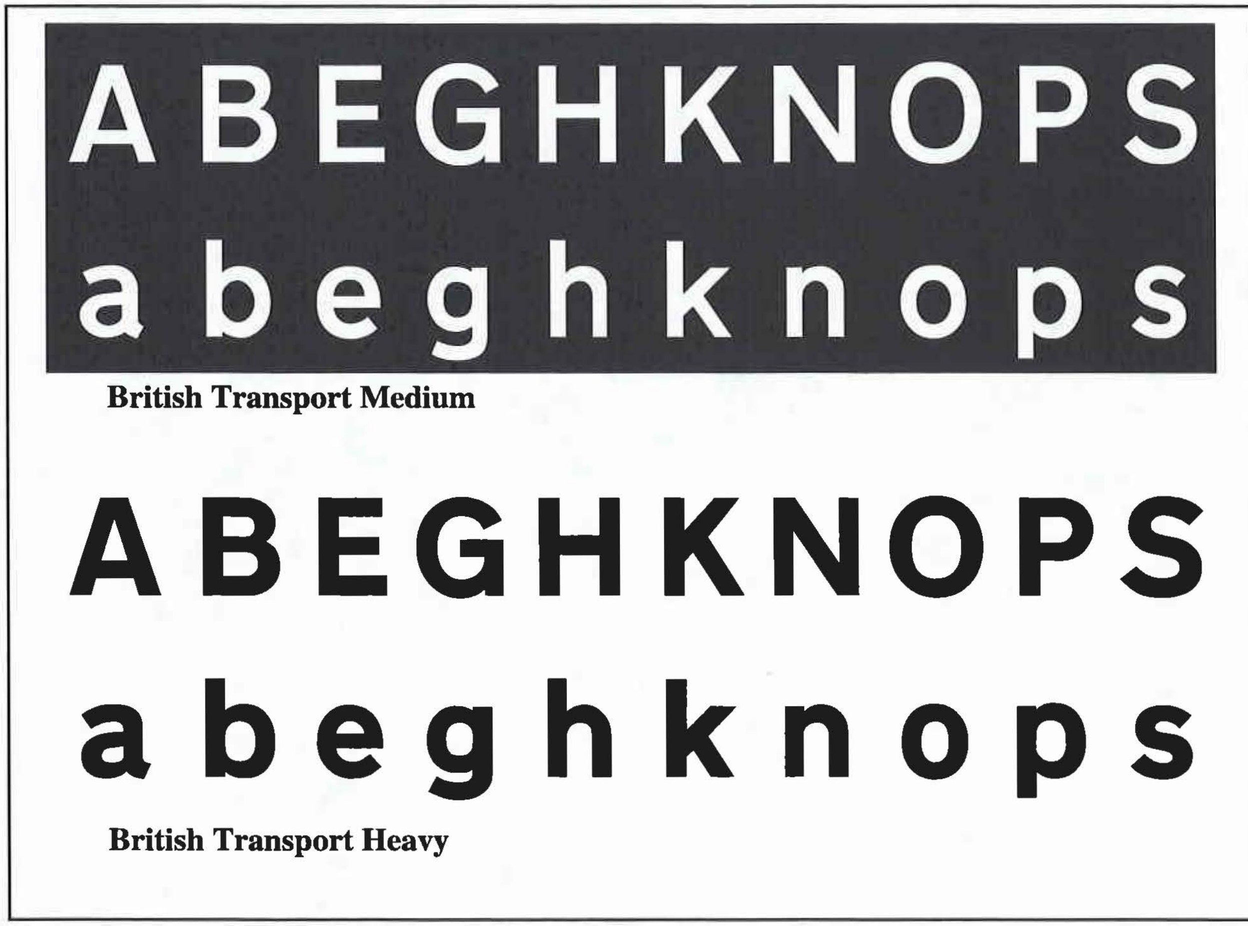
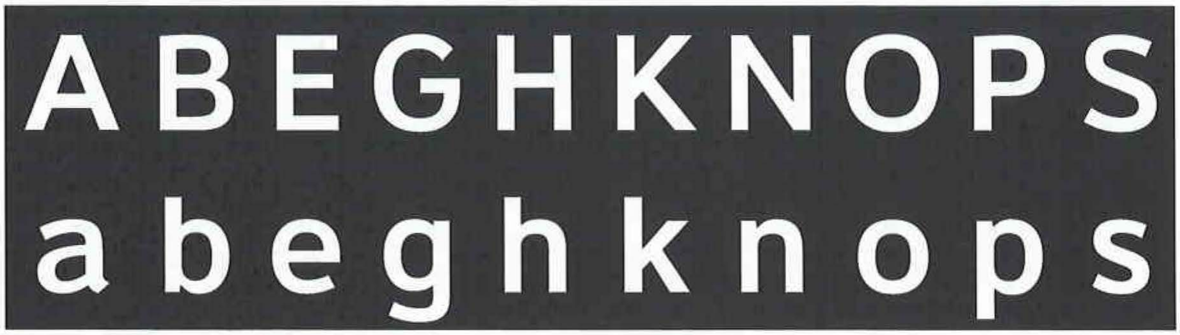



**Figure 5. British Transport Alphabets**

The interesting aspect of the British alphabets is that the Transport Medium alphabet (for white letters on a green, blue, brown, or black background) has a narrower stroke width than the Transport Bold alphabet (for a black letter on a white or yellow background). It should be noted that the green in British guide signs is much darker than the green in U.S. guide signs. Since the performance characteristics of positive and negative contrast signs are different, the use of different alphabets for each is logical and is a feature absent from U.S. signs. Several studies have indicated that the British Transport alphabet has a more pleasing aesthetic appearance than the U.S. alphabet (6, 8, 9).

## Clearview™ Alphabet

The Pennsylvania Transportation Institute (PTI) recently conducted research to identify ways to improve legibility and recognition of legends by using a new alphabet to reduce irradiation (9). Although not the original intent of the study, a new alphabet, named Clearview™, was created to overcome the deficiencies of the current highway alphabet. Clearview™ retains the visual proportions of the existing FHWA alphabets, but also incorporates the desirable attributes of various foreign and domestic typefaces, particularly British Transport Medium. Figure 6 illustrates a few letters of the Clearview™ alphabet. Appendix B presents all the letters of the Clearview™ alphabet.




**Clearview™ Regular Expressway**

**Figure 6. Clearview™ Alphabet**

## Alphabet Legibility

The federal and Texas MUTCDs contain no requirements for the legibility of freeway guide signs other than statements that "*... the lettering should be large enough to provide the necessary legibility distance*" and "*sign size must be fixed primarily in terms of ... the lettering necessary for proper legibility*" (10, 11). Although there is not any information in the MUTCD regarding sign legibility, it has been the subject of extensive research over the years. Some of the most significant research is described later in this chapter.

The legibility index defines the distance at which a letter or word can be read for a given letter height and is expressed in m per mm of letter height (ft/in). The indices used for highway alphabets were established by Forbes' pioneering research in 1939 (14) for Series B (0.40 m/mm, 33 ft/in) and D (0.60 m/mm, 50 ft/in), and by Forbes' 1951 research (4) for Series E(Modified) (0.66 m/mm, 55 ft/in). Table 1 summarizes the legibility indices for the various alphabet series. These numbers generally represent 80th percentile legibility values for drivers with normal (20/20) vision viewing black on white letters with unlimited response times.

In recent times, researchers have suggested that these legibility factors are too high to accommodate the increasing numbers of older drivers and less than ideal driving conditions. For example, Mace (19) has suggested that a legibility index of 0.48 m/mm (40 ft/in) is more appropriate in light of the limitations of older drivers. Mace has also reported that when viewed by a driver with 20/40 vision (the minimum licensing requirement in most states), the legibility index of the Series D alphabet is approximately 0.36 m/mm (30 ft/in) (19).

A person with normal vision (20/20 vision in the Snellen letter chart) can discriminate a stroke width of 1 minute of arc and a letter height of 5 minutes of arc (20). A letter height of 10 minutes of arc is equivalent to 20/40 vision (20), the minimum required visual acuity in most states. Table 2 describes the relationship between Snellen visual acuity, the visual angle, and the resulting legibility index. Note that the legibility index for 20/20 vision is about 0.69 m/mm (57 ft/in), and the legibility index for 20/40 vision is about 0.34 m/mm (29 ft/in).

**Table 2. Visual Acuity and Legibility**

| Snellen Visual Acuity | Visual Angle of Letter (minutes) | Legibility Index | |
|---|---|---|---|
| | | m/mm | ft/in |
| 20/10 | 2.5 | 1.38 | 114.6 |
| 20/20 | 5.0 | 0.69 | 57.3 |
| 20/30 | 7.5 | 0.46 | 38.2 |
| 20/40 | 10.0 | 0.34 | 28.7 |
| 20/50 | 12.5 | 0.28 | 22.9 |
| 20/60 | 15.0 | 0.23 | 19.1 |

## FREEWAY SIGN DESIGN PARAMETERS

The legibility of freeway signs is determined by numerous factors, some of which are a function of the sign design. The Texas MUTCD (11) establishes the following design requirements for freeway guide signs:

- white legend on green background,
- legend to be retroreflectorized,
- overhead signs that are not retroreflectorized shall be illuminated,
- alphabet to be Series E(Modified) upper and lowercase letters, and
- legend size specified in Table II-2 of the Texas MUTCD.

### Legend

The legend on freeway guide signs consists of words, numbers, route markers, and/or arrows. The current alphabet used for the legend in freeway signs is the Series E(Modified) alphabet from the FHWA *Standard Alphabets for Highway Signs* (12, 13). There are two methods of producing a retroreflectorized letter. When first introduced in the 1950s, the Series E(Modified) alphabet was available in aluminum letters that had retroreflector buttons centered in the stroke. This type of letter is often called button copy or "AGA" letters. The other method is to produce a fully retroreflectorized letter by cutting it directly from retroreflective sheeting.

This type of letter is often called cut-out letters. The sheeting can be applied to an aluminum letter that is affixed to the sign, or the sheeting can be applied directly to the sign background. Figures 1 and 2 compare button copy and cut-out letters.

The size of the legend varies according to the type of information being presented and the location of the sign. Table 3 summarizes some of the legend sizes used in freeway guide signs.

**Table 3. Summary of Legend Sizes**

| Type of Legend | Type of Freeway | | | |
|---|---|---|---|---|
| | Major | Intermediate | Minor | Overhead |
| Name of Place, Street, or Highway in Advance Guide and Exit Direction Signs | 500/375 mm (20/15") | 400/300 mm (16/12") | 333/250 mm (13.3/10") | 400/300 mm (16/12") |
| Pull Through Signs | 400/300 mm (16/12") | | | |
| Interchange Sequence Signs | 333/250 mm (13.3/10") | | | |
| Name of Destination in Distance Sign | 200/150 mm (8/6") | | | |

Note: Slash (/) differentiates height of upper/lowercase letters.

## Background Materials

As indicated previously, the MUTCD requires the sign background of overhead guide signs to be retroreflectorized or illuminated. As described in the following section of this chapter, most states use retroreflective backgrounds for all freeway guide signs. Many of these signs are also illuminated. The type of sheeting used for guide sign backgrounds ranges from engineering grade to super high intensity grade (e.g., Diamond Grade™).

## Location

Freeway guide signs can be mounted overhead above the traffic lanes or on the ground on the right or left side of the freeway. The Texas MUTCD indicates that overhead guide signs may be justified or should be considered under any of the conditions listed below (11). The existence of any one or more of these conditions does not automatically justify the use of overhead signs:

- traffic volume at or near capacity,
- complex interchange design,
- three or more lanes in each direction,
- restricted sight distance,
- closely spaced interchanges,
- multilane exits,
- large percentage of trucks,
- street lighting background,
- high speed traffic,
- consistency of sign message location through a series of interchanges,
- insufficient space for ground-mounted signs,

- junction of an Interstate route with another freeway, and
- left exit ramps.

The bottom of ground-mounted signs is generally located 2.1 m (7 ft) above the near edge of the pavement. The lateral placement of a ground-mounted sign is often 9.2 m (30 ft) from the edge of the travel lane. Overhead signs generally have a vertical clearance of not less than 5.3 m (17 ft, 6 in) to the bottom of the sign or sign structure.

**Layout**

There is no standard design for freeway guide signs as there are for regulatory, warning, and construction signs. Each guide sign contains different information and must therefore be individually designed. The Texas MUTCD (11) and *Standard Highway Sign Designs for Texas* (21) contain guidelines for the layout of freeway guide signs. Some of the more significant of these guidelines are listed below:

- Sign size is based on the letter height necessary for proper legibility and the corresponding length of the legend.
- A sign mounted over and applying to a specific lane may place horizontal restrictions on the width of a sign.
- Names of places, streets, and highways shall be composed of Series E(Modified) lowercase letters with an initial uppercase letter. Other word legends shall be Series E(Modified) uppercase letters.
- Interline spacing of uppercase letters should be approximately three-fourths of the uppercase letter height.
- The spacing to the top and bottom borders should be approximately equal to the letter height of the adjacent line of letters.
- The lateral spacing to the vertical borders should be essentially the same as the height of the largest letter.
- For signs larger than 3×1.8 m (10×6 ft), the border should have a width of approximately 50 mm (2 in). For smaller signs, a border width of approximately 32 mm (1¼ in) may be used, but the border width should not generally exceed the stroke width of the major lettering on the sign.
- The corner radius should be approximately ⅛ of the minimum sign dimension, not to exceed 300 mm (12 in).

## REVIEW OF CURRENT PRACTICES

Previous TTI research on traffic control devices has found that, although there may be typical or standard practices at the state and national level, there can be significant variation between the practices of any two agencies. Therefore, the researchers conducted a survey of state practices and compared these to TxDOT practices.

**TxDOT Freeway Sign Design Practice**

The current TxDOT policy for freeway sign materials and fabrication was established in a September 22, 1993, memorandum to District Engineers from the Traffic Operations Division. The memo indicated that, beginning in January 1994, all signs except white should use Type C (high intensity) sheeting, including overhead signs. The memo further indicated that white legends should be fabricated by cutting the legend directly from the retroreflective sheeting. The memo stated that button copy would no longer be used on freeway signs.

In addition to the change in sheeting practice, the memo indicated that sign lighting was not required for overhead signs made from high intensity sheeting, except where sight distance or geometric conditions warrant the use of lighting.

The current edition of the Texas MUTCD (11) contains the following statements regarding the retroreflectorization or illumination of freeway signs:

> "*In general, where there is no serious interference from extraneous light sources, reflectorized signs will usually be adequate. However, on expressways and freeways where much driving at night is done with low beam headlights, the amount of headlight illumination incident to an overhead sign display is relatively small. On freeways, all overhead signs that are not independently illuminated shall be reflectorized. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message.*"

*Survey of State DOT Practices*

One of the early efforts of the project was to identify the freeway sign design practices used in the other 49 state departments of transportation (DOT). This survey was one part of a larger survey addressing the key issues on four TxDOT/TTI research projects. The survey instrument for freeway signs consisted of five questions addressing freeway sign materials, sign illumination, and freeway sign legend. A total of 37 states responded to the survey (a response rate of 76 percent). Appendix A presents the survey questions, responses, and comments.

*Sign Materials*

One of the primary purposes of the survey was to identify the types of materials that states are using in overhead and ground-mounted freeway guide signs. The first survey question asked states to indicate the materials used in new overhead signs. Appendix A contains the frequencies and percentages for each material type. Table 4 summarizes the various combinations of materials used by the responding states. This table indicates that the majority of states use high intensity cut-out letters on a high intensity background, the same practice currently used by TxDOT. Only seven states continue to use button copy. The button copy backgrounds range from non-reflective to high intensity. Engineering grade or super engineering grade sheeting is not widely used as a legend material (only one state each). Seven states are using Diamond Grade™ for a legend material, but several of these indicated the use of Diamond Grade™ was experimental at the time of the survey. From the table, it can be seen that 24 states use the same material for both the legend and background (high intensity on high intensity or Diamond Grade™ on Diamond Grade™). Six states indicated more than one material for either the legend, background, or both, so it was not possible to identify the actual material combinations used. The remaining seven states use different materials in the legend and background.

**Table 4. Summary of Material Combinations for Overhead Guide Signs**

| Material Combination | | Number of Responding States | Percentage |
|---|---|---|---|
| Legend | Background | | |
| Button copy | Non-reflective | 1 | 2.7% |
| Button copy | High intensity | 2 | 5.4% |
| High intensity | Super engineering grade | 1 | 2.7% |
| High intensity | High intensity | 23 | 62.2% |
| High intensity | Diamond Grade™ | 1 | 2.7% |
| Diamond Grade™ | Engineering grade | 1 | 2.7% |
| Diamond Grade™ | High intensity | 1 | 2.7% |
| Diamond Grade™ | Diamond Grade™ | 1 | 2.7% |
| Multiple materials indicated | | 6 | 16.2% |

The second question asked for the same material information for ground-mounted signs. Twenty-eight of the 37 states (76 percent) indicate they use the same material combinations on both overhead and ground-mounted signs. For the nine states that use different materials, six use a lower brightness material for the legend and/or the background in the ground-mounted sign.

*Sign Illumination*

The use of sign illumination for overhead signs is divided among the states. Slightly more than a quarter of the responding states illuminate all overhead signs. Another group of slightly over a quarter do not illuminate any overhead guide signs. Slightly less than half of the states use sign lighting for some of their overhead signs.

Of the 10 states that indicated they do not use sign lighting, seven use high intensity letters on high intensity background. One state uses Diamond Grade™ on Diamond Grade™, one state uses button copy on high intensity, and one uses Diamond Grade™ on super engineering grade.

When asked about complaints about sign lighting, 80 percent indicated that they had not received any complaints. For the other 20 percent, the complaints received were viewed as minor.

*Sign Legend Alphabets*

The last question of the survey asked the states if they used an alphabet other than Series E(Modified) for the legend in freeway signs. Thirty-four of 37 states indicated they used Series E(Modified). The other three states that indicated something other than Series E(Modified) are Arizona, California, and Georgia. Arizona indicated that it did not use Series E(Modified) because it used button copy letters. As mentioned previously, although based on Series E(Modified), button copies letters are slightly different than Series E(Modified). California has developed its own alphabet, which is basically the federal Series E(Modified) alphabet with the stroke width increased 10 percent. California allows the use of the federal alphabet, but does not allow the two to be used on the same sign. The Georgia DOT indicated that they use a Series D alphabet in freeway signs. This alphabet has both upper- and lowercase letters that are of a narrower stroke width than Series E(Modified) letters.

## PREVIOUS RESEARCH

Several factors contribute to sign legibility, both during the day and at night. Legend design (height, stroke width, and spacing), reflectance, and internal contrast are three of the dimensions generally considered in attempts to improve sign legibility since other dimensions are more strictly controlled by the MUTCD (11), and therefore, not easily changed. In practice, the size of the legend on a freeway guide sign is established by Section 2F-11 of the MUTCD and adjusted in response to level of service and design speed.

The subject of sign legibility has been extensively researched for over 65 years. During that time, researchers have addressed topics from the pure legibility of specific sign design elements to more specific issues such as the impacts of sheeting type, letter spacing, or other factors on legibility. The extent of previous research prevents a comprehensive description of all previous research on the legibility of sign legends. However, the following pages summarize some of the most significant research findings, with an emphasis on the issues of greatest concern to this research project.

### General Legibility Research

The pioneering work on the legibility of traffic signs was performed by Forbes in two major studies. His 1939 research with Holmes established legibility indices for the Series B and D alphabets (14). His 1951 research with Moskowitz and Morgan established the legibility of the lowercase Series E(Modified) alphabet (4).

In his 1939 study, Forbes evaluated the Series B and D block letter alphabets and found a legibility index of 0.40 m/mm (33 ft/in) for Series B and 0.60 m/mm (50 ft/in) for Series D. These are 80$^{th}$ percentile values from observations by 412 different people representing normal (20/20) vision. Letter size ranged from 150 to 600 mm (6 to 24 in), with 6-letter place names. Letters were black paint on a white board.. Floodlit signs at night gave a legibility distance 10 to 20 percent less than daytime values. Glass ball reflectors were also evaluated with headlights and results were similar up to about 90 m (300 ft). The measurements represented "pure" legibility (test subjects were given an unlimited response time). The visual acuity of the test subjects was measured for only 52 of the 412 subjects. The results of the visual acuity test indicated that the median legibility distances represented better than 20/20 vision, the 80th percentile distances represented 20/20 vision, and the 95th percentile distance represented 20/30 vision.

Forbes (14) also showed a nonlinear relationship between letter size and legibility distance, and showed that wider letters are more effective than narrow ones. The practical importance of a curvilinear relationship between letter size and legibility distance is that experimental relationships among alphabet styles, letter spacing, etc. for small test letters may not be directly applicable for large scale letters.

Forbes 1951 research (4) is the basis for the modern Series E(Modified) alphabet and laid the groundwork for the adoption of the lowercase alphabet for freeway guide signs. The purpose of this experiment was to determine the distances at which lowercase signs could be read as compared to rounded capital letters on overhead mounted signs. Experiments on ordinary printed pages with type forms have shown that lowercase printing gives more rapid reading than solid block printing with capital letters. This advantage has been attributed to more definite pattern characteristics of the lowercase words. However, the factors which produce the rapid reading at a close range may not be the same as the factors that allow the reading of large signs at a maximum distance.

The letters used in Forbes' study were 125 to 450 mm (5 to 18 in) in height. The letters were white, standard Series E rounded letters, with the stroke widened to correspond to that deemed most satisfactory from experience of the California Highway Division. They were placed on a black background. The lowercase letters were approximately the same average width-height ratio. When an initial uppercase letter was used with the lowercase letters, it was Series D of 1.5 times the loop height of lowercase. The letters were placed on an experimental sign bridge which had a background 7.2×1.8 m (24×6 ft) high. The bottom edge of the sign was 5.1 m (17 ft) above the ground. Letters and sign background were both non-retroreflectorized. Nighttime conditions had illumination levels of 41.1 to 61.7 candela/m$^2$ (12 to 18 foot lamberts) from fluorescent lighting.

To obtain the best control possible and still obtain a comparison of familiar and unfamiliar words created from upper/lowercase letters and capital letters, observations of three types were used:

1. Six letter "scrambled" combinations (uppercase not used with lowercase),
2. 12 place names (6 to 9 letter California cities and counties) "without knowledge" (lowercase had initial uppercase), and
3. 12 place names (6 to 9 letter California cities and counties) "with knowledge" (lowercase had initial uppercase).

Each of the words was presented in both capital letter and lowercase letter (with uppercase letters as indicated above) formats. A total of 3,939 observations were made by an average of 55 observers for each condition. Each observer made six observation trips "reading" six different signs on each trip during a given afternoon or evening. These observations were carried out during two afternoon and evening sessions in July 1950. The observers consisted of both males and females between the ages of 18 to 70 years and consisted of office staff from departments other than the traffic department. The 85th percentile acuity was 20/20. The observers would start from a distance where no one could identify the six test words. They then walked toward the sign boards until they could read each word and the exact spelling of each word. Once a word was "read," they would record the next distance marker ahead. The observers also faced in an easterly direction so that the afternoon observations could be made with the sun directly on the sign boards and out of the direct field of vision.

In general, the researchers found that the 85th percentile daytime legibility distance (representing 20/20 vision) was 0.38 m/mm (32 ft/in) of letter height for lowercase scrambled letters and 0.58 m/mm (48 ft/in) for lowercase place names "without prior knowledge." The nighttime legibility index was found to be 0.40 m/mm (33 ft/in) for scrambled lowercase letters and 0.64 m/mm (53 ft/in) for lowercase place names "without prior knowledge." Both day and night legibility indices are calculated using the uppercase letter height appropriate to the lowercase letter. Table 5 summarizes legibility results for the 85th percentile "without knowledge" words. The Forbes researchers recommended that these values be used for design purposes.

**Table 5. 85th Percentile Legibility Index for Place Names "Without Knowledge"**

| Letter or Loop Height | | Legibility Index | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Daytime | | | | Nighttime | | | |
| | | Capitals | | Lowercase | | Capitals | | Lowercase | |
| mm | in | m/mm | ft/in | m/mm | ft/in | m/mm | ft/in | m/mm | ft/in |
| 150 | 6 | 0.89 | 74 | 0.54 | 45 | 0.72 | 60 | 0.78 | 65 |
| 200 | 8 | 0.91 | 76 | 0.58 | 48 | 0.77 | 64 | 0.64 | 53 |
| 300 | 12 | 0.95 | 79 | 0.60 | 50 | 0.80 | 67 | 0.64 | 53 |

Source: Reference (4)

Some research has been conducted on the required sight distance for overhead guide signs. Overhead guide signs are unique since drivers needing the information contained in those signs have the advantage of knowing that these signs will be large, rectangular, green, and located either on a structure over the roadway lane or on the side of the freeway. The drivers' tasks of responding to highway signs are broken into components, each with an estimate of time for each task. For example, the time for the detection and identification task is estimated at 1.0 to 1.5 seconds, since drivers are actively searching for overhead guide signs. Gordon (22) recommended sight distances of up to 457 m (1,500 ft) for guide signs. If older drivers and higher speeds (110 km/h, 65 mph) are considered, that sight distance increases to over 610 m (2,000 ft).

## Impacts of Retroreflective Materials and Illumination

Guide sign materials have a significant impact on the legibility of the legend. Woods and Rowan (23) compared the legibility of high intensity legend on high intensity background guide signs with button copy legend on engineering grade background. Their button copy signs were externally illuminated while the high intensity signs depended on headlight illumination. Woods and Rowan showed that the observed legibility distance was 19 percent less with low beams on high intensity sheeting than on engineering grade sheeting with external illumination. Legibility distances for the high intensity signs were 5 percent greater with high beams than the engineering grade signs. However, low beam illumination still provided an acceptable legibility of 0.84 m/mm (70 ft/in) for a straight roadway alignment.

McNees and Jones (24) investigated the legibility characteristics of eight different combinations of legend and background material. They found that high intensity legend with high intensity background, button copy legend with nonreflective background, and button copy legend with engineering grade background all provided legibility indices of 0.6 m/mm (50 ft/in) or better. They concluded that these combinations of background and legend material were acceptable for freeway guide signs. A combination of high intensity legend with engineering grade background had the lowest legibility index resulting from the irradiation produced by the approaching vehicle headlights. In addition, they noted that background material affected sign legibility to a greater extent than did legend material.

Mace et al. (7) evaluated four combinations of white on green guide signs: high intensity on engineering grade, Diamond Grade™ on high intensity, Diamond Grade™ on Diamond Grade™, and Diamond Grade™ on engineering grade. Except for the high contrast Diamond Grade™ on engineering grade combination, the researchers did not find significant differences in legibility indices of the various material combinations. As part of the evaluation, the Series E(Modified) alphabet was modified by reducing the stroke width of the letters. While the nighttime legibility of the high contrast combination was significantly improved by using a very narrow stroke width, it was only accomplished by significantly sacrificing the daytime legibility. The researchers recommended against using the high contrast combination. The Diamond Grade™ on Diamond Grade™ combination offered slightly better legibility than the high intensity on engineering grade combination, but only with wider letter spacing that would necessitate a larger sign. Furthermore, taller letters would offer more improvement than the increased spacing. The researchers indicated that the use of Diamond Grade™ material increases the legibility distance by about the same amount as an increase in letter height of 25-50 mm (1-2 in).

Shepard investigated the influence of sign luminance and lettering style on legibility (25). Luminance is particularly critical for nighttime legibility of guide signs. Overall, the legibility index increases as the level of reflected light increases and as the height-to-stroke width increases. However, letters with low height-to-stroke width ratios may experience degraded legibility due to irradiation. Irradiation is the overglow, or spreading, of bright legend material onto the darker background material. It occurs at night when a driver's eyes (adapted to a low level of luminance) encounter a legend of very high luminance. Irradiation makes the letters appear "fatter" and reduces legibility. Smith (26) explains that letter legibility is limited by visual acuity with the lower limit being one minute of arc for 20/20 acuity. That is, to distinguish for a fine visual detail from its background, it must subtend a visual angle of at least one arc-minute. Irradiation narrows the apparent space between letters (and the space within letters). Letter details subtend a smaller angle and are less legible.

In 1995, the Minnesota DOT (MnDOT) conducted an evaluation of freeway sign lighting policies (5). The evaluation was performed by a committee of MnDOT staff that was charged with answering the question: "*Is it possible to eliminate the lighting from some overhead signs without compromising the safety of the drivers?*" The committee reviewed accident information and previous research, surveyed other states, and conducted field observations of high intensity signs where the lights had been turned off. Based on the results of the evaluations, the committee determined that there was no need to light the majority of high intensity overhead signs. The committee developed the proposed guidelines described in Figure 7.

One or more of the following guidelines may make it necessary to light overhead signs:

1. Advertising devices and/or lighting sources competing for drivers' attention.
2. Engineering judgement based on various factors including, but not limited to:
    - At least 195 m (640 ft) of legibility distance.
    - At least 305 m (1000 ft) of detection distance.
    - Roadway and interchange geometrics.
    - High weaving traffic volumes.
    - Three or more overhead mounted sign panels on the same sign structure facing one direction of traffic (sign message overload).
    - Number of lanes (horizontal and vertical alignment).
    - Major forks.
3. High density fog areas.
4. Roadway lighting located in close proximity to overhead signs causing glare.
5. Sign(s) located on skewed bridges or horizontal curves.
6. Diagrammatic signs.
7. Regulatory signs.

If one sign panel on a structure is lit, all the other signs on the same structure should also be lit.

Source: Reference (5)

**Figure 7. MnDOT Sign Lighting Proposed Guidelines**

## Comparison of Day and Night Legibility

The nighttime legibility of signs is a complicated issue affected by many different factors. Research on nighttime sign legibility has drawn attention to variability in recommended luminance levels (27, 28).

Hahn, McNaught, and Bryden (29) investigated the nighttime legibility of guide signs in New York State. They observed significant differences in luminance between overhead and ground-mounted signs, but differences in legibility were much less. They attributed the near constant legibility to a logarithmic relationship between legibility distance and luminance. A change in legibility distance was proportional to the common logarithm of the change in luminance. Large changes in luminance resulted in proportionately smaller changes in legibility.

They concluded that nighttime legibility does not differ greatly between overhead and ground-mounted signs in spite of different amounts of light striking the signs.

In his 1951 research, Forbes used subjects with an 85th percentile corrected acuity of 20/20 and found night visibility distances to be 15 percent to 20 percent shorter than daytime visibility distances (4). The 85th percentile legibility index for Series E was 0.66 m/mm (55 ft/in) in the daytime and 0.53 m/mm (44 ft/in) at night. Allen, using subjects with normal vision to read three-letter nonsense syllables at night, found that legibility distance increased with letter width (30). The maximum values were 0.54 m/mm (45 ft/in) for Series A, 0.70 m/mm (58 ft/in) for Series C, and 1.08 m/mm (90 ft/in) for Series F.

**Impacts of Older Drivers**

Age is an important factor in sign legibility due to the expected growth in elderly drivers over the next twenty years and the higher accident rate among older drivers (31). Mace (19) studied the characteristics of guide sign legibility regarding luminance, contrast, and the age of the motorist and found that:

- Older drivers require more contrast between legend and background to achieve the same level of recognition as younger drivers.
- Legibility losses with age are greater at low levels of background luminance.
- Legibility losses with age increase when luminance increases beyond the optimum level on partially reflectorized signs.

In other words, older drivers are less sensitive to contrast, but are more sensitive to the degrading effects of brightness extremes than younger drivers. In addition, the aging process diminishes depth perception, glare recovery (the ability of the eye to readapt to low light levels after exposure to high light levels), and the ability of the eye to focus. While Forbes (32) stated that the legibility index of Series E lettering was 0.66 m/mm (55 ft/in) and 0.60 m/mm (50 ft/in) is a generally accepted minimum legibility index for guide signs within the professional community, Mace contends that safety engineers should not expect a legibility index of more than 0.48 m/mm (40 ft/in) for older drivers (19).

A report from the University of Michigan (33) found that with partially retroreflectorized signs, irradiation is particularly serious for older drivers. The authors recommend that at high levels of luminance, the stroke width of white letters on dark backgrounds (as is the case with freeway guide signs) be decreased to offset the effects of irradiation. With regard to the effect of driver age on sign legibility, the report noted the following generalizations (33):

- Older drivers require more contrast between the legend and the background of a sign than younger drivers to achieve the same level of legibility.
- Legibility losses with age are greater at low levels of background luminance. A reduction in legibility distance of between 10 to 20 percent should be assumed when signs are not fully reflectorized.
- Signs are more likely to suffer a loss in legibility for older drivers when luminance is increased beyond the optimum level on a partially reflectorized sign.

- Higher surround luminance improved the legibility of signs more for older drivers and reduced the negative effects of excessive contrast.

Increasing luminance extends legibility up to a point, after which irradiation begins to degrade legibility. The loss of legibility is difficult to document with any confidence since conflicting results have been found in the literature. Some researchers report a small loss, only occurring with very high levels of luminance (30). Others have shown irradiation to be a more pervasive problem, particularly for older drivers (34).

A 1979 paper suggested that older drivers should not be expected to achieve a legibility index of 0.60 m/mm (50 ft/in) under most nighttime circumstances (35). The data provided by this report gives some expectation that 0.48 m/mm (40 ft/in) is a reasonable goal under most conditions. Their data compared younger and older drivers on luminance and contrast requirements for different legibility criteria, different colors, background, and surrounding luminance. A 0.48 m/mm (40 ft/in) index can generally be achieved by older drivers with contrast ratios greater than 5:1 (slightly higher for guide signs) and luminance greater than 10 cd/m$^2$ (2.92 fL) for partially retroreflectorized signs.

**Impacts of Contrast and Irradiation**

Contrast between legend and background is another critical variable in legend legibility. Contrast is the ratio in luminance between legend and background. Forbes (36) quantified contrast both as percent of contrast ($(L_1 - L_2)/L_1$) or as luminance ratio ($L_1/L_2$) where $L_1$ represents the brighter legend luminance and $L_2$ represents background luminance. Forbes (32) found that legibility decreased sharply when the contrast percentage fell below 60 percent. The optimum contrast percentage for legibility was between 83 and 92 percent. Sivak, Olson, and Pastalan (37) confirmed that legibility increases with contrast up to approximately 90 percent after which it leveled off. They also noted that for older drivers (above 61 years of age), the mean legibility distances were 65 to 77 percent of those for younger drivers (less than 25) under similar conditions. Older drivers were much more sensitive to the debilitating effects of high contrast on legend legibility.

Sivak and Olson (28) reviewed the current state of legibility research and developed a set of optimal luminance characteristics for retroreflectorized signs. They defined contrast value as the ratio of legend luminance to background luminance ($L_1/L_2$). Thus, if legend luminance was 16 cd/m$^2$ (4.7 fl) and background luminance was 2 cd/m$^2$ (0.6 fl), the contrast value was 8:1. By comparing the "best" contrast value from six separate studies, where contrasts ranged from 3:1 to 45:1, the authors determined a geometric mean contrast ratio of 12:1. Their recommended optimal legend-background contrast for fully reflectorized signs was therefore 12:1. They noted further that a sign's background color, the observer's age, and the complexity of the visual environment influenced the optimal luminance requirements for retroreflective signs.

Based upon a review of the literature, a 1988 paper (19) examining fully retroreflective signs suggested a contrast ratio range of 4:1 to 15:1 as appropriate for most conditions. For example, if the luminance of the green background is 5 cd/m$^2$ (1.5 fl), the luminance of the legend should be at least 20 cd/m$^2$. Lower contrast ratios are not acceptable, and contrast as high as 50:1 is typically not considered to be a problem.

Observer characteristics provide models for predicting guide sign legibility. Finley and Wilkinson (38) showed a negative correlation between contrast sensitivity and glare sensitivity. They found that subjects with low contrast sensitivity would be more susceptible to glare than subjects with high contrast sensitivity. Sturgis and Osgood (39) showed that contrast sensitivity can account for a substantial portion of the variability in visual acuity, and that decreased visual acuity is strongly correlated with age.

A Virginia DOT-sponsored study addressed the problem of irradiation effects caused by Virginia's widespread use of high intensity sheeting (25). The report suggested that the way to increase legibility for negative image signs (dark legend on light background) with brighter materials is to increase the stroke width. However, for positive contrast signs, the stroke width may need to be decreased. The only apparent empirical research on this subject is a 1992 paper (40) that concluded that widening the stroke width did not improve the legibility of black on orange signs.

**Sign Design and Layout**

Forbes (41) reports that vertical spacing between legend lines is yet another variable affecting guide sign legibility. However, the MUTCD establishes vertical spacing between legend lines at three-fourths of the uppercase letter height (paragraph 2E-12) (10). Indeed, most of the variables discussed thus far are established either by statute or by policy. Economic limitations constrain letter height; luminance and contrast are dependent upon guide sign construction materials and are fixed by TxDOT policy; height-to-stroke width ratio, letter width, and letter spacing are set forth in the *Standard Alphabets for Highway Signs and Pavement Markings* (13). Therefore, any study that attempts to improve the legibility of guide signs should investigate how changes in alphabet *style* could improve legibility.

As shown in several studies, mixed-case legends have slightly better legibility distance than those made from all uppercase letters. Mace (7) looked at manipulating letter case and whether words composed of mixed-case (lowercase letters with initial uppercase letter) would have legibility equal to the same words composed of all capital letters. The improvements found were generally small, and given that signs with mixed-case legends would be wider and more costly, the improvement might be questionable based on legibility alone.

Mace's comparisons (7) of legibility of mixed-case and uppercase letters found that when letter height was controlled such that loop height of lowercase letters matched the height of the uppercase letter, mixed-case provided longer legibility distances. The improvements were small, however, particularly for low-contrast signs. When word width was held constant, no difference was found for uppercase 250 mm (10 in) letters, but uppercase had superior legibility for 300 mm (12 in) letters.

## Impacts of Alphabet Design

There are several different aspects of alphabet design that can be manipulated to improve legibility. These include changing the letter spacing, height-to-stroke width ratio, and the alphabet style itself.

*Letter Spacing*

Recommendations in the literature for the optimization of inter-letter spacing (or kerning) are limited to daytime situations. In general, legibility improves with increased spacing, but at some point reaches an optimal level beyond which further increases in spacing reduces legibility (42). Some authors have recommended letter spacing equal to 50 to 100 percent of letter width (43, 44).

In the early 1950s Case, Michael, Mount, and Brenner (45) conducted a study of the effects of letter spacing on sign legibility. They constructed twenty word legends using eight-letter words. For ten of these legends, the inter-letter spacing was one-half of the letter height. For the remaining legends, inter-letter spacing was one and one-third times the letter height. The authors confined their study to younger subjects with visual acuities of 20/40 or better. The results showed that the wide spacing gave much better legibility. Case et al. offered the following explanation for the greater legibility of widely spaced letters:

> "*Due to head movements, eye movements, and instability in the visual mechanism, the image of an object shifts about slightly on the retina, even though the observer may try to keep his head and eyes still. When there is wide spacing between two objects, the only effect of this shifting is a slight blurring of the edges of the objects. If the spacing between them becomes sufficiently small, the net result of the shifting is a superposition of adjacent letter parts which could decrease letter legibility*" (45).

Solomon (46) supported the findings of Case (45) that increasing the space between letters could increase legibility. Solomon experimented with three different alphabets. He cut standard Series C and Series E letters from reflective sheeting. A third alphabet, identified as Series ED, contained 32 mm (1¼ in) plastic reflectors embedded in plastic letters (button copy). The author noted that Series ED alphabet was similar in form and spacing to Series E lettering. Solomon increased the spacing between letters for each alphabet from normal to 20, 40, and 60 percent above normal. As inter-letter spacing increased, the legibility distances also increased for all three alphabets until word lengths were 40 percent above normal. Beyond 40 percent, legibility leveled off or declined. The results showed that Series ED lettering provided superior legibility at normal spacing. Series E letters had the highest legibility distances at the wider spacing. Solomon concluded that where vertical dimensions are restricted, and therefore lettering height is restricted, increased letter spacing can help to compensate for the loss of legibility distance that would occur from a smaller letter size.

Mace (7) examined the effects of increasing inter-letter spacing on nighttime legibility of a word and whether enhanced legibility due to the spacing held for different retroreflective materials, letter series, and letter heights. Three spacings (standard, 140 percent, and 200 percent) were investigated for white on green signs with Series E(Modified) letters. Some words were all uppercase and some were upper-lowercase combinations. One finding was that wider spacing had little to no effect on legibility index for high-contrast signs (white high intensity legend on green engineering grade background). With the low-contrast signs (white Diamond Grade™ legend on white Diamond Grade™ background), the 200 percent letter spacing improved the legibility index by 0.02 m/mm (2 ft/in). Because letter height and case (upper vs. lower) were also manipulated with spacing, further useful conclusions regarding increased spacing were unclear.

*Height-to-Stroke Width Ratio*

The letter height-to-stroke width ratio (H:SW) is another important variable in legend legibility. In the early 1960s, Hodge (44) determined that the optimal height-to-stroke width ratio was 4.6:1 for lowercase letters and 5.6:1 for uppercase letters (Series E(Modified) letters have a 5:1 height-to-stroke width ratio). Letters with height-to-stroke width ratios below four and above seven have notably lower legibility indices.

The study by Mace, Garvey, and Heckard (7) tested the effects of retroreflectivity and stroke width on the legibility index of guide signs. Since irradiation increases the *perceived* stroke width of high-contrast letters mounted on lower contrast backgrounds, they decreased the stroke width on the interior of Series E(Modified) letters, in effect, "carving out" the interior. They maintained constant Series E(Modified) width for one set of 200 mm (8 in) letters and another set of 300 mm (12 in) letters, but they decreased the interior stroke width incrementally by 0 percent, 25 percent, and 62.5 percent. Mace tested these modified alphabets under both daytime and nighttime conditions using a group of fifteen younger observers and another group of fifteen older observers (ages 65 and up). They converted the observed legibility distances into legibility indices (in ft per inch of letter height) to allow comparison between different letter sizes, and they used different combinations of legend and background materials to create a range of contrast values from 10:1 to 100:1. For white on green signs with high contrast, the study found that nighttime legibility was significantly improved with a narrower stroke width. For older drivers, the data analysis of the high intensity on high intensity signs found that the narrowest stroke width (reduced by 62.5 percent) resulted in a legibility index of approximately 0.64 m/mm (53 ft/in); the legibility index for the medium stroke width (reduced by 25 percent) was 0.76 m/mm (63 ft/in), while the legibility index for unchanged Series E(Modified) was 0.72 m/mm (60 ft/in). Thus, narrowing the stroke width did improve legibility distance over the standard stroke width letters. However, when the narrower stroke width was used instead of Series E(Modified) letters to overcome the irradiation effects, the daytime legibility was sacrificed. Older subjects needed the wider standard stroke width for optimal daytime legibility. All other materials maintained maximum legibility for older subjects with the normal stroke width for both daytime and nighttime viewing conditions. The authors recommended the adoption of a 0.48 m/mm (40 ft/in) legibility index to accommodate 75 to 85 percent of older drivers.

*Alternative Alphabets*

A study by Tan compared the legibility indices of several different letter styles to Series C, D, and E(Modified) alphabets among older and younger drivers (47). Tan's experiment used a total of 40 subjects, with half the subjects aged 65 or older. All subjects had a minimum visual acuity of 20/40 or better. The results showed that no particular alphabet style performed significantly better than the standard alphabet styles and that all of the alphabets had experimental legibility values that were very close to 0.60 m/mm (50 ft/in). Although some alternative alphabets provided better legibility among certain groups, the variation in legibility indices for the subjects taken as a whole was only 0.02 m/mm (2 ft/in). For a motorist traveling at 115 km/h (70 mph), the best alternative alphabet would provide an additional quarter of a second decision time when 300 mm (12 in) letters form the legend.

In the research for which Clearview™ was created, PTI compared Clearview™ and Clearview™ Condensed to Series E(Modified) letters (9). The uppercase letter height was 125 mm (5 in). Each version of Clearview™ was presented in two sizes, normal and expanded. The expanded Clearview™ was created by increasing the footprint of a word to fill the same area as the same word in Series E(Modified). This was possible because Clearview™ used a tighter letter spacing than Series E(Modified). The footprint expansion resulted in a 12 percent increase in letter size. Day/night recognition and day/night legibility field experiments exposed 48 older drivers (age 65 and over) to high-brightness guide signs using each of the alphabets. In the daytime evaluations, there was no difference in recognition or legibility distances between either Clearview™ or Series E(Modified). At night, the expanded Clearview™ alphabet was found to result in recognition distances 16 percent greater than Series E(Modified) without increasing overall sign dimensions. It is important to note that this increase in legibility was achieved partly by expanding the letters by 12 percent so that the Clearview™ footprint was equal in size to the Series E(Modified) footprint (9).

# CHAPTER 3
# EXPERIMENTAL APPROACH

The basic concept of the experimental plan was to start a test subject a long distance from a freeway guide sign, then to move the subject closer to the sign until he/she could read the legend. While simple in principle, the process of developing the experimental procedure and the necessary infrastructure was a time-consuming activity of the research project. The following sections describe key activities in developing the experimental procedure and infrastructure.

## EXPERIMENTAL FACTORS

The development of the experimental plan began with the identification of the various factors related to freeway guide sign legibility, followed by an assessment of the various factors that could be accommodated within the resources of this project. After establishing the variables that would be evaluated, the researchers developed a procedure for collecting the data.

The effort began with a review of previous research on legibility of highway signs. The review confirmed the need to evaluate daytime and nighttime legibility and the need to include a large proportion of older drivers. The researchers also determined that previous research on letter spacing indicated that the effects of letter spacing were known and need not be further evaluated in this project.

### Selection of Alphabets

The most significant issue to be resolved in the development of the experimental plan was the selection of the alphabets to be evaluated. From the outset of the project, the researchers and TxDOT Project Advisors agreed that cut-out Series E(Modified) needed to be one of the alphabets evaluated to provide a basis of comparison to current TxDOT practice and previous research efforts. They also agreed that Clearview™ should be one of the other alphabets, as the initial PTI research indicated that it had favorable performance, and their research was receiving significant interest from FHWA and other state transportation agencies. However, the actual version of Clearview™ to be evaluated was not determined until the Preliminary Clearview™ Investigation (described on page 35) was conducted. The remaining questions were to determine *how many* other alphabets should be evaluated and *which ones* should be included in the evaluation?

As described in the infrastructure section of this chapter, the sign panels upon which the words were displayed provided space to display three words. After evaluating various options for presenting words in three or four alphabet designs, the researchers determined that three alphabets would provide the best balance between the experimental design and the variations between different alphabets. There were four possibilities from which to choose the third alphabet:

- **Series E(Modified) Button Copy** - This type of alphabet was the previous TxDOT standard, although the previous standard used an engineering grade background. There are a large number of freeway guide signs in Texas that still have this type of lettering. This alphabet was rejected based upon input from the Project Advisors that indicated TxDOT was unlikely to revert to button copy due to the cost of the letters and maintenance difficulties.
- **Second Clearview™** - Clearview™ was developed in multiple height/stroke width ratios. The use of Clearview™ in a different height/stroke width ratio would provide a different performance comparison. The use of two Clearview™ alphabets was rejected, however, because of the desire to address other alphabet designs beyond just Series E(Modified) and Clearview™.
- **TxDOT Lowercase Series D or Series E** - Prior to this research project, TxDOT's Traffic Operations Division had created lowercase alphabets that have the same height-to-stroke width ratios as Series D and Series E. However, these alphabets have not been used in actual practice. The use of these alphabets in the research project would provide the opportunity to focus a part of the evaluation specifically on the effects of stroke width on legibility. These alphabets were rejected because they were not sufficiently different from Series E(Modified) to provide a range of performance. Furthermore, they were not in a format that would provide for simple fabrication of the letters.
- **British Transport Medium** - This alphabet is used in the United Kingdom for positive contrast, overhead freeway signs. However, the background color of British green guide signs is much darker than the U.S. green. This alphabet was finally selected as the third alphabet. It represents a readily available alphabet that is already in use. It had also been identified by previous researchers as an alphabet with features that enhanced legibility (6, 8, 9). The alphabet also possessed characteristics sufficiently different from Series E(Modified) and Clearview™ to provide a good point of comparison.

Figure 8 illustrates some key letters of the three alphabets selected for evaluation. Appendix B presents more letters in each of these three alphabets.

## Determination of Experimental Variables

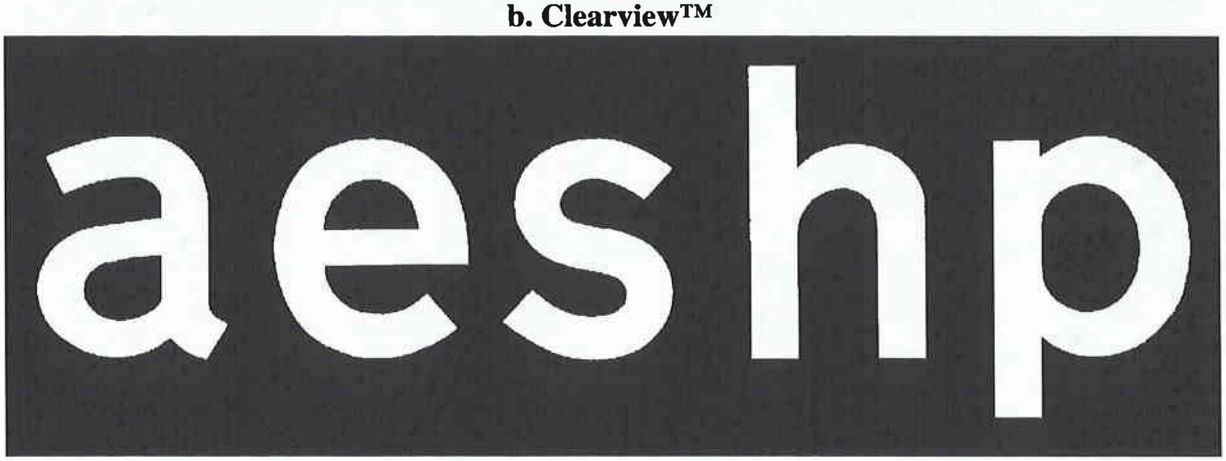
Having established the alphabets to be evaluated, the researchers began assessing various factors that have an impact on guide sign legibility and the ability to accommodate the factors within the experimental design. The researchers identified the dependent and independent variables, plus the fixed factors for the experiment. It should be noted that all measurements in the experiment were made in U.S. units. For this report, legibility/recognition distances are converted to metric using a soft conversion (1 ft = .305 m), and letter heights are converted using a hard conversion (1 in = 25 mm).

### *Dependent Variables*

Previous research has consistently used two measures of legibility performance. The most common is the legibility distance, the distance at which a subject can read an unknown word. Less frequently used is the recognition distance, the distance at which a subject can identify a word that has been specified beforehand (a known word). The legibility distance provides the truest measure of the readability and performance of a given alphabet. On the other hand, the recognition distance most closely relates to the driving task of finding a desired destination in a guide sign. The researchers decided to measure both of these distances in this project. Prior to each experimental trial, the researcher would inform the test subject of one of the three words on the sign. As the test subject approached the sign, he/she had to read all three words on the sign and identify the position (top, middle, bottom) of each word.


**a. Series E(Modified)**


**b. Clearview™**




**c. British Transport Medium**

**Figure 8. Comparison of Lowercase Sign Alphabets**

*Independent Variables*

To keep the scope of legibility performance within the resources of the project, the researchers identified three independent variables for the sign and four for the test subjects.

- **Independent Sign Variables** - The following are factors associated with the sign stimuli that were varied between trials.
  - *Type of Alphabet* - As described previously, three alphabets were selected for evaluation: Series E(Modified), Clearview™, and British Transport Medium. Only one alphabet was displayed on a sign for a given trial.
  - *Words* - A total of 21 words in each alphabet were used. Each word was composed of six letters. These words were "everyday" or common words and not associated with the name of a city or destination. The list included ten neutral words and eleven words with both one ascender and one descender. Table 6 lists the words used in the experiment.
  - *Sign Position* - Freeway guide signs have two basic mounting positions, overhead and ground-mounted. Both were selected for evaluation, with the overhead mounted sign being 6.1 m (20 ft) directly above the travel lane of the vehicle and the ground-mounted sign located 2.1 m (7 ft) above the travel lane and 9.1 m (30 ft) to the right of the edge of the lane.
  - *Sign Lighting Conditions* - The benefit of the alternative alphabets was expected to be the greatest in nighttime conditions, when the blooming effect is present. Daytime measurements were also needed to ensure that daytime legibility was not sacrificed. Since current TxDOT practice is to not use sign lighting, no external lighting was used in this experiment.

**Table 6. Words Used as Legends**

| Neutral Words | Ascender/Descender Words |
|---|---|
| Honors | Barley |
| Houses | Bishop |
| Nerves | Dearly |
| Nurses | Eatery |
| Oceans | Felony |
| Ounces | Flange |
| Season | Forget |
| Senior | Player |
| Sensor | Plunge |
| Series | Shapes |
| | Target |

- **Independent Subject Variables** - For this experiment, potential test subjects were recruited from the Brazos County area using the newspaper advertisement presented in Appendix C. The researchers established a goal of at least 48 participants, but were able to achieve an actual sample size of 54 test subjects. Those subjects who were not employees of the Texas Transportation Institute received financial compensation for participating in the study. Each driver possessed individual characteristics that might affect his/her ability to discern the sign legend. These factors were measured prior to data collection activities and are described below.
    - *Age* - The researchers and TxDOT Project Advisors determined that the research should emphasize alphabet performance among older drivers to be consistent with the findings of previous legibility research. Sekuler and Blake (48) reported that the declining visual performance associated with age results from the increased light absorption and light scattering in the lens of the eye that adds layers of cells throughout life. Therefore, older drivers provide the best subjects for legibility tests because they represent a "worst-case" model. A sign with legibility distance "*X*" for older drivers would have a greater legibility distance for the rest of the population. The researchers established a goal to have at least 75 percent of the test sample to be drivers over the age of 55. A small sample of younger drivers (less than 35 years old) were needed to provide a basis of comparison for the older drivers. A newspaper ad was used to recruit test subjects. The ad is provided in Appendix C.
    - *Visual Acuity* - Because legibility is a function of vision, the visual acuity of each test subject was measured using a standard Snellen eye chart (shown in Figure 9) at a distance of 6.1 m (20 ft).
    - *Contrast Sensitivity* - Contrast sensitivity tests were conducted using a Vistech VCTS® contrast sensitivity chart at a distance of 3.1 m (10 ft). This chart is shown in Figure 10. An advantage of using contrast sensitivity as an independent variable is that it provides a comprehensive measure of visual function across a range of sizes and contrasts that appear in the roadside environment (49). In addition, contrast sensitivity provides a predictor of glare sensitivity.
    - *Reaction Time* - The reaction time test used the PORTO-CLINIC® driver testing unit. This test required the subjects to release an accelerator in response to an unexpected signal. Further, the subject had to decide if a brake pedal should be pressed. Reaction time scores were expressed in hundredths of a second (sec/100).
    - *Seat Position* - As described later in the experimental procedure, more than one subject might be in the vehicle for any given trial. Therefore, the researchers also recorded the seat position of each subject.

### Fixed Factors

There were numerous factors that remained constant throughout the data collection effort. These factors included the following:

- **Type of Vehicle** - The same 1991 Ford Crown Victoria was used throughout the data collection effort. A photo of this vehicle is shown in Figure 11.

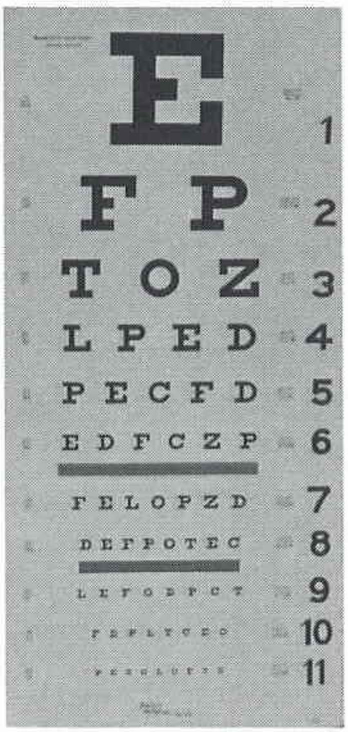



**Figure 9. Snellen Chart for Visual Acuity**

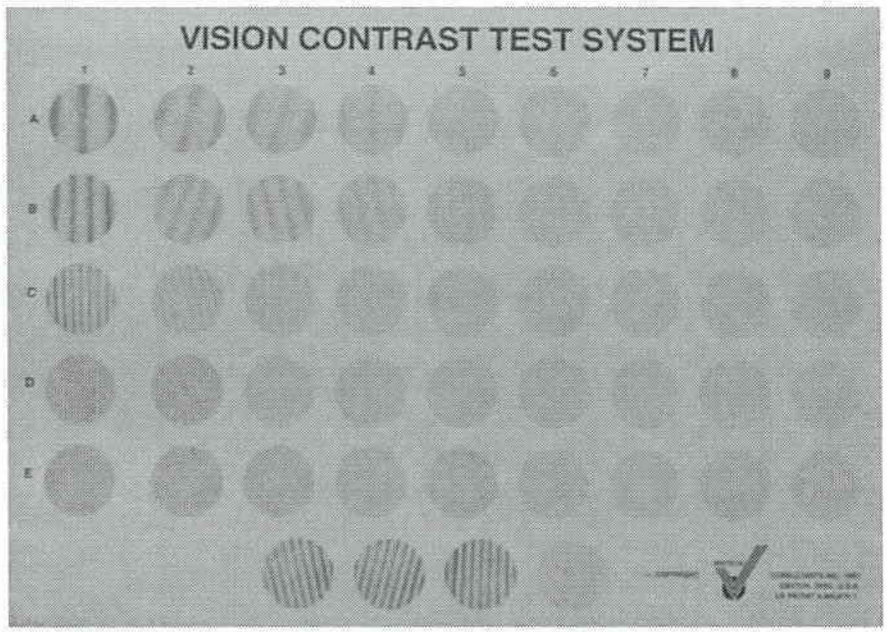



**Figure 10. Vistech Chart for Contrast Sensitivity**

**Figure 11. 1991 Crown Victoria Used Throughout Data Collection**

- **Type of Sheeting** - All sign background and sign legends were fabricated from high intensity, encapsulated lens sheeting (TxDOT Type C, ASTM Type III) purchased from the 3M Corporation.
- **Inter-letter Spacing** - Spacing between letters remained the same for all words in all three alphabets. For Series E(Modified), the standard spacing was used (12). For Clearview™, the spacing determined in the Preliminary Clearview™ Investigation was used (described below). During the Preliminary Clearview™ Investigation, the standard spacing for the Transport Medium alphabet was found to be too tight. For this research effort, the Transport Medium alphabet used a letter spacing that approximated the spacing used for Clearview™.
- **Inter-line Spacing** - The spacing between lines of legend was 356 mm (14 in). The same dimension was used between the edge of the border and the uppercase legend.
- **Sign Illumination** - No external sign illumination was used other than the vehicle headlights.
- **Alphabet Size** - All alphabets used a 400 mm (16 in) uppercase letter, with the appropriate lowercase letter height. For the Series E(Modified) alphabet, the loop height of the lowercase letter was 300 mm (12 in). For the other two, the lowercase height varied between letters.
- **Sign Panel Size** - All words were presented on a sign background that was 3.66×2.74 m (12×9 ft). The sign panel was originally 3.66×2.44 m (12×8 ft), but was increased in height by 0.31 m (1 ft) as a result of the Preliminary Clearview™ Investigation (described below).

**Preliminary Clearview™ Investigation**

At the time Clearview™ was selected as one of the alphabets for evaluation, the research at PTI was still underway and the results of that research had not been finalized. Also, there were some important differences between the PTI and TTI research that could have an impact on the legibility of Clearview™. The most significant of these was the difference in scale between the two experiments. The PTI research was conducted using a 125 mm (5 in) uppercase letter, while the TTI research was conducted with a 400 mm (16 in) uppercase letter. There was also uncertainty over which Clearview™ alphabet to include in the evaluation. Therefore, the researchers conducted a Preliminary Clearview™ Investigation with the following objectives:

- Select the version of Clearview™ to be evaluated.
- Determine the letter spacing to be used with Clearview™.
- Conduct initial assessments of the relative legibility of Series E(Modified), Clearview™, and British Transport Medium alphabets.

The preliminary investigation was conducted at the Texas A&M University Riverside Campus (the site of the formal data collection for this project). Participants included the researchers, the TxDOT Project Advisors, and several individuals involved in the development of Clearview™ as part of the PTI research. In preparation for the preliminary investigation, the researchers prepared 400/300 mm (16/12 in) upper/lowercase legends for the following alphabets:

- **Series E(Modified)** - Standard high intensity cut-out letters on high intensity background with standard letter spacing.
- **British Transport Medium** - Standard high intensity cut-out letters on high intensity background with standard British Transport letter spacing. This letter spacing produced a word with much tighter spacing than the Series E(Modified) spacing.
- **Clearview™** - Three height-to-stroke width versions of Clearview™ were produced on individual letter tiles. The tiles were used so that letter spacing could be varied to determine the optimal spacing. The three height-to-stroke width ratios were 5.2, 5.7, and 6.1, referred to as Clearview™ 5.2, Clearview™ 5.7, and Clearview™ 6.1.

Daytime and nighttime observations of all three alphabets were conducted using both ground-mounted and overhead sign panels. The investigation proved to be very beneficial and contributed significantly to the preparation of the experimental procedure. The following findings resulted from the investigation:

- For the letter sizes used in this investigation, the optimal letter spacing for Clearview™ was approximately the same as the spacing for Series E(Modified). This finding was contrary to the findings of the PTI study that indicated a tighter letter spacing could be achieved with Clearview™. The assessment of this finding was made easier by having individuals involved in the PTI research present for the investigation.
- The letter spacing for British Transport Medium was too tight and needed to be expanded to approximate the spacing for Clearview™ and Series E(Modified).
- The relative performance of the alphabets was different at different distances from the sign. Where one alphabet might be more legible at a long distance, a different alphabet would be more legible at a closer distance.
- Full-scale observations of Clearview™ letters in both daytime and nighttime conditions indicated the need for additional refinements of several letters.
- The height of the sign panels (2.44 m/8 ft) did not provide adequate spacing between lines of legend and required an increase in the sign height.
- Clearview™ 5.7 provided the best daytime legibility, and Clearview™ 6.1 appeared best at night. The general opinion of the participants was that Clearview™ 5.7 should be used in the formal data collection, with the assumption that the refinements to specific letters would improve the nighttime legibility.

## EXPERIMENTAL INFRASTRUCTURE

As the experimental plan evolved, the researchers recognized that, to conduct the experiment, they needed the ability to quickly present a variety of words in different alphabets in both overhead and ground-mounted positions. The need for quick and accurate data collection also indicated the need for somewhat automated data collection procedures within the experimental vehicle.

### Mock-Up Evaluations

One of the earliest experimental questions to be answered was the most effective means of presenting stimuli to test subjects in a manner that would minimize the setup time for each experimental trial. To experiment with different options, the researchers fabricated a reduced-scale mock-up guide sign using a 1.2×2.4 m (4×8 ft) sheet of plywood covered with green high intensity sheeting. Two words were fabricated from 300/225 mm (12/9 in) cut-out upper/lowercase letters. These letters were attached to 900×450 mm (36×18 in) aluminum blanks. Each word filled two blanks. Various means of attaching the blanks to the panel were evaluated until a satisfactory method was established that would allow for quick and accurate changing of the legends. Consideration was also given to the use of legend blanks made from other materials such as plastic or foam board. These materials were rejected over concerns about their durability and ability to survive weather and temperature extremes without warping. The researchers also used the mock-up to conduct some initial legibility evaluations to assess the range of legibility distances and the criticality of alignment for the legend blanks.

**Word Blanks**

Based on the identification of experimental factors and the results of the mock-up evaluations, the researchers determined that the full-scale 400/300 mm (16/12 in) legends should be presented on 1200×600×2 mm (4 ft ×2 ft × 0.080 in) aluminum blanks covered with green high intensity sheeting. Each word covered two blanks and was fabricated from cut-out letters using white high intensity sheeting. Figure 12 illustrates the use of these blanks.


**Figure 12. Sign Blanks for Presenting Stimuli**

**Sign Structures**

The infrastructure used two sign structures that could present three guide sign panels. Each of the panels was 3.66×2.74 m (12×9 ft). The panels were originally sized at 3.66×2.44 m (12×8 ft), but the Preliminary Clearview™ Investigation indicated that additional vertical spacing was needed between legends, and the height was increased by 0.31 m (1 ft). The panels were covered with green high intensity sheeting with a white high intensity border. Figure 13 illustrates the overall dimensions of the sign panels, the spacing of the legends, and the position of the aluminum blanks on the panels.

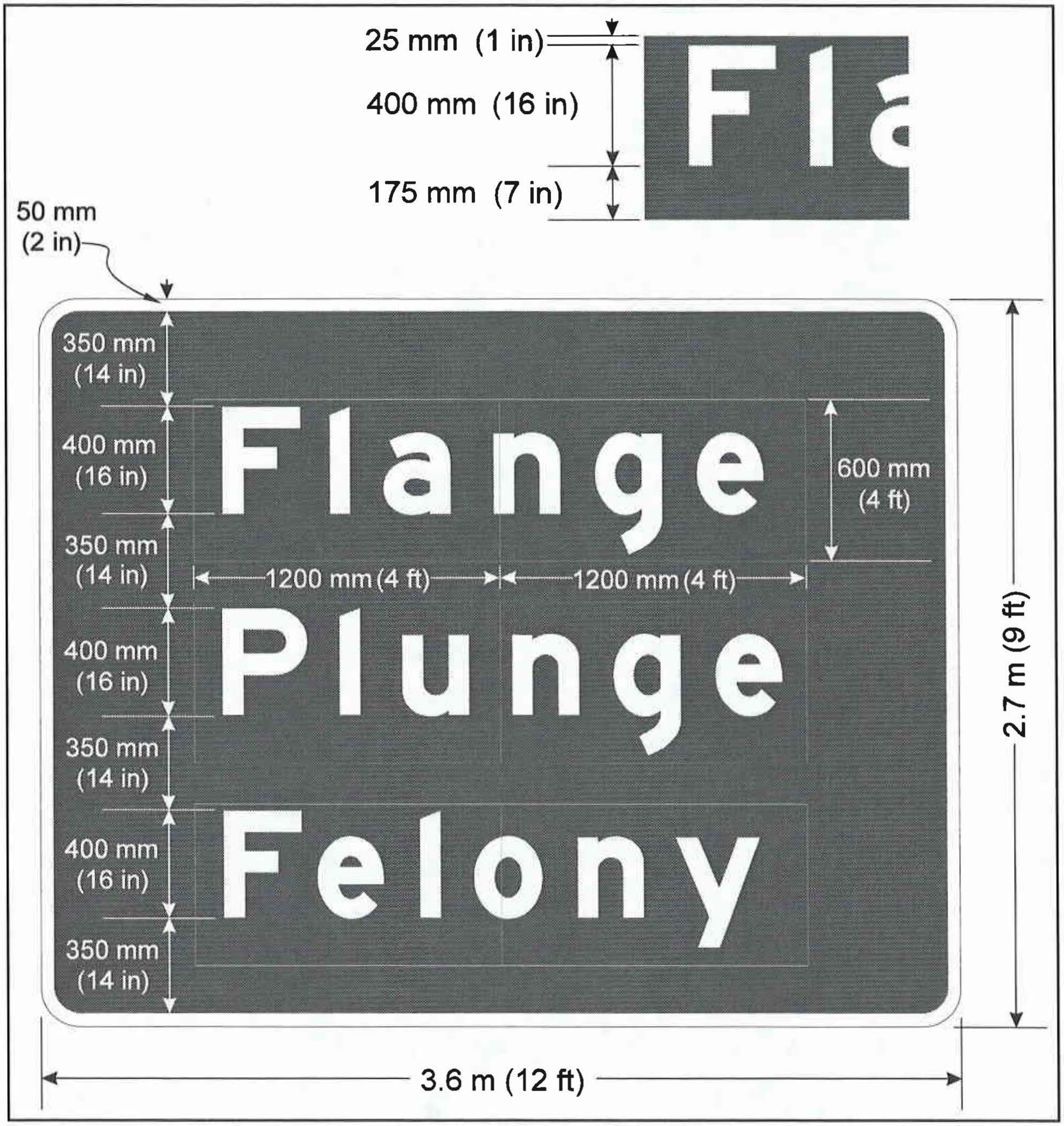



**Figure 13. Layout of Sign Panel and Legend**

The two sign structures were located on one of the runways at the Texas A&M University Riverside Campus. This facility is a decommissioned Air Force Base that was donated to Texas A&M University around 1950. It is located about 10 mi from the main campus. Figure 14 illustrates the arrangement of runways and taxiways at the Riverside Campus and indicates where the sign structures used in this experiment were located. The overhead structure had about 600 m (2,000 ft) of sight distance in each direction. The runway was level with no sight distance obstructions.

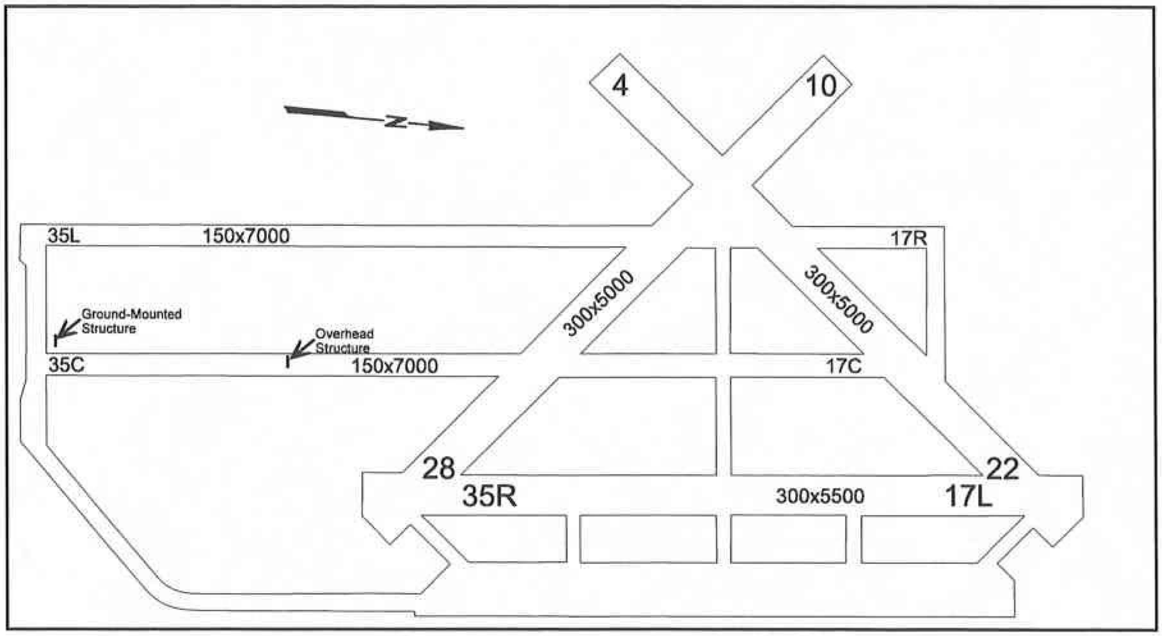



**Figure 14. Layout of Runways at Riverside Campus**

The ground-mounted structure at the south end of Runway 35C was mounted 2.1 m (7 ft) above the runway surface, with a lateral clearance of 9.2 m (30 ft) from the right edge of the indicated travel lane. This structure presented only one sign panel and could function only as a ground-mounted sign. The overhead structure contained two sign panels. Each panel could be presented in an overhead or ground-mounted position. However, since the 9.2 m (30 ft) lateral offset could only be achieved by a southbound vehicle, the sign panel facing northbound traffic was used only in the overhead position. The bottom of the overhead sign panel was 6.1 m (20 ft) above the pavement. Subjects approached this panel "head on" with zero lateral clearance. Figure 15 illustrates the approach paths of the vehicle for each sign position.

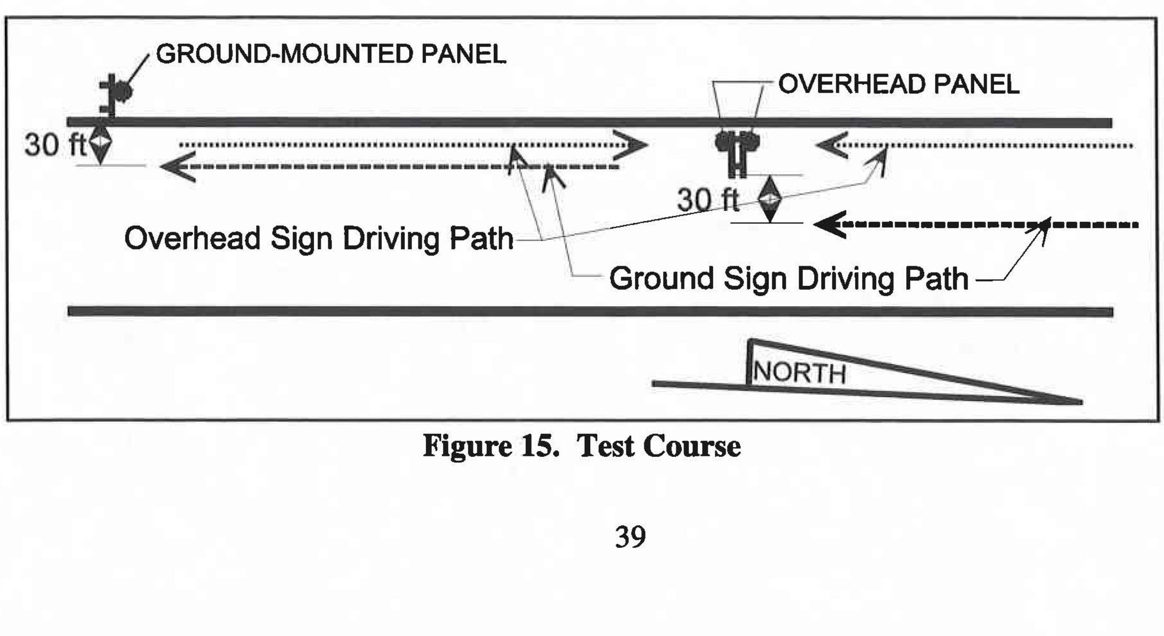



**Figure 15. Test Course**

Figure 16 is a photo of the combination ground/overhead sign structure and the ground-mounted sign structure. This structure was built with sign panels on each side of the assembly. Cables connecting the panels ran through pulleys to a manual winch. Each panel had its own winch and a separate counter weight. When a winch raised one panel to viewing height, the other panel could rest on the ground. This arrangement allowed the legends to be changed at ground level and increased safety for the sign crews.

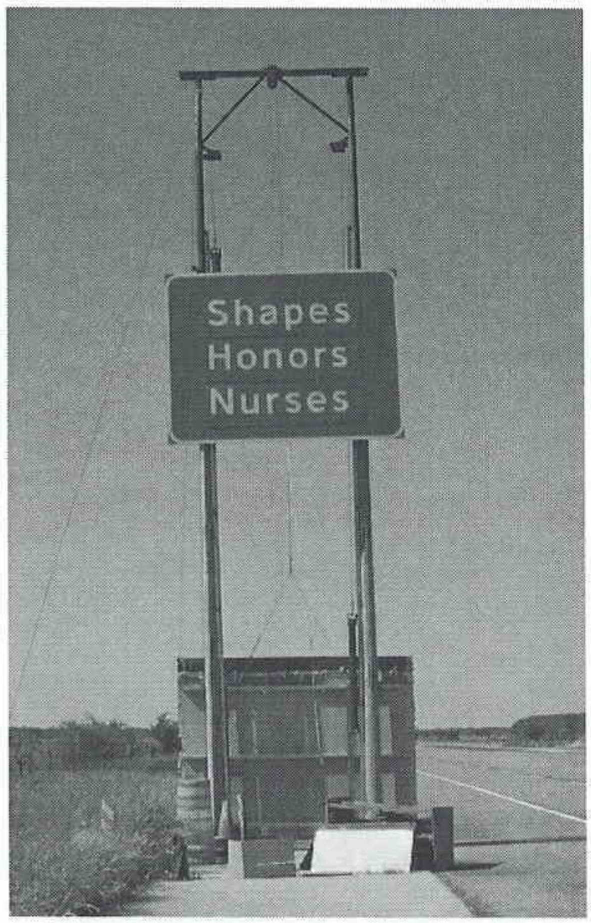



**Figure 16. Overhead Sign Structure**

## Vehicle and Data Recording

The experiment used a 4-door 1991 Ford Crown Victoria equipped with an Ash Instrumentation® Model S distance measuring instrument (DMI) and custom-built electronic keypads. Both the DMI and the keypads were connected to a Digital Equipment® Model HiNote VP laptop computer. Figure 17 shows a photo of the keypad. The experimenter set the DMI at a known distance from the sign before each trial. As the vehicle approached the sign, the DMI counted down the distance to the sign. When a test subject could read a word, he/she pressed a key corresponding to a word's position on the panel (top, middle, or bottom). The computer recorded the subject number, the trial number, the position of the word that the subject had identified (top, middle, or bottom), whether the task for the word was recognition or legibility, and the distance to the sign panel (obtained from the DMI at the time a button was pressed). This information was stored in an ASCII text file and was later downloaded into a spreadsheet program for analysis. Thus, the computer recorded all subject responses and provided a convenient method of data retrieval. A display (not visible to the subjects) indicated to the experimenter the subjects' responses (i.e., subject one pushed the top button). This was used by the experimenter to monitor and indicate incorrect responses.

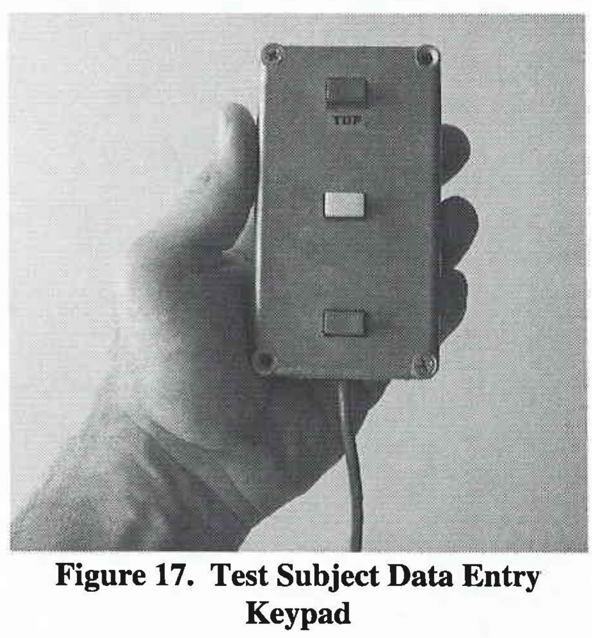



**Figure 17. Test Subject Data Entry Keypad**

## EXPERIMENTAL PLAN

As the researchers were narrowing down the various factors that would be addressed in the experiment, they were also developing the procedure that would be followed to collect the data. After this plan was developed, it was submitted to TxDOT and the Texas A&M Institutional Review Board (IRB) for approval.

### Experimental Plan Preparation

The experimental procedure was based on measuring legibility and recognition distances at three sign structures (the sign structures are described on page 37). One sign structure served as a ground-mounted sign, one as an overhead sign, and a third as either an overhead or ground-mounted sign. Because this experiment used human test subjects, differences in the responses of different people to the same treatment were very large. Consequently, a repeated measures design was used in the study, in which each of the three alphabet treatments were tested using each subject.

The experiment tested 21 words. Each word appeared three times in three different alphabets. Any given word appeared at least once as a legibility word and once as a recognition word. The experiment varied the word positions (overhead or ground-mounted) and their location on the sign panel (top, middle, bottom). Thus, the Clearview™ word *Senior*, for example, might appear on the top of an overhead sign as a legibility word, on the bottom of an overhead sign as a legibility word, and on the middle of a ground-mounted sign as a recognition word.

Individual panel displays were prepared, consisting of the three words to appear on each sign for a given trial. Recognition words that had ascenders or descenders were paired with at least one legibility word that had an ascender or descender; neutral words were paired with at least one neutral legibility word. All three words on a given sign display used the same alphabet. The order of the displays was assigned randomly and differed from day to night.

This experiment contained two parts, a legibility procedure and a recognition procedure (the procedures were conducted simultaneously). The experiment ran a pilot study before the actual data collection phase to practice each procedure. To obtain the best experimental control possible, every subject who participated in the study received the same set of instructions. Instructions for the legibility and recognition procedures are presented in Appendix C.

Subjects rode out to the test track in the Crown Victoria and were told to wear corrective lenses if they normally wore them while driving; subjects were not allowed to wear sunglasses. One subject sat in the front passenger side seat while two subjects sat in the rear seat. An experimenter drove the vehicle. Upon reaching the starting point, 600 m (2,000 ft) (day) or 500 m (1,600 ft) (night) from the first sign, the experimenter told the subjects that there were three words on the sign ahead and held up a card showing one of those three words (the recognition word). The word shown was in a large capital/small capital format that did not show ascenders or descenders (i.e., NURSES). For the night tests, experimenters illuminated the cards using a flashlight with a red filter, thus minimizing adverse impacts on the subjects' night visual adaptation.

Subjects were informed that whenever they could read a word, they should press the button on their keypads corresponding to that word's position on the sign (top, middle, or bottom) and then say the word aloud. Throughout the experiment, subjects wore headsets (earphones) and listened to white noise from a tape recorder in the front seat. White noise, or "static," tends to distort and filter out external sounds. It provided an effective means to prevent the subjects from hearing the other subjects' responses.

The experimenter drove the test vehicle forward along a straight path at 32 km/h (20 mph). As the subjects read the text and pushed buttons on their keypads, the experimenter monitored their responses. All responses were recorded using a laptop computer that automatically recorded the distance to the sign, trial number, subject number, and word position on the panel. If a subject made an incorrect response, the experimenter pushed a button on a separate keypad that attached an ERROR message in the ASCII file to the subject's response. The subjects were informed to be "*reasonably certain*" of their responses. As a baseline reference regarding their level of certainty, subjects were asked to respond when they were sure enough of the word that they would change lanes if they were driving and they saw their destination on a freeway guide sign. If they realized they made an error, (read one of the words incorrectly and/or pushed the wrong button on the keypad), they were instructed to correct themselves by saying the correct word and pressing the correct button. No penalty was assessed for errors. When all subjects had correctly read the first sign panel, the experimenter drove to the next starting point and reset the DMI. This procedure was repeated for a total of 54 trials.

### TxDOT and IRB Approval

Once a draft of the experimental plan was developed, it was forwarded to the TxDOT Project Advisors for review and comment. The plan was approved by the TxDOT panel, and it was forwarded to the Texas A&M University Institutional Review Board (IRB) for approval. The IRB approval is a federal requirement for any experiment or research that involves human subjects. The experimental plan submitted to IRB was approved with minor modifications. As part of the IRB approval requirements, test subjects were required to sign the informed consent form contained in Appendix C.

# CHAPTER 4
# RESULTS OF EVALUATIONS

The data collection effort followed the experimental plan described in the previous chapter and took place between January and June 1997. A total of 8,645 daytime and 8,652 nighttime data points were collected. This data represented the legibility and recognition distances of three alphabets in two different positions in both day and night conditions.

## SUBJECT DATA ANALYSIS

A total of 54 subjects participated in the data collection effort, with each subject providing both a full set of daytime and nighttime data. Prior to collecting the legibility data, each subject was tested to determine the subject's characteristics that were being used as the independent variables as described in the previous chapter (age, visual acuity, contrast sensitivity, reaction time). Appendix D presents a complete listing of the independent variables for each of the 54 test subjects.

### Age

The test subjects were grouped into three groupings: young (less than 35 years old), young-old (55-64 years old), and old-old (65 or more years old). The young drivers ranged in age from 21 to 35, the young-old drivers ranged in age from 56 to 64, and the old-old drivers ranged from 65 to 84 years old. There were no test subjects between the ages of 36 and 54. Of the 54 drivers participating in the experiment, there were 7 young drivers (13 percent of the sample), 18 young-old drivers (33 percent), and 29 old-old drivers (54 percent).

### Visual Acuity

The visual acuity of the drivers ranged from 20/15 to 20/70. Although the minimum visual acuity requirement in Texas for a driver's license is typically 20/40, the subjects with acuity levels below 20/40 were included in the sample because they all had valid Texas driver's licenses. Test subjects were grouped into three visual acuity groups for analysis: sharp (20/15 to 20/20), good (20/25 to 20/30), and marginal (20/40 to 20/70). Table 7 summarizes the number of subjects in each age and visual acuity group. Of the 13 drivers in the marginal acuity group, 6 of them had acuity levels worse than 20/40—4 at 20/50 and 2 at 20/70.

### Contrast Sensitivity

Another measure of visual capability is the contrast sensitivity. Contrast sensitivity was measured with the Vistech contrast sensitivity chart, as described in the previous chapter. Results of the test were plotted on charts similar to those shown in Figure 18. If the line connecting the individual scores fell largely within the shaded gray area, the driver was classified as having normal contrast sensitivity. If the line fell largely below the shaded area, then the contrast sensitivity was classified as marginal. Table 8 summarizes the contrast sensitivity by age group.

Table 7. Number of Subjects by Age and Visual Acuity

| Age Group | Visual Acuity | | | Totals |
|---|---|---|---|---|
| | Sharp (20/15 to 20/20) | Good (20/25 to 20/30) | Marginal (20/40 to 20/70) | |
| Young (<35) | 5 | 2 | 0 | 7 |
| Young-Old (55-64) | 11 | 4 | 3 | 18 |
| Old-Old (65+) | 7 | 12 | 10 | 29 |
| **Totals** | 23 | 18 | 13 | 54 |

Note: Each subject participated in both daytime and nighttime trials

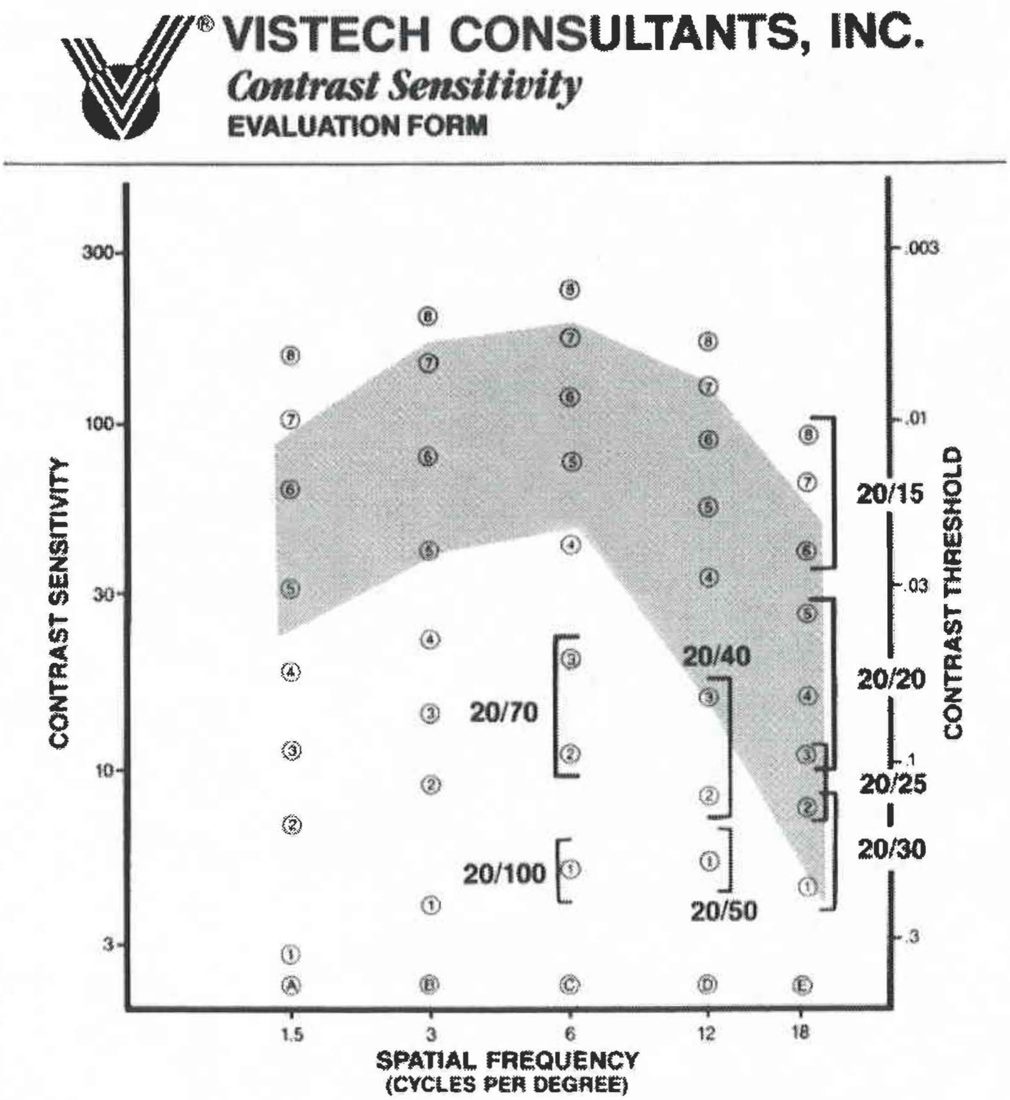



Figure 18. Contrast Sensitivity Rating Chart

**Table 8. Number of Subjects by Age and Contrast Sensitivity**

| Age Group | Contrast Sensitivity | | Totals |
|---|---|---|---|
| | Normal | Marginal | |
| Young (<35) | 2 | 5 | 7 |
| Young-Old (55-64) | 16 | 2 | 18 |
| Old-Old (65+) | 17 | 12 | 29 |
| **Totals** | 35 | 19 | 54 |

Note: Each subject participated in both daytime and nighttime trials

## Reaction Time

Although it is not a function of visual ability, the researchers also measured the reaction time of test subjects to determine if there is a relationship between legibility and reaction time. As described in the previous chapter, reaction time was measured with a Porto-Clinic® driver testing unit. The results of the reaction time test were arbitrarily divided into three groups as shown in Table 9. The values used to group the results were determined by having an equal number of test subjects in each group.

**Table 9. Number of Subjects by Age and Reaction Time**

| Age Group | Reaction Time (seconds) | | | Totals |
|---|---|---|---|---|
| | < 0.75 | 0.75-0.99 | ≥ 1.00 | |
| Young (<35) | 1 | 0 | 6 | 7 |
| Young-Old (55-64) | 8 | 8 | 2 | 18 |
| Old-Old (65+) | 9 | 10 | 10 | 29 |
| **Totals** | 18 | 18 | 18 | 54 |

Note: Each subject participated in both daytime and nighttime trials

## ANALYSIS OF DEPENDENT VARIABLES

The legibility and recognition distances were the dependent variables for the evaluations. The legibility distance was the distance (measured in feet) at which a test subject could read an unknown word. The recognition distance was the distance (measured in feet) at which a test subject could identify the position (top, middle, bottom) of a word that was specified before beginning the trial. There were two legibility words and one recognition word in each trial.

In analyzing the legibility and recognition data, the researchers calculated both mean and 85$^{th}$ percentile values for each alphabet (Series E(Modified), Clearview™, and Transport Medium) in each sign position (ground or overhead) under each lighting condition (day and night). The mean values represent the average legibility/recognition distance for the given set of conditions. The 85$^{th}$ percentile values represent the distance at which 85 percent of the test subjects could read/recognize the sign legend. The 85$^{th}$ percentile legibility/recognition distance is always less than the mean. As the percentile of driver accommodated increases, the legibility/recognition distances decrease (i.e., a 95$^{th}$ percentile distance would be less than the 85$^{th}$ percentile). The mean and 85$^{th}$ percentile values were calculated for the subject sample as a whole and further analyzed by age, visual acuity, and contrast sensitivity groupings.

**Legibility Distances**

Legibility distance, or the distance at which a person can read an unknown legend, is traditionally used as the measure of sign legibility. Figure 19 graphically presents the mean and 85$^{th}$ percentile legibility data for all drivers. Figure 20 graphically presents the mean legibility data as a function of driver age. The actual 85$^{th}$ percentile and mean legibility distances are presented in several tables as a function of age (Tables 10 and 11), visual acuity (Tables 12 and 13), contrast sensitivity (Tables 14 and 15), and reaction time (Tables 16 and 17).

**Recognition Distances**

Recognition distance, or the distance at which a person can recognize a legend or word that is known to the driver, is probably closer to the actual driver performance task (looking for and recognizing a known destination), but is not often reported. Figure 21 graphically presents the mean and 85$^{th}$ percentile recognition data for all drivers. Figure 22 graphically presents the mean recognition data as a function of driver age. The actual 85$^{th}$ percentile and mean recognition distances are presented in several tables as a function of age (Tables 18 and 19), visual acuity (Tables 20 and 21), contrast sensitivity (Tables 22 and 23), and reaction time (Tables 24 and 25).

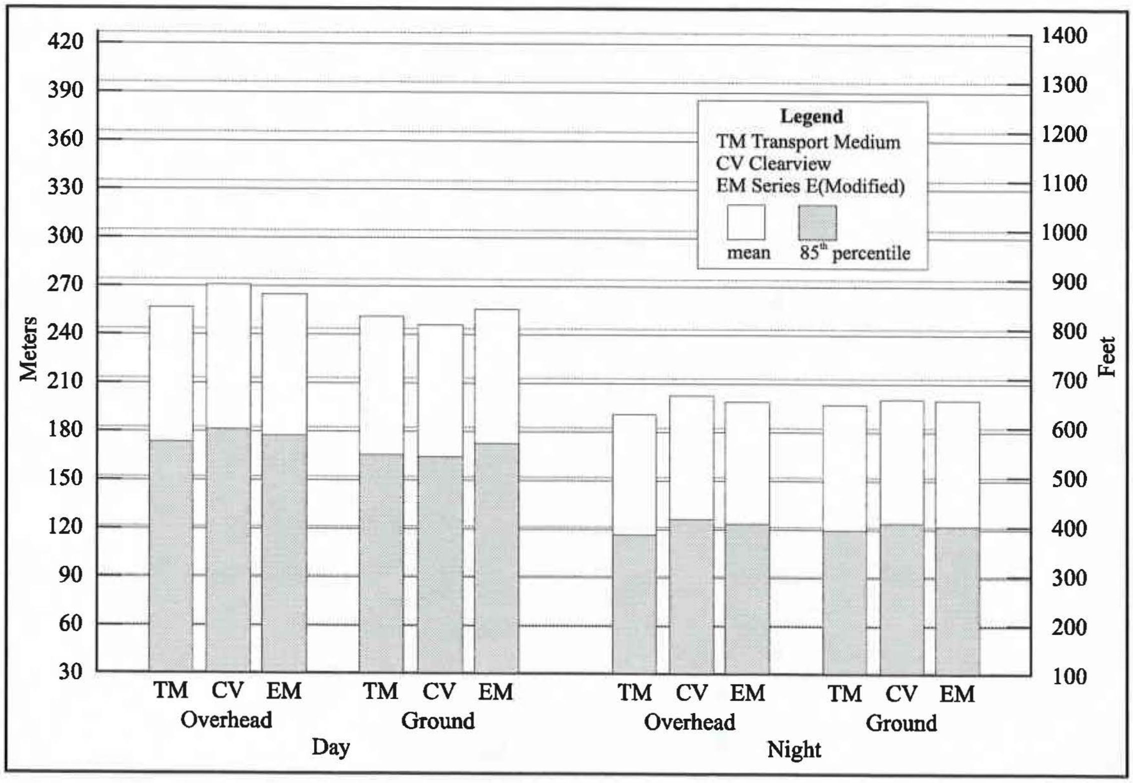



**Figure 19. Legibility Distance for All Drivers**

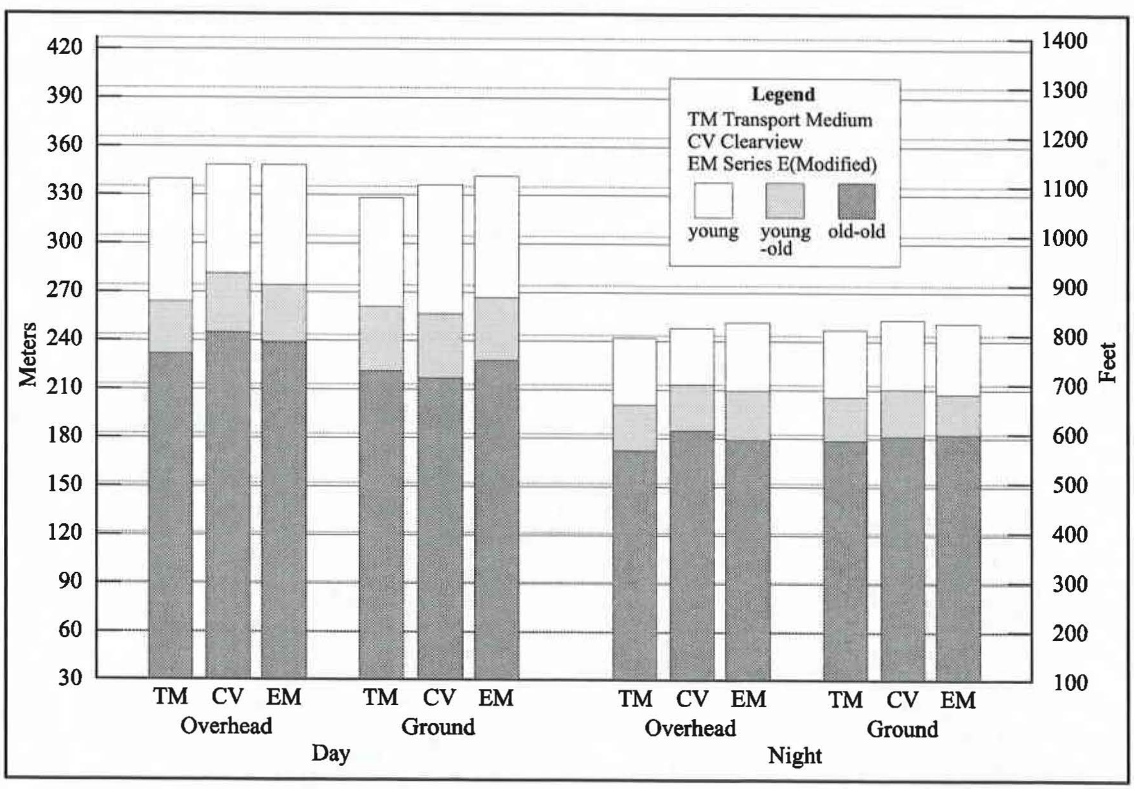



**Figure 20. Mean Legibility Distance by Driver Age**

**Table 10. 85th Percentile Legibility Distances by Driver Age**

| Time of Day | Alphabet | Sign Position | Driver Age All (m) | <40 (m) | 55-64 (m) | 65+ (m) | All (ft) | <40 (ft) | 55-64 (ft) | 65+ (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 172.9 | 270.8 | 194.9 | 150.4 | 567 | 888 | 639 | 493 |
| | | Ground | 165.0 | 255.3 | 194.9 | 145.5 | 541 | 837 | 639 | 477 |
| | Clearview™ | Overhead | 180.6 | 280.9 | 213.5 | 158.9 | 592 | 921 | 700 | 521 |
| | | Ground | 163.8 | 260.8 | 192.8 | 141.2 | 537 | 855 | 632 | 463 |
| | Series E(Modified) | Overhead | 176.9 | 272.1 | 199.8 | 157.4 | 580 | 892 | 655 | 516 |
| | | Ground | 172.0 | 269.6 | 202.8 | 151.6 | 564 | 884 | 665 | 497 |
| Night | Transport Medium | Overhead | 115.9 | 162.3 | 134.5 | 100.7 | 380 | 532 | 441 | 330 |
| | | Ground | 119.0 | 166.8 | 136.3 | 105.2 | 390 | 547 | 447 | 345 |
| | Clearview™ | Overhead | 125.7 | 171.7 | 140.6 | 108.6 | 412 | 563 | 461 | 356 |
| | | Ground | 123.2 | 168.1 | 143.0 | 107.7 | 404 | 551 | 469 | 353 |
| | Series E(Modified) | Overhead | 122.9 | 173.5 | 149.1 | 108.0 | 403 | 569 | 489 | 354 |
| | | Ground | 121.4 | 175.4 | 133.9 | 107.4 | 398 | 575 | 439 | 352 |
| Day | Minimum | | 163.8 | 255.3 | 192.8 | 141.2 | 537 | 837 | 632 | 463 |
| | Maximum | | 180.6 | 280.9 | 213.5 | 158.9 | 592 | 921 | 700 | 521 |
| Night | Minimum | | 115.9 | 162.3 | 133.9 | 100.7 | 380 | 532 | 439 | 330 |
| | Maximum | | 125.7 | 175.4 | 149.1 | 108.6 | 412 | 575 | 489 | 356 |

**Table 11. Mean Legibility Distances by Driver Age**

| Time of Day | Alphabet | Sign Position | Driver Age All (m) | <40 (m) | 55-64 (m) | 65+ (m) | All (ft) | <40 (ft) | 55-64 (ft) | 65+ (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 255.9 | 338.9 | 263.2 | 230.9 | 839 | 1111 | 863 | 757 |
| | | Ground | 250.4 | 327.3 | 260.2 | 220.5 | 821 | 1073 | 853 | 723 |
| | Clearview™ | Overhead | 269.9 | 347.7 | 280.6 | 244.3 | 885 | 1140 | 920 | 801 |
| | | Ground | 245.2 | 335.5 | 255.9 | 216.2 | 804 | 1100 | 839 | 709 |
| | Series E(Modified) | Overhead | 264.1 | 347.7 | 273.6 | 238.2 | 866 | 1140 | 897 | 781 |
| | | Ground | 255.0 | 341.0 | 266.0 | 227.2 | 836 | 1118 | 872 | 745 |
| Night | Transport Medium | Overhead | 190.3 | 241.3 | 200.1 | 171.7 | 624 | 791 | 656 | 563 |
| | | Ground | 196.1 | 246.4 | 205.0 | 178.1 | 643 | 808 | 672 | 584 |
| | Clearview™ | Overhead | 201.9 | 247.4 | 212.6 | 184.2 | 662 | 811 | 697 | 604 |
| | | Ground | 199.8 | 252.5 | 209.5 | 180.6 | 655 | 828 | 687 | 592 |
| | Series E(Modified) | Overhead | 198.3 | 251.0 | 208.9 | 178.4 | 650 | 823 | 685 | 585 |
| | | Ground | 199.2 | 250.4 | 206.8 | 181.8 | 653 | 821 | 678 | 596 |
| Day | Minimum | | 245.2 | 327.3 | 255.9 | 216.2 | 804 | 1073 | 839 | 709 |
| | Maximum | | 269.9 | 347.7 | 280.6 | 244.3 | 885 | 1140 | 920 | 801 |
| Night | Minimum | | 190.3 | 241.3 | 200.1 | 171.7 | 624 | 791 | 656 | 563 |
| | Maximum | | 201.9 | 252.5 | 212.6 | 184.2 | 662 | 828 | 697 | 604 |

## Table 12. 85th Percentile Legibility Distances by Visual Acuity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | Sharp | Good | Marginal | All | Sharp | Good | Marginal |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 215.0 | 189.7 | 126.9 | 567 | 705 | 622 | 416 |
| | | Ground | 165.0 | 222.0 | 172.6 | 108.0 | 541 | 728 | 566 | 354 |
| | Clearview™ | Overhead | 180.6 | 233.9 | 183.9 | 131.5 | 592 | 767 | 603 | 431 |
| | | Ground | 163.8 | 212.3 | 177.2 | 109.2 | 537 | 696 | 581 | 358 |
| | Series E(Modified) | Overhead | 176.9 | 235.2 | 185.1 | 133.0 | 580 | 771 | 607 | 436 |
| | | Ground | 172.0 | 231.5 | 176.9 | 122.0 | 564 | 759 | 580 | 400 |
| Night | Transport Medium | Overhead | 115.9 | 170.5 | 122.0 | 66.8 | 380 | 559 | 400 | 219 |
| | | Ground | 119.0 | 178.1 | 131.5 | 74.7 | 390 | 584 | 431 | 245 |
| | Clearview™ | Overhead | 125.7 | 181.8 | 133.6 | 82.0 | 412 | 596 | 438 | 269 |
| | | Ground | 123.2 | 181.5 | 129.9 | 71.7 | 404 | 595 | 426 | 235 |
| | Series E(Modified) | Overhead | 122.9 | 178.7 | 130.2 | 77.2 | 403 | 586 | 427 | 253 |
| | | Ground | 121.4 | 177.8 | 130.2 | 75.0 | 398 | 583 | 427 | 246 |
| Day | Minimum | | 163.8 | 212.3 | 172.6 | 108.0 | 537 | 696 | 566 | 354 |
| | Maximum | | 180.6 | 235.2 | 189.7 | 133.0 | 592 | 771 | 622 | 436 |
| Night | Minimum | | 115.9 | 170.5 | 122.0 | 66.8 | 380 | 559 | 400 | 219 |
| | Maximum | | 125.7 | 181.8 | 133.6 | 82.0 | 412 | 596 | 438 | 269 |

## Table 13. Mean Legibility Distances by Visual Acuity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | Sharp | Good | Marginal | All | Sharp | Good | Marginal |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 299.2 | 243.7 | 194.9 | 567 | 981 | 799 | 639 |
| | | Ground | 165.0 | 291.3 | 234.2 | 188.5 | 541 | 955 | 768 | 618 |
| | Clearview™ | Overhead | 180.6 | 316.3 | 252.2 | 211.1 | 592 | 1037 | 827 | 692 |
| | | Ground | 163.8 | 287.3 | 235.2 | 183.0 | 537 | 942 | 771 | 600 |
| | Series E(Modified) | Overhead | 176.9 | 308.4 | 250.7 | 204.7 | 580 | 1011 | 822 | 671 |
| | | Ground | 172.0 | 300.4 | 241.0 | 194.0 | 564 | 985 | 790 | 636 |
| Night | Transport Medium | Overhead | 115.9 | 232.7 | 174.5 | 134.8 | 380 | 763 | 572 | 442 |
| | | Ground | 119.0 | 241.6 | 181.5 | 135.1 | 390 | 792 | 595 | 443 |
| | Clearview™ | Overhead | 125.7 | 248.9 | 185.7 | 142.1 | 412 | 816 | 609 | 466 |
| | | Ground | 123.2 | 244.9 | 185.1 | 138.8 | 404 | 803 | 607 | 455 |
| | Series E(Modified) | Overhead | 122.9 | 244.3 | 183.3 | 136.3 | 403 | 801 | 601 | 447 |
| | | Ground | 121.4 | 244.0 | 184.2 | 139.7 | 398 | 800 | 604 | 458 |
| Day | Minimum | | 163.8 | 287.3 | 234.2 | 183.0 | 537 | 942 | 768 | 600 |
| | Maximum | | 180.6 | 316.3 | 252.2 | 211.1 | 592 | 1037 | 827 | 692 |
| Night | Minimum | | 115.9 | 232.7 | 174.5 | 134.8 | 380 | 763 | 572 | 442 |
| | Maximum | | 125.7 | 248.9 | 185.7 | 142.1 | 412 | 816 | 609 | 466 |

## Table 14. 85th Percentile Legibility Distances by Contrast Sensitivity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | All | Normal | Marginal | All | Normal | Marginal |
| | | | m | | | ft | | |
| Day | Transport Medium | Overhead | 172.9 | 194.6 | 138.5 | 567 | 638 | 454 |
| | | Ground | 165.0 | 198.3 | 126.6 | 541 | 650 | 415 |
| | Clearview™ | Overhead | 180.6 | 210.5 | 148.5 | 592 | 690 | 487 |
| | | Ground | 163.8 | 194.9 | 124.1 | 537 | 639 | 407 |
| | Series E(Modified) | Overhead | 176.9 | 212.6 | 144.9 | 580 | 697 | 475 |
| | | Ground | 172.0 | 201.6 | 135.1 | 564 | 661 | 443 |
| Night | Transport Medium | Overhead | 115.9 | 151.6 | 71.4 | 380 | 497 | 234 |
| | | Ground | 119.0 | 150.7 | 81.1 | 390 | 494 | 266 |
| | Clearview™ | Overhead | 125.7 | 155.2 | 86.0 | 412 | 509 | 282 |
| | | Ground | 123.2 | 151.3 | 76.6 | 404 | 496 | 251 |
| | Series E(Modified) | Overhead | 122.9 | 155.2 | 84.5 | 403 | 509 | 277 |
| | | Ground | 121.4 | 146.7 | 83.3 | 398 | 481 | 273 |
| Day | Minimum | | 163.8 | 194.6 | 124.1 | 537 | 638 | 407 |
| | Maximum | | 180.6 | 212.6 | 148.5 | 592 | 697 | 487 |
| Night | Minimum | | 115.9 | 146.7 | 71.4 | 380 | 481 | 234 |
| | Maximum | | 125.7 | 155.2 | 86.0 | 412 | 509 | 282 |

## Table 15. Mean Legibility Distances by Contrast Sensitivity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | All | Normal | Marginal | All | Normal | Marginal |
| | | | m | | | ft | | |
| Day | Transport Medium | Overhead | 172.9 | 270.8 | 228.1 | 567 | 888 | 748 |
| | | Ground | 165.0 | 267.8 | 210.5 | 541 | 878 | 690 |
| | Clearview™ | Overhead | 180.6 | 288.8 | 234.2 | 592 | 947 | 768 |
| | | Ground | 163.8 | 262.9 | 212.3 | 537 | 862 | 696 |
| | Series E(Modified) | Overhead | 176.9 | 284.6 | 226.6 | 580 | 933 | 743 |
| | | Ground | 172.0 | 274.5 | 218.7 | 564 | 900 | 717 |
| Night | Transport Medium | Overhead | 115.9 | 210.8 | 148.2 | 380 | 691 | 486 |
| | | Ground | 119.0 | 215.9 | 155.9 | 390 | 708 | 511 |
| | Clearview™ | Overhead | 125.7 | 222.0 | 162.3 | 412 | 728 | 532 |
| | | Ground | 123.2 | 219.9 | 158.9 | 404 | 721 | 521 |
| | Series E(Modified) | Overhead | 122.9 | 218.1 | 158.3 | 403 | 715 | 519 |
| | | Ground | 121.4 | 217.5 | 162.0 | 398 | 713 | 531 |
| Day | Minimum | | 163.8 | 262.9 | 210.5 | 537 | 862 | 690 |
| | Maximum | | 180.6 | 288.8 | 234.2 | 592 | 947 | 768 |
| Night | Minimum | | 115.9 | 210.8 | 148.2 | 380 | 691 | 486 |
| | Maximum | | 125.7 | 222.0 | 162.3 | 412 | 728 | 532 |

**Table 16. 85th Percentile Legibility Distances by Reaction Time**

| Time of Day | Alphabet | Sign Position | Driver Reaction Time (seconds) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <0.75 | .75-.99 | ≥1.00 | All | <0.75 | .75-.99 | ≥1.00 |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 199.2 | 159.8 | 160.1 | 567 | 653 | 524 | 525 |
| | | Ground | 165.0 | 196.7 | 145.8 | 158.3 | 541 | 645 | 478 | 519 |
| | Clearview™ | Overhead | 180.6 | 214.7 | 158.9 | 173.2 | 592 | 704 | 521 | 568 |
| | | Ground | 163.8 | 197.3 | 138.5 | 158.9 | 537 | 647 | 454 | 521 |
| | Series E(Modified) | Overhead | 176.9 | 208.0 | 159.2 | 172.9 | 580 | 682 | 522 | 567 |
| | | Ground | 172.0 | 202.8 | 146.1 | 163.8 | 564 | 665 | 479 | 537 |
| Night | Transport Medium | Overhead | 115.9 | 147.6 | 88.5 | 110.1 | 380 | 484 | 290 | 361 |
| | | Ground | 119.0 | 147.9 | 95.5 | 101.0 | 390 | 485 | 313 | 331 |
| | Clearview™ | Overhead | 125.7 | 158.6 | 103.7 | 112.5 | 412 | 520 | 340 | 369 |
| | | Ground | 123.2 | 150.1 | 85.1 | 112.5 | 404 | 492 | 279 | 369 |
| | Series E(Modified) | Overhead | 122.9 | 153.7 | 102.8 | 110.7 | 403 | 504 | 337 | 363 |
| | | Ground | 121.4 | 144.9 | 102.5 | 107.1 | 398 | 475 | 336 | 351 |
| Day | Minimum | | 163.8 | 196.7 | 138.5 | 158.3 | 537 | 645 | 454 | 519 |
| | Maximum | | 180.6 | 214.7 | 159.8 | 173.2 | 592 | 704 | 524 | 568 |
| Night | Minimum | | 115.9 | 144.9 | 85.1 | 101.0 | 380 | 475 | 279 | 331 |
| | Maximum | | 125.7 | 158.6 | 103.7 | 112.5 | 412 | 520 | 340 | 369 |

**Table 17. Mean Legibility Distances by Reaction Time**

| Time of Day | Alphabet | Sign Position | Driver Reaction Time (seconds) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <0.75 | .75-.99 | ≥1.00 | All | <0.75 | .75-.99 | ≥1.00 |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 281.8 | 231.8 | 254.1 | 567 | 924 | 760 | 833 |
| | | Ground | 165.0 | 274.2 | 224.2 | 244.9 | 541 | 899 | 735 | 803 |
| | Clearview™ | Overhead | 180.6 | 299.8 | 244.6 | 264.7 | 592 | 983 | 802 | 868 |
| | | Ground | 163.8 | 270.2 | 219.3 | 245.8 | 537 | 886 | 719 | 806 |
| | Series E(Modified) | Overhead | 176.9 | 290.1 | 241.3 | 261.7 | 580 | 951 | 791 | 858 |
| | | Ground | 172.0 | 283.7 | 231.2 | 250.4 | 564 | 930 | 758 | 821 |
| Night | Transport Medium | Overhead | 115.9 | 220.5 | 170.2 | 179.3 | 380 | 723 | 558 | 588 |
| | | Ground | 119.0 | 221.4 | 184.2 | 181.5 | 390 | 726 | 604 | 595 |
| | Clearview™ | Overhead | 125.7 | 232.4 | 186.7 | 186.7 | 412 | 762 | 612 | 612 |
| | | Ground | 123.2 | 226.6 | 184.5 | 187.0 | 404 | 743 | 605 | 613 |
| | Series E(Modified) | Overhead | 122.9 | 226.9 | 182.1 | 184.2 | 403 | 744 | 597 | 604 |
| | | Ground | 121.4 | 225.1 | 186.4 | 185.1 | 398 | 738 | 611 | 607 |
| Day | Minimum | | 163.8 | 270.2 | 219.3 | 244.9 | 537 | 886 | 719 | 803 |
| | Maximum | | 180.6 | 299.8 | 244.6 | 264.7 | 592 | 983 | 802 | 868 |
| Night | Minimum | | 115.9 | 220.5 | 170.2 | 179.3 | 380 | 723 | 558 | 588 |
| | Maximum | | 125.7 | 232.4 | 186.7 | 187.0 | 412 | 762 | 612 | 613 |

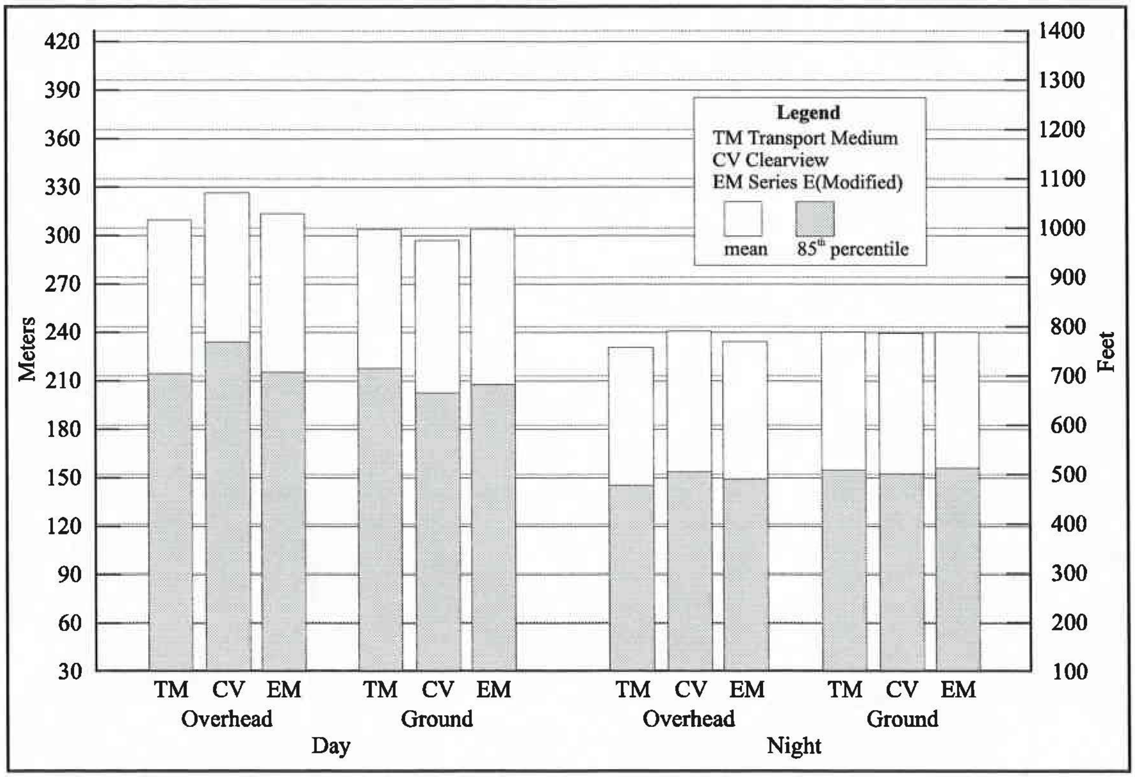



**Figure 21. Recognition Distance for All Drivers**

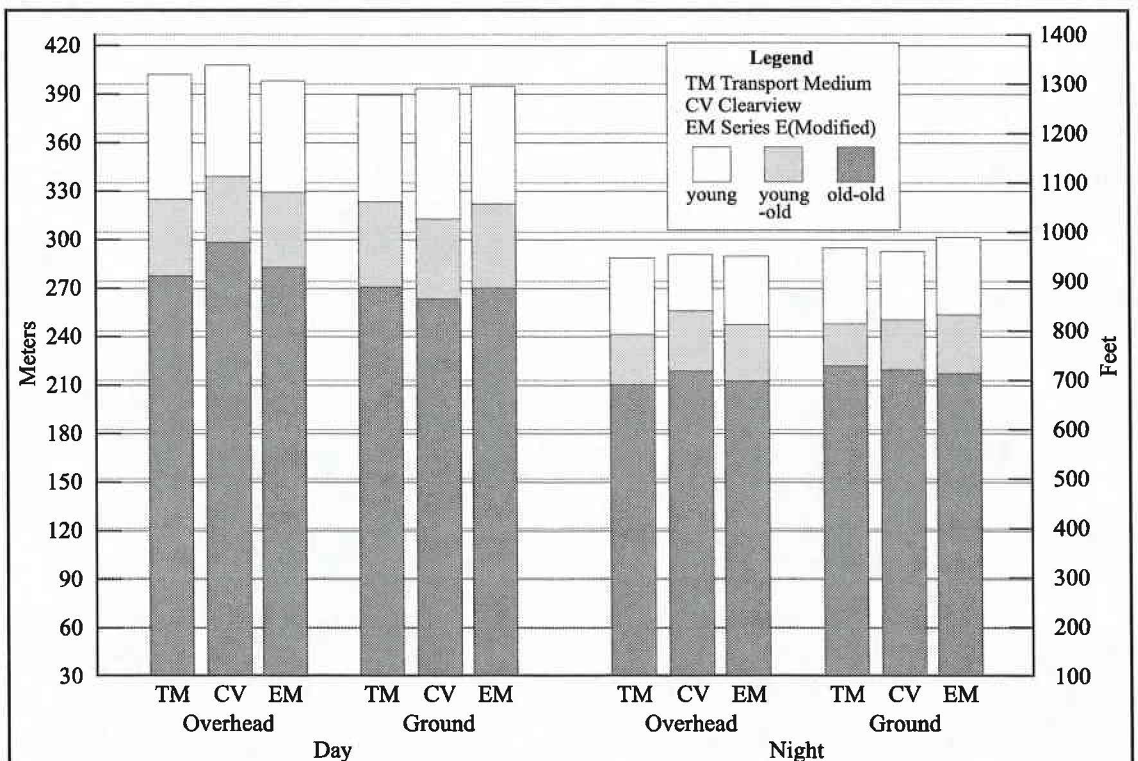



**Figure 22. Mean Recognition Distance by Driver Age**

**Table 18. 85th Percentile Recognition Distances by Driver Age**

| Time of Day | Alphabet | Sign Position | Driver Age All (m) | <40 (m) | 55-64 (m) | 65+ (m) | All (ft) | <40 (ft) | 55-64 (ft) | 65+ (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 213.8 | 302.6 | 261.4 | 179.3 | 701 | 992 | 857 | 588 |
| | | Ground | 217.2 | 284.0 | 248.3 | 181.5 | 712 | 931 | 814 | 595 |
| | Clearview™ | Overhead | 233.3 | 302.6 | 267.5 | 196.1 | 765 | 992 | 877 | 643 |
| | | Ground | 201.9 | 287.6 | 254.1 | 176.3 | 662 | 943 | 833 | 578 |
| | Series E(Modified) | Overhead | 214.7 | 298.3 | 256.2 | 180.6 | 704 | 978 | 840 | 592 |
| | | Ground | 207.1 | 302.3 | 252.2 | 176.3 | 679 | 991 | 827 | 578 |
| Night | Transport Medium | Overhead | 144.9 | 209.2 | 172.0 | 130.5 | 475 | 686 | 564 | 428 |
| | | Ground | 154.3 | 211.4 | 161.0 | 143.0 | 506 | 693 | 528 | 469 |
| | Clearview™ | Overhead | 153.1 | 201.6 | 179.3 | 138.8 | 502 | 661 | 588 | 455 |
| | | Ground | 151.9 | 206.8 | 173.5 | 138.5 | 498 | 678 | 569 | 454 |
| | Series E(Modified) | Overhead | 148.8 | 193.7 | 175.4 | 132.7 | 488 | 635 | 575 | 435 |
| | | Ground | 155.6 | 207.4 | 173.5 | 127.5 | 510 | 680 | 569 | 418 |
| Day | Minimum | | 201.9 | 284.0 | 248.3 | 176.3 | 662 | 931 | 814 | 578 |
| | Maximum | | 233.3 | 302.6 | 267.5 | 196.1 | 765 | 992 | 877 | 643 |
| Night | Minimum | | 144.9 | 193.7 | 161.0 | 127.5 | 475 | 635 | 528 | 418 |
| | Maximum | | 155.6 | 211.4 | 179.3 | 143.0 | 510 | 693 | 588 | 469 |

**Table 19. Mean Recognition Distances by Driver Age**

| Time of Day | Alphabet | Sign Position | Driver Age All (m) | <40 (m) | 55-64 (m) | 65+ (m) | All (ft) | <40 (ft) | 55-64 (ft) | 65+ (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 309.0 | 401.4 | 324.2 | 276.9 | 1013 | 1316 | 1063 | 908 |
| | | Ground | 303.2 | 388.9 | 322.7 | 270.2 | 994 | 1275 | 1058 | 886 |
| | Clearview™ | Overhead | 325.7 | 407.2 | 338.2 | 297.7 | 1068 | 1335 | 1109 | 976 |
| | | Ground | 296.2 | 392.8 | 312.0 | 262.6 | 971 | 1288 | 1023 | 861 |
| | Series E(Modified) | Overhead | 312.9 | 397.4 | 328.8 | 282.1 | 1026 | 1303 | 1078 | 925 |
| | | Ground | 303.2 | 394.1 | 321.5 | 269.3 | 994 | 1292 | 1054 | 883 |
| Night | Transport Medium | Overhead | 230.0 | 287.9 | 240.6 | 209.5 | 754 | 944 | 789 | 687 |
| | | Ground | 239.4 | 294.3 | 247.4 | 221.4 | 785 | 965 | 811 | 726 |
| | Clearview™ | Overhead | 240.0 | 290.1 | 255.3 | 218.1 | 787 | 951 | 837 | 715 |
| | | Ground | 238.8 | 292.2 | 249.8 | 219.0 | 783 | 958 | 819 | 718 |
| | Series E(Modified) | Overhead | 233.6 | 289.1 | 246.7 | 212.0 | 766 | 948 | 809 | 695 |
| | | Ground | 239.4 | 300.7 | 252.8 | 216.6 | 785 | 986 | 829 | 710 |
| Day | Minimum | | 296.2 | 388.9 | 312.0 | 262.6 | 971 | 1275 | 1023 | 861 |
| | Maximum | | 325.7 | 407.2 | 338.2 | 297.7 | 1068 | 1335 | 1109 | 976 |
| Night | Minimum | | 230.0 | 287.9 | 240.6 | 209.5 | 754 | 944 | 789 | 687 |
| | Maximum | | 240.0 | 300.7 | 255.3 | 221.4 | 787 | 986 | 837 | 726 |

## Table 20. 85th Percentile Recognition Distances by Visual Acuity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | Sharp | Good | Marginal | All | Sharp | Good | Marginal |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 282.7 | 216.2 | 164.7 | 567 | 927 | 709 | 540 |
| | | Ground | 165.0 | 273.6 | 218.7 | 135.7 | 541 | 897 | 717 | 445 |
| | Clearview™ | Overhead | 180.6 | 292.2 | 231.8 | 156.2 | 592 | 958 | 760 | 512 |
| | | Ground | 163.8 | 265.0 | 206.8 | 143.7 | 537 | 869 | 678 | 471 |
| | Series E(Modified) | Overhead | 176.9 | 279.4 | 219.0 | 151.3 | 580 | 916 | 718 | 496 |
| | | Ground | 172.0 | 276.9 | 211.1 | 149.1 | 564 | 908 | 692 | 489 |
| Night | Transport Medium | Overhead | 115.9 | 211.4 | 150.4 | 95.5 | 380 | 693 | 493 | 313 |
| | | Ground | 119.0 | 231.5 | 154.3 | 90.9 | 390 | 759 | 506 | 298 |
| | Clearview™ | Overhead | 125.7 | 224.2 | 154.3 | 109.8 | 412 | 735 | 506 | 360 |
| | | Ground | 123.2 | 221.7 | 153.1 | 102.8 | 404 | 727 | 502 | 337 |
| | Series E(Modified) | Overhead | 122.9 | 221.1 | 151.3 | 109.5 | 403 | 725 | 496 | 359 |
| | | Ground | 121.4 | 225.7 | 163.2 | 100.3 | 398 | 740 | 535 | 329 |
| Day | Minimum | | 163.8 | 265.0 | 206.8 | 135.7 | 537 | 869 | 678 | 445 |
| | Maximum | | 180.6 | 292.2 | 231.8 | 164.7 | 592 | 958 | 760 | 540 |
| Night | Minimum | | 115.9 | 211.4 | 150.4 | 90.9 | 380 | 693 | 493 | 298 |
| | Maximum | | 125.7 | 231.5 | 163.2 | 109.8 | 412 | 759 | 535 | 360 |

## Table 21. Mean Recognition Distances by Visual Acuity

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | Sharp | Good | Marginal | All | Sharp | Good | Marginal |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 362.0 | 284.9 | 247.1 | 567 | 1187 | 934 | 810 |
| | | Ground | 165.0 | 357.8 | 278.8 | 240.3 | 541 | 1173 | 914 | 788 |
| | Clearview™ | Overhead | 180.6 | 378.8 | 300.1 | 265.7 | 592 | 1242 | 984 | 871 |
| | | Ground | 163.8 | 345.6 | 273.0 | 240.3 | 537 | 1133 | 895 | 788 |
| | Series E(Modified) | Overhead | 176.9 | 363.6 | 292.5 | 251.6 | 580 | 1192 | 959 | 825 |
| | | Ground | 172.0 | 359.0 | 277.2 | 240.0 | 564 | 1177 | 909 | 787 |
| Night | Transport Medium | Overhead | 115.9 | 276.9 | 211.4 | 172.9 | 380 | 908 | 693 | 567 |
| | | Ground | 119.0 | 290.1 | 219.6 | 178.1 | 390 | 951 | 720 | 584 |
| | Clearview™ | Overhead | 125.7 | 292.2 | 215.0 | 183.9 | 412 | 958 | 705 | 603 |
| | | Ground | 123.2 | 287.0 | 217.2 | 182.1 | 404 | 941 | 712 | 597 |
| | Series E(Modified) | Overhead | 122.9 | 284.0 | 214.4 | 171.4 | 403 | 931 | 703 | 562 |
| | | Ground | 121.4 | 290.1 | 219.6 | 178.4 | 398 | 951 | 720 | 585 |
| Day | Minimum | | 163.8 | 345.6 | 273.0 | 240.0 | 537 | 1133 | 895 | 787 |
| | Maximum | | 180.6 | 378.8 | 300.1 | 265.7 | 592 | 1242 | 984 | 871 |
| Night | Minimum | | 115.9 | 276.9 | 211.4 | 171.4 | 380 | 908 | 693 | 562 |
| | Maximum | | 125.7 | 292.2 | 219.6 | 183.9 | 412 | 958 | 720 | 603 |

**Table 22. 85th Percentile Recognition Distances by Contrast Sensitivity**

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | All | Normal | Marginal | All | Normal | Marginal |
| | | | m | | | ft | | |
| Day | Transport Medium | Overhead | 172.9 | 253.5 | 164.7 | 567 | 831 | 540 |
| | | Ground | 165.0 | 244.6 | 151.3 | 541 | 802 | 496 |
| | Clearview™ | Overhead | 180.6 | 263.8 | 168.4 | 592 | 865 | 552 |
| | | Ground | 163.8 | 246.4 | 157.7 | 537 | 808 | 517 |
| | Series E(Modified) | Overhead | 176.9 | 258.3 | 162.6 | 580 | 847 | 533 |
| | | Ground | 172.0 | 254.1 | 161.3 | 564 | 833 | 529 |
| Night | Transport Medium | Overhead | 115.9 | 186.1 | 101.3 | 380 | 610 | 332 |
| | | Ground | 119.0 | 192.5 | 104.6 | 390 | 631 | 343 |
| | Clearview™ | Overhead | 125.7 | 196.1 | 111.0 | 412 | 643 | 364 |
| | | Ground | 123.2 | 186.7 | 104.6 | 404 | 612 | 343 |
| | Series E(Modified) | Overhead | 122.9 | 188.2 | 111.9 | 403 | 617 | 367 |
| | | Ground | 121.4 | 187.6 | 113.2 | 398 | 615 | 371 |
| Day | Minimum | | 163.8 | 244.6 | 151.3 | 537 | 802 | 496 |
| | Maximum | | 180.6 | 263.8 | 168.4 | 592 | 865 | 552 |
| Night | Minimum | | 115.9 | 186.1 | 101.3 | 380 | 610 | 332 |
| | Maximum | | 125.7 | 196.1 | 113.2 | 412 | 643 | 371 |

**Table 23. Mean Recognition Distances by Contrast Sensitivity**

| Time of Day | Alphabet | Sign Position | Driver Contrast Sensitivity | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | All | Normal | Marginal | All | Normal | Marginal |
| | | | m | | | ft | | |
| Day | Transport Medium | Overhead | 172.9 | 330.9 | 269.0 | 567 | 1085 | 882 |
| | | Ground | 165.0 | 328.2 | 256.2 | 541 | 1076 | 840 |
| | Clearview™ | Overhead | 180.6 | 350.1 | 280.3 | 592 | 1148 | 919 |
| | | Ground | 163.8 | 318.4 | 255.0 | 537 | 1044 | 836 |
| | Series E(Modified) | Overhead | 176.9 | 337.0 | 267.8 | 580 | 1105 | 878 |
| | | Ground | 172.0 | 328.2 | 256.5 | 564 | 1076 | 841 |
| Night | Transport Medium | Overhead | 115.9 | 253.2 | 183.0 | 380 | 830 | 600 |
| | | Ground | 119.0 | 263.2 | 191.2 | 390 | 863 | 627 |
| | Clearview™ | Overhead | 125.7 | 264.7 | 190.9 | 412 | 868 | 626 |
| | | Ground | 123.2 | 262.9 | 190.3 | 404 | 862 | 624 |
| | Series E(Modified) | Overhead | 122.9 | 257.1 | 186.1 | 403 | 843 | 610 |
| | | Ground | 121.4 | 260.8 | 197.3 | 398 | 855 | 647 |
| Day | Minimum | | 163.8 | 318.4 | 255.0 | 537 | 1044 | 836 |
| | Maximum | | 180.6 | 350.1 | 280.3 | 592 | 1148 | 919 |
| Night | Minimum | | 115.9 | 253.2 | 183.0 | 380 | 830 | 600 |
| | Maximum | | 125.7 | 264.7 | 197.3 | 412 | 868 | 647 |

## Table 24. 85th Percentile Recognition Distances by Reaction Time

| Time of Day | Alphabet | Sign Position | Driver Reaction Time (seconds) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <0.75 | .75-.99 | ≥1.00 | All | <0.75 | .75-.99 | ≥1.00 |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 267.2 | 201.3 | 184.5 | 567 | 876 | 660 | 605 |
| | | Ground | 165.0 | 257.1 | 196.1 | 182.4 | 541 | 843 | 643 | 598 |
| | Clearview™ | Overhead | 180.6 | 276.9 | 216.2 | 217.2 | 592 | 908 | 709 | 712 |
| | | Ground | 163.8 | 259.3 | 182.7 | 186.4 | 537 | 850 | 599 | 611 |
| | Series E(Modified) | Overhead | 176.9 | 266.6 | 186.1 | 194.9 | 580 | 874 | 610 | 639 |
| | | Ground | 172.0 | 256.8 | 173.2 | 187.6 | 564 | 842 | 568 | 615 |
| Night | Transport Medium | Overhead | 115.9 | 183.9 | 120.8 | 132.1 | 380 | 603 | 396 | 433 |
| | | Ground | 119.0 | 198.3 | 129.9 | 140.0 | 390 | 650 | 426 | 459 |
| | Clearview™ | Overhead | 125.7 | 200.4 | 125.4 | 144.9 | 412 | 657 | 411 | 475 |
| | | Ground | 123.2 | 185.1 | 118.3 | 142.4 | 404 | 607 | 388 | 467 |
| | Series E(Modified) | Overhead | 122.9 | 186.1 | 130.5 | 138.5 | 403 | 610 | 428 | 454 |
| | | Ground | 121.4 | 182.4 | 140.9 | 132.4 | 398 | 598 | 462 | 434 |
| Day | Minimum | | 163.8 | 256.8 | 173.2 | 182.4 | 537 | 842 | 568 | 598 |
| | Maximum | | 180.6 | 276.9 | 216.2 | 217.2 | 592 | 908 | 709 | 712 |
| Night | Minimum | | 115.9 | 182.4 | 118.3 | 132.1 | 380 | 598 | 388 | 433 |
| | Maximum | | 125.7 | 200.4 | 140.9 | 144.9 | 412 | 657 | 462 | 475 |

## Table 25. Mean Recognition Distances by Reaction Time

| Time of Day | Alphabet | Sign Position | Driver Reaction Time (seconds) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <0.75 | .75-.99 | ≥1.00 | All | <0.75 | .75-.99 | ≥1.00 |
| | | | m | | | | ft | | | |
| Day | Transport Medium | Overhead | 172.9 | 341.9 | 286.4 | 299.2 | 567 | 1121 | 939 | 981 |
| | | Ground | 165.0 | 339.8 | 279.4 | 290.7 | 541 | 1114 | 916 | 953 |
| | Clearview™ | Overhead | 180.6 | 364.2 | 296.2 | 316.6 | 592 | 1194 | 971 | 1038 |
| | | Ground | 163.8 | 330.0 | 268.1 | 290.4 | 537 | 1082 | 879 | 952 |
| | Series E(Modified) | Overhead | 176.9 | 347.7 | 287.9 | 303.5 | 580 | 1140 | 944 | 995 |
| | | Ground | 172.0 | 336.4 | 277.2 | 294.9 | 564 | 1103 | 909 | 967 |
| Night | Transport Medium | Overhead | 115.9 | 259.9 | 212.6 | 216.6 | 380 | 852 | 697 | 710 |
| | | Ground | 119.0 | 269.9 | 222.0 | 225.1 | 390 | 885 | 728 | 738 |
| | Clearview™ | Overhead | 125.7 | 271.8 | 222.7 | 225.4 | 412 | 891 | 730 | 739 |
| | | Ground | 123.2 | 268.4 | 223.0 | 224.2 | 404 | 880 | 731 | 735 |
| | Series E(Modified) | Overhead | 122.9 | 263.8 | 217.2 | 219.0 | 403 | 865 | 712 | 718 |
| | | Ground | 121.4 | 265.7 | 227.5 | 225.1 | 398 | 871 | 746 | 738 |
| Day | Minimum | | 163.8 | 330.0 | 268.1 | 290.4 | 537 | 1082 | 879 | 952 |
| | Maximum | | 180.6 | 364.2 | 296.2 | 316.6 | 592 | 1194 | 971 | 1038 |
| Night | Minimum | | 115.9 | 259.9 | 212.6 | 216.6 | 380 | 852 | 697 | 710 |
| | Maximum | | 125.7 | 271.8 | 227.5 | 225.4 | 412 | 891 | 746 | 739 |

### Comparison of Legibility and Recognition Performance

Table 26 indicates the ratio of legibility distance to recognition distance for various ages of drivers, viewing conditions, and sign position. The ratios are relatively consistent, ranging from a low of 0.74 to a high of 0.93. The majority of ratios are between 0.80 and 0.85, meaning that legibility is approximately 80 to 85 percent of the recognition distance.

**Table 26. Legibility/Recognition Ratios by Driver Age**

| Time of Day | Alphabet | Sign Position | 85th Percentile | | | | Mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <40 | 55-64 | 65+ | All | <40 | 55-64 | 65+ |
| Day | Transport Medium | Overhead | 0.81 | 0.90 | 0.75 | 0.84 | 0.83 | 0.84 | 0.81 | 0.83 |
| | | Ground | 0.76 | 0.90 | 0.79 | 0.80 | 0.83 | 0.84 | 0.81 | 0.82 |
| | Clearview™ | Overhead | 0.77 | 0.93 | 0.80 | 0.81 | 0.83 | 0.85 | 0.83 | 0.82 |
| | | Ground | 0.81 | 0.91 | 0.76 | 0.80 | 0.83 | 0.85 | 0.83 | 0.82 |
| | Series E(Modified) | Overhead | 0.82 | 0.91 | 0.78 | 0.87 | 0.84 | 0.87 | 0.82 | 0.84 |
| | | Ground | 0.83 | 0.89 | 0.80 | 0.86 | 0.84 | 0.87 | 0.83 | 0.84 |
| Night | Transport Medium | Overhead | 0.80 | 0.78 | 0.78 | 0.77 | 0.83 | 0.84 | 0.83 | 0.82 |
| | | Ground | 0.77 | 0.79 | 0.85 | 0.74 | 0.82 | 0.84 | 0.83 | 0.80 |
| | Clearview™ | Overhead | 0.82 | 0.85 | 0.78 | 0.78 | 0.84 | 0.85 | 0.83 | 0.84 |
| | | Ground | 0.81 | 0.81 | 0.82 | 0.78 | 0.84 | 0.86 | 0.84 | 0.82 |
| | Series E(Modified) | Overhead | 0.83 | 0.90 | 0.85 | 0.81 | 0.85 | 0.87 | 0.85 | 0.84 |
| | | Ground | 0.78 | 0.85 | 0.77 | 0.84 | 0.83 | 0.83 | 0.82 | 0.84 |
| Day | Minimum | | 0.76 | 0.89 | 0.75 | 0.80 | 0.83 | 0.84 | 0.81 | 0.82 |
| | Maximum | | 0.83 | 0.93 | 0.80 | 0.87 | 0.84 | 0.87 | 0.83 | 0.84 |
| Night | Minimum | | 0.77 | 0.78 | 0.77 | 0.74 | 0.82 | 0.83 | 0.82 | 0.80 |
| | Maximum | | 0.83 | 0.90 | 0.85 | 0.84 | 0.85 | 0.87 | 0.85 | 0.84 |

## SUMMARY OF IMPROVEMENT LEVELS

The preceding tables in this chapter present the actual legibility/recognition distances that were measured for the three alphabets for the various experimental conditions. Tables 27 through 30 indicate the percentage gain or loss in legibility and recognition for the alternative alphabets (Clearview™ and Transport Medium) compared to Series E(Modified). A positive percentage indicates that Clearview™ or Transport Medium is more legible/recognizable than Series E(Modified), while a negative percentage indicates that Series E(Modified) is more legible/recognizable. In general, these tables indicate that some small improvements in legibility and recognition could be achieved by using the Clearview™ alphabet in overhead signs. A more limited improvement was also apparent for the ground-mounted signs at night. The next section of this chapter addresses the statistical significance of these levels of improvement.

**Table 27. Summary of Improvement Levels - 85th Percentile Legibility Distance**

| Driver Category | | Percent Improvement[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | from E(Modified) to Clearview™ | | | | from E(Modified) to British Transport | | | |
| | | Daytime | | Nighttime | | Daytime | | Nighttime | |
| | | Overhead | Ground | Overhead | Ground | Overhead | Ground | Overhead | Ground |
| All Drivers | | +2.07 | -4.79 | +2.23 | +1.51 | -2.24 | -4.08 | -5.71 | -2.01 |
| Age | Young | +3.25 | -3.28 | -1.05 | -4.17 | -0.45 | -5.32 | -6.50 | -4.87 |
| | Young-Old | +6.87 | -4.96 | -5.73 | +6.83 | -2.44 | -3.91 | -9.82 | +1.82 |
| | Old-Old | +0.97 | -6.84 | +0.56 | +0.28 | -4.46 | -4.02 | -6.78 | -1.99 |
| Visual Acuity | Sharp | -0.52 | -8.30 | +1.71 | +2.06 | -8.56 | -4.08 | -4.61 | +0.17 |
| | Good | -0.66 | +0.17 | +2.58 | -0.23 | +2.47 | -2.41 | -6.32 | +0.94 |
| | Marginal | -1.15 | -10.50 | +6.32 | -4.47 | -4.59 | -11.50 | -13.44 | -0.41 |
| Contrast Sensitivity | Normal | -1.00 | -3.33 | 0.00 | 3.12 | -8.46 | -1.66 | -2.36 | +2.70 |
| | Marginal | +2.53 | -8.13 | +1.81 | -8.06 | -4.42 | -6.32 | -15.52 | -2.56 |
| Reaction Time | <0.75 sec | +3.23 | -2.71 | +3.17 | +3.58 | -4.25 | -3.01 | -3.97 | +2.11 |
| | 0.75-0.99 | -0.19 | -5.22 | +0.89 | -16.96 | +0.38 | -0.21 | -13.95 | -6.85 |
| | ≥ 1.00 | +0.18 | -2.98 | +1.65 | +5.13 | -7.41 | -3.35 | -0.55 | -5.70 |

Notes: [1]Positive percentage (indicated by shading) indicates alternative alphabet more legible than E(Modified).

**Table 28. Summary of Improvement Levels - Mean Legibility Distance**

| Driver Category | | Percent Improvement[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | from E(Modified) to Clearview™ | | | | from E(Modified) to British Transport | | | |
| | | Daytime | | Nighttime | | Daytime | | Nighttime | |
| | | Overhead | Ground | Overhead | Ground | Overhead | Ground | Overhead | Ground |
| All Drivers | | +2.19 | -3.83 | +1.85 | +0.31 | -3.12 | -2.87 | -4.00 | -1.53 |
| Age | Young | 0.00 | -1.61 | -1.46 | +0.85 | -2.54 | -4.03 | -3.89 | -1.58 |
| | Young-Old | +2.56 | -3.78 | +1.75 | +1.33 | -3.79 | -2.18 | -4.23 | -0.88 |
| | Old-Old | +2.56 | -4.83 | +3.25 | -0.67 | -3.07 | -2.95 | -3.76 | -2.01 |
| Visual Acuity | Sharp | +2.57 | -4.37 | +1.87 | +0.38 | -2.97 | -3.05 | -4.74 | -1.00 |
| | Good | +0.61 | -2.41 | +1.33 | +0.50 | -2.80 | -2.78 | -4.83 | -1.49 |
| | Marginal | +3.13 | -5.66 | +4.25 | -0.66 | -4.77 | -2.83 | -1.12 | -3.28 |
| Contrast Sensitivity | Normal | +1.50 | -4.22 | +1.82 | +1.12 | -4.82 | -2.44 | -3.36 | -0.70 |
| | Marginal | +3.36 | -2.93 | +2.50 | -1.88 | +0.67 | -3.77 | -6.36 | -3.77 |
| Reaction Time | <0.75 sec | +3.36 | -4.73 | +2.42 | +0.68 | -2.84 | -3.33 | -2.82 | -1.63 |
| | 0.75-0.99 | +1.39 | -5.15 | +2.51 | -0.98 | -3.92 | -3.03 | -6.53 | -1.15 |
| | ≥ 1.00 | +1.17 | -1.83 | +1.32 | +0.99 | -2.91 | -1.45 | -2.65 | -1.98 |

Notes: [1]Positive percentage (indicated by shading) indicates alternative alphabet more legible than E(Modified).

## Table 29. Summary of Improvement Levels - 85th Percentile Recognition Distance

| Driver Category | | Percent Improvement[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | from E(Modified) to Clearview™ | | | | from E(Modified) to British Transport | | | |
| | | Daytime | | Nighttime | | Daytime | | Nighttime | |
| | | Overhead | Ground | Overhead | Ground | Overhead | Ground | Overhead | Ground |
| All Drivers | | +8.66 | -2.50 | +2.87 | -2.35 | -0.43 | +4.86 | -2.66 | -0.78 |
| Age | Young | +1.43 | -4.84 | +4.09 | -0.29 | +1.43 | -6.05 | -6.50 | -4.87 |
| | Young-Old | +4.40 | +0.73 | +2.26 | 0.00 | +2.02 | -1.57 | -1.91 | -7.21 |
| | Old-Old | +8.61 | 0.00 | +4.60 | +8.61 | -0.68 | +2.94 | -1.61 | +12.20 |
| Visual Acuity | Sharp | +4.59 | -4.30 | +1.38 | -1.76 | 1.20 | -1.21 | -4.41 | +2.57 |
| | Good | +5.85 | -2.02 | +2.02 | -6.17 | -1.25 | +3.61 | -0.60 | -5.42 |
| | Marginal | +3.23 | -3.68 | +0.28 | +2.43 | +8.87 | -9.00 | -12.81 | -9.42 |
| Contrast Sensitivity | Normal | +2.13 | -3.00 | +4.21 | -0.49 | -1.89 | -3.72 | -1.13 | 2.60 |
| | Marginal | +3.56 | -2.27 | -0.82 | -7.55 | +1.31 | -6.24 | -9.54 | -7.55 |
| Reaction Time | <0.75 sec | +3.89 | +0.95 | +7.70 | +1.51 | +0.23 | +0.12 | -1.15 | +8.70 |
| | 0.75-0.99 | +16.23 | +5.46 | -3.97 | -16.02 | +8.20 | +13.20 | -7.48 | -7.79 |
| | ≥ 1.00 | +11.42 | -0.65 | +4.63 | +7.60 | -5.32 | -2.76 | -4.63 | +5.76 |

Notes: [1]Positive percentage (indicated by shading) indicates alternative alphabet more legible than E(Modified).

## Table 30. Summary of Improvement Levels - Mean Recognition Distance

| Driver Category | | Percent Improvement[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | from E(Modified) to Clearview™ | | | | from E(Modified) to British Transport | | | |
| | | Daytime | | Nighttime | | Daytime | | Nighttime | |
| | | Overhead | Ground | Overhead | Ground | Overhead | Ground | Overhead | Ground |
| All Drivers | | +4.09 | -2.31 | +2.74 | -0.28 | -1.27 | 0.00 | -1.57 | 0.00 |
| Age | Young | +2.46 | -0.31 | +0.32 | -2.84 | 1.00 | -1.32 | -0.42 | -2.13 |
| | Young-Old | +2.88 | -2.94 | +3.46 | -1.21 | -1.39 | +0.38 | -2.47 | -2.17 |
| | Old-Old | +5.51 | -2.49 | +2.88 | +1.13 | -1.84 | +0.34 | -1.15 | +2.25 |
| Visual Acuity | Sharp | +4.19 | -3.74 | +2.90 | -1.05 | -0.42 | -0.34 | -2.47 | 0.00 |
| | Good | +2.61 | -1.54 | +0.28 | -1.11 | -2.61 | +0.55 | -1.42 | 0.00 |
| | Marginal | +5.58 | +0.13 | +7.30 | +2.05 | -1.82 | +0.13 | +0.89 | -0.17 |
| Contrast Sensitivity | Normal | +3.89 | +1.50 | +2.97 | +0.82 | -1.81 | 0.00 | -1.54 | +0.94 |
| | Marginal | +4.67 | -0.59 | +2.62 | -3.55 | +0.46 | -0.12 | -1.64 | -3.09 |
| Reaction Time | <0.75 sec | +4.74 | -1.90 | +3.01 | +1.03 | -1.67 | +1.00 | -1.50 | +1.61 |
| | 0.75-0.99 | +2.86 | -3.30 | +2.53 | -2.01 | -0.53 | +0.77 | -2.11 | -2.41 |
| | ≥ 1.00 | +4.32 | -1.55 | +2.92 | -0.41 | -1.41 | -1.45 | -1.11 | 0.00 |

Notes: [1]Positive percentage (indicated by shading) indicates alternative alphabet more legible than E(Modified).

## STATISTICAL ANALYSIS OF DEPENDENT VARIABLES

In order to gain an understanding of the significance of the improvement levels indicated in the previous four tables, a statistical analysis of the means was conducted to determine statistical significance. Two test methods were used: Duncan's Multiple Range Test and Scheffe's Method for Multiple Comparisons. Duncan's is a multiple-comparison procedure for obtaining all pairwise comparisons among *t* sample means. This is a powerful procedure in that there is a high probability of declaring a difference when there is actually a difference between two population means. Scheffe's method is a more general procedure. It is more conservative (less sensitive) than Duncan's procedure for detecting significant differences among pairs of population means. Both methods were used to obtain a relative indication of the magnitude of statistically significant differences.

The results of the statistical analysis are provided in Appendix E. Table 31 summarizes the results of the statistical analysis. There are only two cells in this table where one of the alternative alphabets was statistically better than the current alphabet (Series E(Modified)). In both cases, the better alphabet was Clearview™ and the experiment condition was daytime recognition of an overhead sign.

**Table 31. Summary of Statistical Analysis**

| Driver group | | Day | | | | Night | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Legibility | | Recognition | | Legibility | | Recognition | |
| | | Ground | Overhead | Ground | Overhead | Ground | Overhead | Ground | Overhead |
| All drivers | | E>C<br>E>B | E>B<br>C>B | | C>E<br>C>B | | E>B<br>C>B | | C>B |
| Age | Young | | | | | | | | |
| | Young-old | E>C | E>B<br>C>B | | | | C>B | | |
| | Old-old | E>C | C>B | | C>B | | C>B | | |
| Acuity | Good | E>C | C>B | | | | C>B<br>E>B | | C>B |
| | Normal | | | | | | C>B | | |
| | Marginal | | C>B | | | | | | |
| Contrast Sensitivity | Normal | E>C | C>B | | C>E<br>C>B | | C>B<br>E>B | | C>B |
| | Marginal | | | | | | C>B | | |
| Reaction Time | <0.75 | E>C | C>B | | C>B | | C>B | | |
| | 0.75-0.99 | E>C | C>B | | | | C>B | | |
| | ≥1.00 | | | | | | | | |

Notes: All comparisons reflect results of Duncan's procedure.
Notation: E=Series E(Modified), C=Clearview™, B=British Transport Medium, blank cell=no difference.
E>C means Series E(Modified) is statistically better than Clearview™.
Shading indicates alternative alphabet better than Series E(Modified).

The statistical analysis indicates that, overall, neither Clearview™ or British Transport Medium is statistically better than the current standard alphabet, Series E(Modified).

## COMPARISON OF INDEPENDENT VARIABLES

In an effort to gain greater understanding of the relationships between the various legibility and recognition distances, the researchers also analyzed the results by several of the sign independent variables.

### Comparison of Daytime and Nighttime Performance

Table 32 compares the night/day ratio for legibility and recognition performance as a function of alphabet, sign position, and driver age. The night/day ratios have greater variability than the legibility/recognition ratios. There are also noticeable differences between the 85th percentile and mean values. As a general rule, the data indicate that nighttime legibility is about 70 to 75 percent of the daytime values.

**Table 32. Night/Day Ratios by Driver Age**

| Distance | Alphabet | Sign Position | 85th Percentile | | | | Mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <40 | 55-64 | 65+ | All | <40 | 55-64 | 65+ |
| Legibility | Transport Medium | Overhead | 0.67 | 0.60 | 0.69 | 0.67 | 0.74 | 0.71 | 0.76 | 0.74 |
| | | Ground | 0.72 | 0.65 | 0.70 | 0.72 | 0.78 | 0.75 | 0.79 | 0.81 |
| | Clearview™ | Overhead | 0.70 | 0.61 | 0.66 | 0.68 | 0.75 | 0.71 | 0.76 | 0.75 |
| | | Ground | 0.75 | 0.64 | 0.74 | 0.76 | 0.81 | 0.75 | 0.82 | 0.83 |
| | Series E(Modified) | Overhead | 0.69 | 0.64 | 0.75 | 0.69 | 0.75 | 0.72 | 0.76 | 0.75 |
| | | Ground | 0.71 | 0.65 | 0.66 | 0.71 | 0.78 | 0.73 | 0.82 | 0.80 |
| Recognition | Transport Medium | Overhead | 0.68 | 0.69 | 0.66 | 0.73 | 0.74 | 0.72 | 0.74 | 0.76 |
| | | Ground | 0.71 | 0.74 | 0.65 | 0.79 | 0.79 | 0.76 | 0.77 | 0.82 |
| | Clearview™ | Overhead | 0.66 | 0.67 | 0.67 | 0.71 | 0.74 | 0.71 | 0.75 | 0.73 |
| | | Ground | 0.75 | 0.72 | 0.68 | 0.79 | 0.81 | 0.74 | 0.80 | 0.83 |
| | Series E(Modified) | Overhead | 0.69 | 0.65 | 0.68 | 0.73 | 0.75 | 0.73 | 0.75 | 0.75 |
| | | Ground | 0.75 | 0.69 | 0.69 | 0.72 | 0.79 | 0.76 | 0.79 | 0.80 |
| Legibility | Minimum | | 0.67 | 0.60 | 0.66 | 0.67 | 0.74 | 0.71 | 0.76 | 0.74 |
| | Maximum | | 0.75 | 0.65 | 0.75 | 0.76 | 0.81 | 0.75 | 0.82 | 0.83 |
| Recognition | Minimum | | 0.66 | 0.65 | 0.65 | 0.71 | 0.74 | 0.71 | 0.74 | 0.73 |
| | Maximum | | 0.75 | 0.74 | 0.69 | 0.79 | 0.81 | 0.76 | 0.80 | 0.83 |

### Comparison of Sign Location Performance

Table 33 indicates the difference in performance for overhead and ground-mounted signs. These results indicate that overhead signs are more visible than ground-mounted signs in the daytime. At night, the overhead and ground-mounted signs generally have similar performance distances.

**Table 33. Overhead/Ground Ratios by Driver Age**

| Time of Day | Alphabet | Sign Position | 85th Percentile | | | | Mean | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All | <40 | 55-64 | 65+ | All | <40 | 55-64 | 65+ |
| Day | Transport Medium | Legibility | 1.05 | 1.06 | 1.00 | 1.03 | 1.02 | 1.04 | 1.01 | 1.05 |
| | | Recognition | 0.98 | 1.07 | 1.05 | 0.99 | 1.02 | 1.03 | 1.00 | 1.02 |
| | Clearview™ | Legibility | 1.10 | 1.08 | 1.11 | 1.13 | 1.10 | 1.04 | 1.10 | 1.13 |
| | | Recognition | 1.16 | 1.05 | 1.05 | 1.11 | 1.10 | 1.04 | 1.08 | 1.13 |
| | Series E(Modified) | Legibility | 1.03 | 1.01 | 0.98 | 1.04 | 1.04 | 1.02 | 1.03 | 1.05 |
| | | Recognition | 1.04 | 0.99 | 1.02 | 1.02 | 1.03 | 1.01 | 1.02 | 1.05 |
| Night | Transport Medium | Legibility | 0.97 | 0.97 | 0.99 | 0.96 | 0.97 | 0.98 | 0.98 | 0.96 |
| | | Recognition | 0.94 | 0.99 | 1.07 | 0.91 | 0.96 | 0.98 | 0.97 | 0.95 |
| | Clearview™ | Legibility | 1.02 | 1.02 | 0.98 | 1.01 | 1.01 | 0.98 | 1.01 | 1.02 |
| | | Recognition | 1.01 | 0.97 | 1.03 | 1.00 | 1.01 | 0.99 | 1.02 | 1.00 |
| | Series E(Modified) | Legibility | 1.01 | 0.99 | 1.11 | 1.01 | 1.00 | 1.00 | 1.01 | 0.98 |
| | | Recognition | 0.96 | 0.93 | 1.01 | 1.04 | 0.98 | 0.96 | 0.98 | 0.98 |
| Day | Minimum | | 0.98 | 0.99 | 0.98 | 0.99 | 1.02 | 1.01 | 1.00 | 1.02 |
| | Maximum | | 1.16 | 1.08 | 1.11 | 1.13 | 1.10 | 1.04 | 1.10 | 1.13 |
| Night | Minimum | | 0.94 | 0.93 | 0.98 | 0.91 | 0.96 | 0.96 | 0.97 | 0.95 |
| | Maximum | | 1.02 | 1.02 | 1.11 | 1.04 | 1.01 | 1.00 | 1.02 | 1.02 |

## LEGIBILITY INDEX ANALYSIS

A legibility index calculated from the measured legibility distances provides the most consistent comparison to previous legibility research. Tables 34 and 35 indicate the legibility indices that were calculated by dividing the legibility distances by 406 mm (16 in).

Traditionally, the Series E(Modified) alphabet has been considered to have a legibility index of 0.66 m/mm (55 ft/in) in the daytime and about 15 percent less at night. This number is intended to represent about 80 percent of the driving population. The results of this research indicate that a daytime legibility index of 0.66 m/mm (55 ft/in) is appropriate for younger drivers, but significantly higher than the legibility index that can be achieved by older drivers. The 85th percentile daytime legibility index for young-old drivers was about 0.48 m/mm (40 ft/in) and, for old-old drivers, about 0.36 m/mm (30 ft/in). At night, the 85th percentile legibility indices for the older driver groups were about 60-70 percent of the daytime indices. Even the mean legibility indices of the older driver groups were lower than the traditional values.

## Table 34. 85th Percentile Legibility Indices by Driver Age

| Time of Day | Alphabet | Sign Position | Driver Age: All (m/mm) | <40 (m/mm) | 55-64 (m/mm) | 65+ (m/mm) | All (ft/in) | <40 (ft/in) | 55-64 (ft/in) | 65+ (ft/in) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 0.43 | 0.67 | 0.48 | 0.37 | 35.4 | 55.5 | 39.9 | 30.8 |
| | | Ground | 0.41 | 0.63 | 0.48 | 0.36 | 33.8 | 52.3 | 39.9 | 29.8 |
| | Clearview™ | Overhead | 0.44 | 0.69 | 0.53 | 0.39 | 37.0 | 57.6 | 43.8 | 32.6 |
| | | Ground | 0.40 | 0.64 | 0.47 | 0.35 | 33.6 | 53.4 | 39.5 | 28.9 |
| | Series E(Modified) | Overhead | 0.44 | 0.67 | 0.49 | 0.39 | 36.3 | 55.8 | 40.9 | 32.3 |
| | | Ground | 0.42 | 0.66 | 0.50 | 0.37 | 35.3 | 55.3 | 41.6 | 31.1 |
| Night | Transport Medium | Overhead | 0.29 | 0.40 | 0.33 | 0.25 | 23.8 | 33.3 | 27.6 | 20.6 |
| | | Ground | 0.29 | 0.41 | 0.33 | 0.26 | 24.4 | 34.2 | 27.6 | 21.6 |
| | Clearview™ | Overhead | 0.31 | 0.42 | 0.35 | 0.27 | 25.8 | 35.2 | 28.8 | 22.3 |
| | | Ground | 0.30 | 0.41 | 0.35 | 0.27 | 25.3 | 34.4 | 29.3 | 22.1 |
| | Series E(Modified) | Overhead | 0.30 | 0.43 | 0.37 | 0.27 | 25.2 | 35.6 | 30.6 | 22.1 |
| | | Ground | 0.30 | 0.43 | 0.33 | 0.26 | 24.9 | 35.9 | 27.4 | 22.0 |
| Day | Minimum | | 0.40 | 0.63 | 0.47 | 0.35 | 33.6 | 52.3 | 39.5 | 28.9 |
| | Maximum | | 0.44 | 0.69 | 0.53 | 0.39 | 37.0 | 57.6 | 43.8 | 32.6 |
| Night | Minimum | | 0.29 | 0.40 | 0.33 | 0.25 | 23.8 | 33.3 | 27.4 | 20.6 |
| | Maximum | | 0.31 | 0.43 | 0.37 | 0.27 | 25.8 | 35.9 | 30.6 | 22.3 |

## Table 35. Mean Legibility Indices by Driver Age

| Time of Day | Alphabet | Sign Position | Driver Age: All (m/mm) | <40 (m/mm) | 55-64 (m/mm) | 65+ (m/mm) | All (ft/in) | <40 (ft/in) | 55-64 (ft/in) | 65+ (ft/in) |
|---|---|---|---|---|---|---|---|---|---|---|
| Day | Transport Medium | Overhead | 0.63 | 0.83 | 0.65 | 0.57 | 52.4 | 69.4 | 53.9 | 47.3 |
| | | Ground | 0.61 | 0.81 | 0.64 | 0.54 | 50.8 | 67.1 | 53.3 | 45.2 |
| | Clearview™ | Overhead | 0.66 | 0.86 | 0.69 | 0.60 | 55.3 | 71.3 | 57.5 | 50.1 |
| | | Ground | 0.60 | 0.83 | 0.63 | 0.53 | 50.3 | 68.8 | 52.4 | 44.3 |
| | Series E(Modified) | Overhead | 0.65 | 0.86 | 0.67 | 0.59 | 54.1 | 71.3 | 56.1 | 48.8 |
| | | Ground | 0.63 | 0.84 | 0.65 | 0.56 | 52.3 | 69.9 | 54.5 | 46.6 |
| Night | Transport Medium | Overhead | 0.47 | 0.59 | 0.49 | 0.42 | 39.0 | 49.4 | 41.0 | 35.2 |
| | | Ground | 0.48 | 0.61 | 0.50 | 0.44 | 40.2 | 50.5 | 42.0 | 36.5 |
| | Clearview™ | Overhead | 0.50 | 0.61 | 0.52 | 0.45 | 41.4 | 50.7 | 43.6 | 37.8 |
| | | Ground | 0.49 | 0.62 | 0.52 | 0.44 | 40.9 | 51.8 | 42.9 | 37.0 |
| | Series E(Modified) | Overhead | 0.49 | 0.62 | 0.51 | 0.44 | 40.6 | 51.4 | 42.8 | 36.6 |
| | | Ground | 0.49 | 0.62 | 0.51 | 0.45 | 40.8 | 51.3 | 42.4 | 37.3 |
| Day | Minimum | | 0.60 | 0.81 | 0.63 | 0.53 | 50.3 | 67.1 | 52.4 | 44.3 |
| | Maximum | | 0.66 | 0.86 | 0.69 | 0.60 | 55.3 | 71.3 | 57.5 | 50.1 |
| Night | Minimum | | 0.47 | 0.59 | 0.49 | 0.42 | 39 | 49.4 | 41 | 35.2 |
| | Maximum | | 0.50 | 0.62 | 0.52 | 0.45 | 41.4 | 51.8 | 43.6 | 37.8 |

# CHAPTER 5
# CONCLUSIONS AND RECOMMENDATIONS

The basic objective of this research project was to determine if the legibility and/or recognition of freeway sign legends could be improved through the use of an alphabet different from the standard Series E(Modified) used in the U.S. for all lowercase freeway guide sign legends. The impetus for the research originated over concerns that the fully retroreflective cut-out legend now used in TxDOT freeway guide signs creates a blooming effect (also referred to as overglow, irradiation, or halation) that decreases legibility, particularly among older drivers.

The research evaluation was conducted by driving test subjects on a closed course where words were displayed on overhead and ground-mounted signs. Each sign had three common (non-destination) words presented at one time. Drivers were asked to read and identify the position (top, middle, bottom) of a word specified before beginning the experiment (recognition task) and to read and identify the position of the two remaining words on the sign (legibility task). Legibility and recognition data were collected for three alphabets presented in two sign positions (overhead and ground-mounted) during both daytime and nighttime conditions. The signs were illuminated only by the vehicle headlights during the nighttime conditions. A total of 54 test subjects participated in the data collection effort. Subjects were categorized by age, visual acuity, contrast sensitivity, and reaction time for the data analysis.

## DESCRIPTION OF ALPHABETS

The three alphabets evaluated in this research project were Series E(Modified), Clearview™, and British Transport Medium. The alphabets were selected after reviewing all available alphabets used on traffic signs around the world. Appendix B provides examples of the three alphabets that were used in the evaluation.

### Series E(Modified)

Series E(Modified) is the federal standard alphabet for the United States. It is the only U.S. sign alphabet that has lowercase letters. It was first used in California over 40 years ago and continues to be widely used today. Series E(Modified) legend can be created from button copy letters or cut-out letters. The cut-out letters are more commonly used than button copy.

### Clearview™

The Clearview™ alphabet was recently developed as part of a research study conducted at the Pennsylvania Transportation Institute (PTI) (9). The intent of that research was to improve the legibility of guide signs by reducing the halation (or blooming) effect observed in the Series E(Modified) alphabet. The PTI research used 125 mm (5 in) letters in their research. They found a significant increase in legibility with Clearview™, but some portion of this improvement was achieved by increasing the size of the Clearview™ footprint (and thereby increasing the letter height) to equal the size of a Series E(Modified) footprint.

Several of the researchers involved in the PTI effort helped the TTI researchers incorporate the Clearview™ alphabet into this research. The initial contribution was to provide TTI with sample letters and participate in a preliminary investigation of Clearview™ using 400 mm (16 in) letters. The results of the preliminary investigation were used by Meeker & Associates (a member of the PTI team) to further refine Clearview™. The refined Clearview™ was used to fabricate the letters for this research.

After the Clearview™ alphabet was provided to TTI for the data collection effort, it was sent to a type foundry so that it could be converted to a TrueType font that could be used in sign-cutting equipment. During that process, additional refinements were made to the Clearview™ alphabet by the cartographer. Most of these refinements were made to uppercase letters that were not a part of this research effort, but small changes were made to lowercase letters. This version is ClearviewOne™, and TTI was provided with several disks of this alphabet for use in the TxDOT district sign shops. As a result, the ClearviewOne™ that is available on disk is slightly different from that evaluated in this research project. The ClearviewOne™ alphabet is available in several different styles as illustrated in Table 36. Only the Expressway Regular alphabet should be used by TxDOT sign shops to fabricate overhead and ground-mounted freeway guide signs. The other versions of ClearviewOne™ were developed to take advantage of the flexibility provided by modern sign fabricating procedures. It is now possible to easily adjust the height-to-stroke width ratio of an alphabet to accommodate differences in applications (such as the expected amount of illumination, the legend and background materials, and the combination of legend and background color). The range of height-to-stroke width, letter width, and letter spacing available in the ClearviewOne™ alphabet provides significant flexibility to custom design each sign. However, at the present time, there are no guidelines on the use of these versions of ClearviewOne™ to take advantage of that flexibility.

**Table 36. ClearviewOne™ Alphabet Provided to TTI**

| Clearview™ Style | Letter Spacing and Stroke Width | Examples of Style and Spacing | |
|---|---|---|---|
| Street | Condensed | aeshp | Highway |
| | Light | aeshp | Highway |
| | Regular | aeshp | Highway |
| Road | Condensed | aeshp | Highway |
| | Light | aeshp | Highway |
| | Regular | aeshp | Highway |
| Expressway | Light | aeshp | Highway |
| | Regular | aeshp | Highway |

Note: These alphabets are slight modifications of the alphabet evaluated in this research. Each alphabet is shown in the actual font for that style.

Development of ClearviewOne™ continued after the completion of this research project. The current version is ClearviewOne HWY™ typefaces, of which there are nine, as identified in Figure 23. The Bold, Regular, and Condensed typefaces are roughly similar to the typefaces provided to TTI (Regular, Light, and Condensed, respectively). The number at the end of the type name is the letterspace based on the approach speed. These speeds are roughly similar to the style names (expressway, road, and street) of the typeface provided to TTI. The ultra condensed typeface is new and is not included on the ClearviewOne™ disks provided to TTI.

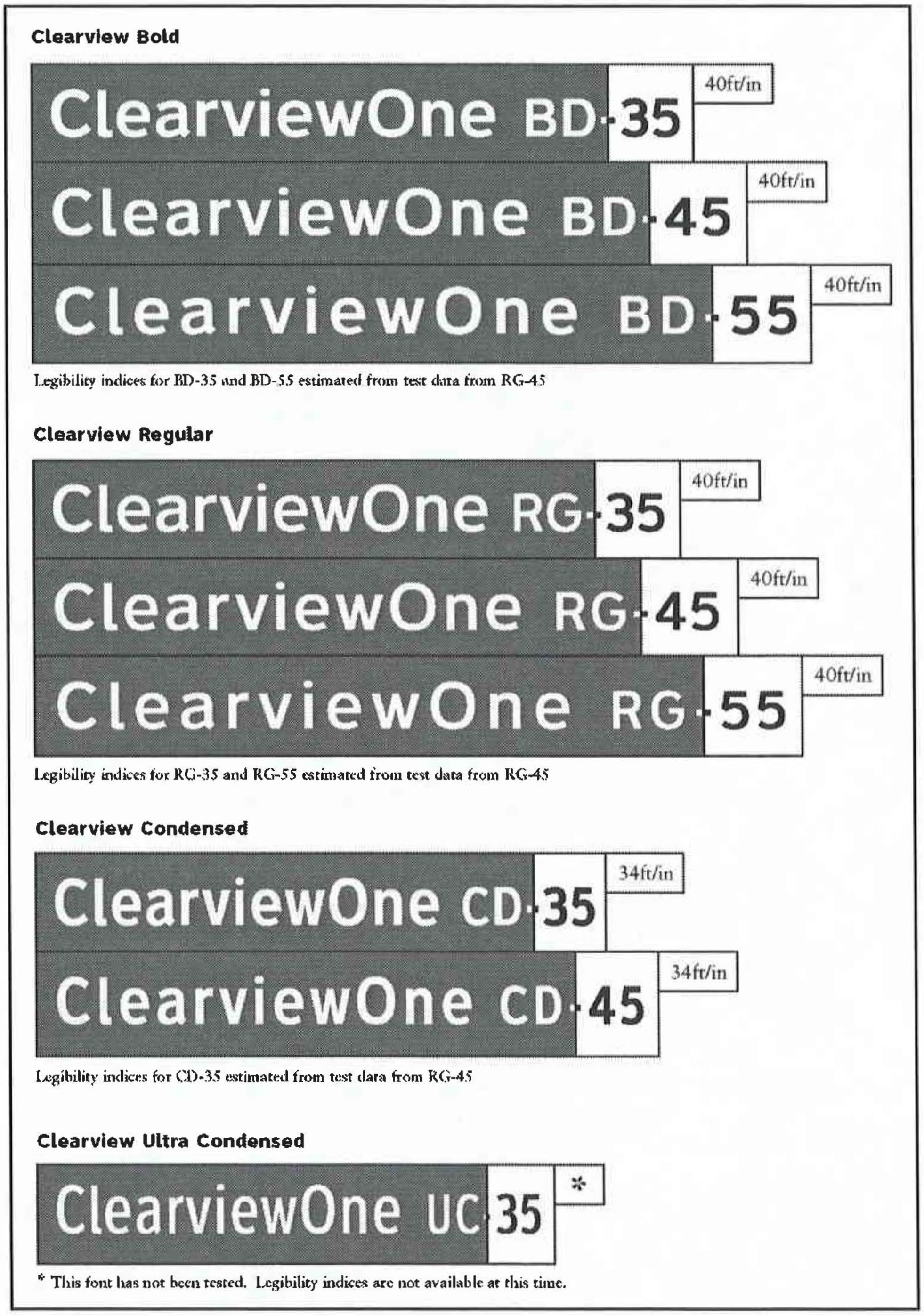



**Figure 23. Current ClearviewOne HWY™ Type System**

### British Transport Medium

The British Transport Medium alphabet is used in the United Kingdom for positive contrast (white on dark) signs. An alphabet with a heavier stroke width is used for negative contrast signs. The letter spacing for the Transport Medium alphabet was found to be too tight in the preliminary Clearview™ investigation, so the letter spacing was increased for this research to a degree that approximated the spacing for the Clearview™ alphabet.

## SUMMARY OF RESEARCH RESULTS

The previous chapter presented the actual legibility/recognition distances that were measured for the three alphabets for the various experimental conditions. The following sections interpret those distances and indicate the relative performance of the alphabets.

### Percent Improvement

There was significant variability in the results of the various experimental conditions. In general, the results (as summarized in Table 37) indicated that Clearview™ was more effective than Series E(Modified) in the overhead position in both daytime and nighttime conditions. The extent of improvement was generally in the range of 2 to 8 percent over Series E(Modified). Also, the improvement was greater in the recognition task than the legibility task. Clearview™ ground-mounted signs were no better than Series E(Modified) in daytime conditions. The night-time ground-mounted sign demonstrated mixed results, with Series E(Modified) being better for some conditions and worse for others. British Transport Medium was typically less effective than Series E(Modified), but several recognition conditions existed where it was slightly more effective than Series E(Modified). All of the conditions where it was more effective were for the ground-mounted sign. In those cases where it was more recognizable, the extent of improvement was generally less than 3 percent. Table 37 summarizes the evaluation results for the entire driver sample (54 drivers) and the old-old driver sample (29 drivers). The shaded values in this table indicate a positive improvement, conditions where the alternative alphabet performed better than the Series E(Modified) alphabet.

### Summary of Statistical Analysis

Although the research found that Clearview™ did provide some improvement in performance, a statistical analysis of the mean legibility and recognition distances indicated that the degree of improvement was not statistically significant.

### Legibility Indices

The results of the legibility evaluations found that, for older drivers, the legibility index for Series E(Modified) is significantly lower than the 0.66 m/mm (55 ft/in) value traditionally used for sign design. The 85$^{th}$ percentile daytime legibility index for young-old drivers was about 0.48 m/mm (40 ft/in) and, for old-old drivers, about 0.36 m/mm (30 ft/in). At night, the 85$^{th}$ percentile legibility indices for the older driver groups were about 60 to 70 percent of the daytime legibility. Even the mean legibility indices of the older driver groups were lower than the traditional value of 0.66 m/mm (55 ft/in).

**Table 37. Summary of Research Results**

| Comparison Alphabet | Experimental Condition | | Percent Improvement over Series E(Modified) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Legibility Distance | | | | Recognition Distance | | | |
| | | | 85th Percentile | | Mean | | 85th Percentile | | Mean | |
| | | | All[1] | 65+[2] | All | 65+ | All | 65+ | All | 65+ |
| Clearview™ | Daytime | Overhead | +2.1% | +1.0% | +2.2% | +2.6% | +8.7% | +8.6% | +4.1% | +5.5% |
| | | Ground | -4.8% | -6.8% | -3.8% | -4.9% | -2.5% | 0.0% | -2.3% | -2.5% |
| | Nighttime | Overhead | +2.2% | +0.6% | +1.9% | +3.3% | +2.9% | +4.6% | +2.7% | +2.9% |
| | | Ground | +1.5% | +0.3% | +0.3% | -0.7% | -2.4% | +8.6% | -0.3% | +1.1% |
| Transport Medium | Daytime | Overhead | -2.2% | -4.5% | -3.1% | -3.1% | -0.4% | -0.7% | -1.3% | -1.8% |
| | | Ground | -4.1% | -4.0% | -1.8% | -3.0% | +4.9% | +2.9% | 0.0% | +0.3% |
| | Nighttime | Overhead | -5.7% | -6.8% | -4.0% | -3.8% | -2.7% | -1.6% | -1.6% | -1.2% |
| | | Ground | -2.0% | -2.0% | -1.5% | -2.0% | -0.8% | +12.2% | 0.0% | 2.3% |

Notes: [1]All 54 drivers in the sample.
[2]29 drivers age 65 and older.
Shaded values indicate a positive improvement.

## SUMMARY OF RESULTS

The following summarizes the results of the research for the legibility and recognition evaluations.

### Legibility Data

The following observations can be made about the legibility data presented in the preceding chapter:

- Clearview™ is generally more legible at both the mean and 85th percentile levels than Series E(Modified) for signs in the overhead position in both daytime and nighttime conditions. This improvement was greatest for drivers with poor vision (worse than 20/40). The extent of improvement was generally in the range of 2 percent, although some driver groups experienced improvements over 9 percent greater than Series E(Modified). This improvement was not statistically significant.
- For ground-mounted signs, Clearview™ was less legible in daytime conditions than Series E(Modified) and only slightly more legible at night. Where the ground-mounted Clearview™ was more legible at night than Series E(Modified), it was generally by less than 2 percent.
- There were very few conditions where the Transport Medium alphabet was more legible than Series E(Modified).

## Recognition Data

The following observations can be made about the recognition data presented in the preceding chapter:

- In the overhead position, Clearview™ was more recognizable than Series E(Modified) in both daytime and nighttime conditions, except in nighttime conditions for drivers with minimum (20/40) vision. The extent of improvement was considerably higher than the improvement realized in the legibility data. However, although greater than the legibility improvement, the improvement was not statistically significant.
- In the ground-mounted position, Clearview™ demonstrated some small improvement at night among worse-case drivers, but no improvement in daytime conditions.
- In contrast to the legibility results, there were several conditions where the Transport Medium alphabet was more recognizable than Series E(Modified). However, the improvement was generally small (less than 3 percent) and not statistically significant.

The recognition data showed significant variability from one condition to the next. For example, for the 85$^{th}$ percentile recognition improvement for drivers with minimum (20/40) vision, the daytime overhead Clearview™ was 20.8 percent more recognizable than Series E(Modified), while for the nighttime overhead sign, Series E(Modified) was 21.6 percent more legible than Clearview™. This type of variability indicates the difficulties of interpreting legibility/recognition data and the care that must be put into applying the results.

## CONCLUSIONS

The following conclusions can be drawn from the results summarized above:

- The evaluation of recognition and legibility performance found:
  - Clearview™ appears to be a slightly more effective alphabet when used in the overhead position. The extent of this improvement ranges from 2 to 8 percent, which translates into an increase in legibility or recognition distance for the driver up to 15 m (50 ft). This improvement is not statistically significant.
  - In comparison, the ground-mounted Clearview™ is generally less effective than Series E(Modified) in the daytime conditions. Because daytime legibility is generally 35 to 45 percent greater than nighttime legibility, the loss of daytime legibility to the benefit of nighttime legibility may not be a significant sacrifice.
  - In nighttime conditions, the ground-mounted Clearview™ did not demonstrate a consistently better performance than Series E(Modified). Clearview™ performed better than Series E(Modified) in some conditions and worse in others.
  - British Transport Medium does not appear to be as effective an alphabet as the Series E(Modified).
- No data were measured or identified that could explain the difference in performance between the overhead and ground-mounted signs. The researchers believe that, for the illuminance falling upon the overhead sign, the redesign and reduction in stroke width with Clearview™ was sufficient to reduce halation and improve legibility in the overhead position. However, the greater amount of illuminance reaching the ground-

mounted sign is such that halation continues to exist and additional refinements are needed to the alphabet to further reduce halation when used on ground-mounted signs.

- The difference in performance of overhead and ground-mounted signs indicate that the effectiveness of an alphabet is a function of the amount of illuminance. Because only one vehicle was used throughout the evaluation, the impact of a variation in illuminance could not be evaluated.
- The difference in performance between overhead and ground-mounted signs may indicate the need for different design parameters for each type of sign.
- For most of the conditions analyzed, the maximum difference between the best and worst alphabet was generally less than 15 m (50 ft). At 100 km/h (60 mph), this maximum difference in performance correlates to about half a second of additional viewing time.
- The findings from this research and those of others indicate that it is not reasonable to expect that legibility can be significantly increased through a change in the design of the alphabet. Only modest improvements are realistic, and more benefit may be gained from trying to balance the daytime/nighttime and overhead/ground performance characteristics. The most effective means of improving legibility continues to be the use of a larger letter.
  - The relatively small increases in performance found in this research (generally less than 10 percent) are consistent with the findings of Tan's research (47), which showed that only marginal improvements could be achieved with other types of alphabets.
  - Mace (7) found significant increases in nighttime legibility by greatly reducing the stroke width, but only by greatly sacrificing daytime legibility.
  - The 16 percent improvement that PTI realized with Clearview™ was in part due to the fact that the letter height of Clearview™ was 12 percent greater than the Series E(Modified) letter height.
- The legibility indices measured in this research indicate that the traditional values (0.66 m/mm, 55 ft/in) do not accommodate the older driver population.
  - A legibility index of 0.36 m/mm (30 ft/in) is a more accurate representation of the actual legibility of freeway signs at night.
  - The experiments conducted in this research evaluated only a 400 mm (16 in) letter height. Previous research has shown a non-linear relationship for the legibility index. Therefore, the legibility index determined for the 400/300 mm (16/12 in) size letters may not be appropriate for larger or smaller letters.
- There are many other factors that were not evaluated in this research that could influence the effectiveness of a freeway alphabet. These factors include:
  - use of different sheeting materials,
  - variation in vehicle headlights,
  - optimization of letter spacing, and
  - the impact of sign lighting.
- In the final panel meeting of the TxDOT Project Advisors, the researchers presented the evaluation results and conducted a demonstration of the performance of the three alphabets in both daytime and nighttime conditions. The Project Advisors agreed that Clearview™ had a more pleasing visual appearance that Series E(Modified) and appeared to them to be more legible.

## FREEWAY ALPHABET RECOMMENDATIONS

Based on the findings of the evaluations described in this report, the researchers offer the following recommendations regarding the use of legends in freeway guide signs:

1. Clearview™ and British Transport should not be implemented on a widespread basis.
2. Because of the small, but consistent, improvement over Series E(Modified) in overhead signs, limited field experiments of Clearview™ are appropriate.
   a. Field experiments should be limited to overhead signs only.
   b. Permission to experiment should be requested from the Federal Highway Administration. The request should indicate that the Clearview™ legend will remain on the signs throughout their service life.
   c. Experimental use of Clearview™ should be limited to specific locations.
   d. Factors to be considered in evaluating the experimental use of Clearview™ should be the visual appearance of the signs and input (positive or negative) from the driving public.
   e. If the results of the evaluations are positive, then Clearview™ may be implemented statewide after letter spacing, stoke width, and material effects issues are investigated (see recommendations for future research).
3. If implemented on a statewide basis, use of Clearview™ should include the following conditions:
   a. Clearview™ should be an option for overhead freeway signs legends only. It should not eliminate the ability to use Series E(Modified).
   b. If used on an overhead freeway, sign panels using the Clearview™ alphabet should not be mixed on the same overhead sign bridge as signs panels using Series E(Modified).
4. Consideration should be given to using different design parameters for overhead and ground-mounted signs to account for the different performance characteristics of each. Series E(Modified) should continue to be used for all ground-mounted signs.
5. Clearview™ is a developing alphabet. This research represents the second evaluation of the alphabet. As such, there are several aspects of the Clearview™ alphabet that have not been evaluated or need refinement. These include:
   a. Uppercase letters - The two evaluations of Clearview™ used very limited samples of uppercase letters. As such, many of the uppercase Clearview™ letters have not been observed in full-scale real-world signing applications.
   b. Numbers - There have not been any evaluations of the numbers in the Clearview™ alphabet.
   c. Letter spacing - The letter spacing for Clearview™ has not been evaluated in a scientific manner.
   d. Stroke width - The difference in performance between overhead and ground-mounted signs indicates the need to evaluate other height-to-stroke width ratios of Clearview™ to determine the optimal balance between the two sign positions or the individual stroke widths that should be used with each type of sign.
   e. Colors - To date, the only evaluations of Clearview™ have been for white letters on a green background. The effectiveness of white letters on other color backgrounds should be assessed before using these color combinations.

f. Material effects - As the survey of state practices found, many different combinations of sign materials are used on freeway guide signs. The performance of sign legends as a function of materials should be evaluated so that the selection of an alphabet will reflect the performance characteristics of the materials it will be fabricated from.
g. The Clearview™ alphabet that will be available for fabricating signs is slightly different from the Clearview™ evaluated in this research. Some limited comparisons of the old and new Clearview™ should be conducted to ensure that the refinements have not reduced the performance of the alphabet.

## CHAPTER 6
# REFERENCES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## APPENDIX A
# RESULTS OF STATE DOT SURVEY

A survey of all state traffic engineers was conducted in January 1996. A total of 37 states returned the portion of the state survey addressing freeway guide sign practices. These states are listed below.

Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Georgia
Idaho
Indiana
Iowa
Kansas
Kentucky
Maine
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Nebraska
New Hampshire
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
Utah
Vermont
Virginia
Washington
West Virginia
Wyoming

It should be noted that, due to multiple responses to some questions, many of the response percentages add up to over 100 percent.

# STATE DOT SURVEY - LEGIBILITY OF FREEWAY SIGNS

1. What materials does your agency currently use for **NEW OVERHEAD** freeway guide signs? You may check more than one material in each category. If more than one material is used, please indicate the primary material.

**Legend Materials**

| | | |
|---|---|---|
| 7 | 15.9% | Button copy with reflector buttons |
| 1 | 2.3% | Engineering Grade |
| 1 | 2.3% | Super Engineering Grade |
| 28 | 63.6% | High Intensity or High Performance Grade |
| 7 | 15.9% | Diamond or VIP Grade |
| 0 | 0% | Other (please describe) |

**Background Materials**

| | | |
|---|---|---|
| 2 | 4.9% | Non-reflective |
| 3 | 7.3% | Engineering Grade |
| 3 | 7.3% | Super Engineering Grade |
| 31 | 75.6% | High Intensity or High Performance Grade |
| 2 | 4.9% | Diamond or VIP Grade |
| 0 | 0% | Other (please describe) |

**Comments**

- Looking to use high intensity or diamond grade for legend. Have decided to use super engineering grade on backgrounds and guide.
- Diamond and VIP grades are being used on a limited basis at this time.
- Cut-out copy replacing buttons on Interstate Highway signs.
- Have been using Hi Performance material since 1984.
- Switched from painted to high intensity background on 11/25/86.
- Our standard for 15 years.
- Diamond grade is being tested on a few overhead signs for legends and borders only. Test projects have been selected for button copy and super engineering grade.
- We use high intensity on Interstate Highway signing. We use engineering grade background with high intensity legends for all other highways. Red background and yellow background signs are high intensity material for all highways.
- Exit only panels use diamond grade sheeting but regular guide signs use high intensity.

2. What material combinations does your agency use for **NEW GROUND-MOUNTED** freeway guide signs? You may check more than one material in each category. If more than one material is used, please indicate the primary material.

12 states indicated the same material combinations as used for overhead signs.

**Legend Materials**

| | | |
|---|---|---|
| 3 | 10.3% | Cutout copy with reflector buttons |
| 2 | 6.9% | Engineering Grade |
| 3 | 10.3% | Super Engineering Grade |
| 20 | 69.0% | High Intensity or High Performance Grade |
| 1 | 3.4% | Diamond or VIP Grade |
| 0 | 0% | Other (please describe) |

**Background Materials**

| | | |
|---|---|---|
| 1 | 3.3% | Non-reflective |
| 6 | 20.0% | Engineering Grade |
| 2 | 6.7% | Super Engineering Grade |
| 20 | 66.7% | High Intensity or High Performance Grade |
| 1 | 3.3% | Diamond or VIP Grade |
| 0 | 0% | Other (please describe) |

**Comments**

- Some signs are allowed to be made by silk screening green ink background over where reflective sheeting which does make the background somewhat reflective.
- Engineering grade used sparingly.
- Our standard for years.
- We have selected several expressway projects to use super engineering grade.
- We use high intensity on Interstate Highway signing. We use engineering grade background with high intensity legends for all other highways. Red background and yellow background signs are high intensity material for all highways.
- VIP used on one project for legend material and evaluation.

3. Does your agency use sign illumination for overhead guide signs?

| | | |
|---|---|---|
| 9 | 24.3% | Yes - all overhead freeway signs are illuminated. |
| 11 | 29.7% | No - no overhead freeway signs are illuminated. |
| 17 | 45.9% | Some - lighting is used only for selected overhead freeway signs (please comment on the basis for deciding which signs to illuminate) |

**Comments**

- Most are intersecting street name signs.
- Action signs (signs w/ arrows) and signs that are particularly hard to read (because of extreme skew angles, etc.) are illuminated.
- Very few have no lights due to no available power source.
- Engineering judgement. Few signs are illuminated.
- We are in the process of replacing all illuminated overhead signs with high intensity sheeting and removing luminaires.
- All new signs are illuminated. Some cases, street lighting is sufficient. Priority is given to high-volume sections.
- Urban areas.
- Overhead guide signs are illuminated in metro areas where traffic is higher and power is readily available. In rural areas, signs are normally not lighted.
- Will eventually light all overheads, but will not at time of installation if power source is not nearby. Butterfly median overhead signs are not illuminated at any time.
- See attached guidelines for lighting for overhead sign panels.
- So far as I know, we have never had illuminated signs. Some of our manuals have hardware that can be bought as an add on.
- In the Albuquerque urban area, overhead signs are illuminated.
- 98 percent of overhead guide signs are illuminated.
- See attached policy.
- We are in the process of phasing out illumination except for Interstate Highway to Interstate Highway connections and areas of highways where there is a negative grade approaching guide signs.
- Sign lighting is included on all overhead guide signs except signs on tangent roadways where you have a clear view of the sign for a minimum of 1,200 ft and the vertical alignment is such that low beam headlights will illuminate the signs.
- Most urban overhead signs are illuminated. Most rural are not.

- Illumination is provided on freeway to freeway, left exits, and other interchanges which may require complex maneuvers and decisions.
- See attached.
- Urban areas and overhead warnings.

4. If your agency does not use sign illumination for all freeway signs, have you experienced complaints from drivers or traffic/maintenance personnel?

| | | |
|---|---|---|
| 4 | 16.7% | Yes - please comment on the nature of complaints |
| 20 | 83.3% | No |

**Comments**

- Generally, when someone raises the question that causes an article on the subject to appear in a newspaper or magazine, we will get a few letters, otherwise we do not hear a word.
- Very few complaints - all related to visibility.
- Legibility studies show Series E(Modified) is best if high-contrast materials are avoided. Any change in this would create maintenance havoc.
- Retroreflectivity seems to work satisfactorily where lights are not used.
- Lack of retroreflectivity on older signs.
- Only a few comments since we began turning off sign illumination in 7 county Metro area.
- Maintenance does not want any signs illuminated due to added responsibilities.

5. Does your agency use the Series E(Modified) (federal standard) alphabet for the legend in large freeway guide signs?

| | | |
|---|---|---|
| 32 | 94.1% | Yes |
| 2 | 5.9% | No (please identify type of alphabet used) |

**Comments**

- California has its own alphabet, which is basically the federal alphabet with the stroke width increased 10 percent. We also allow the federal alphabet but do not allow the two to be used on the same sign.
- But with increased inter-letter spacing.
- Series D use 20" - 15" lettering.
- Have been using 3M spacing. Will now use AASHTO spacing with GUIDSIGN computer program.
- Until Dec. 1995, we used E-Modified. Now we use SIGN CADD which uses all current federal standards.
- Use if at all possible. We follow Table 2 Guide Signs for Freeways in the MUTCD.
- Some overhead freeway signs on selected highways in NYC/Long Island Area local government pays for energy.
- We are aware of the Clearview™ legend.
- See attached.

## APPENDIX B
# ALPHABETS USED IN EVALUATIONS

The figures in this appendix present some of the key letters in each of the three alphabets evaluated in this research project. Table 38 summarizes some of the key ratios for the three alphabets. These ratios were determined from measurements of the actual letters "H" and "n" used in the legibility evaluations.

**Table 38. Summary of Alphabet Characteristics**

| Characteristics | Alphabet | | |
|---|---|---|---|
| | Series E(Modified) | Clearview ™ | Transport Medium |
| Height-to-Stroke Width Ratio | 4.86 | 5.61 | 5.73 |
| Height-to-Letter Width Ratio (Letter H) | 1.23 | 1.28 | 1.25 |
| x height percentage[1] | 74% | 75% | 72% |

[1]Also referred to as loop height.

Figures 24 and 25 present all of the letters of each alphabet. Not all of the letters were evaluated in this research effort. It should be noted that the Clearview™ alphabet presented in these figures represents the version as revised after the evaluations were conducted. As such, it is slightly different than that used in the evaluations. Figure 26 presents the numbers in each alphabet. None of the numbers were evaluated in this research project.

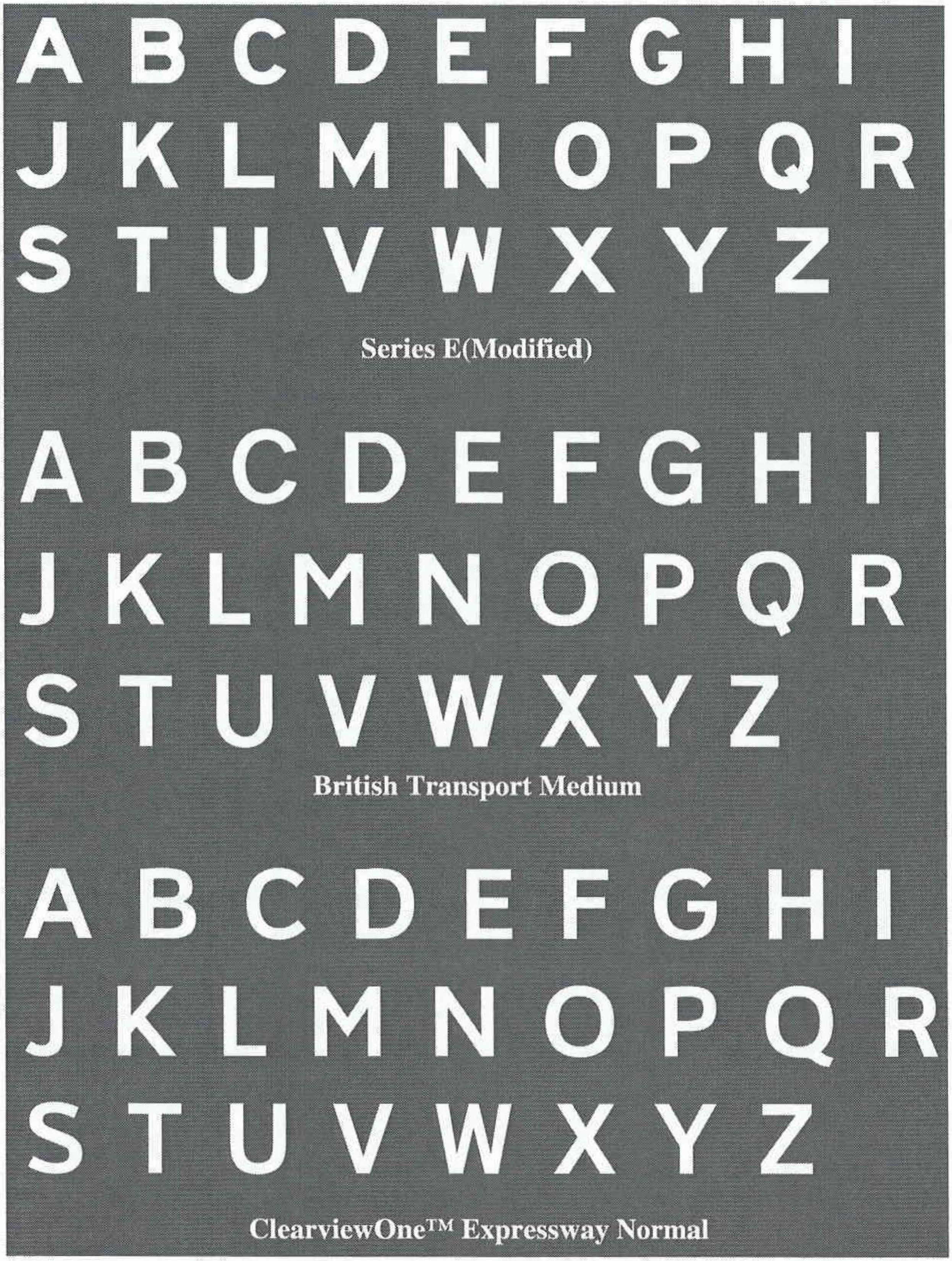


**Figure 24. Uppercase Letters of the Three Alphabets**


**Figure 25. Lowercase Letters of the Three Alphabets**

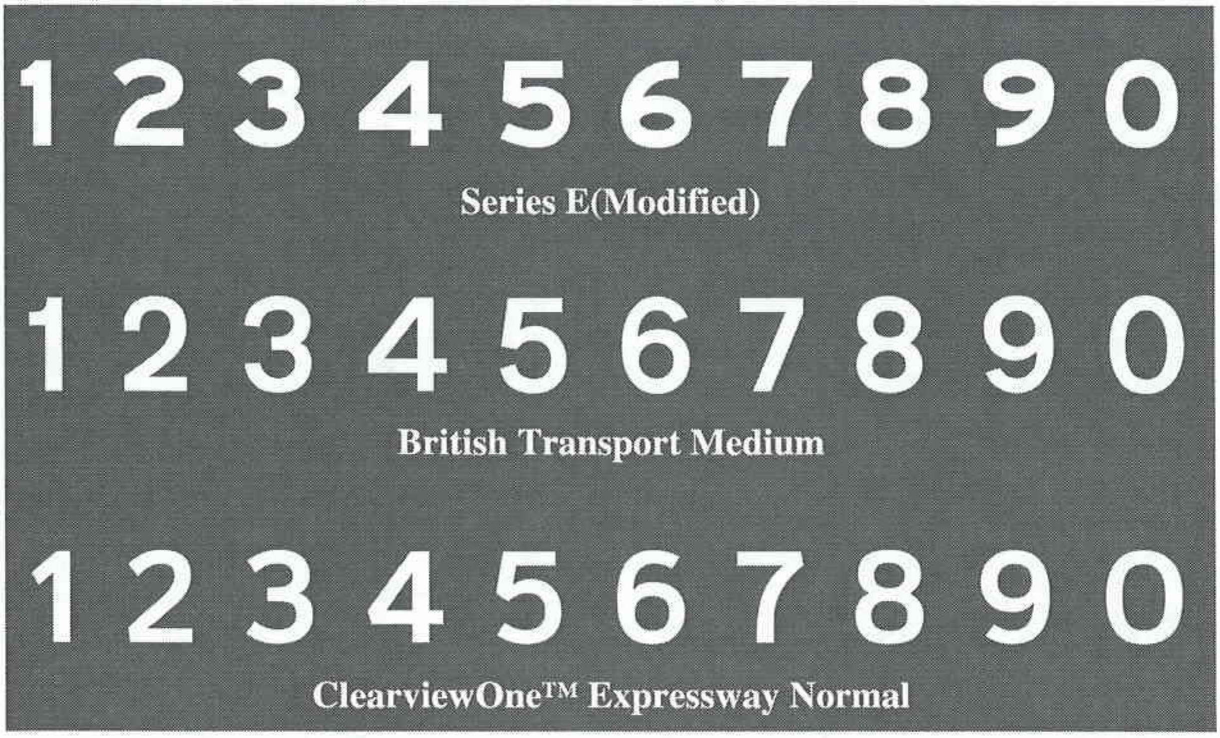


**Figure 26. Numbers of the Three Alphabets**

APPENDIX C

# EXPERIMENTAL PROCEDURE INFORMATION

This appendix contains the following information that was used in the preparation or conduct of the experimental procedure:

- newspaper advertisement used to recruit evaluation participants (Figure 27),
- experimental procedure information provided to participants prior to beginning data collection (Figure 28), and
- informed consent form that test subjects were required to sign (Figure 29).

**Drivers Wanted for Study Aimed at Improving Guide Signs for Older Drivers**

Highways in Texas use guide signs (large green signs with white letters) to give directions, identify routes, show distance to destinations, and provide other information of value to the driver. The Texas Department of Transportation (TxDOT) has recently changed its design for freeway guide signs by adopting a highly reflective material for the message text. The new signs, when viewed at night with a car's headlights, may increase the level of reflected glare and, therefore, reduce guide sign legibility. Reduced legibility forces drivers to switch their attention away from the road and lessens the time available to make a maneuver (exit, change lanes, etc.). Changes in the TxDOT design can have a significant impact on the ability of all drivers, but especially older drivers, to read and react to guide signs. A study is being conducted by the Texas Transportation Institute (TTI) to evaluate the legibility of large freeway guide signs with reflective letters.

The alphabet used by TxDOT on all their current guide signs was developed before this new generation of highly reflective material was available. Preliminary tests conducted by TxDOT suggest that using an alternative alphabet with narrower letters may improve the sign's nighttime legibility. If a particular alphabet increases a sign's legibility, the benefit to the motorist is a gain in additional time to make a maneuver. However, improvements in nighttime legibility cannot come at the expense of daytime legibility. The legibility of an alphabet with narrower letters is now being tested at the Texas Transportation Institute in College Station.

The Texas Transportation Institute seeks licensed drivers to take part in a guide sign experiment. Test participants must have a valid driver's license. Transportation from your home to the Riverside Campus can be provided, if requested. Participants will ride as a passenger in a car and will be asked to observe and read various words on a sign panel. These tests will be done during both the day and at night. Monetary compensation in the amount of $50 will be paid to all qualified participants, after completion of both the daytime and nighttime sessions. Each session is expected to last less than 2 hours. We are particularly interested in drivers over the age of 65, but are recruiting in the age group of 55 - 90. Younger drivers must be under 35. Call 845-2736 for further details.

**Figure 27. Newspaper Recruiting Advertisement**

Thank you for your participation in this important research on highway signs. You will perform at least two sessions, one during the day and one at night. The task you will perform is the same for all sessions.

You will be riding with these other participants in a vehicle along a closed course here at Riverside Annex. An experimenter will be driving the car very slowly towards some signs. Because you will be reading words on the sign aloud, you will be asked to wear a set of headphones during the test. The headphones play a static noise so that you cannot hear the responses of your neighbors; if the noise on the headphones is uncomfortable, please tell me so we can make adjustments.

Here is a model of the course layout and a sample response box. In the car, each of you will have a response box. On this course layout, you can see that there are three signs. Each sign will have three words on it just as you see here. Before the car moves towards each sign, the experimenter will hold up a card showing one of the three words on the sign. Your task is to look at the sign and try to read all of the words on it. As soon as you can read any of the words, press the button on your responses box that matches the position of the word on the sign (top, middle, or bottom) and say the word aloud. You will repeat this as soon as you can read any of the words, pressing the button corresponding to each and saying them aloud. Please remember to hold your box so that the cord is coming out the bottom and the green button is on top.

There is NO PENALTY for being incorrect. However, you need to be reasonably certain of a word before you respond. How certain? Certain enough to change lanes if you were driving on an actual freeway. Do you understand the criteria for making a response?

If you get closer to the sign and feel that the word is different than your first response, simply press the button for whichever word you are reading and give your new response to the word aloud. I will not tell you if you are right or wrong, but please correct yourself if you make a mistake. I would like to stress that you must press the button BEFORE making a verbal response. This is very important.

We will be taking breaks from time to time to stretch and for a rest. If at any time you would like to stop or take a break, please let me know.

After this session is complete, there may be a need to return and finish the rest of this session (day or night), depending on how long it takes to finish today. Then you will be asked to return for the final session (day or night - as appropriate). We will review the procedure again at that time.

**Figure 28. Procedure Read to Participants - Guide Signs - Day or Night**

This research is being conducted to assist the Texas Department of Transportation in determining how well drivers can see and read the words on overhead and ground-mounted freeway guide signs. The research results will be used to determine the need for improving these signs. Approximately 48 - 60 drivers will take part in the study.

I have a valid driver's license. I will be paid a monetary compensation of $50 upon completion of participation in each of two sessions. I will receive $5 if I withdraw prior to completion of the experiment. The experiment should take no more than 2 and one-half to 3 hours per session, for a total of 6 hours for two sessions. The experimenter and I will be the only people conducting the experiment at the time I am involved.

This experiment consists of the following steps. First, I will have some simple vision tests performed to determine my visual acuity and how well I can distinguish areas of different brightness. Then I will ride in a car driven by an experimenter along a test course located on a runway at the Riverside Campus where I will be asked to read words on some highway signs. I will be riding in this vehicle while it moves slowly toward the signs. I will first be asked to look for a specific word by location on the sign, and then I will read the remaining two words on each sign. In both cases, I will press a button on a response box before reading the word aloud to signal which word I am reading. A computer will record my responses. This process will be repeated until I have read all three words on three different sign structures. I will drive past the signs approximately 20 times, each time with different words on the signs.

I understand that detailed instructions will be provided before each session of the study. I am aware that my participation in this study is voluntary and I may quit at any time. The information I give will only be reported in coded form and never with my name or any other identifying information.

This research study has been reviewed and approved by the Institutional Review Board - Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subject's rights, the Institutional Review Board may be contacted through Dr. Richard E. Miller, IRB coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies, (409) 845-xxxx.

I have read and understand the explanation provided me and voluntarily agree to participate in this study.

I have been given a copy of this consent form.

____________________________ ____________________________

Signature of Subject Date Signature of Researcher Date

If I have further questions, I may contact:

Dr. Fran Greene (845-xxxx) or Dr. Gene Hawkins (845-xxxx)
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

**Figure 29. Informed Consent Form**

# APPENDIX D
# SUMMARY OF SUBJECT DATA

Tables 39, 40, and 41 present the subject data for each of the 54 subjects participating in the evaluations. Each subject completed both a full daytime and full nighttime trial.

**Table 39. Summary of Young Subjects (<35 years old) Independent Variables**

| Subject Number[1] | Age | Gender | Visual Acuity[2] | Contrast Sensitivity[3] | Contrast Sensitivity | Reaction Time[5] | Seat Position[6] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Day | Night |
| 81 | 35 | M | 15 | 11111 | Marginal | 1.00 | 1 | 1 |
| 82 | 26 | F | 15 | 77876 | Good | 1.00 | 1,2 | 1 |
| 83 | 25 | F | 25 | 67752 | Good | 1.00 | 2,1 | 2,3 |
| 86 | 25 | F | 25 | 11111 | Marginal | 1.00 | 1,3 | 3,1 |
| 87 | 23 | M | 20 | 11111 | Marginal | 1.00 | 3 | 3 |
| 92 | 21 | M | 15 | 67776 | Good | 0.70 | 3 | 3 |
| 99 | 33 | F | 15 | 11111 | Marginal | 1.00 | 2 | 2 |
| Minimum | 21 | ---- | 15 | ---- | ---- | 0.70 | ---- | ---- |
| Maximum | 35 | ---- | 25 | ---- | ---- | 1.00 | ---- | ---- |

Notes:

[1]Subject number is the number assigned to individuals indicating an interest in participating in the study. For various reasons, some of these individuals were not able to take part in the experiment. Therefore, there are some missing subject numbers in the table.

[2]The visual acuity was measured using a Snellen chart. The number is the bottom of the Snellen visual acuity, i.e., 25 for a person with 20/25 visual acuity.

[3]The value was measured using a Vistech contrast sensitivity chart. Each digit represents a spatial frequency of 1.5, 3, 6, 12, and 18 cycles per degree, respectively.

[4]The overall contrast sensitivity was determined by plotting the values.

[5]Measured in seconds.

[6]Front right seat is Position 1, rear right is Position 2, and rear left is Position 3.

**Table 40. Summary of Young-Old Subjects (55-64 years old) Independent Variables**

| Subject Number[1] | Age | Gender | Visual Acuity[2] | Contrast Sensitivity[3] | Contrast Sensitivity | Reaction Time[5] | Seat Position[6] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Day | Night |
| 4 | 57 | F | 20 | 55533 | Acceptable | 0.78 | 1 | 1 |
| 5 | 64 | F | 20 | 56454 | Marginal | 0.85 | 1,2 | 3 |
| 15 | 63 | M | 20 | 66631 | Acceptable | 0.82 | 3 | 2 |
| 17 | 64 | F | 25 | 56634 | Acceptable | 0.62 | 1,3 | 1 |
| 19 | 56 | M | 20 | 65655 | Acceptable | 0.90 | 2 | 1 |
| 20 | 62 | F | 40 | 56534 | Acceptable | 0.66 | 3 | 3 |
| 21 | 62 | M | 25 | 67534 | Acceptable | 0.90 | 2,3 | 1 |
| 27 | 63 | M | 30 | 55433 | Marginal | 0.62 | 3 | 3 |
| 29 | 58 | F | 70 | 66322 | Marginal | 1.03 | 1 | 2 |
| 30 | 58 | M | 20 | 56434 | Marginal | 0.64 | 2 | 3 |
| 33 | 62 | M | 40 | 55421 | Marginal | 0.87 | 1 | 1 |
| 39 | 57 | F | 20 | 67742 | Acceptable | 0.70 | 1 | 1 |
| 42 | 61 | F | 20 | 67544 | Acceptable | 0.90 | 3,1 | 1 |
| 43 | 64 | M | 15 | 67776 | Good | 0.70 | 1 | 2 |
| 44 | 59 | M | 25 | 67433 | Marginal | 0.87 | 2 | 2 |
| 61 | 64 | M | 20 | 66662 | Acceptable | 0.52 | 2 | 1 |
| 77 | 64 | F | 20 | 67533 | Acceptable | 0.55 | 3 | 3 |
| 79 | 59 | F | 20 | 66651 | Acceptable | 1.00 | 1 | 3,1 |
| Minimum | 56 | ---- | 15 | ---- | ---- | .52 | ---- | ---- |
| Maximum | 64 | ---- | 70 | ---- | ---- | 1.03 | ---- | ---- |

Notes:
[1]Subject number is the number assigned to individuals indicating an interest in participating in the study. For various reasons, some of these individuals were not able to take part in the experiment. Therefore, there are some missing subject numbers in the table.
[2]The visual acuity was measured using a Snellen chart. The number is the bottom of the Snellen visual acuity, i.e., 25 for a person with 20/25 visual acuity.
[3]The value was measured using a Vistech contrast sensitivity chart. Each digit represents a spatial frequency of 1.5, 3, 6, 12, and 18 cycles per degree, respectively.
[4]The overall contrast sensitivity was determined by plotting the values.
[5]Measured in seconds.
[6]Front right seat is Position 1, rear right is Position 2, and rear left is Position 3.

**Table 41. Summary of Old-Old Subjects (65+ years old) Independent Variables**

| Subject Number[1] | Age | Gender | Visual Acuity[2] | Contrast Sensitivity[3] | Contrast Sensitivity | Reaction Time[5] | Seat Position[6] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Day | Night |
| 2 | 73 | F | 25 | 54433 | Marginal | 0.93 | 1 | 3 |
| 3 | 84 | M | 40 | 54333 | Marginal | 1.03 | 3,1 | 3 |
| 6 | 74 | F | 20 | 55432 | Marginal | 0.77 | 2,1 | 1,2 |
| 7 | 77 | M | 50 | 56433 | Marginal | 1.22 | 3 | 1 |
| 8 | 75 | F | 25 | 65422 | Marginal | 1.07 | 3,2 | 2 |
| 9 | 67 | M | 25 | 55432 | Marginal | 0.85 | 3 | 1 |
| 10 | 75 | M | 30 | 56533 | Acceptable | 0.73 | 2 | 1 |
| 11 | 79 | M | 30 | 55300 | Marginal | 1.00 | 2,1 | 1 |
| 12 | 82 | M | 50 | 55421 | Marginal | 0.95 | 3 | 1,3 |
| 13 | 82 | F | 40 | 44423 | Marginal | 0.98 | 2 | 2 |
| 16 | 78 | F | 25 | 67431 | Marginal | 1.00 | 2,1 | 1 |
| 18 | 76 | F | 30 | 56434 | Marginal | 0.96 | 3 | 2 |
| 22 | 65 | M | 20 | 76531 | Acceptable | 0.98 | 3 | 3 |
| 23 | 67 | F | 40 | 56544 | Acceptable | 1.31 | 1 | 3 |
| 24 | 71 | F | 40 | 55439 | Marginal | 0.69 | 3,1 | 1 |
| 25 | 65 | M | 25 | 56221 | Marginal | 0.71 | 2 | 3 |
| 28 | 70 | M | 25 | 67421 | Marginal | 0.68 | 2 | 2 |
| 40 | 73 | M | 40 | 67431 | Marginal | 0.90 | 1 | 2 |
| 41 | 74 | M | 20 | 66433 | Marginal | 0.66 | 1,2 | 1 |
| 47 | 75 | F | 30 | 55411 | Marginal | 0.86 | 2,3 | 3 |
| 50 | 73 | F | 50 | 56442 | Marginal | 1.14 | 2 | 3 |
| 54 | 71 | M | 20 | 66633 | Acceptable | 0.71 | 2 | 1 |
| 55 | 71 | M | 25 | 56534 | Acceptable | 0.82 | 2 | 2,3 |
| 58 | 76 | M | 50 | 55321 | Marginal | 1.00 | 1 | 2,1 |
| 69 | 80 | F | 70 | 14399 | Marginal | 1.57 | 2,1 | 1 |
| 74 | 71 | M | 20 | 66734 | Acceptable | 0.67 | 3 | 2,3 |
| 75 | 82 | M | 30 | 55321 | Marginal | 1.02 | 1 | 1 |
| 76 | 66 | M | 20 | 66665 | Good | 0.56 | 1,2 | 2 |
| 78 | 65 | F | 20 | 56654 | Acceptable | 0.65 | 1 | 1,2 |
| Minimum | 65 | ---- | 20 | ---- | ---- | 0.56 | ---- | ---- |
| Maximum | 84 | ---- | 70 | ---- | ---- | 1.57 | ---- | ---- |

Notes:
[1]Subject number is the number assigned to individuals indicating an interest in participating in the study. For various reasons, some of these individuals were not able to take part in the experiment. Therefore, there are some missing subject numbers in the table.
[2]The visual acuity was measured using a Snellen chart. The number is the bottom of the Snellen visual acuity, i.e., 25 for a person with 20/25 visual acuity.
[3]The value was measured using a Vistech contrast sensitivity chart. Each digit represents a spatial frequency of 1.5, 3, 6, 12, and 18 cycles per degree, respectively.
[4]The overall contrast sensitivity was determined by plotting the values.
[5]Measured in seconds.
[6]Front right seat is Position 1, rear right is Position 2, and rear left is Position 3.

## APPENDIX E

# STATISTICAL ANALYSIS

The tables in this appendix provide a statistical comparison of the legibility and recognition distances for the various population groups. Each table presents legibility and recognition mean distances for various driver sample groups. The mean values were compared using Duncan's Multiple Range Test and Scheffe's Method for Multiple Comparisons. For each type of analysis an alpha ($\alpha$) of 0.05 was used.

For consistency purposes, the mean values in each table are presented in the same order. From left-to-right, the order is Series E(Modified) (E-M), Clearview™ (CV), and British Transport Medium (BT). The means are not arranged in descending order, as is normally done with the Duncan or Scheffe methods. The letters (A, B, or AB) below each mean indicate statistically significant differences. If two means have the same letter (A and A, A and AB, B and B, or B and AB), then there is no statistically significant difference between those means.

In general, there were only two cases where either of the alternative alphabets were statistically better than the Series E(Modified) alphabet. In both cases, Clearview™ was better than Series E(Modified) for the daytime recognition of overhead signs. One case was for all drivers and the other was for drivers with normal contrast sensitivity.

### Table 42. Statistical Analysis for All Drivers

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 836 | 804 | 812 | 866 | 885 | 839 | 994 | 971 | 994 | 1026 | 1068 | 1014 |
| Duncan | A | B | B | A | A | B | A | A | A | B | A | B |
| Scheffe's | A | B | B | A | A | B | A | A | A | B | A | B |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 653 | 655 | 643 | 650 | 663 | 624 | 786 | 783 | 785 | 766 | 787 | 754 |
| Duncan | A | A | A | A | A | B | A | A | A | AB | A | B |
| Scheffe's | A | A | A | A | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.

### Table 43. Statistical Analysis for Young Drivers

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 1118 | 1100 | 1073 | 1140 | 1140 | 1111 | 1292 | 1288 | 1275 | 1303 | 1335 | 1316 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 821 | 828 | 808 | 823 | 811 | 791 | 986 | 958 | 965 | 948 | 951 | 944 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Driver age <35 years old.

**Table 44. Statistical Analysis for Young-Old Drivers**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 872 | 838 | 853 | 897 | 920 | 863 | 1054 | 1023 | 1058 | 1078 | 1109 | 1063 |
| Duncan | A | B | AB | A | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |
| **Time** | Nighttime | | | | | | | | | | | |
| **Variable** | Legibility | | | | | | Recognition | | | | | |
| **Position** | Ground | | | Overhead | | | Ground | | | Overhead | | |
| **Alphabet** | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| **Mean** | 678 | 687 | 672 | 685 | 697 | 656 | 829 | 819 | 811 | 809 | 837 | 789 |
| **Duncan** | A | A | A | AB | A | B | A | A | A | A | A | A |
| **Scheffe's** | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Driver age 55-64 years old.

**Table 45. Statistical Analysis for Old-Old Drivers**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 745 | 709 | 723 | 781 | 801 | 757 | 883 | 861 | 886 | 925 | 976 | 908 |
| Duncan | A | B | AB | AB | A | B | A | A | A | AB | A | B |
| Scheffe's | A | A | A | AB | A | B | A | A | A | AB | A | B |
| **Time** | Nighttime | | | | | | | | | | | |
| **Variable** | Legibility | | | | | | Recognition | | | | | |
| **Position** | Ground | | | Overhead | | | Ground | | | Overhead | | |
| **Alphabet** | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| **Mean** | 596 | 592 | 584 | 585 | 604 | 563 | 710 | 718 | 726 | 695 | 715 | 687 |
| **Duncan** | A | A | A | AB | A | B | A | A | A | A | A | A |
| **Scheffe's** | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Driver age ≥65 years old.

### Table 46. Statistical Analysis for Drivers with Good Visual Acuity

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 985 | 942 | 955 | 1011 | 1037 | 981 | 1177 | 1133 | 1173 | 1192 | 1242 | 1187 |
| Duncan | A | B | AB | AB | A | B | A | A | A | A | A | A |
| Scheffe's | A | B | AB | AB | A | B | A | A | A | A | A | A |
| **Time** | **Nighttime** | | | | | | | | | | | |
| **Variable** | **Legibility** | | | | | | **Recognition** | | | | | |
| **Position** | **Ground** | | | **Overhead** | | | **Ground** | | | **Overhead** | | |
| **Alphabet** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** |
| Mean | 800 | 803 | 792 | 801 | 816 | 763 | 951 | 941 | 951 | 931 | 958 | 908 |
| Duncan | A | A | A | A | A | B | A | A | A | AB | A | B |
| Scheffe's | A | A | A | A | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Visual acuity of 20/20 or better.

### Table 47. Statistical Analysis for Drivers with Normal Visual Acuity

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 790 | 771 | 768 | 822 | 827 | 799 | 909 | 895 | 914 | 959 | 984 | 934 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |
| **Time** | **Nighttime** | | | | | | | | | | | |
| **Variable** | **Legibility** | | | | | | **Recognition** | | | | | |
| **Position** | **Ground** | | | **Overhead** | | | **Ground** | | | **Overhead** | | |
| **Alphabet** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** | **E-M** | **CV** | **BT** |
| Mean | 604 | 607 | 595 | 601 | 609 | 572 | 720 | 712 | 720 | 703 | 705 | 693 |
| Duncan | A | A | A | A | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Visual acuity of 20/25 to 20/30.

**Table 48. Statistical Analysis for Drivers with Marginal Visual Acuity**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 636 | 600 | 618 | 671 | 692 | 639 | 787 | 788 | 788 | 825 | 871 | 810 |
| Duncan | A | A | A | AB | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 458 | 455 | 443 | 447 | 466 | 442 | 585 | 597 | 584 | 562 | 603 | 567 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Visual acuity of 20/40 to 20/70.

**Table 49. Statistical Analysis for Drivers with Normal Contrast Sensitivity**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 900 | 862 | 878 | 933 | 947 | 888 | 1076 | 1044 | 1076 | 1105 | 1148 | 1085 |
| Duncan | A | B | AB | A | A | B | A | A | A | B | A | B |
| Scheffe's | A | B | AB | A | A | B | A | A | A | AB | A | B |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 713 | 721 | 708 | 715 | 728 | 691 | 855 | 862 | 863 | 843 | 868 | 830 |
| Duncan | A | A | A | A | A | B | A | A | A | AB | A | B |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Normal contrast sensitivity as determined from a VCTS chart.

**Table 50. Statistical Analysis for Drivers with Marginal Contrast Sensitivity**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 717 | 696 | 690 | 743 | 768 | 748 | 841 | 836 | 840 | 878 | 919 | 882 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 531 | 521 | 511 | 519 | 532 | 486 | 647 | 624 | 627 | 610 | 626 | 600 |
| Duncan | A | A | A | AB | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Marginal contrast sensitivity as determined from a VCTS chart.

**Table 51. Statistical Analysis for Drivers with Faster Reaction Time**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 930 | 886 | 899 | 951 | 983 | 924 | 1103 | 1082 | 1114 | 1140 | 1194 | 1121 |
| Duncan | A | B | AB | AB | A | B | A | A | A | AB | A | B |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 738 | 743 | 726 | 744 | 762 | 723 | 871 | 880 | 885 | 865 | 891 | 852 |
| Duncan | A | A | A | AB | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Reaction time <0.75 seconds.

**Table 52. Statistical Analysis for Drivers with Moderate Reaction Time**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 758 | 719 | 735 | 791 | 802 | 760 | 909 | 879 | 916 | 944 | 971 | 939 |
| Duncan | A | B | AB | AB | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 611 | 605 | 604 | 597 | 612 | 558 | 746 | 731 | 728 | 712 | 730 | 697 |
| Duncan | A | A | A | A | A | B | A | A | A | A | A | A |
| Scheffe's | A | A | A | AB | A | B | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Reaction time 0.75-0.99 seconds.

**Table 53. Statistical Analysis for Drivers with Slower Reaction Time**

| Time | Daytime | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 821 | 806 | 803 | 858 | 868 | 833 | 967 | 952 | 953 | 995 | 1038 | 981 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |
| Time | Nighttime | | | | | | | | | | | |
| Variable | Legibility | | | | | | Recognition | | | | | |
| Position | Ground | | | Overhead | | | Ground | | | Overhead | | |
| Alphabet | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT | E-M | CV | BT |
| Mean | 607 | 613 | 595 | 604 | 612 | 588 | 738 | 735 | 738 | 718 | 739 | 710 |
| Duncan | A | A | A | A | A | A | A | A | A | A | A | A |
| Scheffe's | A | A | A | A | A | A | A | A | A | A | A | A |

Note: There are no statistically significant differences between means with the same letter.
Reaction time $\geq 1.00$ seconds.