EVALUATION OF THE EFFECT OF CLEARVIEW FONT AND RETRO-REFLECTIVE SHEETING MATERIALS ON LEGIBILITY DISTANCE

by

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Abstract

During the last several decades, the number of drivers and the number of senior citizens driving on U.S highways has increased significantly along with the number of traffic signs. The median age of the drivers has also increased due to the aging population. Traffic signs provide a plethora of necessary information - directions, guidance, warnings, regulations, and recreation. With today's congestion and higher speed, it's very important to recognize the need for brighter and easier to read signs to increase safety among drivers. In the recent years, there has been innovation in the field of traffic engineering, giving rise to numerous innovations in retro-reflective sheeting materials and fonts. It is important to identify the combination of font and retro-reflective sheeting material, which performs best by increasing the legibility distance between the driver and the sign during both day and night time conditions.

The objective of the research was to determine the combination of font (among Clearview 5-W, Series E-Modified and Clearview 5-W-R) and retro-reflective sheeting materials (DG3, Type 4 and Type 1) that produces maximum legibility distance. The objective was also to study the safety benefits of the Clearview font. Both field and computer based tests were carried out to find out which combination of font and retro-reflective material produced maximum legibility distance. From field tests it was found that the Clearview 5-W-R font along with Type 1 reflective material produced the maximum legibility distance in day time conditions, whereas Clearview 5-W-R along with Type 4 reflective material produced the maximum legibility distance at night conditions. It was also seen that while the Type 1 sheeting material performed well during day time, it failed to produce good results during night time. In fact it ended up as the worst performing sheeting material during night time. Based on these observations, it is recommended to use the Clearview 5-W-R in combination with Type 4 retro-reflective sheeting as it showed the most consistent performance compared to all other combinations of fonts and DG3 or Type 1 retro-reflective material.

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CHAPTER 1 - Introduction

Traffic control devices are an essential part of traffic control. They are the sole means of providing information to motorists about the road ahead of them. Since they are highly essential for safety and effectiveness, they should be well understood by motorists and also clearly visible in order for the drivers to have a safe journey on highways and roadways.

1.1 Problem identification

During the last several decades, the number of drivers and the number of senior citizens (aged 65 and over) on Urban/Rural Traffic has increased significantly along with the number of traffic signs. The median age of the drivers has also increased due to the aging population. According to the NHTSA Traffic Safety Facts (2008), there were 31 million older licensed drivers in 2007 — a 19 percent increase from 1997. In contrast, the total number of licensed drivers increased by only 13 percent from 1997 to 2007. Older drivers made up 15 percent of all licensed drivers in 2007, compared with 14 percent in 1997. By 2020 the number of licensed older drivers is set to reach 50 million.

Traffic signs provide a plethora of necessary information - directions, guidance, warnings, regulations, and recreation. With today's congestion and higher speed, it's very important to recognize the need for brighter and easier to read signs to increase safety among drivers. In the recent years, there has been innovation in the field of traffic engineering, giving rise to numerous innovations in retro-reflective sheeting material and new fonts. It is important to identify the combination of font and retro-reflective sheeting material, which performs best by increasing the legibility distance between the driver and the sign during both day and night time conditions and thus increase safety among drivers.

1.2 New fonts and retro-reflective sheeting material tested

Two new fonts and two new retro-reflective sheeting materials were chosen to be tested against an existing font and retro-reflective material in this experiment. The new fonts that were

tested in our experiments were the Clearview 5-W, Clearview 5-W-R along with the existing Series E-Modified font. The retro-reflective materials tested were the existing Type 1 retro-reflective material and the new Type 4 and DG3. The font and retro-reflective materials mostly used in the U.S roadways are the Type 1 sheeting material along with the Series E-Modified font. Although previous research experiments point to a 10-12% increase in the legibility distance when using Clearview font on a Type 1 retro-reflective sheeting material, little research exists on the performance of the font when used in combination with the new retro-reflective sheeting materials like DG3 and Type 4 sheeting materials. Thus the objective of this research was to evaluate the effectiveness of the Clearview font when used along with different combinations of retro-reflective sheeting material.

1.3 Method

Tests were developed based on the literature review regarding design and evaluation of new fonts and retro-reflective sheeting material. Both computer based screen based tests and field tests of the font along with combinations of retro-reflective sheeting material were carried out. Participants of the study were mainly students from the college of engineering at Kansas State University holding valid driver's license and with several years of driving experience. Computer based tests were carried out in laboratory whereas field based studies were carried out in Kansas State University's Bill Snyder Family Football Stadium parking lot. All sign fonts, retro-reflective sheeting material, sign boards were provided by the Kansas Department of Transportation.

1.4 Thesis outline

Chapter 2 is a review of literature related to the development of the Clearview font, design of experiments and testing the new fonts. The review includes discussions on: various types of signs; general rules and regulations for the installation of the guide signs; the Clearview font development. Chapter 3 contains discussion of the results of the e-mail survey of Departments of Transportation (DOTs) in U.S regarding use of Clearview font. Chapter 4 contains discussion of the experimental procedure for the computer screen study and discussions of the results from the study. In chapter 5, the field study and the results of the Clearview font and high performance sheeting material are discussed. Conclusions and scope for future work is discussed in chapter 6.

CHAPTER 2 - Literature Review

2.1 Introduction to different types of signs

The road signs used on U.S highways are classified into three main categories (MUTCD, 2009). The categories into which they are classified are given below. The functions of signs are to provide regulations, warnings, and guidance information for road users. Words, symbols, and arrows are used to convey the messages. Signs are not typically used to confirm rules of the road. The Manual on Uniform Traffic Control Devices (MUTCD) contains standards, guidance, and options for the signing of all types of highways and private roads open to public travel.

2.1.1 Warning signs and Regulatory Signs

Warning signs are used to warn motorists about the hazards or hazardous conditions they may face on the roadway. The MUTCD contains the standards for these types of signs. All warning signs are diamond shaped signs with black legend on a yellow or orange background (MUTCD, 2009). Regulatory signs are used to inform motorists about the traffic laws/regulations that have to be followed on the roadway. The regulatory signs are vertically oriented rectangles with a black legend on a white background (MUTCD, 2009).

2.1.2 Pavement markings

Pavement markings are mainly used to designate traffic lanes on roads. Mostly yellow lines are used to separate traffic traveling in opposite direction and white lines are used to separate traffic carried in the same direction (MUTCD, 2009).

2.1.3 Guide signs

Guide signs are signs whose purpose is to direct road users along streets and highways, to inform them of intersecting routes, to direct them to cities, towns, villages, or other important destinations, to identify nearby rivers and streams, parks, forests, and historical sites, and generally to give such information as will help them along their way in the most simple, direct manner possible (MUTCD, 2009).

2.2 General rules and regulations for the installation of guide signs

2.2.1 Design of signs

The basic requirements of a sign are that it be legible to those for whom it is intended and that it be understandable in time to permit a proper response. Desirable attributes include:

A. High visibility by day and night; and

B. High legibility (adequately sized letters, symbols, or arrows, and a short legend for quick comprehension by a road user approaching a sign). Standardized colors and shapes are specified so that the several classes of traffic signs can be promptly recognized. Simplicity and uniformity in design, position, and application are important (MUTCD, 2009).

2.2.2 Retro-reflectivity and illumination

There are many materials currently available for retro-reflection and various methods currently available for the illumination of signs and object markers. New materials and methods continue to emerge. New materials and methods can be used as long as the signs and object markers meet the standard requirements for color, both by day and by night.

Regulatory, warning, and guide signs and object markers should be retro-reflective or illuminated to show the same shape and similar color by both day and night. The requirements for sign illumination should not be considered to be satisfied by street or highway lighting. Table 2.1 shows the retro-reflection needed for the sign element and Table 2.2 shows the means of illumination required for the sign element to be illuminated.

Table 2.1 Retro-reflection needed for the sign element (MUTCD, 2009)

Means of Retroreflection	Sign Element
Reflector "buttons" or similar units	Symbol Word message Border
A material that has a smooth, sealed outer surface over a microstructure that reflects light	Symbol Word message Border Background

Table 2.2 Retro-reflection needed for the sign element (MUTCD, 2009)

Means of Illumination	Sign Element to be Illuminated
Light behind the sign face	• Symbol or word message • Background • Symbol, word message, and background (through a translucent material)
Attached or independently mounted light source designed to direct essentially uniform illumination onto the sign face	• Entire sign face
Light emitting diodes (LEDs)	• Symbol or word message • Portions of the sign border
Other devices, or treatments that highlight the sign shape, color, or message: Luminous tubing Fiber optics Incandescent light bulbs Luminescent panels	• Symbol or word message • Entire sign face

2.2.3 Standardization of location

Standardization of position cannot always be attained in practice. Examples of heights and lateral locations of signs for typical installations are illustrated in Figure 2.1.

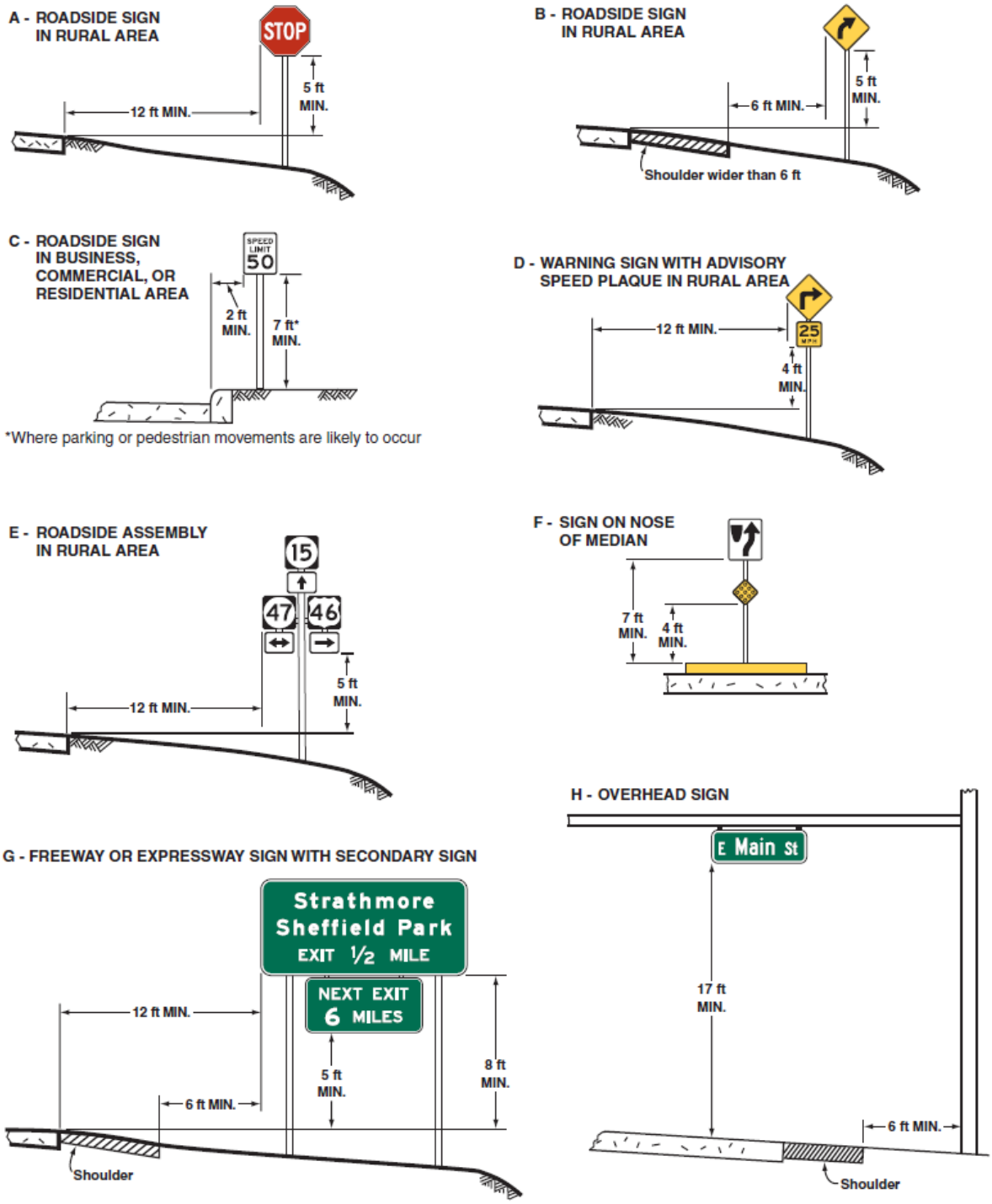
Standard:

Signs requiring separate decisions by the road user should be spaced sufficiently far apart for the appropriate decisions to be made. One of the factors considered when determining the appropriate spacing should be the posted or 85th-percentile speed.

Signs should be located on the right-hand side of the roadway where they are easily recognized and understood by road users. Signs in other locations should be considered only as supplementary to signs in the normal locations, except as otherwise provided in the MUTCD. Signs should also be individually installed on separate posts or mountings except where:

1. One sign supplements another
2. Route or directional signs are grouped to clarify information to motorists

Figure 2.1 Examples of heights and lateral locations of signs for typical installations (MUTCD, 2009)



Note:
See Section 2A.19 for reduced lateral offset distances that may be used in areas where lateral offsets are limited, and in business, commercial, or residential areas where sidewalk width is limited or where existing poles are close to the curb.

2.2.4 Guide Signs on conventional roads

Scope of Conventional Road Guide Sign Standards as issued by the MUTCD is given in the following sections. The provisions mentioned in this chapter apply to any road or street other than low-volume roads expressways and freeways.

Requirements for color, retro-reflection, and illumination:

Requirements for illumination, retro-reflection, and color are stated under the specific headings for individual guide signs or groups of signs. General provisions are given in Sections 2A.07, 2A.08, and 2A.10. of the MUTCD. Except where otherwise provided in the MUTCD for individual signs or groups of signs, guide signs on streets and highways shall have a white message and border on a green background. All messages, borders, and legends shall be retro-reflective and all backgrounds shall be retro-reflective or illuminated.

Color coding is sometimes used to help road users distinguish between multiple potentially confusing destinations. Examples of valuable uses of color coding include guide signs for roadways approaching or inside an airport property with multiple terminals serving multiple airlines, and community way finding guide signs for various traffic generator destinations within a community or area.

Except where otherwise provided in the MUTCD, different color sign backgrounds shall not be used to provide color coding of destinations. The color coding shall be accomplished by the use of different colored square or rectangular sign panels on the face of the guide signs.

The different colored sign panels may include a black or white (whichever provides the better contrast with the panel color) letter, numeral, or other appropriate designation to identify an airport terminal or other destination (MUTCD, 2009).

Lettering style:

According to the MUTCD, the design of upper-case letters, lower-case letters, numerals, route shields, and spacing should be as provided in the “Standard Highway Signs and Markings” book. The lettering for names of places, streets, and highways on conventional road guide signs should be a combination of lower-case letters with initial upper-case letters. The nominal loop

height of the lower-case letters should be 3/4 the height of the initial upper-case letter. When a mixed-case legend letter height is specified referring only to the initial upper-case letter, the height of the lower-case letters that follow should be determined by this proportion. When the height of a lower-case letter is referenced, the reference is made to the nominal loop height and the height of the initial upper-case letter should also be determined by this proportion. All other word legends on conventional road guide signs should be in upper-case letters. The unique letter forms for each of the Standard Alphabet series should not be stretched, compressed, warped, or otherwise manipulated (MUTCD, 2009).

Size of lettering:

According to the MUTCD, sign legibility is a direct function of letter size and spacing. Legibility distance has to be sufficient to give road users enough time to read and comprehend the sign. Under optimum conditions, a guide sign message can be read and understood in a brief glance. The legibility distance takes into account factors such as inattention, blocking of view by other vehicles, unfavorable weather, inferior eyesight, or other causes for delayed or slow reading. Where conditions permit, repetition of guide information on successive signs gives the road user more than one opportunity to obtain the information needed (MUTCD, 2009).

Table 2.3 Conventional road sign and guide sign sizes (Source: MUTCD, 2009)

Sign	Sign Designation	Section	Conventional Road	Minimum	Oversized
Interstate Route Sign (1 or 2 digits)	M1-1	2D.11	24 x 24	24 x 24	36 x 36
Interstate Route Sign (3 digits)	M1-1	2D.11	30 x 24	30 x 24	45 x 36
Off-Interstate Route Sign (1 or 2 digits)	M1-2,3	2D.11	24 x 24	24 x 24	36 x 36
Off-Interstate Route Sign (3 digits)	M1-2,3	2D.11	30 x 24	30 x 24	45 x 36
U.S. Route Sign (1 or 2 digits)	M1-4	2D.11	24 x 24	24 x 24	36 x 36
U.S. Route Sign (3 digits)	M1-4	2D.11	30 x 24	30 x 24	45 x 36
State Route Sign (1 or 2 digits)	M1-5	2D.11	24 x 24	24 x 24	36 x 36
State Route Sign (3 digits)	M1-5	2D.11	30 x 24	30 x 24	45 x 36
County Route Sign (1, 2, or 3 digits)	M1-6	2D.11	24 x 24	24 x 24	36 x 36
Forest Route (1, 2, or 3 digits)	M1-7	2D.11	24 x 24	18 x 18	36 x 36
Junction	M2-1	2D.13	21 x 15	21 x 15	30 x 21
Combination Junction (2 route signs)	M2-2	2D.14	60 x 48*	—	—
Cardinal Direction	M3-1,2,3,4	2D.15	24 x 12	24 x 12	36 x 18
Alternate	M4-1,1a	2D.17	24 x 12	24 x 12	36 x 18
By-Pass	M4-2	2D.18	24 x 12	24 x 12	36 x 18
Business	M4-3	2D.19	24 x 12	24 x 12	36 x 18
Truck	M4-4	2D.20	24 x 12	24 x 12	36 x 18
To	M4-5	2D.21	24 x 12	24 x 12	36 x 18
End	M4-6	2D.22	24 x 12	24 x 12	36 x 18
Temporary	M4-7,7a	2D.24	24 x 12	24 x 12	36 x 18
Begin	M4-14	2D.23	24 x 12	24 x 12	36 x 18
Advance Turn Arrow	M5-1,2,3	2D.28	21 x 15	21 x 15	—
Lane Designation	M5-4,5,6	2D.33	24 x 18	24 x 18	36 x 24
Directional Arrow	M6-1,2,2a,3,4, 5,6,7	2D.29	21 x 15	21 x 15	30 x 21
Destination (1 line)	D1-1	2D.39	Varies x 18	Varies x 18	—
Destination and Distance (1 line)	D1-1a	2D.39	Varies x 18	Varies x 18	—
Circluar Intersection Destination (1 line)	D1-1d	2D.40	Varies x 18	Varies x 18	—
Circluar Intersection Departure Guide	D1-1e	2D.40	Varies x 42*	—	—
Destination (2 lines)	D1-2	2D.39	Varies x 30	Varies x 30	—
Destination and Distance (2 lines)	D1-2a	2D.39	Varies x 30	Varies x 30	—
Circluar Intersection Destination (2 lines)	D1-2d	2D.40	Varies x 30	Varies x 30	—
Destination (3 lines)	D1-3	2D.39	Varies x 42	Varies x 42	—
Destination and Distance (3 lines)	D1-3a	2D.39	Varies x 42	Varies x 42	—
Circluar Intersection Destination (3 lines)	D1-3d	2D.40	Varies x 42	Varies x 42	—
Distance (1 line)	D2-1	2D.43	Varies x 18	Varies x 18	—
Distance (2 lines)	D2-2	2D.43	Varies x 30	Varies x 30	—
Distance (3 lines)	D2-3	2D.43	Varies x 42	Varies x 42	—
Street Name (1 line)	D3-1,1a	2D.45	Varies x 12	Varies x 8	Varies x 18
Advance Street Name (2 lines)	D3-2	2D.46	Varies x 30*	—	—
Advance Street Name (3 lines)	D3-2	2D.46	Varies x 42*	—	—
Advance Street Name (4 lines)	D3-2	2D.46	Varies x 60*	—	—
Parking Area	D4-1	2D.49	30 x 24	18 x 15	—
Park - Ride	D4-2	2D.50	30 x 36	24 x 30	36 x 48
National Scenic Byways	D6-4	2D.56	24 x 24	24 x 24	—
National Scenic Byways	D6-4a	2D.56	24 x 12	24 x 12	—
Weigh Station XX Miles	D8-1	2D.51	78 x 60	60 x 48	96 x 72
Weigh Station Next Right	D8-2	2D.51	84 x 72	66 x 54	108 x 90
Weigh Station (with arrow)	D8-3	2D.51	66 x 60	48 x 42	84 x 78
Crossover	D13-1,2	2D.55	60 x 30	60 x 30	78 x 42
Freeway Entrance	D13-3	2D.48	48 x 30	48 x 30	—
Freeway Entrance (with arrow)	D13-3a	2D.48	48 x 42	48 x 42	—
Combination Lane Use / Destination	D15-1	2D.35	Varies x 96	Varies x 96	—
Next Truck Lane XX Miles	D17-1	2D.53	42 x 48	42 x 48	60 x 66
Truck Lane XX Miles	D17-2	2D.53	42 x 42	42 x 42	60 x 54
Slow Vehicle Turn-Out XX Miles	D17-7	2D.54	72 x 42	72 x 42	96 x 54

2.2.5 Scope of freeway and expressway guide sign standards

The provisions of this section provide a uniform and effective system of signing for high-volume, high-speed motor vehicle traffic on freeways and expressways.

Freeway and expressway signing principles:

The development of a signing system for freeways and expressways is approached on the premise that the signing is primarily for the benefit and direction of road users who are not familiar with the route or area.

Color of guide signs:

Guide signs on freeways and expressways, except as otherwise provided in the MUTCD, should have white letters, symbols, arrows, and borders on a green background. Color requirements for route signs and trailblazers, signs with blank-out or changeable messages, signs for services, rest areas, park and recreational areas, and for certain miscellaneous signs are not the same as the guide signs (MUTCD, 2009).

Retro-reflection or illumination:

According to the MUTCD, letters, numerals, symbols, arrows, and borders of all guide signs should be retro-reflectorized. The background of all guide signs that are not independently illuminated should be retro-reflective. Overhead sign installations should be illuminated unless an engineering study shows that retro-reflectorization alone will perform effectively. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message (MUTCD, 2009).

Characteristics of rural signing:

The MUTCD states that rural areas ordinarily have greater distances between interchanges, which permit adequate spacing for the sequences of signs on the approach to and departure from each interchange. However, the absence of traffic in adjoining lanes and on entering or exiting ramps often adds monotony or inattention to rural driving. This increases the importance of signs that call for decisions or actions (MUTCD, 2009).

Amount of legend on guide signs:

The MUTCD states that no more than two destination names or street names should be displayed on any Advance Guide sign or Exit Direction sign. A city name and street name on the same sign should be avoided. Where two or three signs are placed on the same supports, destinations or names should be limited to one per sign, or to a total of three in the display. Sign legends should not exceed three lines of copy, exclusive of the exit number and action or distance information (MUTCD, 2009).

Number of signs at an overhead installation and sign spreading:

If overhead signs are warranted, the number of signs at these locations should be limited to only those essential in communicating pertinent destination information to the road user. Exit Direction signs for a single exit and the Advance Guide signs should have only one sign with one or two destinations. Regulatory signs, such as speed limits, should not be used in conjunction with overhead guide sign installations. Because road users have limited time to read and comprehend sign messages, there should not be more than three guide signs displayed at any one location either on the overhead structure or its support (MUTCD, 2009).

Size and style of letters and signs:

The sizes of freeway and expressway guide signs that have standardized designs should be as shown in Table D.4 in the appendix section. For all freeway and expressway signs that do not have a standardized design, the message dimensions should be determined first, and the outside sign dimensions secondarily. Word messages in the legend of expressway guide signs should be in letters at least 8 inches high. Larger lettering should be used for major guide signs at or in advance of interchanges and for all overhead signs. Minimum numeral and letter sizes for expressway guide signs according to interchange classification, type of sign, and component of sign legend should be as shown in Tables D.4 and D.5 in the appendix section. Minimum numeral and letter sizes for freeway guide signs according to interchange classification, type of sign, and component of sign legend should be as shown in Tables D.4 and D.5 in the appendix section. All names of places, streets, and highways on freeway and expressway guide signs

should be composed of lower-case letters with initial upper-case letters. The nominal loop height of the lower-case letters should be 3/4 of the height of the initial upper-case letter. Lettering size on freeway and expressway signs should be the same for both rural and urban conditions.

Tables D.1 to D.3 in the appendix section are guidelines for freeway or expressway guide signs and plaque sizes. Tables D.4 to D.6 in the appendix section show minimum letter and numeral sizes for guide signs (MUTCD, 2009).

2.3 Standard alphabets for traffic control devices

The following is the excerpt from the Federal Highway Administration (FHWA) Regarding Standard Alphabets for Traffic Control Devices.

> "The Standard alphabets for traffic control devices were prepared by the Federal Highway Administration for signing and marking all streets, highways, bike routes, trails and other by-ways open to public travel.
>
> The alphabets were first adopted nationwide sometime in the late 1940's and early 1950's after completion of studies by the California Department of Transportation. A modified version of the Gothic style alphabet was adopted having openness in the rounded shaped characters. This modification provided better legibility and readability for traffic control devices.
>
> The *Manual on Uniform Traffic Control Devices* or MUTCD defines the standards used by road managers nationwide to install and maintain traffic control devices on all streets and highways. The FHWA publishes the MUTCD. The 2009 edition of the Standard Alphabets for Traffic Control Devices contains a complete functional specification for designing standard highway alphabets."

2.4 The Clearview font

The ClearviewHwy^{TM} font, hereafter referred to as the Clearview font is a relatively new font developed to increase the traffic sign legibility and improve the ease with which traffic legends can be recognized. The Clearview font was developed by Donald Meeker and Christopher O'Hara of Meeker and Associates, Inc., which is a graphics design firm, through a decade of research starting in the early 1990s. Clearview font has been researched by the

Pennsylvania Transport Institute (PTI) at Pennsylvania State University and the Texas Transportation Institute (TTI).

The developers of the Clearview font claim that the Clearview font reduces the phenomenon of irradiation or halation. Irradiation is a phenomenon wherein the stroke is so bright that it bleeds into the characters' open spaces, creating a blobbing effect that reduces character legibility. The Clearview font's wide open spaces allow irradiation without decreasing the distance at which the alphabet is legible.

Figure 2.2 Halation phenomenon observed in different font types (http://clearviewhwy.com/WhatIsClearviewHwy/SystemAttributes/reducedHalation.php)

2.5 The Clearview font development

The Clearview font can be electronically produced using the ClearviewHwy font software. ClearviewHwy is the font software produced by the design team (Meeker and Associates, Inc.) that developed Clearview. This font is identical to the Clearview displayed in the Standard Highway Signs book; however as font software ClearviewHwy contains kerning data (Kerning refers to data included in a font that specifies how to adjust the spacing) in

addition to approved letter spacing in default mode, it is compatible with all standard computer operating systems and sign manufacturing software. In the ten years of research and development, ClearviewHwy has evolved into a type system with six distinct weights, with each weight having a version for positive and negative contrast applications. (www.clearviewhwy.com Date accesses: 03/24/2010).

a. Positive contrast applications: Lighter tone letters (White) on a dark background (Green)
b. Negative contrast version: Darker tone letters (Black) on a light background (White).

Figure 2.3 shows the various font weights in which Clearview font is available. The different types of Clearview font weights are the equivalents for the FHWA font that is currently used on road signs. The Table 2.4 below gives the comparison of the Clearview font with the equivalent FHWA font.

Figure 2.3 Clearview font weights or font types
(http://clearviewhwy.com/TypefaceDisplay/index.php)

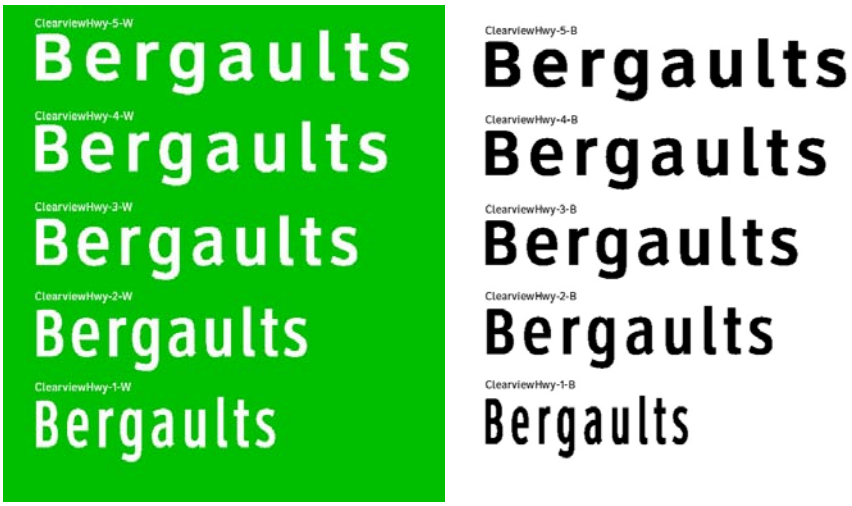


Table 2.4 Comparison of Clearview and FHWA weights

Clearview font type	FHWA Series font
Clearview 1-W	FHWA Series A
Clearview 2-W	FHWA Series B
Clearview 3-W	FHWA Series C
Clearview 4-W	FHWA Series D
Clearview 5-W	FHWA Series E
Clearview 5-W-R	FHWA Series E-Modified
Clearview 6-W	FHWA Series F

The Clearview font is available in both positive contrast; that is, white letters on dark green backgrounds and negative contrast fonts; that is; Clearview font in black letters on fluorescent yellow, fluorescent orange and white backgrounds. Figure 2.5 shows the positive contrast and Figure 2.7 shows the negative contrast fonts of the Clearview font.

Figure 2.4 Clearview positive contrast font type face display (http://clearviewhwy.com/TypefaceDisplay/index.php)

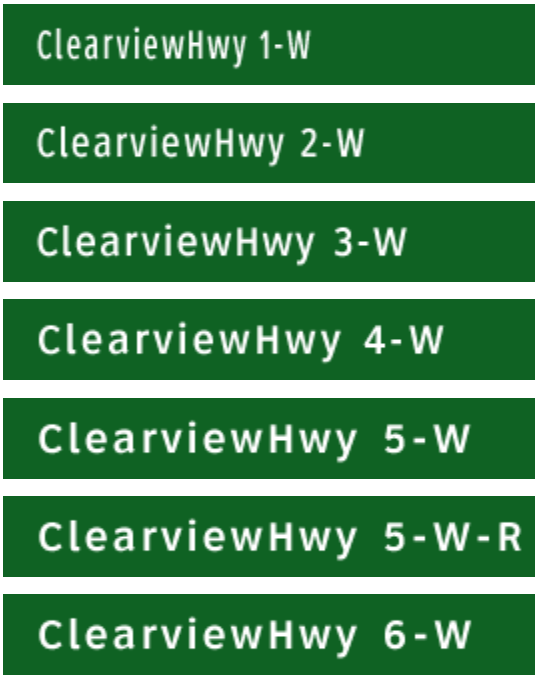


Figure 2.5 Clearview positive contrast font characters for the Series 6-W typeface (http://clearviewhwy.com/TypefaceDisplay/index.php)

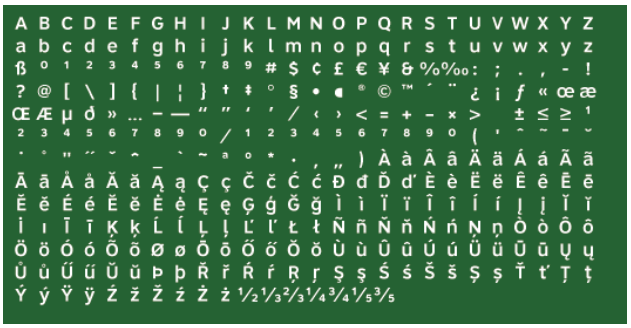


Figure 2.6 Clearview negative contrast font typeface display (http://clearviewhwy.com/TypefaceDisplay/index.php)

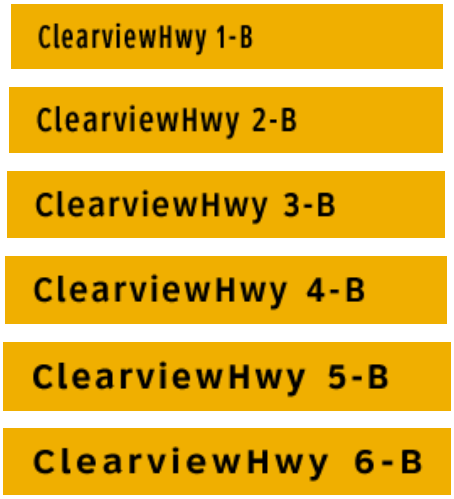


Figure 2.7 Clearview negative contrast font characters for the Series 6-W typeface (http://clearviewhwy.com/TypefaceDisplay/index.php)

2.6 Retro-reflective sheeting material

According to the Federal Highway Administration (FHWA) (Source: http://safety.fhwa.dot.gov/roadway_dept/night_visib/ Last accessed: 04/08/2010), retro-reflective sheeting materials are white or colored sheeting having a smooth outer surface and that essentially have the property of retro-reflectivity over their entire surface.

The FHWA 2009, also states that there are nine types and five classes of retro-reflective sheeting. Types are determined by conformance to the retro-reflectance, color, and durability requirements and may be of any construction providing that those requirements are met. Type designation is provided as a means for differentiating functional performance. These types are defined in the following section.

2.6.1 Retro-reflective sheeting types as described by the FHWA

"Retro-reflective sheeting shall be classified as follows:

Type 1 – Medium-intensity retro-reflective sheeting referred to as 'engineering grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Type II – Medium-high-intensity retro-reflective sheeting sometimes referred to as "super Engineer grade" and typically enclosed lens glass-bead sheeting. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Type III – High-intensity retro-reflective sheeting that is typically encapsulated glass-bead retro-reflective material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Type IV – High-intensity retro-reflective sheeting. This sheeting is typically an unmetallized Micro prismatic retro-reflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Type V – Super-high-intensity retro-reflective sheeting. This sheeting is typically a metallized Micro prismatic retro-reflective element material. This sheeting is typically used for delineators.

Type VI – Elastomeric high-intensity retro-reflective sheeting without adhesive. This sheeting is typically a vinyl Micro prismatic retro-reflective material. This sheeting is typically used for orange temporary roll-up warning signs, traffic cone collars, and post bands.

Type VII – Super-high-intensity retro-reflective sheeting having highest retro reflectivity characteristics at long and medium road distances. This sheeting is typically an unmetallized Micro prismatic retro-reflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators.

Type VIII – Super-high-intensity retro-reflective sheeting having highest retro reflectivity characteristics at long and medium road distances. This sheeting is typically an unmetallized Micro prismatic retro-reflective element material. Typical applications for this material are permanent highway signing, construction zone devices and delineators.

Type IX – Very-high-intensity retro-reflective sheeting having highest retro reflectivity characteristics at short road distances. This sheeting is typically an unmetallized Micro prismatic retro-reflective element material. Typical applications for this material are permanent highway signing, construction zone devices, and delineators."

Table 2.5 Retro-reflector type and applications (MUTCD, 2009)

Type	*Typical Application*
I	Highway Signing, construction-zone devices, and delineators
II	Highway Signing, construction-zone devices, and delineators
III	Highway Signing, construction-zone devices, and delineators
IV	Highway Signing, construction-zone devices, and delineators
V	Delineators
VI	Temporary roll-up signs, warning signs, and post bands
VII	Highway Signing, construction-zone devices, and delineators
VIII	Highway Signing, construction-zone devices, and delineators
IX	Highway Signing, construction-zone devices, and delineators

2.7 Legibility and recognition tests conducted on the Clearview font and combinations of retro-reflective (high-Performance) sheeting materials.

Carlson and Holick (2003) in a study called "Maximizing Legibility of Unlit Freeway Guide Signs with Clearview Font and Combinations of Retro-reflective Sheeting Materials" focused on maximizing guide sign legibility through the use of fonts and a combination of retro-reflective sheeting materials. Their study showed that freeway guide signs with Micro prismatic legends (ASTM Types 7, 8 and 9) produced significantly longer legibility distances than freeway guide signs made with type 3 legends. Their study also showed that that the longest legibility distances were achieved with a Micro prismatic legend on a Micro prismatic background, but the legibility distances were not statistically different from those achieved with Micro prismatic legends on type 3 backgrounds. This is an important finding because of cost savings involved in using these materials.

The above study also included a test of two different fonts used recently for highway guide signs: Series E-Modified and Clearview 5-W-R, a version of Clearview that is almost similar in terms of word length as the Series E-Modified. The results obtained from the study showed that Clearview 5-W-R produced significantly longer legibility distances than Series E-Modified font currently used on most highway signs.

Garvey et al. (1997) in a study called “Effects of Font and Capitalization on Legibility of Guide Signs” studied the effect of font, case and reflective sheeting on word recognition. The objective of the study was to compare the recognition distances of words displayed in mixed case Clearview font with an all uppercase Standard Highway Series-D font and mixed case Standard Highway Series E-Modified currently being used on most guide signs and street signs. The study also evaluated the effect of high performance sheeting material on recognition distances.

The Garvey study group consisted of 12 subjects of age 65 and above, who were tested individually. The experiment involved driving the subject towards the target word at 10 mph until the subject correctly stated the target word position: top, middle or bottom. If the word was correctly stated by the subject, the experimenter stopped the vehicle and the threshold distance was recorded. The study showed that the mixed case Clearview characters outperformed the all uppercase Series D by as much as 14 percent in day time and 16 percent at night as long as the mixed-case font subtended an equivalent sign area.

Garvey et al., (1997) in the same study tried to determine the effect of font and reflective sheeting on word legibility. The objective of their study was to compare the legibility distances of words displayed in the mixed case Clearview font with the Standard Highway Series D all-uppercase font and the mixed-case Standard Highway Series E-Modified font under both day and night time viewing conditions. The effect of the sheeting material on the legibility distance of the words was also evaluated.

The procedure used in the study was similar to the one used in the experiment conducted before. The study found a significant overall reduction in the legibility index. It showed that the subjects were twice as successful in recognizing known words as in reading unknown words. The study concluded that Clearview font produced significantly longer reading distances under night time viewing conditions.

Carlson and Brinkmeyer (2002) in a study called “Evaluation of Clearview on Freeway Guide Signs with Micro Prismatic Sheeting”, studied the legibility of the Clearview alphabet on freeway guide signs constructed with Micro prismatic retro-reflective sheeting and the results of

the Clearview legibility test were compared with that of the free guide signs constructed using the Series E font. The study found that the Clearview font provided statistically longer legibility distances than the Series E-Modified alphabet. Depending on the speed, these improvements provide a driver with up to 0.7 second more time to read the signs. The study also found that the age group that benefited the most from the Clearview font was the older age group.

Holick et al. (2005) in a study called "Evaluation of the Clearview Font for Negative Contrast Traffic Signs" evaluated the performance of the Clearview font for the negative contrast background guide signs, i.e., Clearview font in black letters on fluorescent yellow, fluorescent orange and white backgrounds. The researchers performed a laptop-based survey and a field study. In the laptop survey, they used static images of the font while the field study consisted to dynamic legibility and recognition tests. The tests were conducted using full-scale retro-reflective signs and were performed during both day and night times.

The study showed that the Clearview font provided the same performance as the existing FHWA series for negative contrast traffic signs with the exception of night time recognition.

2.8 Letter height of words used in Clearview font tests

2.8.1 Experiment: Evaluation of Clearview on freeway guide signs with micro prismatic sheeting (Carlson and Brinkmeyer, 2002)

Fonts used: Series E-Modified and Clearview express typeface.

Alphabets height: Series D and Uppercase Series E letters were 5 inches high.

The standard Clearview alphabet (Clearview 100 as shown in Figure 2.8) had the same size characteristics as Series E but Clearview 112% was 12% larger and was 5.6 inches high.

Figure 2.8 Clearview alphabets used in the study in comparison with standard E-Modified font (Carlson and Brinkmeyer, 2002)

Test words used:

21 test words were used. They were Honors, Houses, Nerves, Nurses, Ounces, Oceans, Season, Senior, Sensor, Series, Barley, Bishop, Dearly, Eatery, Felony, Flange, Forget, Player, Plunge, Shapes and Target.

2.8.2 Experiment: Maximum legibility of unlit freeway guide signs with Clearview font and combinations of retro-reflective material (Carlson and Holick, 2005)

Clearview fonts used: Series E-Modified and Clearview 5-W-R.

Alphabets height: Series E letters were 5 inches high. Clearview 5-W-R letter height was 5.6 inches high. The alphabets that were used were not mentioned in the experiment report.

2.8.3 Experiment: Effect of font, case and retro-reflective sheeting on word recognition (Garvey, Pietrucha and Meeker, 1997)

Fonts used: Standard Highway Series D (all upper case font), mixed case Series E-Modified, Clearview Condensed (at 100 % and mixed case), Clearview Condensed (at 112% and mixed case).

Alphabet Size: Two 1.2 square meter (4 square feet) aluminum sign panels were created. 64 white on green word panels were created for display on 2 sign panels. The Series D letter height was 12.7 cm (5 in.). Series E-Modified had a capital letter height of 12.7 cm with a 9.9 cm lowercase loop height as specified in standard alphabets for highway signs. The Clearview and

Clearview condensed uppercase letter heights were also 12.7 cm and a lowercase loop height of 9.9 cm. Clearview at 112 percent had a lowercase loop height 11.2 cm.

Word selection: Some of the words used for the testing of the font were Purcel, Dorset, Conyer, Bergen, Ordway and Gurley. Words with similar initial letters were selected to avoid word recognition based solely on initial letter recognition. Words with dissimilar footprints were selected to allow global word shape to affect word recognition distance.

2.8.4 Experiment: Evaluation of the Clearview font for negative contrast traffic signs (Holick, Chrysler, Park, and Carlson, 2005)

Font used: Standard all uppercase alphabet (Highway Gothic Series C or D) and spacing; Clearview replacement using 2B for Series C and 3B for Series D; Increase in the series of Clearview. If a sign had Series C, use 3B instead of 2B.

Alphabet size: The following modifications were made to the Clearview font before testing

Modification 1: Straight Clearview Replacement. The first change made was to do a straight replacement of the existing Highway Gothic font with the appropriate Clearview font as show in the Table 2.6.

Table 2.6 Highway to Clearview font conversion

Highway Font	Clearview Font
Series B	Clearview 1-B
Series C	Clearview 2-B
Series D	Clearview 3-B
Series E	Clearview 4-B
Series E-Modified	Clearview 5-B
Series F	Clearview 6-B

Modification 2: Clearview replacement at 100 percent spacing. The second modification took the new Clearview sign and changed the legend spacing to 100 percent.

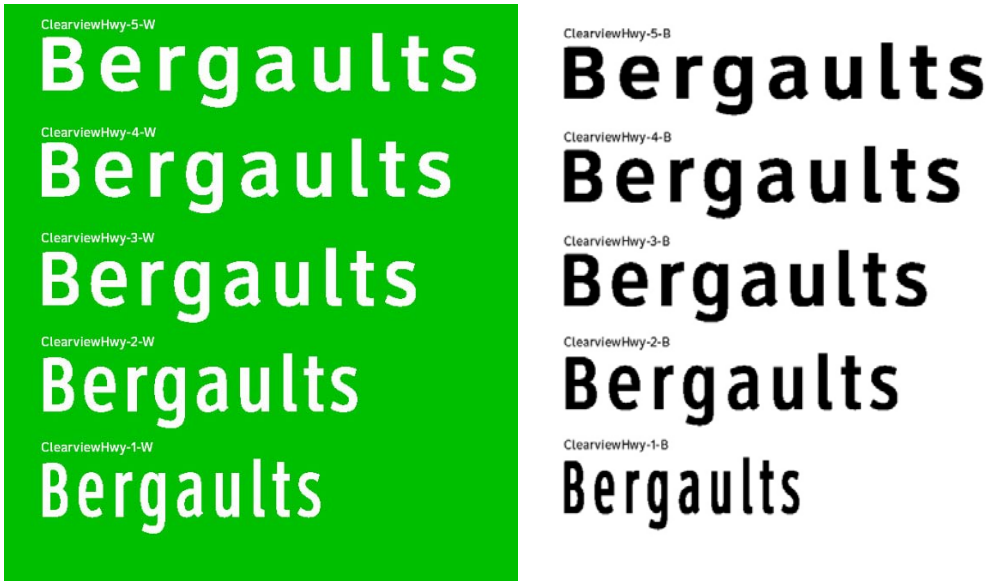
Modification 3: Change in inter-letter spacing. Beginning with the straight Clearview replacement sign, the inter-letter spacing was altered manually per line of text to allow approximately one border length clearance when conducting the perpendicular test. This

modification increased or decreased the inter-letter spacing for each individual word to fit the sign blank.

Modification 4: Change in series. Beginning with the straight Clearview replacement, the font type was changed to another Clearview "B" font so that the legend allowed approximately one border length clearance when conducting the perpendicular test. The change in series was dependent on the sign legend. Longer legends were typically reduced to a lower number series, which had a narrower stroke width, and more condensed letterform, while shorter legends were increased to a larger number series with a thicker stroke width.

Modification 5: Change in inter-line spacing. Beginning with the straight Clearview replacement sign, the inter-line spacing was changed in ¼-inch increments to allow approximately one border length clearance when conducting the perpendicular test.

Figure 2.9 Clearview positive and negative contrast font signs (http://clearviewhwy.com/TypefaceDisplay/positive.php)



2.8.5 Experiment: Elder roadway user program test sections and effectiveness study. **(Guerrier and Fu, 2002)**

Font Used: Highway Series C, D and Clearview for advanced street name sign and ground-mounted street name signs.

Alphabet Size: Each advanced street name sign was produced in 8-inch upper case letters. Each advanced street way sign was printed on 24X48 blanks and ground mounted signs were printed on 9X36 blanks except for one sign for which 9X24 was used.

Words used for test: The words or street names used for testing were:

For advanced street names: Curtiss Rd., Bennett Rd., Musick Rd.,

For ground mounted street way signs: Langley Rd., Ely Rd. and Wright Rd.

CHAPTER 3 - Summary of the e-mail survey of DOTs in U.S regarding use of Clearview font

3.1 Agency: Iowa DOT

Current status on the use of Clearview font: Iowa DOT has switched to Clearview font for all guide signs.

Usage: The new Clearview font is being used on all new and replacement signs on state highway system.

Estimated cost increase: Cost estimate for the change not available.

Estimated increase in the size of the signs: Signs estimated to be a little wider than existing signs with the highway series font. Estimated increase in the size of the signs is between 5 to 10 percent increase.

3.2 Agency: Idaho DOT.

Current status on the use of Clearview font: Idaho DOT reviewed the possibility of using Clearview font for the highway signs; however, Idaho DOT has chosen not to do so at this time and has simply chosen to upgrade its existing sheeting to a higher retro-reflectivity.

Idaho DOT's Clearview font review: Idaho DOT believes that Clearview font is 17% larger than the standard highway alphabet and so it would require replacement of several sign structures and assemblies. Also Idaho DOT says that there has been no set FHWA standard Clearview alphabet and currently the fractions (fractions here refer to the fractions like ½ in numerical) in Clearview have to be calculated as they do not come out the same as the standard highway font. Another problem in implementing Clearview font is the cost of replacing the plotter software, templates, inventory of direct applied legend etc.

Clearview field test conducted by Idaho DOT: For the field test, Idaho DOT built 3 guide signs side by side and ran a test study to see if there was enough difference to overcome the visibility and halation problems. The far right sign was the standard Type 1, Engineer grade background with TYPE III, Hi-Intensity legend and border in Series E-Modified font, the middle sign was TYPE IV background with TYPE IX Legend and Border but still with the Series E-Modified font, the far left sign was the Clearview font and the High Intensity sheeting.

Idaho DOT noticed a considerable difference in sheeting but the difference in the Series E-Modified font with the higher intensity sheeting and the Clearview with the High-Intensity sheeting was considered minimal at best.

Final decision on the use of Clearview font: Idaho DOT's final decision was to save money and just change the sheeting and retain the standard highway font.

3.3 Agency: Arkansas DOT

Current status on the use of Clearview font: Arkansas DOT has already switched over to Clearview fonts on all of their highway guide signs. A formal request to the Federal Highway Administration (FHWA) was made to be able to use the fonts based on their interim approval a few years ago.

Estimated increase in the size of the signs: Arkansas DOT states that there is usually only a slight increase in sign size using the Clearview fonts as compared to the traditional Standard Highway Sign Series E-Modified fonts previously used. Exact dimensional increase of the sign boards has not been confirmed.

Usage of the Clearview font: Clearview fonts are being used on all of their highway guide signs.

Additional increase in cost of implementation: Arkansas DOT has not documented the additional costs.

3.4 Agency: Texas DOT.

Texas DOT's Clearview font review: Texas DOT's Research validated that Clearview offered greater legibility and less overglow (which is similar to the halation phenomenon described in page 1) than the FHWA Highway font. But their research only investigated Clearview on positive contrast (white legend on green background) guide signs.

With the positive results Texas DOT has seen with Clearview, TxDOT sponsored research investigating Clearview on negative contrast (black legend on white or yellow background) signs. The research conducted by the Texas Transportation Institute showed that Clearview offered no benefit to the legibility of these signs.

Current status on the use of Clearview font: Texas DOT has adopted the Clearview font for all overhead, large ground mounted, and small roadside guide signs. All these signs are typically destination names. At this time, Texas DOT has limited the use of the Clearview font to positive contrast on all overhead, large ground mounted, and small roadside guide signs. Texas DOT is making the transition to Clearview font on a maintenance/replacement basis. Signs are being upgraded to Clearview when they have met their life expectancy and no longer meet minimum retro-reflective levels and need to be replaced.

Estimated increase in the size of the signs: No additional increase in the size of the signs has been documented.

Cost of Clearview font implementation: Transition to Clearview is based on maintenance or replacement basis. Only old and damaged signs, which do not meet the necessary retro-reflectivity standards, are being replaced.

3.5 Agency: Michigan DOT

Michigan DOT's guidelines on Clearview font usage: Spacing of Clearview font shall follow the spacing tables for Clearview, and not Standard Highway Series E-modified. This includes the use of the Clearview 5-W-R spacing tables for overhead conditions that may not accommodate a Clearview 5-W legend in replacement of existing E-modified legends. Action word messages and cardinal directions shall remain in all upper case letters and the first upper case letter of a cardinal direction shall be 10 percent greater in height for conventional road guide signs as per Table 2E.1 through Table 2E.4 of the 2003 MUTCD for expressway/freeway guide signs. The MUTCD also states that Clearview font should not be used on negative contrast signs until research demonstrates the effectiveness.

A general comparison guide for application to SHS Standard Alphabet letters is as follows: (Source: FHWA Research Study, 1994).

SHS Standard Alphabet Clearview "W" series

Series B Clearview 1-W

Series C Clearview 2-W

Series D Clearview 3-W

Series E Clearview 4-W

Series E-Modified Clearview 5-W and Clearview 5-W-R*

Series F Clearview 6-W

Clearview 5-W-R has tighter letter space than 5-W and is designed for replacement of overhead guide signs in which the 5-W is too wide for the specific application. The use of Clearview font for positive contrast guide signs provides increased legibility of highway sign word messages at the same cost of SHS Standard Alphabet letters. A research study by FHWA published in 1994 recommended a 20 percent increase in letter height of SHS Alphabets for highway signs in order to accommodate the viewing distance and reaction time requirements of older drivers. The use of the Clearview font will help in achieving this increase in sign visibility.

Current status on the use of Clearview font: Michigan DOT started using Clearview fonts in 2004 in all freeway-signing projects. Michigan DOT uses the Federal Highway Administration guidelines for Clearview fonts. For the design of signs, Michigan DOT uses SignCad with the Clearview font plug-in software.

Cost of implementation of Clearview: Michigan DOT did not have too much cost of implementation for the use of Clearview fonts, because Michigan DOT was already using Sign-Cad for Sign Design and the only extra cost was to buy the Clearview font plug-in software. On fabrication, Michigan DOT saved some money because at the same time they started using Clearview fonts, they changed the sign sheeting from type III to type IV for sign background. Type IV sheeting is a little cheaper than type III. For sign letters Michigan DOT uses type IX sheeting.

3.6 Agency: Kentucky Transportation Cabinet.

Current status on the use of Clearview font:

Kentucky Transportation Cabinet uses the Clearview positive contrast fonts on all new panel signs. Kentucky Transportation Cabinet has no plans to undertake widespread replacements. When a replacement sign is necessary, because of damage or loss of retro-reflectivity, Kentucky DOT uses the Clearview positive contrast fonts in the replacement of that sign. Kentucky Transportation Cabinet has not implemented the change to Clearview fonts on other types of Retro-reflective sheeting signs yet.

Kentucky Transportation Cabinet guidelines on Clearview font usage: Kentucky Transportation Cabinet requested and received interim approval, from the FHWA, for the use of Clearview font on all positive contrast guide signs. Kentucky Transportation Cabinet determined that this new font was compatible with their current sign design software(s). The software utilized by the Transportation Cabinet for panel sign design (Guide Sign) was updated to utilize the guidelines as per Terminal Design, Inc. (**Terminal Design, Inc.** is an independent digital type design and lettering studio, creating original and custom typeface and lettering designs for advertising, editorial, corporate, and government clients.) The software has been tested by them and determined to be compatible. All sign design personnel must be licensed to use the fonts. The Kentucky Transportation Cabinet currently has 4 users doing sign design in various forms. When using the Clearview positive contrast fonts, the use of 'mixed case' for portions of the legends that are usually reserved for all 'upper case' is encouraged.

The comparison of the FHWA Standard Highway Gothic Series fonts vs. the new Clearview fonts is as follows:

- FHWA Standard Alphabet Series B, upper case – use - Clearview 1-W (7.1% longer, based on the length of the full alphabet. Word lengths will vary)

- FHWA Standard Alphabet Series C, upper case – use - Clearview 2-W (2.9% longer, based on the length of the full alphabet. Word lengths will vary)

- FHWA Standard Alphabet Series D, upper case – use - Clearview 3-W (1.8% shorter, based on the length of the full alphabet. Word lengths will vary)

- FHWA Standard Alphabet Series E, mixed case – use - Clearview 4-W (19.4% longer, based on the length of the full alphabet. Word lengths will vary)

- FHWA Standard Alphabet Series E-Modified, mixed case – use - Clearview 5-W (4.7% longer, based on the length of the full alphabet. Word lengths will vary)
- (Or Clearview 5-W-R is 1% shorter)

Cost of implementing Clearview font: According to Kentucky Transportation Cabinet the cost for the purchase of the font - Clearview Complete Family - was around $800.00 for a 5 user license. As seen in the comparisons above, the spacing for various words using the Clearview fonts are generally a little larger than the FHWA Standard Highway Series fonts. This does tend to make some of the new panel signs a bit wider than normal, thereby increasing the cost of panel signs slightly.

Example, assuming a cost of $20.00 per square ft of extruded panel sign material: A sign with one 36" interstate shield, 2 destinations (16" EM) and 1 action message (10" E) using the FHWA Std fonts is 12' tall x 13.5' wide for a total of 162 square feet = $3,240.00. A sign using the same height Clearview fonts only increased the sign width. The new sign size is 12 inches tall x 14 inches wide, (only 6 inches wider), for a total of 168 square feet = $3,360.00. The extra 6 square feet difference cost $120.00 extra to use the Clearview fonts.

Using this cost analysis, a new interchange requiring approximately 16 new panel signs, the total cost increase would be around $2,000.00 to utilize the Clearview fonts instead of the standard FHWA Standard Hwy fonts. The use of the Clearview 5-W-R font (reduced spacing) in place of the Clearview 5-W font has allowed no cost increase to be incurred with respect to the replacements of damaged panel signs where the existing supports can be reused and the replacement sign needs to be the same size as the original sign or for overhead signs where the width of the sign, due to an overly wide legend, is greater than desired.

The following few pages show a number of new style signs that have been installed in Kentucky in late 2006 and early 2007. Most prevalent are the use of Clearview font on new installations of guide signs, and the new style of signage for Kentucky's roadways.

Figure 3.1 A comparison of the old font (right) and the new Clearview font (left) (http://www.millenniumhwy.net/new_signs_ky_2007/new_signs_ky_2007.html)

Several other states have experimented with the use of the Clearview font. States like Florida, Arizona and Pennsylvania have partially implemented use of Clearview font and are awaiting FHWA approval for widespread implementation.

As on February 20, 2010, The states that are currently not using the Clearview font are: Louisiana, Indiana, South Dakota, Massachusetts, Tennessee, New York, Montana, Utah, California, Georgia, New Mexico, Maine, North Carolina, Wisconsin, Illinois, Missouri, Wyoming, Nevada, Oregon, Washington, Hawaii, Delaware, Minnesota, North Dakota, North Carolina and Alabama.

CHAPTER 4 - Experimental Procedures

4.1 Computer Screen Study

Based on literature review and DOT surveys, it was determined that the Clearview font is being used on guide signs in some states in the U.S. Before a field study of the fonts was carried out, an experiment was conducted to determine the word recognition of the Clearview font in comparison with the Series E-Modified font and Series E-Modified at 120%. The experimental details are as mentioned below.

4.1.1 Computer legibility test of Clearview font and standard FHWA series font

The types of signs tested were guide signs with mixed case alphabets. The fonts compared were Series E-Modified, the Clearview 5-W-R both with font size 44 and Series E-Modified at 120%. In this experiment, the word recognition of the new Clearview font was compared with the existing Standard Highway Series font that is being used on all traffic control devices in the U.S. In the test, several street/road name signs were displayed on the computer screen. The sign was displayed only for one second and then the screen would go blank. The subjects had to identify the word on the sign, the name of the street, avenue or boulevard and then write it down on the data sheet provided.

A small experiment was conducted to match the color perception of the background color with the ones used on the highway guide signs (Type 1). A Chromatometer was used and from the chromatograph readings, and by trial and error method, the brightness of the screen and the color of the background were adjusted until a close match was obtained. The alphabets and the background color were nearly similar to the actual signs found on U.S roadways. The size of the computer screen (HP DV2000 laptop with a 14" screen) on which the signs were displayed was 32 cm X 18 cm. The height of the Clearview 5-W-R letters used in the computer test was 1.5 cm and the height of the Series E-Modified font was also about 1.5 cm. The length of the words varied between 7 cm and 11 cm. The height of the Series E-Modified font was about 1.8 cm and the word length was between 9 cm and 13 cm. Before the start of the test, a visual acuity test was carried out on the subjects.

The test procedure that was carried out is as follows:

a) A quick Visual Acuity test (See section on visual acuity for description of the test) was carried out on the subject to find out their visual acuity. If the subject did not pass the acuity test, the subject was not allowed to participate in the experiment.

b) The experiment was carried out on one subject at a time and the subject was seated on a chair at a specified viewing distance. The distance between the subject and the computer screen was found using equations from similar triangles. The subject was instructed to stay stationary without moving around during the course of the experiment.

c) The street signs were displayed on the screen for only about a second. The subject had only one second to correctly identify the street name displayed on the screen and then had to write down the answer on the data collection sheet.

d) As soon the subject finished writing the answer down, the next slide was displayed and the experiment was continued.

e) This experiment was repeated for 96 slides and took approximately 15 minutes to be completed. The test signs consisted of 32 signs in Series E-Modified font, 32 signs in Clearview 5-W-R font and 32 signs in Series E-Modified font at 120% the size of the regular Series E-Modified font. Figures B.1 – B.3 in Appendix B show the examples of slides that were used for the computer based testing of fonts.

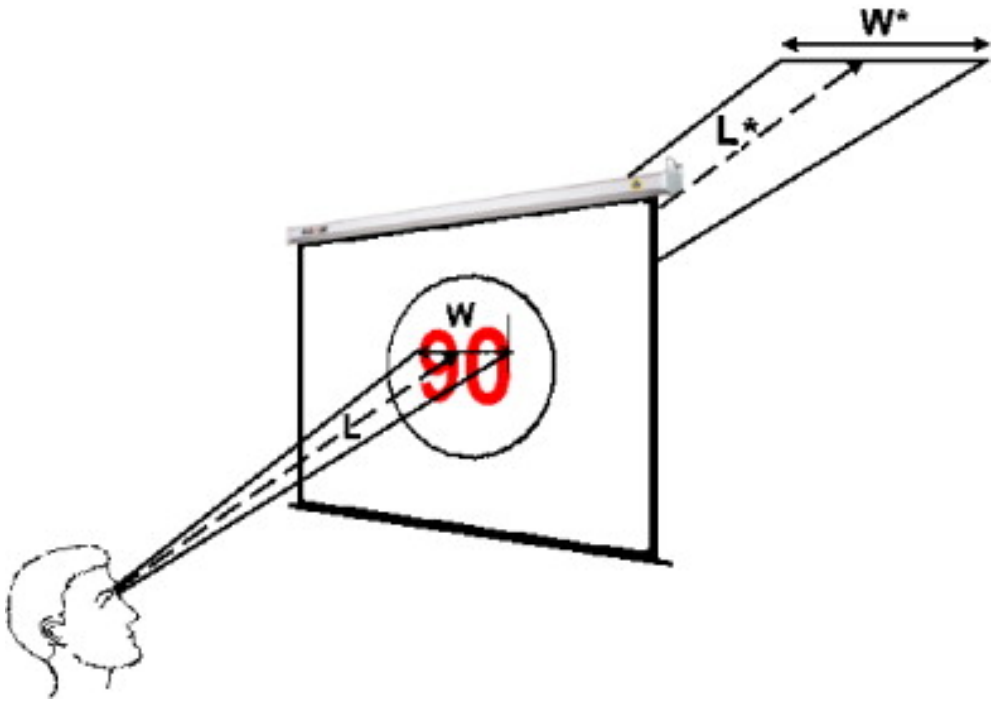
4.1.2 Visual angle between the driver and the sign posts.

The viewing distance between the test subject and the display screen was found by using the equations used in rectification of legibility distance in a driving simulator by Ting et al. 2007. The aim of the study was to reduce the difference between the legibility distance in a driving simulator and that in a real road environment. To reduce this difference, this study proposed a theoretical equation for predicting legibility distance and a simple algorithm for determining the magnifying power of traffic signs in a simulator display system.

4.1.3 Theoretical equation for predicting legibility distance

Legibility distance, *L*, can be easily calculated using a basic formula of similar triangles (Fig 4.1) as follows: $L^*/w^*=L/w$. Where w^* is the width of the actual road sign, *L* the distance between the simulator driver and the screen, and *w* the width of the virtual object shown on the screen.

Figure 4.1 Basic formula of similar triangles is used to calculate legibility distance L*. (Ting et al. 2007)



According to Staplin (2004) the average legibility distance of a Series E-modified font is 101 m or 10100 cm. This constitutes L*. The average length of the word that was used in out experiments was 9 cm. Now the signs used in the field study have a word length between 3.5 feet (106 cm) and 3.8 feet (110 cm). Taking the width of the guide sign to be 3.5 feet or 110 cm, it was found that from the theory of similar triangles, the distance between the test subject and the screen is

$L^*/w^*=L/w$

10,100/106 = L/9

Therefore, L=850 cm or 8.5 m

According to the MUTCD, the signpost containing warning signs or street names or shoulder mounted guide signs has to follow the standard installation procedure. The procedure states that the signpost should be at least 2.1m or 7 feet tall and at least 0.6 meter or 2 feet away from the road curb. Now assuming that the driver is 331.3 feet (Staplin, 2004) away from the signpost and about 6 feet from the curb of the road, it can be seen from the Figure 4.3 that the visual angle between the driver and the signpost is (90-88.96) that is around 1 degree. That is the driver has to turn his/her head horizontally to about 1 degree from the sitting position.

Figure 4.2 Warning sign installation Standard (Warning Signs installation standard, MUTCD 2009)

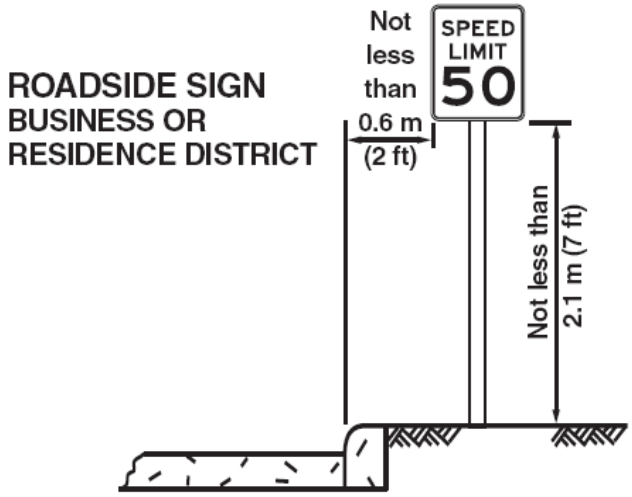
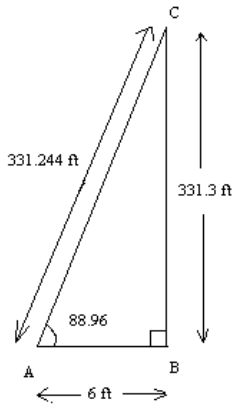


Figure 4.3 Top view of viewing angle between the driver of the vehicle and the sign



The visual angle as typically encountered while driving on the streets was simulated when conducting of the experiment. The subject will be seated in a chair to simulate the driving position.

4.1.4 Checking visual acuity of the participants

According to Konz and Johnson (2008), visual acuity is acuteness or clearness of vision; especially form vision, which is dependent on the sharpness of the retinal focus within the eye and the sensitivity of the interpretative faculty of the brain. The visual acuity is given by the formula:

VA = 1/ Visual angle of minimum object detectable, min of arc.

Visual acuity depends upon how accurately light is focused on the retina, the integrity of the eye's neural elements, and the interpretative faculty of the brain. By convention, normal vision is the ability to detect an object with 1 min of arc at 6 meters or 20 feet.

Dynamic visual acuity:

According to Konz and Johnson (2008), dynamic visual acuity is the ability to discriminate detail in a moving target. Under most favorable conditions, an object is detectable when it moves over 2 min of arc/s. Discrimination of detail in a moving target is satisfactory if the eye can lock on to the target. The section also mentions that the ability to lock on worsens rapidly beyond velocities of 50 degrees/second.

Illumination:

According to Konz and Johnson (2008), the basic criteria for lighting a task are the following:

Have satisfactory visual performance,

Minimize cost of lighting,

Have satisfactory ethics.

The recommended amount of lighting for a public space is 30 lux and for a working space where simple visual tasks are performed, the recommended lighting is 100 lux. However the lighting recommendations are based on visual needs. So based on the recommendations by Konz and Johnson (2008), for the experiment which was conducted in a lab setting, the illumination chosen was around 30-50 lux.

How visual acuity is measured:

According to Watt "How Visual Acuity Is Measured" (2003) a standard eye chart is necessary to make comparisons and to record people's visual acuity. The most common chart used in most doctors' offices is the Snellen eye chart.

Measurement of visual acuity:

According to Duane's clinical Ophthalmology, 2001, the following steps have to be followed to measure the visual acuity of a person.

1. The chart is placed at 20 feet (or 6 meters) and illuminated to 480 lux at that distance.
2. If the patient uses glasses, then the test is performed using them.
3. An occluder is placed in front of the eye that is not being evaluated. The first evaluated eye is the one that is believed to see less or the one the patient says that is seeing less.
4. The measurement is started first with the big optotypes and continued to the smaller ones. The patient has to identify every alphabet on the line being presented and communicate it to the examiner
5. Then the occluder is changed to the other eye and continued again from the 4th step.
6. After both eyes have been evaluated in distant visual acuity, the testing is continued to proceed to evaluate near visual acuity
7. In some cases, binocular visual acuity will be measured, because usually binocular visual acuity is slightly better than monocular visual acuity.

4.2 Selection of test words used for the computer based test

Prior to the word recognition test, to select the test words of equal difficulty, a small experiment was conducted. Several words were flashed on a screen using Microsoft Power Point for just one

second. The students were asked to write down what they saw on the screen. The output was studied and based on the mistakes in properly identifying the words, six words were chosen since they were equally difficult to identify by many students.

4.3 Discussions on computer based study

The computer-based test was carried out and the results were analyzed. Twenty five test subjects participated in the study. The age of the test subjects varied between 20-24 years of age. All test subjects were students from the department of Industrial and Manufacturing Systems Engineering at Kansas State University. From box plots (see Appendix B, Figure B.11 to B.13), the test words that were used in the analysis of the results showed that there was no statistical difference between the Series E-Modified font and the Clearview 5-W font. But the test showed a significant increase in the legibility of Series E-Modified at 120% when compared to both the Series E-Modified font and the Clearview 5-W font. The box plots in Figures B.11 to B.13, Appendix B show that there is no significant difference in the performance between the Series E-Modified font and the Clearview 5-W font. The number of signs that were not recognized were 5 signs for Series E-Modified, 4 for Clearview 5-W and 3 for Series E-Modified at 120%.

The words were chosen based on the mistakes made by students in identifying the words correctly. The words with the highest number of mistakes were:
Chalmette, Tauromee, Roanoke, Montegut, Montgall and Mirabeau
Of these 6 words, Montgall, Mirabeau and Montegut were selected for the field study. The reason for choosing these words was due to the presence of letters like a,g,e,t,l,b and o. These letters were important in the study since, they had different stroke lengths in different fonts and it was also important to observe any halation effect during night time testing.

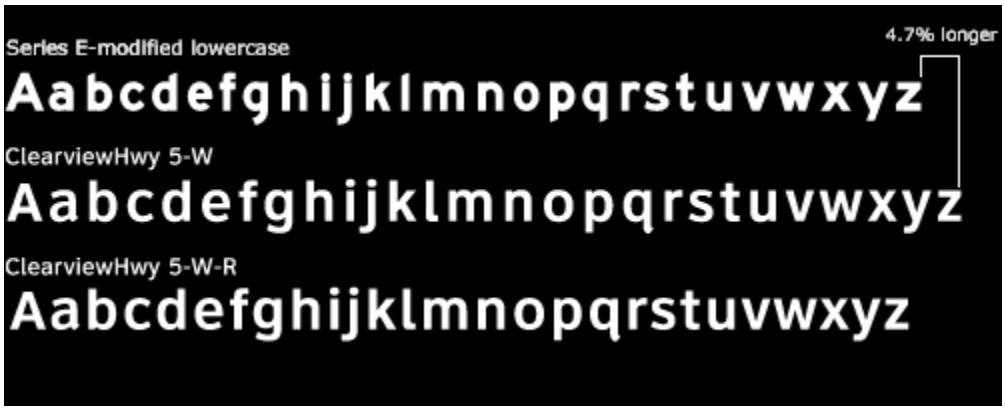
CHAPTER 5 - Field study of the Clearview font and retro-reflective sheeting material

5.1 Experimental procedure design

Sign types to be compared:

In the field test, the sign types compared were the Clearview 5-W font, Series E-Modified font and the Clearview 5-W-R font. According to the MUTCD, the typeface display that has to be used on regular and overhead guide signs is the Series E-Modified font. The equivalent of Series E-Modified font in Clearview font terms is the Clearview 5-W series font. There is another font developed by the Clearview team called the Clearview 5-W-R which is similar to the Clearview 5-W font but requires a lesser signboard real estate than the Clearview 5-W font. Figure 5.1 below shows the three different fonts. Notice that the Clearview 5-W font is 4.7 % longer than the Series E-modified font.

Figure 5.1 Series E-Modified font, Clearview 5-W and Clearview 5-W-R fonts (http://clearviewhwy.com/WhatIsClearviewHwy/Compare)



Retro-reflective material to be compared:

The retro-reflective materials that were compared along with the fonts were Type-1, Type-4 and DG3 retro-reflective sheeting materials. According to the MUTCD, Type 1 is the sheeting material currently used on all guide signs across the U.S. The DG3 reflective sheeting material manufactured by 3M consists of full cube prismatic lens elements with a distinctive diamond seal pattern visible from the face of a smooth surface. 3M claims that its optical

elements are 100% efficient, returning almost 60% of available light, nearly double that of traditional prismatic sheeting. According to 3M, the Type 4 sheeting is typically an unmetallized microprismatic retro-reflective element material. Since, DG3 and Type 4 retro-reflective sheeting materials have not been tested for visual distance; they were used to detect any increased performance against existing Type-1 retro-reflective material. The objective of the research was to identify the difference in legibility distance when new and old fonts are used in combination with existing and new retro-reflective sheeting materials.

Signs used in the experiment:

The number of signs used for the experiment was 9. To determine the number of signs, and the combination of the fonts and retro-reflective materials, a fractional factorial design of experiment was used. The order in which the signs were displayed and the combination of fonts and reflective material is shown in Table A.1 in Appendix A. Figures A.1 to A.9 in Appendix A show the signs that were used for the field test. The signs

Design of Experiment:

The design chosen for the experiment was the Fractional Factorial Experimental Design. According to Montgomery (2009), a factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors. Since our experiment tries to identify the interaction of three factors like font, retro-reflective sheeting and the name on the guide sign, the factorial design of experiment best suits our requirement.

The factors considered for the design were:
Main effect: Fonts (Clearview 5-W-R, Clearview 5-W and Series E-Modified)
Second Factor Interaction: Retro-reflective sheeting material (Type 1, Type 4 and DG3)
Names on the guide signs (Montgall, Montegut and Mirabeau) were not considered to be a factor since the words chosen for the experiment were determined to be of equal difficulty. Due to this, the total number of factorials or combinations of font and retro-reflective material that have to be tested was reduced to 3^2 or 9 combinations. The final combination of fonts and retro-reflective material that have to be tested is shown in Figure A. 3 in the Appendix A.

Location of the field trial:

The pilot experiment and the field tests were carried out in the west side parking lot of the Bill Snyder Family Football Stadium. The west side parking lot has dimensions of 370 m by 220 m. During the field test, the subjects were driving from the north end of the stadium to the south end. The field tests were only conducted during days with good visibility and lighting conditions. The day time field tests were conducted between 1:00 P.M and 3:00 P.M and the night time testing was conducted between 8:00 P.M and 9:00 P.M. The parking lot had a speed limit of 30 mph and had little or no traffic during the field tests. Field tests were never conducted during game days or practice sessions in order to avoid unnecessary traffic and interference from the passersby.

Test Subjects:

32 subjects participated in the field test. Some of the subjects participated in both day time and night time testing. All test subjects were students from the college of engineering at Kansas State. The age of the test subjects varied from 20 years to 26 years. All of the test subjects had valid driver's license and had more than 4 years of driving experience.

Measurements and instrumentation:

The distance measuring device used to measure the legibility distance was the JAMAR Technologies' RAC Plus 1 Distance measuring instrument. The JAMAR Technologies Road Analysis Computer (RAC) Plus I is a measuring instrument (DMI) that uses microprocessor and a modular distance sensor technology to accurately measure distance. Figure 5.2 shows the installation procedure of the RAC Plus 1 system with the vehicle's electronic circuitry.

Figure 5.2 Distance measuring instrument connection circuitry (RAC Plus 1 user manual)

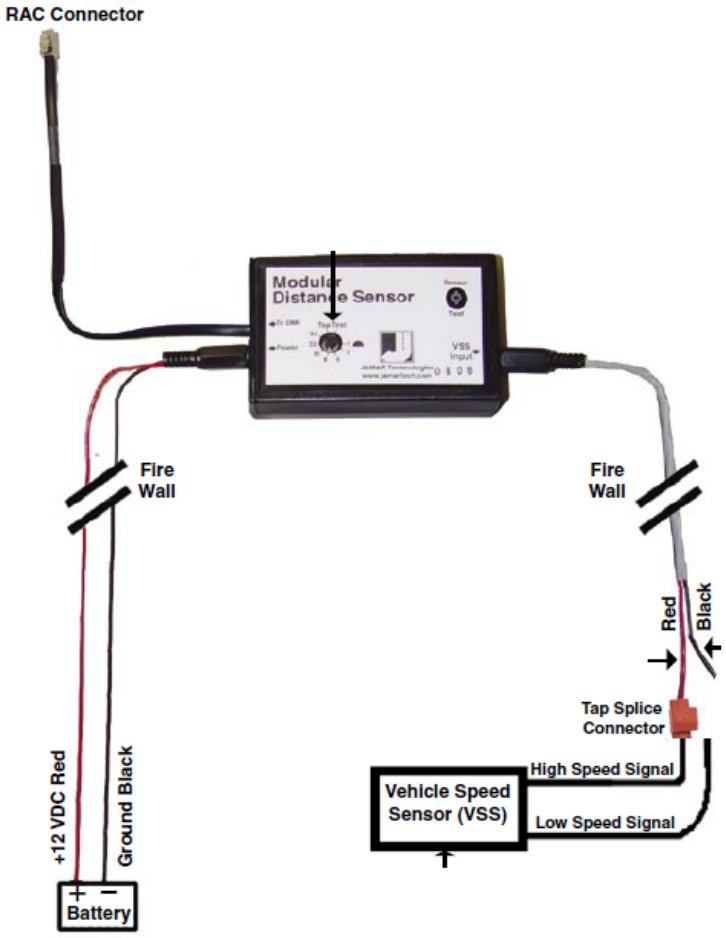


Figure 5.3 Distance measuring instrument initial reading

Figure 5.4 Distance measuring instrument measuring distance during the experiment

Procedure:

The field test of the guide signs was carried out at day time and at night time to evaluate the performance of the signs in both lighting conditions. Since the test subject drove from north to south, the interference of direct sunlight or glare was avoided. Further, all field tests were carried out between 1:00 P.M and 3:00 P.M for day time testing and between 8:00 PM and 9:00 P.M for the night time testing. A field test was not conducted during cloudy days or dull days to ensure equal lighting and visibility conditions for all test subjects. Each volunteer had to complete a vision screening test and fill out questionnaires about driving patterns and vision health and then sign an informed consent sheet. In addition to this, the experimenters read instructions to each subject when in the vehicle. The preliminary preparations for the experiment lasted for about 5 minutes for each test subject.

The vehicle that was used for the experiment was a 2000 Pontiac Grand Prix SE Sedan. It was important to have a clean windshield, so the windshield and the headlamps were wiped clean before the beginning of each experiment. During the testing, the subject was in control of the vehicle at all times during the experiment. The experimenter was seated in the passenger seat next to the subject and was in charge of monitoring the speed of the vehicle and also measurement of legibility distances. During the experiment, the subjects were driving as instructed by the experimenters at a speed of approximately 30 mph.

The route for the pilot experiment has been shown in the Figure 5.4. The point B represents the spot where the signs to be tested were placed. During the experiment, the subject

would drive from point A towards point B at a speed of about 30 mph. The distance measuring instrument was activated at the beginning of the experiment and the subject drove the vehicle. As soon as the subject recognized the sign, the name on the sign was read out loud. The distance measuring device was stopped and the reading was recorded. The subject then took a U-turn and heads back to point A while another experimenter changes the sign. This process is repeated for the remaining 8 signs. Figure 5.6 shows the vehicle used in the experiment. Figure 5.7 shows the test vehicle approaching the signs during day time. Figure 5.8 shows the view of the signs from inside the vehicle. Figure 5.9 shows the distance measuring instrument at work.

Figure 5.5 Route map of the pilot experiment (Google Maps)

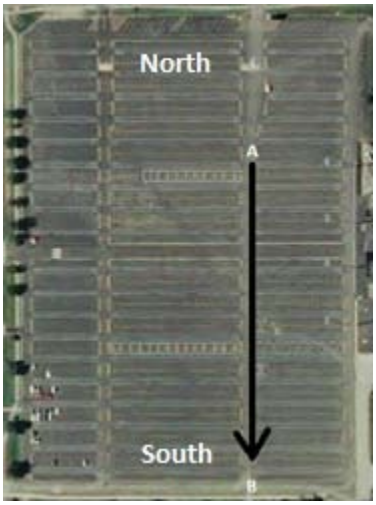


Figure 5.6 Vehicle used for the experiment

Figure 5.7 Vehicle with test subject approaching the sign

Figure 5.8 View of the test sign from inside the vehicle

Figure 5.9 Distance measuring instrument at work

Dependent variables and independent variables:

Dependent variables:

Based on the literature review, the legibility distance is the measure of effectiveness of signs. In all other experiments, the measure of effectiveness of street signs or fonts has been the legibility distance. Therefore legibility distance was chosen in this experiment to be the dependent variable that was to be tested.

Independent variables:

Alphabets and Fonts: In this experiment we compare fonts Clearview 5-W, Clearview 5-W-R and Standard highway Series E-Modified font.

Retro-reflective Sheeting Material: The retro-reflective sheeting materials tested were the Type 1, Type 4 and the DG3 sheeting materials. These three sheeting materials were chosen because, Type 1 retro-reflective material is currently being used on all guide signs on U.S highways and Type 4 and DG3 are the new retro-reflective sheeting types that are proposed by Kansas Department of Transportation to replace the Type 1 retro-reflective sheeting material in the near future.

5.2 Discussions on field test study

A statistical analysis of the results obtained from the field test was carried out to find differences between the fonts and materials. Statistical Analysis Software (SAS) and Minitab

was used to carry out the statistical analysis. The P value of 0.1755 obtained from SAS analysis showed that there was no practice effect on subjects who participated in both day time and night time testing. That means there was no statistical improvement in legibility distance among the subjects who participated in more than once in the field test. The following tables below show the performance of the signs and fonts and the percentage increase in performance compared to the neighboring combination.

Average legibility distance of each combination of font and retro-reflective material for day time and night time is shown in the tables below. Table 5.1 gives the mean legibility distance of the signs during day time testing and Table 5.2 shows the performance of the signs during night time. From Table 5.1, it can be seen that Type 1 retro-reflective sheeting material performs the best compared to both DG3 and Type-4 sheeting material. The Type 1 retro-reflective material along with Clearview 5-W-R font produced a legibility distance of about 123 feet more than the Type 4 sheeting along with the Series E-Modified font. This means that if the car is travelling at about 30 mph, it travels 43.8 feet per second and the driver will be able to read, for example, Sign No. 1 about 2.79 seconds faster than Sign No. 9.

Table 5.1 Order of performance of the signs during day time testing

Order of performance	Reflective Material	Font Type	Legibility Dist (Feet)
1.	Type 1	Clearview 5-W-R	416
2.	Type 1	Clearview 5-W	407
3.	Type 1	Series E-Modified	390
4.	Type 4	Clearview 5-W-R	381
5.	DG3	Clearview 5-W-R	377
6.	DG 3	Series E-Modified	362
7.	DG 3	Clearview 5-W	340
8.	Type 4	Clearview 5-W	331
9.	Type 4	Series E-Modified	293

Table 5.2 gives the mean legibility distance of the signs during night time testing. From Table 5.2, it can be seen that Type 4 retro-reflective sheeting material performs the best compared to both DG3 and Type-1 sheeting material. The Type 4 retro-reflective material along with Clearview 5-W-R font produced a legibility distance of about 109 feet more than the Type 4

sheeting along with the Series E-Modified font. This means that if the car is travelling at about 30 mph, the driver will be able to read, for example, Sign No. 1 about 2.47 seconds faster than Sign No. 9.

Table 5.2 Order of performance of the signs during night time testing

Order of performance	Reflective Material	Font Type	Legibility Distance (Feet)
1.	Type 4	Clearview 5-W-R	377
2.	DG3	Clearview 5-W-R	359
3.	Type 4	Clearview 5-W	327
4.	Type 1	Series E-Modified	323
5.	DG3	Series E-Modified	321
6.	DG 3	Clearview 5-W	319
7.	Type 1	Clearview 5-W	317
8.	Type 1	Clearview 5-W-R	291
9.	Type 4	Series E-Modified	268

Table 5.3 gives the mean legibility distance of the signs during both day and night time testing. From Table 5.3, it can be seen that Type 4 retro-reflective sheeting material along with Clearview 5-W-R performs the best compared to both DG3 and Type-1 sheeting material. Type 4 retro-reflective material along with Series E font produced a legibility distance of only about 282 feet and was therefore the least performing combination of font and retro-reflective sheeting material. Further discussions on the selection of the font and retro-reflective sheeting material are given in the latter part of this section.

Table 5.3 Order of performance of the signs during both day and night time combined

Order of performance	Reflective Material	Font Type	Legibility Distance (Feet)
1.	Type 4	Clearview 5-W-R	377
2.	DG3	Clearview 5-W-R	365
3.	Type 1	Clearview 5-W	360
4.	Type 1	Series E-Modified	355
5.	Type 1	Clearview 5-W-R	352
6.	DG 3	Series E-Modified	341
7.	Type 4	Clearview 5-W	322
8.	DG 3	Clearview 5-W	321
9.	Type 4	Series E-Modified	282

Table 5.4 Performance of retro-reflective sheeting during day time

Sign Number	Reflective Material	Legibility Distance (Feet)
1,2,3	Type 1	414
5,6,7	DG3	358
4,8,9	Type 4	338

Table 5.5 Performance of retro-reflective sheeting during night time

Sign Number	Reflective Material	Legibility Distance (Feet)
2,5,6	DG3	333
1,3,9	Type 4	324
1,3,9	Type 1	306

Table 5.6 Performance of fonts during day time

Sign Number	Reflective Material	Legibility Distance (Feet)
1,4,5	Clearview 5-W-R	392
2,7,8	Clearview 5-W	362
3,6,9	Series E-Modified	347

Table 5.7 Performance of fonts during night time

Sign Number	Reflective Material	Legibility Distance (Feet)
1,2,8	Clearview 5-W-R	341
3,7,8	Clearview 5-W	319
5,6,9	Series E-Modified	305

Some of the other conclusions that can be drawn from the field tests are:

1. Type 1 reflective material was the best performing material in day time testing but performed poorly during night time testing. On the average, the Type 1 retro-reflective material produced a legibility distance of 360 feet (109 m), DG3 produced a legibility distance of 346 feet (105.46 m) and Type 4 produced a legibility distance of 331 feet (100.89 m).
2. During day time tests, the Type 1 retro-reflective material along with Clearview 5-W font produced a legibility distance of about 123 feet (37.49 m) longer than the Type 4 sheeting along with the Series E-Modified font. This means that if the car is travelling at about 30 mph, the driver will be able to read sign with Clearview 5-W-R and Type 1 Sheeting about 2.47 seconds faster than sign with Series E- Modified font and Type 4 retro-reflective sheeting material.

3. Type 4 in combination with Clearview 5-W-R (377 feet or 115 m) outperformed DG3 and any other font combination during both day time and night time conditions. Type 4 sheeting along with Series E-Modified font was the least performing Sign with an average of 282 feet or 86 meters of legibility distance during both day and night time combined.
4. Clearview 5-W-R outperformed Clearview 5-W and Series E-Modified in both day time and night time conditions but only when it was used in combination with either DG3 or Type 4 retro-reflective material.
5. The SAS analysis carried out shows significant statistical difference between the signs. The difference and the order is shown in the Table 5.8 below. The signs marked A, show no significant statistical difference in performance when compared to each other. The signs marked B show some statistical difference between signs marked A and C but not among themselves. The signs marked C show very significant difference between those marked A and B.

Table 5.8 Order of performance of the signs

Order of performance	Reflective Material	Font Type	Legibility Distance (Feet)	Type	Type	Type
1.	Type 4	Clearview 5-W-R	377	A		
2.	DG3	Clearview 5-W-R	365	A	B	
3.	Type 1	Clearview 5-W	360	A	B	
4.	Type 1	Series E-Modified	355	A	B	
5.	Type 1	Clearview 5-W-R	352	A	B	
6.	DG 3	Series E-Modified	341	A	B	
7.	Type 4	Clearview 5-W	322		B	
8.	DG 3	Clearview 5-W	321		B	
9.	Type 4	Series E-Modified	282			C

5.3 Comparison of the results with previous studies

The results from the current study show a similar trend when compared to the previous studies. The trend being the Clearview font and micro-prismatic retro-reflective sheeting materials producing longer legibility distance than the existing Series E-Modified font.

Study conducted by Carlson and Holick (2003) showed that freeway guide signs with Micro prismatic legends (ASTM Types 7, 8 and 9) produced significantly longer legibility distances than freeway guide signs made with type 3 legends. Current study also showed that there is a significant increase in the legibility distance of the signs when used in combination with the retro-reflective sheeting with micro-prismatic legends.

The study by Garvey et al. (1997) concluded that Clearview font produced significantly longer reading distances under night time viewing conditions. Current study showed that Clearview 5-W-R, Clearview 5-W outperformed Series E-Modified font during night time conditions.

The study by Carlson and Brinkmeyer (2002) showed that Clearview 5-W font provided nearly 0.7 second more time to read the signs. Current study showed that Clearview 5-W-R font when used in combination with Type 4 retro-reflective sheeting material could be recognized nearly 2.5 seconds faster than Series E-Modified font on Type 1 retro-reflective sheeting material while the car was travelling at about 30 mph.

CHAPTER 6 - Conclusions and future work

It can be seen from the tables in the previous chapter that there is no one font or retro-reflective sheeting that performs best during both day and night time conditions. While some combinations of font and retro-reflective sheeting material like Clearview 5-W-R and Type 4 sheeting material perform consistently well during both day and night time conditions, others like Clearview 5-W-R and Type 1 sheeting material combination perform well during day time but show a significantly reduced performance, a decrease of 125 feet of legibility distance during night time

6.1 Recommendations for use of the fonts and retro-reflective material

Tables 5.1 to 5.7 give an idea on the performance of the three fonts Series E-Modified, Clearview 5-W and Clearview 5-W-R fonts in combination with the retro-reflective material. Since a lot of variation is observed between day time and night time conditions, it is very important to consider the conditions and the environment where the signs are going to be used.

6.1.1 Combination of font and sheeting material recommended by authors

From Tables 5.1, 5.2 and 5.3 in the previous section, it can been seen that Type 1 reflective sheeting along with Clearview 5-W-R performed best during the day time conditions but also performed second to last during night time testing. However, the best overall performance was the combination of Clearview 5-W-R and Type 4 sheeting material, which performed best during night time and 4th best during day time testing. A combination of DG3 and Clearview font or Series E font is not recommended, as it did not outperform any of the other combinations during both day time and night time testing.

6.1.2 Situation with high day time traffic and low night time traffic

If the signs are to be used on the highways with a very heavy day time traffic and moderate or little night time traffic, it would be recommended to use the Type 1 retro-reflective sheeting material with Clearview 5-W-R series font. Type 1 with Series E-Modified font performed second best and then Type 4 with Clearview 5-W-R font. It is not recommended to use Type 4 sheeting because of bad performance in day time conditions compared to DG3 and Type 1.

6.1.3 Situation with low day time traffic and high night time traffic

If the signs are used on highways with little day time traffic and moderate or high night time traffic, it would be recommended to use the Type 4 sheeting material with Clearview 5-W-R font as it produces the maximum legibility distance. The same font along with DG3 sheeting material performed second and the Type 4 sheeting with Clearview 5-W would be the next best choice. However it is not recommended to use the Type 1 sheeting material, as it performed poorly during night time conditions.

6.2 Future work

This research aimed at testing only three types of fonts and three types of sheeting material. For future research, it is advised to consider testing fonts with Typeface other than just the Typeface used on expressway guide signs. There is also scope for a study on the effect of the new font on the general public. A survey on the effectiveness of new fonts can be carried out on drivers.

The study also carried out field tests using only a study group with a small range in age. This study can further be used on a wider range of age.

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Appendix A - Field study data and sign combinations

Table A.1 Day time testing results

Sign Type	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Clearview 5-W on Type 4	364	385	364	354	448
Series E-Modified on DG3	254	485	323	287	446
Series E-Modified on Type 4	254	350	300	271	338
Clearview 5-W on DG3	329	455	345	294	413
Clearview 5-W-R on DG3	369	408	354	349	422
Series E-Modified on Type 1	378	439	346	286	468
Clearview 5-W on Type 1	428	427	407	330	483
Clearview 5-W-R on Type 1	397	426	341	364	546
Clearview 5-W-R on Type 4	378	427	347	343	441
Sign Type	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
Clearview 5-W on Type 4	450	372	299	269	280
Series E-Modified on DG3	507	409	351	252	375
Series E-Modified on Type 4	437	397	249	266	344
Clearview 5-W on DG3	537	376	272	332	374
Clearview 5-W-R on DG3	437	459	300	297	402
Series E-Modified on Type 1	502	414	276	363	364
Clearview 5-W on Type 1	533	447	345	348	417
Clearview 5-W-R on Type 1	568	427	330	405	436
Clearview 5-W-R on Type 4	534	430	328	398	421
Sign Type	Subject 11	Subject 12	Subject 13	Subject 14	Subject 15
Clearview 5-W on Type 4	301	274	402	290	353
Series E-Modified on DG3	364	302	449	288	338
Series E-Modified on Type 4	269	297	395	233	279
Clearview 5-W on DG3	287	316	423	254	330
Clearview 5-W-R on DG3	411	318	482	346	351
Series E-Modified on Type 1	453	435	456	319	359
Clearview 5-W on Type 1	441	388	500	365	401
Clearview 5-W-R on Type 1	526	407	435	300	324
Clearview 5-W-R on Type 4	383	349	458	328	371
Sign Type	Subject 16	Subject 17	Subject 18	Subject 19	Subject 20
Clearview 5-W on Type 4	457	389	406	308	484
Series E-Modified on DG3	417	391	381	279	492
Series E-Modified on Type 4	406	318	413	289	444
Clearview 5-W on DG3	428	399	416	331	313
Clearview 5-W-R on DG3	484	370	456	323	416
Series E-Modified on Type 1	462	407	374	344	428
Clearview 5-W on Type 1	497	440	469	359	500
Clearview 5-W-R on Type 1	458	441	473	283	431

Table A.2 Night time testing results

Sign Type	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Clearview 5-W on Type 4	322	292	365	328	337
Series E-Modified on DG3	317	259	393	331	291
Series E-Modified on Type 4	236	263	291	256	287
Clearview 5-W on DG3	290	315	281	288	339
Clearview 5-W-R on DG3	358	279	377	353	385
Series E-Modified on Type 1	258	276	287	333	321
Clearview 5-W on Type 1	299	264	282	336	341
Clearview 5-W-R on Type 1	267	296	262	245	279
Clearview 5-W-R on Type 4	468	363	399	357	335
Sign Type	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
Clearview 5-W on Type 4	208	356	558	330	262
Series E-Modified on DG3	350	297	486	250	103
Series E-Modified on Type 4	189	291	419	240	153
Clearview 5-W on DG3	287	361	474	308	233
Clearview 5-W-R on DG3	340	421	510	330	283
Series E-Modified on Type 1	301	406	393	258	208
Clearview 5-W on Type 1	265	355	469	249	220
Clearview 5-W-R on Type 1	287	363	374	242	236
Clearview 5-W-R on Type 4	330	379	487	347	330
Sign Type	Subject 11	Subject 12	Subject 13	Subject 14	Subject 15
Clearview 5-W on Type 4	499	465	357	301	449
Series E-Modified on DG3	467	436	367	276	384
Series E-Modified on Type 4	410	435	319	249	431
Clearview 5-W on DG3	438	443	412	329	419
Clearview 5-W-R on DG3	466	470	339	291	403
Series E-Modified on Type 1	382	425	354	339	352
Clearview 5-W on Type 1	359	453	370	264	383
Clearview 5-W-R on Type 1	395	415	349	236	351
Clearview 5-W-R on Type 4	451	407	347	286	364
Sign Type	Subject 16	Subject 17	Subject 18	Subject 19	Subject 20
Clearview 5-W on Type 4	277	275	380	441	343
Series E-Modified on DG3	314	258	367	429	302
Series E-Modified on Type 4	366	268	378	421	268
Clearview 5-W on DG3	397	291	401	447	326
Clearview 5-W-R on DG3	438	264	364	501	337
Series E-Modified on Type 1	311	258	370	481	338
Clearview 5-W on Type 1	357	249	350	500	398
Clearview 5-W-R on Type 1	309	210	303	484	324
Clearview 5-W-R on Type 4	365	281	380	460	320

Table A.3 Specifications of signs used in the field study

SI. NO.	Order of Display	Sign Names	Retro-Reflective sheeting material	Font Type	Legend Size
1.	6	Montegut	Type 1	Series E-Modified	6 Inches
2.	9	Montegut	Type 4	Clearview 5-W-R	6 Inches
3.	4	Montegut	DG 3	Clearview 5-W	6 Inches
4.	8	Montgall	Type 1	Clearview 5-W-R	6 Inches
5.	1	Montgall	Type 4	Clearview 5-W	6 Inches
6.	2	Montgall	DG 3	Series E-Modified	6 Inches
7.	7	Mirabeau	Type 1	Clearview 5-W	6 Inches
8.	3	Mirabeau	Type 4	Series E-Modified	6 Inches
9.	5	Mirabeau	DG 3	Clearview 5-W-R	6 Inches

Figure A.1 Montgall Type 4 retro-reflective material and Clearview 5 –W font

Figure A.2 Montgall DG3 retro-reflective material and Series E-Modified font

Figure A.3 Mirabeau in Type 4 retro-reflective material and Series E-Modified font

Figure A.4 Montegut in DG3 retro-reflective sheeting material and Clearview 5-W font

Figure A.5 Montgall in Type 4 retro-reflective material and Clearview 5 –W font

Figure A.6 Montegut in Type 1 retro-reflective material and Series E-Modified font

Figure A.7 Mirabeau in Type 1 retro-reflective material and Clearview 5-W font

Figure A.8 Montgall in Type 1 retro-reflective material and Clearview 5-W-R font

Figure A.9 Montegut in Type 4 retro-reflective material and Clearview 5-W-R font

Appendix B - Computer test slides, data collection sheet and instructions

Figure B.1 Sample Slide showing a Street name in Clearview 5-W font

Figure B.2 Sample Slide showing a Street name in Series E-Modified font

Figure B.3 Sample Slide showing a Street name in Series E-Modified font at 120%

Table B.1 Data Collection Table for the Computer screen Test

SI. No.	Correct Slide No.	Wrong Slide No.	Total Right	Total Wrong
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Instructions given to participants of the computer study

In this experiment, we try to compare the legibility of the new Clearview font with the existing Standard Highway Series font that is used on all traffic signs by simulating the fonts on a computer screen. Your main task is to read the name that appears on the screen and write it down your observation on the sheet provided. A quick visual acuity test will be carried out on you before beginning the experiment.

The experiment will be conducted in room number 1033 (first floor of Durland hall) and may last for about 10 to 15 minutes. You will need to follow these instructional procedures for the experiment:

1. A quick visual acuity test will be carried out on you to find your visual acuity. If you do not pass the test, you will not be eligible to participate in the experiment.
2. Sit on the chair and remain seated in the sitting position (You may be asked to view the screen in an angle other than the regular viewing position).

3. The test words will be displayed on the screen and the words are shown for only a second on the screen. You have only one second to correctly identify the word displayed on the screen and then you have to write down your answer on the sheet provided.
4. As soon as you finish writing the answer down, the next slide will be displayed and the experiment will continued.
5. This experiment will be repeated for around 96 slides and will take approximately 15 minutes to be completed.
6. At the end of the experiment return your answer sheet to the examiner.

Appendix C - Graphs and plots

Figure C.1 Performance of retro-reflective sheeting and font combination during day

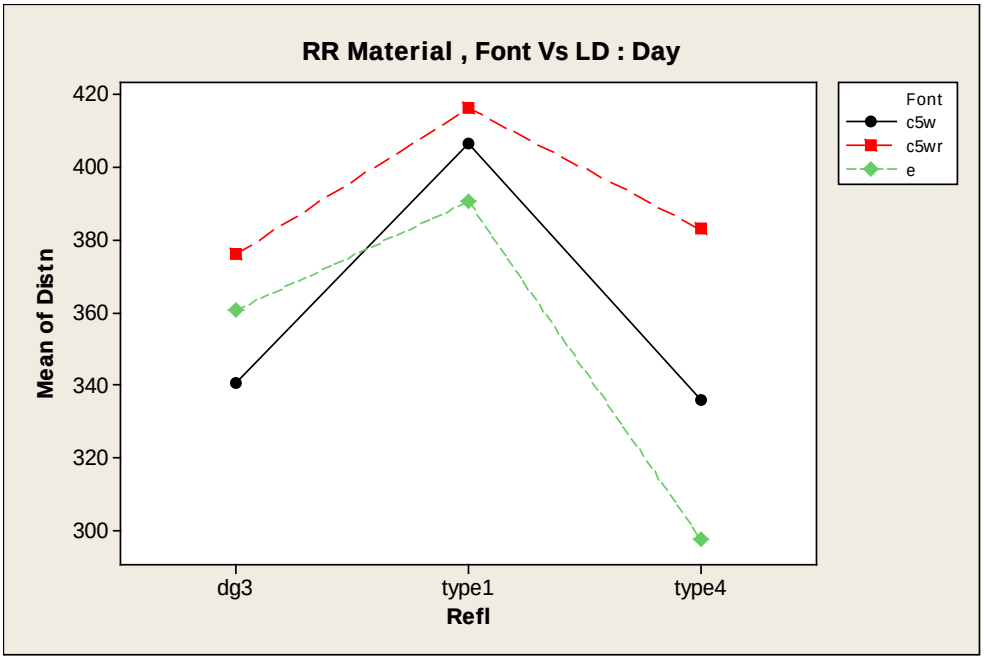


Figure C.2 Performance of retro-reflective sheeting and font combination during night

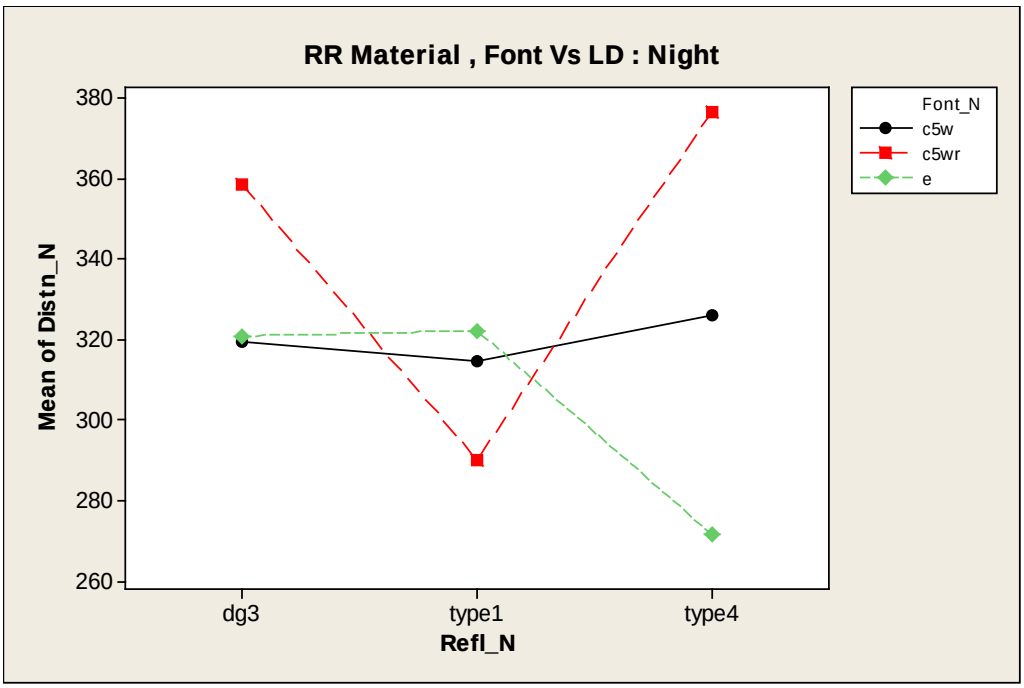


Figure C.3 Performance of retro-reflective sheeting and font during both night and day

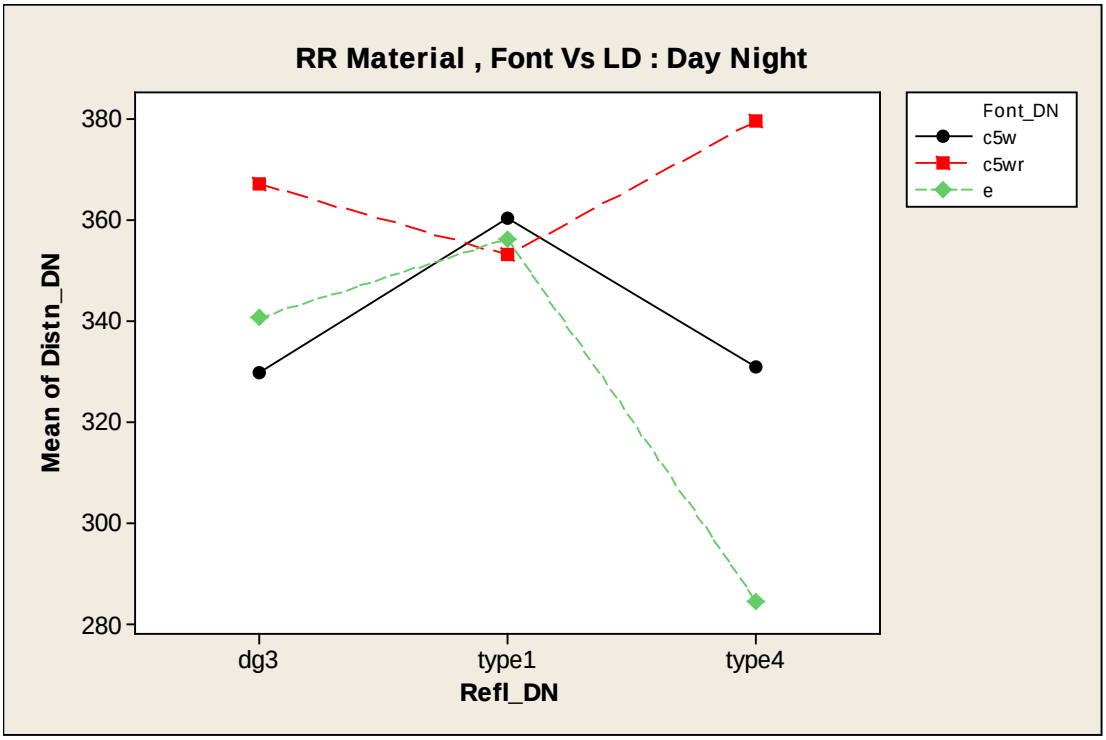


Figure C.4 Performance of retro-reflective sheeting during day

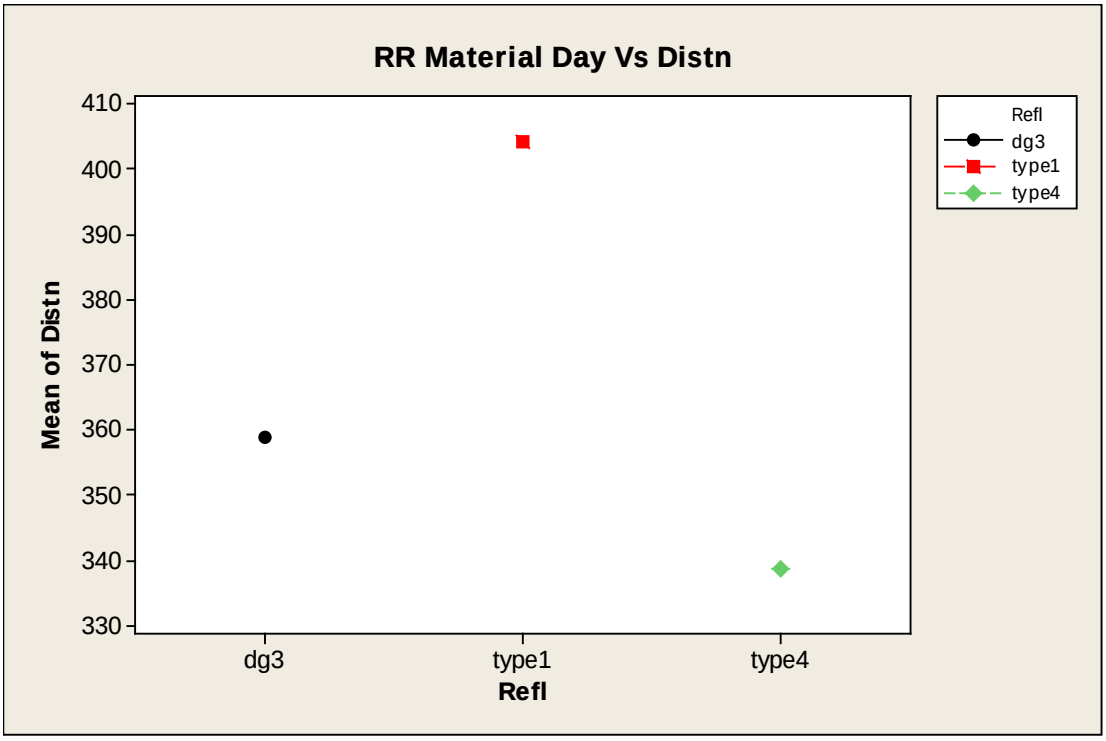


Figure C.5 Performance of retro-reflective sheeting during night time

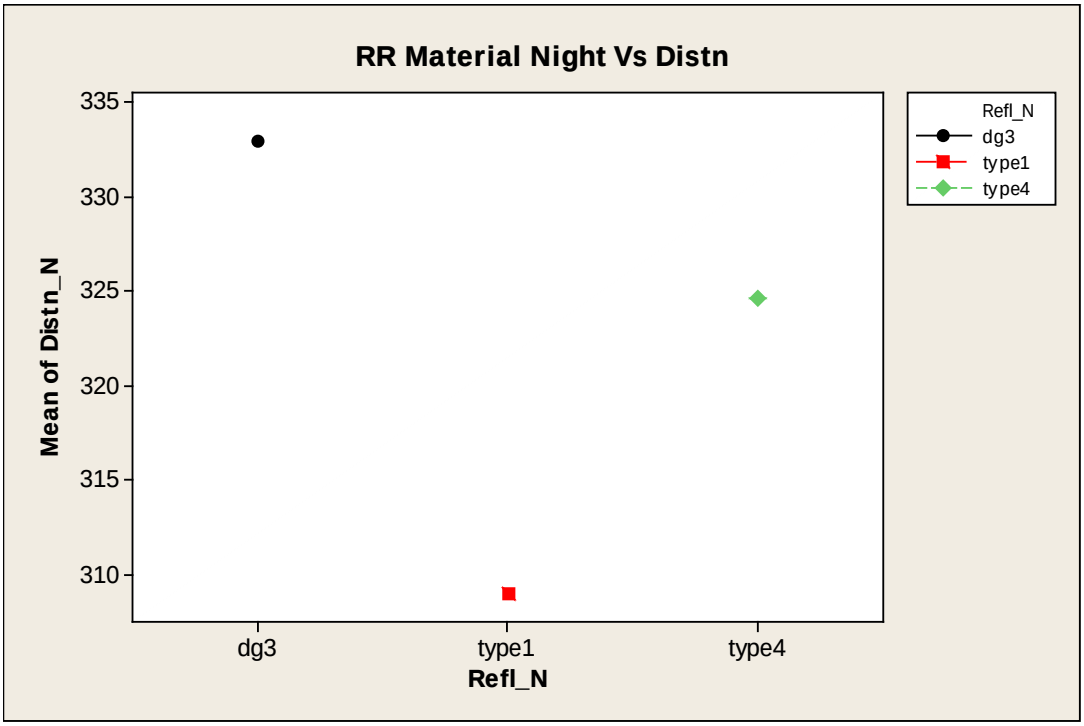


Figure C.6 Performance of font during day time

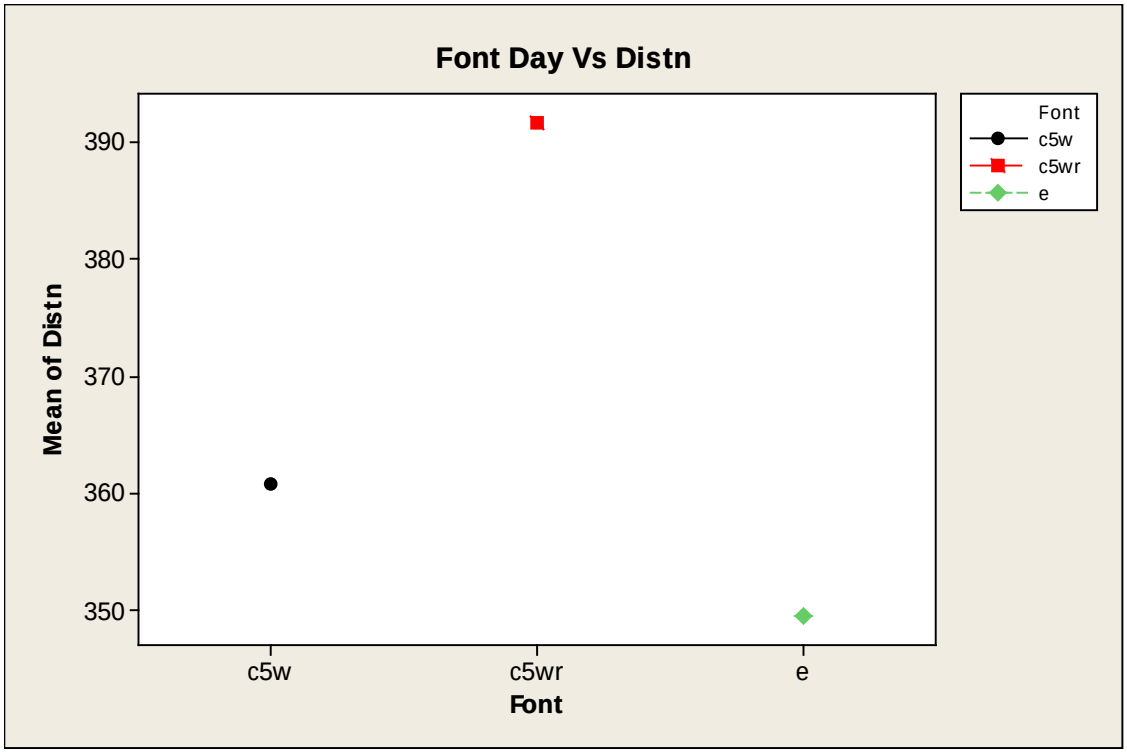


Figure C.7 Performance of font during night time

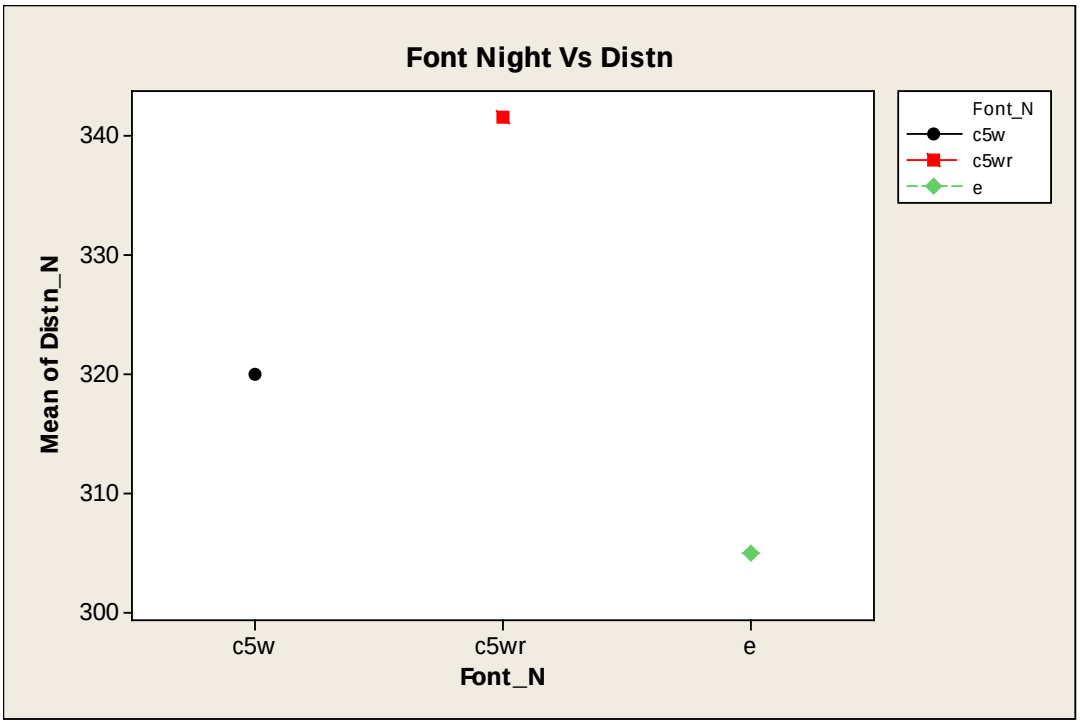


Figure C.8 Box plot of legibility distance of retro-reflective material and font during day

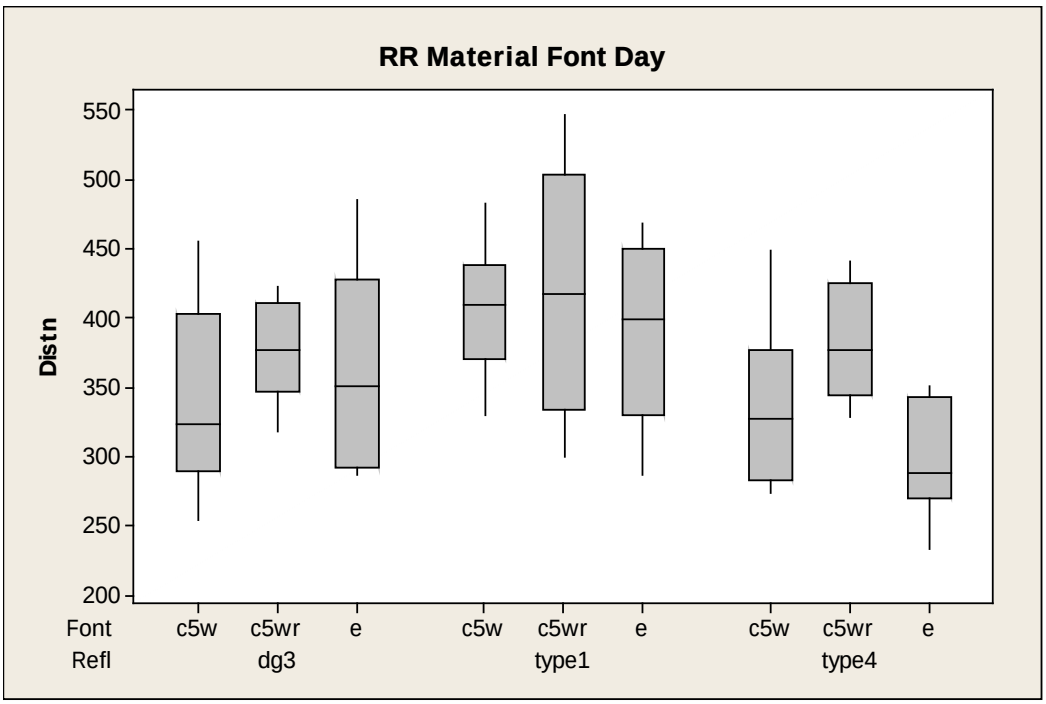


Figure C.9 Box plot of legibility distance of retro-reflective material and font during night

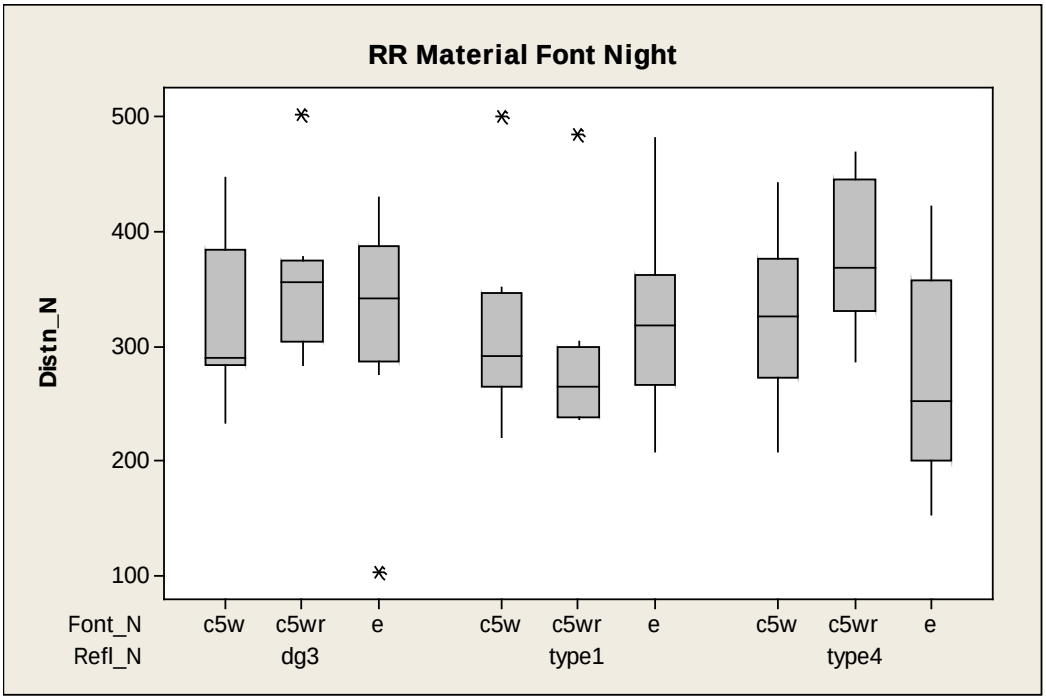


Figure C.10 Box plot of legibility distance of retro-reflective material and font for day/night

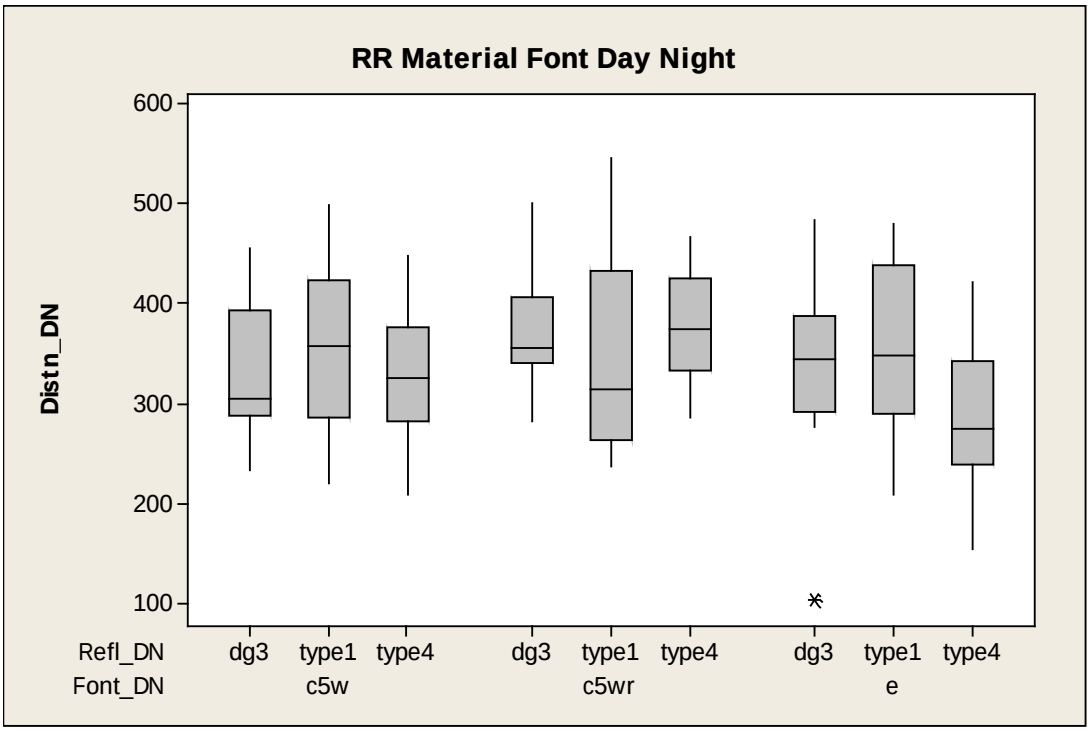


Figure C.11 Box plot of computer-based test, Series E-Modified vs. Clearview 5-W

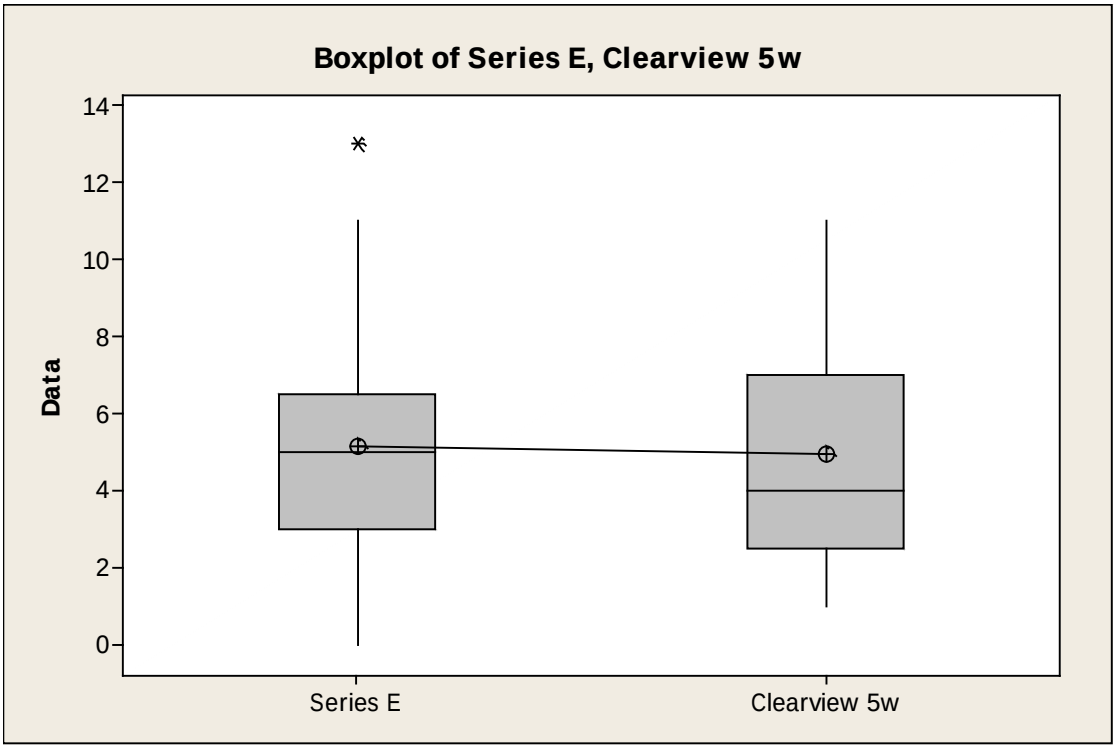


Figure C.12 Individual value plots of Clearview 5-W, Series E-Modified 120%

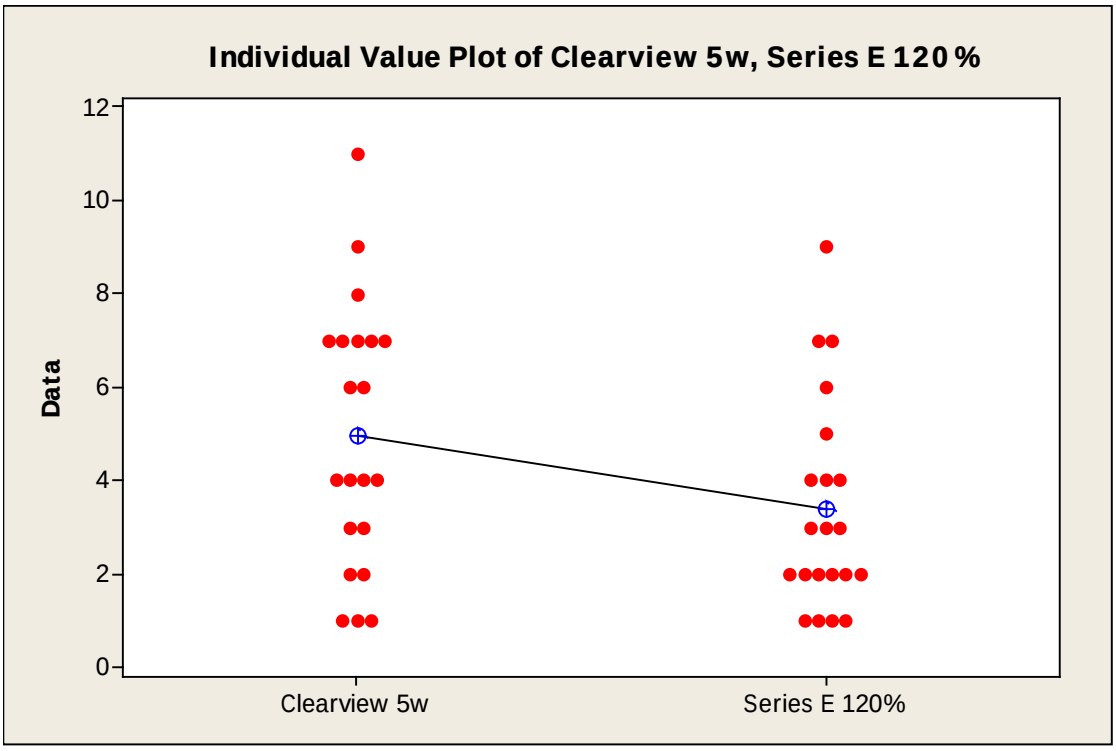
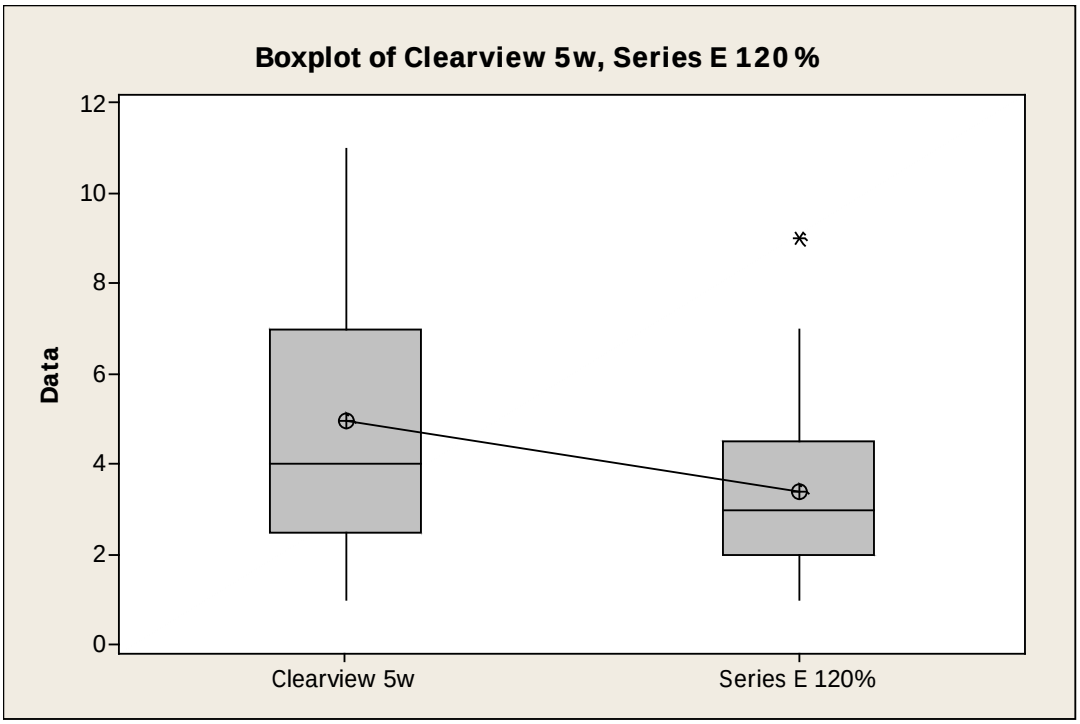


Figure C.13 Box plot of Clearview 5-W, Series E-Modified 120%



Appendix D - MUTCD Guide sign installation rules

Table D.1 Freeway or expressway guide sign and plaque sizes (MUTCD, 2009)

Sign or Plaque	Sign Designation	Section	Minimum Size
Exit Number (plaque)			
1-, 2-Digit Exit Number	E1-5P	2E.31	114 x 30
3-Digit Exit Number	E1-5P	2E.31	132 x 30
1-, 2-Digit Exit Number (with single letter suffix)	E1-5P	2E.31	138 x 30
3-Digit Exit Number (with single letter suffix)	E1-5P	2E.31	156 x 30
1-, 2-Digit Exit Number (with dual letter suffix)	E1-5P	2E.31	168 x 30
3-Digit Exit Number (with dual letter suffix)	E1-5P	2E.31	186 x 30
Left (plaque)	E1-5aP	2E.33	72 x 30
Left Exit Number (plaque)			
1-, 2-Digit Exit Number	E1-5bP	2E.31	114 x 54
3-Digit Exit Number	E1-5bP	2E.31	132 x 54
1-, 2-Digit Exit Number (with single letter suffix)	E1-5bP	2E.31	138 x 54
3-Digit Exit Number (with single letter suffix)	E1-5bP	2E.31	156 x 54
1-, 2-Digit Exit Number (with dual letter suffix)	E1-5bP	2E.31	168 x 54
3-Digit Exit Number (with dual letter suffix)	E1-5bP	2E.31	186 x 54
Next Exit XX Miles (1 line)	—	2E.34	Varies x 24
Next Exit XX Miles (2 lines)	—	2E.34	Varies x 36
Exit Gore (no exit number)	E5-1	2E.37	72 x 60
Exit Gore (with exit number)			
1-, 2-Digit Exit Number	E5-1a	2E.37	78 x 60
3-Digit Exit Number	E5-1a	2E.37	96 x 60
1-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	90 x 60
2-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	108 x 60
3-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	126 x 60
1-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	120 x 60
2-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	138 x 60
3-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	156 x 60
Exit Number (plaque)			
1-, 2-Digit Exit Number	E5-1bP	2E.37	42 x 30
3-Digit Exit Number	E5-1bP	2E.37	60 x 30
1-Digit Exit Number (with single letter suffix)	E5-1bP	2E.37	48 x 30
1-Digit Exit Number (with dual letter suffix)	E5-1bP	2E.37	72 x 30
2-Digit Exit Number (with single or dual letter suffix)	E5-1bP	2E.37	72 x 30
3-Digit Exit Number (with single or dual letter suffix)	E5-1bP	2E.37	72 x 30
Narrow Exit Gore	E5-1c	2E.37	60 x 90*
Pull-Through	E6-2	2E.12	Varies x 120*
Pull-Through	E6-2a	2E.12	Varies x 90*
Exit Only (with arrow)	E11-1,1d	2E.24	174** x 36
Exit	E11-1a	2E.24	66 x 18
Only	E11-1b	2E.24	66 x 18
Exit Only	E11-1c	2E.24	120 x 18
Exit Only (with two arrows)	E11-1e,1f	2E.24	222** x 36
Left	E11-2	2E.40	60 x 18
Exit Gore Advisory Speed (plaque)	E13-1P	2E.37	72 x 24
Exit Direction Advisory Speed	E13-2	2E.36	162 x 24
Interstate Route Sign (1 or 2 digits)	M1-1	2E.27	36 x 36
Interstate Route Sign (3 digits)	M1-1	2E.27	45 x 36
Off-Interstate Route Sign (1 or 2 digits)	M1-2,3	2E.27	36 x 36
Off-Interstate Route Sign (3 digits)	M1-2,3	2E.27	45 x 36
U.S. Route Sign (1 or 2 digits)	M1-4	2E.27	36 x 36
U.S. Route Sign (3 digits)	M1-4	2E.27	45 x 36
State Route Sign (1 or 2 digits)	M1-5	2D.11	36 x 36

Table D.2 Freeway or expressway guide sign and plaque sizes (MUTCD, 2009)

Sign or Plaque	Sign Designation	Section	Minimum Size
State Route Sign (3 digits)	M1-5	2D.11	45 x 36
County Route Sign (1, 2, or 3 digits)	M1-6	2D.11	36 x 36
Forest Route (1, 2, or 3 digits)	M1-7	2D.11	36 x 36
Eisenhower Interstate System	M1-10,10a	2E.28	36 x 36
Junction	M2-1	2D.13	30 x 21
Combination Junction (2 route signs)	M2-2	2D.14	60 x 48*
Cardinal Direction	M3-1,2,3,4	2D.15	36 x 18
Alternate	M4-1,1a	2D.17	36 x 18
By-Pass	M4-2	2D.18	36 x 18
Business	M4-3	2D.19	36 x 18
Truck	M4-4	2D.20	36 x 18
To	M4-5	2D.21	36 x 18
End	M4-6	2D.22	36 x 18
Temporary	M4-7,7a	2D.24	36 x 18
Begin	M4-14	2D.23	36 x 18
Advance Turn Arrow	M5-1,2,3	2D.26	30 x 21
Lane Designation	M5-4,5,6	2D.27	36 x 24
Directional Arrow	M6-1,2,2a,3,4,5,6,7	2D.28	30 x 21
Destination (1 line)	D1-1	2D.37	Varies x 30
Destination and Distance (1 line)	D1-1a	2D.37	Varies x 30
Destination (2 lines)	D1-2	2D.37	Varies x 54
Destination and Distance (2 lines)	D1-2a	2D.37	Varies x 54
Destination (3 lines)	D1-3	2D.37	Varies x 72
Destination and Distance (3 lines)	D1-3a	2D.37	Varies x 72
Distance (1 line)	D2-1	2D.41	Varies x 30
Distance (2 lines)	D2-2	2D.41	Varies x 54
Distance (3 lines)	D2-3	2D.41	Varies x 72
Street Name	D3-1,1a	2D.43	Varies x 18
Advance Street Name (2 lines)	D3-2	2D.44	Varies x 42*
Advance Street Name (3 lines)	D3-2	2D.44	Varies x 66*
Advance Street Name (4 lines)	D3-2	2D.44	Varies x 84*
Park - Ride	D4-2	2D.48	36 x 48
National Scenic Byways	D6-4	2D.55	24 x 24
National Scenic Byways	D6-4a	2D.55	24 x 12
Weigh Station XX Miles	D8-1	2E.54	96 x 72 (F) 78 x 60 (E)
Weigh Station Next Right	D8-2	2E.54	108 x 90 (F) 84 x 72 (E)
Weigh Station (with arrow)	D8-3	2E.54	84 x 78 (F) 66 x 60 (E)
Crossover	D13-1,2	2D.54	78 x 42
Freeway Entrance	D13-3	2D.46	48 x 30
Freeway Entrance (with arrow)	D13-3a	2D.46	48 x 42
Combination Lane Use / Destination	D15-1	2D.33	Varies x 96
Next Truck Lane XX Miles	D17-1	2D.51	60 x 66
Truck Lane XX Miles	D17-2	2D.51	60 x 54
Slow Vehicle Turn-Out XX Miles	D17-7	2D.52	96 x 54

* The size shown is for a typical sign as illustrated in the figures in Chapters 2D and 2E. The size should be determined based on the amount of legend required for the sign.

** The width shown represents the minimum dimension. The width shall be increased as appropriate to match the width of the guide sign.

Notes: 1. Larger signs may be used when appropriate

2. Dimensions in inches are shown as width x height

3. Where two sizes are shown, the larger size is for freeways (F) and the smaller size is for expressways (E)

Table D.3 Minimum letter and numeral sizes for expressway guide signs according to interchange classification (MUTCD, 2009)

Type of Sign	Type of Interchange (see Section 2E.32)				
	Major		Intermediate	Minor	Overhead
	Category a	Category b			
A. Advance Guide, Exit Direction, and Overhead Guide Signs					
Exit Number Plaques					
Words	10	10	10	8	10
Numerals & Letters	15	15	15	12	15
Interstate Route Signs					
Numerals	18	—	—	—	18
1- or 2-Digit Shields	36 x 36	—	—	—	36 x 36
3-Digit Shields	45 x 36	—	—	—	45 x 36
U.S. or State Route Signs					
Numerals	18	18	18	12	18
1- or 2-Digit Shields	36 x 36	36 x 36	36 x 36	24 x 24	36 x 36
3-Digit Shields	45 x 36	45 x 36	45 x 36	30 x 24	45 x 36
U.S. or State Route Text Identification (Example: US 56)					
Numerals & Letters	18	15	15	12	15
Cardinal Directions					
First Letters	18	15	12	10	15
Rest of Words	15	12	10	8	12
Auxiliary and Alternative Route Legends (Examples: JCT, TO, ALT, BUSINESS)					
Words	15	12	10	8	12
Names of Destinations					
Upper-Case Letters	20	16	13.33	10.67	16
Lower-Case Letters	15	12	10	8	12
Distance Numbers	18	15	12	10	15
Distance Fraction Numerals	12	10	10	8	10
Distance Words	12	10	10	8	10
Action Message Words	10	10	10	8	10
B. Gore Signs					
Words	10	10	10	8	—
Numerals & Letters	12	12	12	10	—

Note: Sizes are shown in inches and where applicable are shown as width x height

Table D.4 Minimum letter and numeral sizes for expressway guide signs according to sign type (MUTCD, 2009)

Type of Sign	Minimum Size
A. Pull-Through Signs	
Destinations — Upper-Case Letters	13.33
Destinations — Lower-Case Letters	10
Route Signs	
1- or 2-Digit Shields	36 x 36
3-Digit Shields	45 x 36
Cardinal Directions — First Letters	12
Cardinal Directions — Rest of Word	10
B. Supplemental Guide Signs	
Exit Number — Words	8
Exit Number — Numerals and Letters	12
Place Names — Upper-Case Letters	10.67
Place Names — Lower-Case Letters	8
Action Messages	8
Route Signs	
Numerals	12
1- or 2-Digit Shield	24 x 24
3-Digit Shield	30 x 24
C. Interchange Sequence or Community Interchanges Identification Signs	
Words — Upper-Case Letters	10.67
Words — Lower-Case Letters	8
Numerals	10.67
Fraction Numerals	8
Route Signs	
Numerals	12
1- or 2-Digit Shield	24 x 24
3-Digit Shield	30 x 24
D. Next XX Exits Sign	
Place Names — Upper-Case Letters	10.67
Place Names — Lower-Case Letters	8
NEXT XX EXITS — Words	8
NEXT XX EXITS — Number	12

Type of Sign	Minimum Size
E. Distance Signs	
Words — Upper-Case Letters	8
Words — Lower-Case Letters	6
Numerals	8
Route Signs	
Numerals	9
1- or 2-Digit Shield	18 x 18
3-Digit Shield	22.5 x 18
F. General Services Signs (see Chapter 2I)	
Exit Number — Words	8
Exit Number — Numerals and Letters	12
Services	8
G. Rest Area, Scenic Area, and Roadside Area Signs (see Chapter 2I)	
Words	10
Distance Numerals	12
Distance Fraction Numerals	8
Distance Words	8
Action Message Words	10
H. Reference Location Signs (see Chapter 2H)	
Words	4
Numerals	10
I. Boundary and Orientation Signs (see Chapter 2H)	
Words — Upper-Case Letters	8
Words — Lower-Case Letters	6
J. Next Exit and Next Services Signs	
Words and Numerals	8
K. Exit Only Signs	
Words	12
L. Overhead Arrow-Per-Lane and Diagrammatic Signs	
See Table 2E-5	

Note: Sizes are shown in inches and where applicable are shown as width x height

Table D.5 Minimum letter and numeral Sizes for freeway guide signs according to interchange classification (MUTCD, 2009)

Type of Sign	Type of Interchange (see Section 2E.32)				Overhead
	Major		Intermediate	Minor	
	Category a	Category b			
A. Advance Guide, Exit Direction, and Overhead Guide Signs					
Exit Number Plaques					
Words	10	10	10	10	10
Numerals & Letters	15	15	15	15	15
Interstate Route Signs					
Numerals	24/18	—	—	—	18
1- or 2-Digit Shields	48 x 48/ 36 x 36	—	—	—	36 x 36
3-Digit Shields	60 x 48/ 45 x 36	—	—	—	45 x 36
U.S. or State Route Signs					
Numerals	24/18	18	18	12	18
1- or 2-Digit Shields	48 x 48/ 36 x 36	36 x 36	36 x 36	24 x 24	36 x 36
3-Digit Shields	60 x 48/ 45 x 36	45 x 36	45 x 36	30 x 24	45 x 36
U.S. or State Route Text Identification (Example: US 56)					
Numerals & Letters	18	18/15	15	12	15
Cardinal Directions					
First Letters	18	15	15	10	15
Rest of Words	15	12	12	8	12
Auxiliary and Alternative Route Legends (Examples: JCT, TO, ALT, BUSINESS)					
Words	15	12	12	8	12
Names of Destinations					
Upper-Case Letters	20	20	16	13.33	16
Lower-Case Letters	15	15	12	10	12
Distance Numbers	18	18/15	15	12	15
Distance Fraction Numerals	12	12/10	10	8	10
Distance Words	12	12/10	10	8	10
Action Message Words	12	12/10	10	8	10
B. Gore Signs					
Words	12	12	12	8	—
Numeral & Letters	18	18	18	12	—

Notes: 1. Sizes are shown in inches and where applicable are shown as width x height
2. Slanted line (/) signifies separation of desirable and minimum sizes

Table D.6 Minimum letter and numeral sizes for freeway guide signs according to sign type (MUTCD, 2009)

Type of Sign	Minimum Size
A. Pull-Through Signs	
Destinations — Upper-Case Letters	16
Destinations — Lower-Case Letters	12
Route Signs	
1- or 2-Digit Shields	36 x 36
3-Digit Shields	45 x 36
Cardinal Directions — First Letter	15
Cardinal Directions — Rest of Word	12
B. Supplemental Guide Signs	
Exit Number Words	10
Exit Number Numerals and Letters	15
Place Names — Upper-Case Letters	13.33
Place Names — Lower-Case Letters	10
Action Messages	8
Route Signs	
Numerals	12
1- or 2-Digit Shield	24 x 24
3-Digit Shield	30 x 24
C. Interchange Sequence or Community Interchanges Identification Signs	
Words — Upper-Case Letters	13.33
Words — Lower-Case Letters	10
Numerals	13.33
Fraction Numerals	10
Route Signs	
Numerals	12
1- or 2-Digit Shield	24 x 24
3-Digit Shield	30 x 24
D. Next XX Exits Sign	
Place Names — Upper-Case Letters	13.33
Place Names — Lower-Case Letters	10
NEXT XX EXITS — Words	10
NEXT XX EXITS — Number	15
E. Distance Signs	
Words — Upper-Case Letters	8
Words — Lower-Case Letters	6
Numerals	8
Route Signs	
Numerals	9
1- or 2-Digit Shield	18 x 18
3-Digit Shield	22.5 x 18
F. General Services Signs (see Chapter 2I)	
Exit Number Words	10
Exit Number Numerals and Letters	15
Services	10

Type of Sign	Minimum Size
G. Rest Area, Scenic Area, and Roadside Area Signs (see Chapter 2I)	
Words	12
Distance Numerals	15
Distance Fraction Numerals	10
Distance Words	10
Action Message Words	12
H. Reference Location Signs (see Chapter 2H)	
Words	4
Numerals	10
I. Boundary and Orientation Signs (see Chapter 2H)	
Words — Upper-Case Letters	8
Words — Lower-Case Letters	6
J. Next Exit and Next Services Signs	
Words and Numerals	8
K. Exit Only Signs	
Words	12
L. Overhead Arrow-Per-Lane Signs	
Arrowhead (Type D Directional Arrow)	21.625
Arrow Shaft Width	8
Arrow Height	
Through	72
Left Only	48
Right Only	48
Optional-Diverge (Through with Left or Right)	72
Optional-Split (Left and Right)	66
Vertical Separator Width	2
Vertical Space between Vertical Separator and Top of Nearest Arrow	8
Horizontal Space between Vertical Separator and Top of Nearest Through Arrow	15
Horizontal Space between Arrow Shaft and EXIT and ONLY plaques	10
EXIT and ONLY Panels	60 x 18
M. Diagrammatic Signs	
Arrowhead (Type D Directional Arrow)	13.5*
Lane Widths	5
Lane Line Segments	1 x 6
Spacing between Lane Line Segments	6
Stem Height to Upper Point of Departure	30
Horizontal Space between Arrowhead and Route Shield or Destination	12

* The size shown is the arrowhead width per lane depicted on the corresponding arrow shaft

Note: Sizes are shown in inches and where applicable are shown as width x height

Appendix E - SAS code and output

SAS code used:

```
data gowda1;
      input person $ refl $ font $ time $ distn;
      cards;
      nathen type4 c5w day 364
      nathen dg3 e day 254
      nathen type4 e day 254
      nathen dg3 c5w day 329
      nathen dg3 c5wr day 369
      nathen type1 e day 378
      nathen type1 c5w day 428
      nathen type1 c5wr day 397
      nathen type4 c5wr day 378
      katie type4 c5w day 269
      katie dg3 e day 252
      katie type4 e day 266
      katie dg3 c5w day 332
      katie dg3 c5wr day 297
      katie type1 e day 363
      katie type1 c5w day 348
      katie type1 c5wr day 405
      katie type4 c5wr day 398
      adam type4 c5w day 402
      adam dg3 e day 449
      adam type4 e day 395
      adam dg3 c5w day 423
      adam dg3 c5wr day 482
      adam type1 e day 456
      adam type1 c5w day 500
      adam type1 c5wr day 435
      adam type4 c5wr day 458
      balaji type4 c5w day 389
      balaji dg3 e day 391
      balaji type4 e day 318
      balaji dg3 c5w day 399
      balaji dg3 c5wr day 370
      balaji type1 e day 407
      balaji type1 c5w day 440
      balaji type1 c5wr day 441
      balaji type4 c5wr day 316
      lauren type4 c5w day 450
      lauren dg3 e day 507
      lauren type4 e day 437
      lauren dg3 c5w day 537
      lauren dg3 c5wr day 437
      lauren type1 e day 502
      lauren type1 c5w day 533
      lauren type1 c5wr day 568
      lauren type4 c5wr day 534
      anand type4 c5w day 406
```

```
anand dg3 e day 381
anand type4 e day 413
anand dg3 c5w day 416
anand dg3 c5wr day 456
anand type1 e day 374
anand type1 c5w day 469
anand type1 c5wr day 473
anand type4 c5wr day 427
tirhas type4 c5w day 364
tirhas dg3 e day 323
tirhas type4 e day 300
tirhas dg3 c5w day 345
tirhas dg3 c5wr day 354
tirhas type1 e day 346
tirhas type1 c5w day 407
tirhas type1 c5wr day 341
tirhas type4 c5wr day 347
ashley type4 c5w day 372
ashley dg3 e day 409
ashley type4 e day 397
ashley dg3 c5w day 376
ashley dg3 c5wr day 459
ashley type1 e day 414
ashley type1 c5w day 447
ashley type1 c5wr day 427
ashley type4 c5wr day 430
aditya type4 c5w day 308
aditya dg3 e day 279
aditya type4 e day 289
aditya dg3 c5w day 331
aditya dg3 c5wr day 323
aditya type1 e day 344
aditya type1 c5w day 359
aditya type1 c5wr day 283
aditya type4 c5wr day 335
jordan type4 c5w day 299
jordan dg3 e day 351
jordan type4 e day 249
jordan dg3 c5w day 272
jordan dg3 c5wr day 300
jordan type1 e day 276
jordan type1 c5w day 345
jordan type1 c5wr day 330
jordan type4 c5wr day 328
phil type4 c5w day 457
phil dg3 e day 417
phil type4 e day 406
phil dg3 c5w day 428
phil dg3 c5wr day 484
phil type1 e day 462
phil type1 c5w day 497
phil type1 c5wr day 458
phil type4 c5wr day 442
nivas type4 c5w day 484
nivas dg3 e day 492
nivas type4 e day 444
```

```
nivas dg3 c5w day 313
nivas dg3 c5wr day 416
nivas type1 e day 428
nivas type1 c5w day 500
nivas type1 c5wr day 431
nivas type4 c5wr day 482
nathen type4 c5w night 292
nathen dg3 e night 259
nathen type4 e night 263
nathen dg3 c5w night 315
nathen dg3 c5wr night 279
nathen type1 e night 276
nathen type1 c5w night 264
nathen type1 c5wr night 296
nathen type4 c5wr night 363
phil type4 c5w night 337
phil dg3 e night 291
phil type4 e night 287
phil dg3 c5w night 339
phil dg3 c5wr night 385
phil type1 e night 321
phil type1 c5w night 341
phil type1 c5wr night 279
phil type4 c5wr night 335
ashley type4 c5w night 356
ashley dg3 e night 297
ashley type4 e night 291
ashley dg3 c5w night 361
ashley dg3 c5wr night 421
ashley type1 e night 406
ashley type1 c5w night 355
ashley type1 c5wr night 363
ashley type4 c5wr night 379
lauren type4 c5w night 558
lauren dg3 e night 486
lauren type4 e night 419
lauren dg3 c5w night 474
lauren dg3 c5wr night 510
lauren type1 e night 393
lauren type1 c5w night 469
lauren type1 c5wr night 374
lauren type4 c5wr night 487
jordan type4 c5w night 330
jordan dg3 e night 250
jordan type4 e night 240
jordan dg3 c5w night 308
jordan dg3 c5wr night 330
jordan type1 e night 258
jordan type1 c5w night 249
jordan type1 c5wr night 242
jordan type4 c5wr night 347
adam type4 c5w night 465
adam dg3 e night 436
adam type4 e night 435
adam dg3 c5w night 443
adam dg3 c5wr night 470
```

```
adam type1 e night 425
adam type1 c5w night 453
adam type1 c5wr night 415
adam type4 c5wr night 407
balaji type4 c5w night 449
balaji dg3 e night 384
balaji type4 e night 431
balaji dg3 c5w night 419
balaji dg3 c5wr night 403
balaji type1 e night 352
balaji type1 c5w night 383
balaji type1 c5wr night 351
balaji type4 c5wr night 364
anand type4 c5w night 277
anand dg3 e night 314
anand type4 e night 366
anand dg3 c5w night 397
anand dg3 c5wr night 438
anand type1 e night 311
anand type1 c5w night 357
anand type1 c5wr night 309
anand type4 c5wr night 365
aditya type4 c5w night 275
aditya dg3 e night 258
aditya type4 e night 268
aditya dg3 c5w night 291
aditya dg3 c5wr night 264
aditya type1 e night 258
aditya type1 c5w night 249
aditya type1 c5wr night 210
aditya type4 c5wr night 281
nivas type4 c5w night 499
nivas dg3 e night 467
nivas type4 e night 410
nivas dg3 c5w night 438
nivas dg3 c5wr night 466
nivas type1 e night 382
nivas type1 c5w night 359
nivas type1 c5wr night 395
nivas type4 c5wr night 451
tirhas type4 c5w night 343
tirhas dg3 e night 302
tirhas type4 e night 268
tirhas dg3 c5w night 326
tirhas dg3 c5wr night 337
tirhas type1 e night 338
tirhas type1 c5w night 398
tirhas type1 c5wr night 324
tirhas type4 c5wr night 320
katie type4 c5w night 357
katie dg3 e night 367
katie type4 e night 319
katie dg3 c5w night 412
katie dg3 c5wr night 339
katie type1 e night 354
katie type1 c5w night 370
```

```
      katie type1 c5wr night 349
      katie type4 c5wr night 347
;
data gowda2;
      input person $ refl $ font $ time $ distn;
      cards;
      stacy type4 c5w day 385
      stacy dg3 e day 485
      stacy type4 e day 350
      stacy dg3 c5w day 455
      stacy dg3 c5wr day 408
      stacy type1 e day 439
      stacy type1 c5w day 427
      stacy type1 c5wr day 426
      stacy type4 c5wr day 427
      ahmad type4 c5w day 354
      ahmad dg3 e day 287
      ahmad type4 e day 271
      ahmad dg3 c5w day 294
      ahmad dg3 c5wr day 349
      ahmad type1 e day 286
      ahmad type1 c5w day 330
      ahmad type1 c5wr day 364
      ahmad type4 c5wr day 343
      chris type4 c5w day 448
      chris dg3 e day 446
      chris type4 e day 338
      chris dg3 c5w day 413
      chris dg3 c5wr day 422
      chris type1 e day 468
      chris type1 c5w day 483
      chris type1 c5wr day 546
      chris type4 c5wr day 441
      neil type4 c5w day 280
      neil dg3 e day 375
      neil type4 e day 344
      neil dg3 c5w day 374
      neil dg3 c5wr day 402
      neil type1 e day 364
      neil type1 c5w day 417
      neil type1 c5wr day 436
      neil type4 c5wr day 421
      kyle type4 c5w day 301
      kyle dg3 e day 364
      kyle type4 e day 269
      kyle dg3 c5w day 287
      kyle dg3 c5wr day 411
      kyle type1 e day 453
      kyle type1 c5w day 441
      kyle type1 c5wr day 526
      kyle type4 c5wr day 383
      andrew type4 c5w day 274
      andrew dg3 e day 302
      andrew type4 e day 297
      andrew dg3 c5w day 316
      andrew dg3 c5wr day 318
```

```
andrew type1 e day 435
andrew type1 c5w day 388
andrew type1 c5wr day 407
andrew type4 c5wr day 349
ramiro type4 c5w day 290
ramiro dg3 e day 288
ramiro type4 e day 233
ramiro dg3 c5w day 254
ramiro dg3 c5wr day 346
ramiro type1 e day 319
ramiro type1 c5w day 365
ramiro type1 c5wr day 300
ramiro type4 c5wr day 328
ben type4 c5w day 353
ben dg3 e day 338
ben type4 e day 279
ben dg3 c5w day 330
ben dg3 c5wr day 351
ben type1 e day 359
ben type1 c5w day 401
ben type1 c5wr day 324
ben type4 c5wr day 371
matthew type4 c5w night 322
matthew dg3 e night 317
matthew type4 e night 236
matthew dg3 c5w night 290
matthew dg3 c5wr night 358
matthew type1 e night 258
matthew type1 c5w night 299
matthew type1 c5wr night 267
matthew type4 c5wr night 468
tommy type4 c5w night 365
tommy dg3 e night 393
tommy type4 e night 291
tommy dg3 c5w night 281
tommy dg3 c5wr night 377
tommy type1 e night 287
tommy type1 c5w night 282
tommy type1 c5wr night 262
tommy type4 c5wr night 399
obair type4 c5w night 328
obair dg3 e night 331
obair type4 e night 256
obair dg3 c5w night 288
obair dg3 c5wr night 353
obair type1 e night 333
obair type1 c5w night 336
obair type1 c5wr night 245
obair type4 c5wr night 357
jason type4 c5w night 208
jason dg3 e night 350
jason type4 e night 189
jason dg3 c5w night 287
jason dg3 c5wr night 340
jason type1 e night 301
jason type1 c5w night 265
```

```
      jason type1 c5wr night 287
      jason type4 c5wr night 330
      karl type4 c5w night 262
      karl dg3 e night 103
      karl type4 e night 153
      karl dg3 c5w night 233
      karl dg3 c5wr night 283
      karl type1 e night 208
      karl type1 c5w night 220
      karl type1 c5wr night 236
      karl type4 c5wr night 330
      sarah type4 c5w night 301
      sarah dg3 e night 276
      sarah type4 e night 249
      sarah dg3 c5w night 329
      sarah dg3 c5wr night 291
      sarah type1 e night 339
      sarah type1 c5w night 264
      sarah type1 c5wr night 236
      sarah type4 c5wr night 286
      cathryn type4 c5w night 380
      cathryn dg3 e night 367
      cathryn type4 e night 378
      cathryn dg3 c5w night 401
      cathryn dg3 c5wr night 364
      cathryn type1 e night 370
      cathryn type1 c5w night 350
      cathryn type1 c5wr night 303
      cathryn type4 c5wr night 380
      rohit type4 c5w night 441
      rohit dg3 e night 429
      rohit type4 e night 421
      rohit dg3 c5w night 447
      rohit dg3 c5wr night 501
      rohit type1 e night 481
      rohit type1 c5w night 500
      rohit type1 c5wr night 484
      rohit type4 c5wr night 460
      ;
data gowda3;
      input person $ refl $ font $ time $ prac $ distn;
      cards;
      matthew type4 c5w night n 322
      matthew dg3 e night n 317
      matthew type4 e night n 236
      matthew dg3 c5w night n 290
      matthew dg3 c5wr night n 358
      matthew type1 e night n 258
      matthew type1 c5w night n 299
      matthew type1 c5wr night n 267
      matthew type4 c5wr night n 468
      tommy type4 c5w night n 365
      tommy dg3 e night n 393
      tommy type4 e night n 291
      tommy dg3 c5w night n 281
      tommy dg3 c5wr night n 377
```

```
tommy type1 e night n 287
tommy type1 c5w night n 282
tommy type1 c5wr night n 262
tommy type4 c5wr night n 399
obair type4 c5w night n 328
obair dg3 e night n 331
obair type4 e night n 256
obair dg3 c5w night n 288
obair dg3 c5wr night n 353
obair type1 e night n 333
obair type1 c5w night n 336
obair type1 c5wr night n 245
obair type4 c5wr night n 357
jason type4 c5w night n 208
jason dg3 e night n 350
jason type4 e night n 189
jason dg3 c5w night n 287
jason dg3 c5wr night n 340
jason type1 e night n 301
jason type1 c5w night n 265
jason type1 c5wr night n 287
jason type4 c5wr night n 330
karl type4 c5w night n 262
karl dg3 e night n 103
karl type4 e night n 153
karl dg3 c5w night n 233
karl dg3 c5wr night n 283
karl type1 e night n 208
karl type1 c5w night n 220
karl type1 c5wr night n 236
karl type4 c5wr night n 330
sarah type4 c5w night n 301
sarah dg3 e night n 276
sarah type4 e night n 249
sarah dg3 c5w night n 329
sarah dg3 c5wr night n 291
sarah type1 e night n 339
sarah type1 c5w night n 264
sarah type1 c5wr night n 236
sarah type4 c5wr night n 286
cathryn type4 c5w night n 380
cathryn dg3 e night n 367
cathryn type4 e night n 378
cathryn dg3 c5w night n 401
cathryn dg3 c5wr night n 364
cathryn type1 e night n 370
cathryn type1 c5w night n 350
cathryn type1 c5wr night n 303
cathryn type4 c5wr night n 380
rohit type4 c5w night n 441
rohit dg3 e night n 429
rohit type4 e night n 421
rohit dg3 c5w night n 447
rohit dg3 c5wr night n 501
rohit type1 e night n 481
rohit type1 c5w night n 500
```

```
rohit type1 c5wr night n 484
rohit type4 c5wr night n 60
nathen type4 c5w night y 292
nathen dg3 e night y 259
nathen type4 e night y 263
nathen dg3 c5w night y 315
nathen dg3 c5wr night y 279
nathen type1 e night y 276
nathen type1 c5w night y 264
nathen type1 c5wr night y 296
nathen type4 c5wr night y 363
phil type4 c5w night y 337
phil dg3 e night y 291
phil type4 e night y 287
phil dg3 c5w night y 339
phil dg3 c5wr night y 385
phil type1 e night y 321
phil type1 c5w night y 341
phil type1 c5wr night y 279
phil type4 c5wr night y 335
ashley type4 c5w night y 356
ashley dg3 e night y 297
ashley type4 e night y 291
ashley dg3 c5w night y 361
ashley dg3 c5wr night y 421
ashley type1 e night y 406
ashley type1 c5w night y 355
ashley type1 c5wr night y 363
ashley type4 c5wr night y 379
lauren type4 c5w night y 558
lauren dg3 e night y 486
lauren type4 e night y 419
lauren dg3 c5w night y 474
lauren dg3 c5wr night y 510
lauren type1 e night y 393
lauren type1 c5w night y 469
lauren type1 c5wr night y 374
lauren type4 c5wr night y 487
jordan type4 c5w night y 330
jordan dg3 e night y 250
jordan type4 e night y 240
jordan dg3 c5w night y 308
jordan dg3 c5wr night y 330
jordan type1 e night y 258
jordan type1 c5w night y 249
jordan type1 c5wr night y 242
jordan type4 c5wr night y 347
adam type4 c5w night y 465
adam dg3 e night y 436
adam type4 e night y 435
adam dg3 c5w night y 443
adam dg3 c5wr night y 470
adam type1 e night y 425
adam type1 c5w night y 453
adam type1 c5wr night y 415
adam type4 c5wr night y 407
```

```
      balaji type4 c5w night y 449
      balaji dg3 e night y 384
      balaji type4 e night y 431
      balaji dg3 c5w night y 419
      balaji dg3 c5wr night y 403
      balaji type1 e night y 352
      balaji type1 c5w night y 383
      balaji type1 c5wr night y 351
      balaji type4 c5wr night y 364
      anand type4 c5w night y 277
      anand dg3 e night y 314
      anand type4 e night y 366
      anand dg3 c5w night y 397
      anand dg3 c5wr night y 438
      anand type1 e night y 311
      anand type1 c5w night y 357
      anand type1 c5wr night y 309
      anand type4 c5wr night y 365
      aditya type4 c5w night y 275
      aditya dg3 e night y 258
      aditya type4 e night y 268
      aditya dg3 c5w night y 291
      aditya dg3 c5wr night y 264
      aditya type1 e night y 258
      aditya type1 c5w night y 249
      aditya type1 c5wr night y 210
      aditya type4 c5wr night y 281
      nivas type4 c5w night y 499
      nivas dg3 e night y 467
      nivas type4 e night y 410
      nivas dg3 c5w night y 438
      nivas dg3 c5wr night y 466
      nivas type1 e night y 382
      nivas type1 c5w night y 359
      nivas type1 c5wr night y 395
      nivas type4 c5wr night y 451
      tirhas type4 c5w night y 343
      tirhas dg3 e night y 302
      tirhas type4 e night y 268
      tirhas dg3 c5w night y 326
      tirhas dg3 c5wr night y 337
      tirhas type1 e night y 338
      tirhas type1 c5w night y 398
      tirhas type1 c5wr night y 324
      tirhas type4 c5wr night y 320
      katie type4 c5w night y 357
      katie dg3 e night y 367
      katie type4 e night y 319
      katie dg3 c5w night y 412
      katie dg3 c5wr night y 339
      katie type1 e night y 354
      katie type1 c5w night y 370
      katie type1 c5wr night y 349
      katie type4 c5wr night y 347
;
proc mixed data=gowda3 covtest;
```

```
      class person refl font prac;
      model distn = refl font prac refl*font refl*prac font*prac
refl*font*prac;
      random person(prac);
run;
proc mixed data=gowda1 covtest;
      class person refl font time;
      model distn = refl font time refl*font refl*time font*time
refl*font*time / ddfm=satterth;
      random person(time);
      lsmeans refl*font / pdiff 99adjust=tukey;
      lsmeans refl*time / pdiff adjust=tukey;
run;
proc mixed data=gowda2 covtest;
      class person refl font time;
      model distn = refl font refl*font time refl*time font*time
refl*font*time / ddfm=satterth;
      random person;
      lsmeans refl*font / pdiff adjust=tukey;
      lsmeans refl*time / pdiff adjust=tukey;
run;
quit;
```

SAS output:

```
The SAS System        11:26 Tuesday, March 30, 2010   1

                      The Mixed Procedure

                       Model Information

Data Set                     WORK.GOWDA3
Dependent Variable           distn
Covariance Structure         Variance Components
Estimation Method            REML
Residual Variance Method     Profile
Fixed Effects SE Method      Model-Based
Degrees of Freedom Method    Containment


                  Class Level Information

  Class     Levels    Values

  person        20    adam aditya anand ashley
                      balaji cathryn jason jordan
                      karl katie lauren matthew
                      nathen nivas obair phil rohit
                      sarah tirhas tommy
  refl           3    dg3 type1 type4
  font           3    c5w c5wr e
  prac           2    n y


                      Dimensions

            Covariance Parameters            2
            Columns in X                    48
```

Columns in Z	20
Subjects	1
Max Obs Per Subject	180

Number of Observations

Number of Observations Read	180
Number of Observations Used	180
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	1911.98146585	
1	1	1817.17060298	0.00000000

The Mixed Procedure

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
person(prac)	3539.44	1273.92	2.78	0.0027
Residual	2529.27	298.08	8.49	<.0001

Fit Statistics

-2 Res Log Likelihood	1817.2
AIC (smaller is better)	1821.2
AICC (smaller is better)	1821.2
BIC (smaller is better)	1823.2

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
refl	2	144	4.10	0.0186
font	2	144	3.78	0.0251
prac	1	18	1.99	0.1755
refl*font	4	144	3.41	0.0107
refl*prac	2	144	0.75	0.4763
font*prac	2	144	0.43	0.6517
refl*font*prac	4	144	0.33	0.8595

The Mixed Procedure

Model Information

Data Set	WORK.GOWDA2
Dependent Variable	distn
Covariance Structure	Variance Components

Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Satterthwaite

Class Level Information

Class	Levels	Values
person	16	ahmad andrew ben cathryn chris jason karl kyle matthew neil obair ramiro rohit sarah stacy tommy
refl	3	dg3 type1 type4
font	3	c5w c5wr e
time	2	day night

Dimensions

Covariance Parameters	2
Columns in X	48
Columns in Z	16
Subjects	1
Max Obs Per Subject	144

Number of Observations

Number of Observations Read	144
Number of Observations Used	144
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	1469.47451140	
1	1	1366.15053679	0.00000000

Convergence criteria met.

The Mixed Procedure

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
person	3462.25	1375.58	2.52	0.0059
Residual	1589.83	212.45	7.48	<.0001

Fit Statistics

-2 Res Log Likelihood	1366.2
AIC (smaller is better)	1370.2
AICC (smaller is better)	1370.2
BIC (smaller is better)	1371.7

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F

refl	2	112	4.73	0.0106
font	2	112	12.14	<.0001
refl*font	4	112	7.19	<.0001
time	1	14	2.25	0.1560
refl*time	2	112	14.56	<.0001
font*time	2	112	0.16	0.8511
refl*font*time	4	112	1.30	0.2732

Least Squares Means

Effect	refl	font	time	Estimate	Standard Error	DF	t Value	Pr > |t|
refl*font	dg3	c5w		329.94	17.7695	26.5	18.57	<.0001
refl*font	dg3	c5wr		367.13	17.7695	26.5	20.66	<.0001
refl*font	dg3	e		340.69	17.7695	26.5	19.17	<.0001
refl*font	type1	c5w		360.50	17.7695	26.5	20.29	<.0001
refl*font	type1	c5wr		353.06	17.7695	26.5	19.87	<.0001
refl*font	type1	e		356.25	17.7695	26.5	20.05	<.0001
refl*font	type4	c5w		330.75	17.7695	26.5	18.61	<.0001
refl*font	type4	c5wr		379.56	17.7695	26.5	21.36	<.0001
refl*font	type4	e		284.63	17.7695	26.5	16.02	<.0001
refl*time	dg3		day	358.96	22.3389	16.8	16.07	<.0001
refl*time	dg3		night	332.88	22.3389	16.8	14.90	<.0001
refl*time	type1		day	404.33	22.3389	16.8	18.10	<.0001
refl*time	type1		night	308.88	22.3389	16.8	13.83	<.0001
refl*time	type4		day	338.71	22.3389	16.8	15.16	<.0001
refl*time	type4		night	324.58	22.3389	16.8	14.53	<.0001

The Mixed Procedure

Differences of Least Squares Means

Effect	refl	font	time	_refl	_font	_time	Estimate	Standard Error	DF	t Value	Pr > |t|
refl*font	dg3	c5w		dg3	c5wr		-37.1875	14.0971	112	-2.64	0.0095
refl*font	dg3	c5w		dg3	e		-10.7500	14.0971	112	-0.76	0.4473

```
        refl*font  dg3    c5w          type1  c5w           -30.5625   14.0971   112    -2.17
0.0323
        refl*font  dg3    c5w          type1  c5wr          -23.1250   14.0971   112    -1.64
0.1037
        refl*font  dg3    c5w          type1  e             -26.3125   14.0971   112    -1.87
0.0646
        refl*font  dg3    c5w          type4  c5w            -0.8125   14.0971   112    -0.06
0.9541
        refl*font  dg3    c5w          type4  c5wr          -49.6250   14.0971   112    -3.52
0.0006
        refl*font  dg3    c5w          type4  e              45.3125   14.0971   112     3.21
0.0017
        refl*font  dg3    c5wr         dg3    e              26.4375   14.0971   112     1.88
0.0633
        refl*font  dg3    c5wr         type1  c5w             6.6250   14.0971   112     0.47
0.6393
        refl*font  dg3    c5wr         type1  c5wr           14.0625   14.0971   112     1.00
0.3207
        refl*font  dg3    c5wr         type1  e              10.8750   14.0971   112     0.77
0.4421
        refl*font  dg3    c5wr         type4  c5w            36.3750   14.0971   112     2.58
0.0112
        refl*font  dg3    c5wr         type4  c5wr          -12.4375   14.0971   112    -0.88
0.3795
        refl*font  dg3    c5wr         type4  e              82.5000   14.0971   112     5.85
<.0001
        refl*font  dg3    e            type1  c5w           -19.8125   14.0971   112    -1.41
0.1627
        refl*font  dg3    e            type1  c5wr          -12.3750   14.0971   112    -0.88
0.3819
        refl*font  dg3    e            type1  e             -15.5625   14.0971   112    -1.10
0.2720
        refl*font  dg3    e            type4  c5w             9.9375   14.0971   112     0.70
0.4823
        refl*font  dg3    e            type4  c5wr          -38.8750   14.0971   112    -2.76
0.0068
        refl*font  dg3    e            type4  e              56.0625   14.0971   112     3.98
0.0001
        refl*font  type1  c5w          type1  c5wr            7.4375   14.0971   112     0.53
0.5988
        refl*font  type1  c5w          type1  e               4.2500   14.0971   112     0.30
0.7636
        refl*font  type1  c5w          type4  c5w            29.7500   14.0971   112     2.11
0.0371
        refl*font  type1  c5w          type4  c5wr          -19.0625   14.0971   112    -1.35
0.1790
        refl*font  type1  c5w          type4  e              75.8750   14.0971   112     5.38
<.0001
        refl*font  type1  c5wr         type1  e              -3.1875   14.0971   112    -0.23
0.8215
        refl*font  type1  c5wr         type4  c5w            22.3125   14.0971   112     1.58
0.1163
        refl*font  type1  c5wr         type4  c5wr          -26.5000   14.0971   112    -1.88
0.0627
        refl*font  type1  c5wr         type4  e              68.4375   14.0971   112     4.85
<.0001
        refl*font  type1  e            type4  c5w            25.5000   14.0971   112     1.81
0.0732
        refl*font  type1  e            type4  c5wr          -23.3125   14.0971   112    -1.65
0.1010
        refl*font  type1  e            type4  e              71.6250   14.0971   112     5.08
<.0001
        refl*font  type4  c5w          type4  c5wr          -48.8125   14.0971   112    -3.46
0.0008
        refl*font  type4  c5w          type4  e              46.1250   14.0971   112     3.27
0.0014
        refl*font  type4  c5wr         type4  e              94.9375   14.0971   112     6.73
<.0001
        refl*time  dg3          day    dg3           night   26.0833   31.5919  16.8     0.83
0.4206
```

refl*time	dg3	day	type1	day	-45.3750	11.5102	112	-3.94	0.0001
refl*time	dg3	day	type1	night	50.0833	31.5919	16.8	1.59	0.1315
refl*time	dg3	day	type4	day	20.2500	11.5102	112	1.76	0.0813
refl*time	dg3	day	type4	night	34.3750	31.5919	16.8	1.09	0.2919
refl*time	dg3	night	type1	day	-71.4583	31.5919	16.8	-2.26	0.0372
refl*time	dg3	night	type1	night	24.0000	11.5102	112	2.09	0.0393
refl*time	dg3	night	type4	day	-5.8333	31.5919	16.8	-0.18	0.8557
refl*time	dg3	night	type4	night	8.2917	11.5102	112	0.72	0.4728
refl*time	type1	day	type1	night	95.4583	31.5919	16.8	3.02	

The Mixed Procedure

Differences of Least Squares Means

Effect	refl	font	time	_refl	_font	_time	Adjustment	Adj P
refl*font	dg3	c5w		dg3	c5wr		Tukey-Kramer	0.1831
refl*font	dg3	c5w		dg3	e		Tukey-Kramer	0.9976
refl*font	dg3	c5w		type1	c5w		Tukey-Kramer	0.4336
refl*font	dg3	c5w		type1	c5wr		Tukey-Kramer	0.7804
refl*font	dg3	c5w		type1	e		Tukey-Kramer	0.6379
refl*font	dg3	c5w		type4	c5w		Tukey-Kramer	1.0000
refl*font	dg3	c5w		type4	c5wr		Tukey-Kramer	0.0174
refl*font	dg3	c5w		type4	e		Tukey-Kramer	0.0434
refl*font	dg3	c5wr		dg3	e		Tukey-Kramer	0.6319
refl*font	dg3	c5wr		type1	c5w		Tukey-Kramer	0.9999
refl*font	dg3	c5wr		type1	c5wr		Tukey-Kramer	0.9854
refl*font	dg3	c5wr		type1	e		Tukey-Kramer	0.9974
refl*font	dg3	c5wr		type4	c5w		Tukey-Kramer	0.2068
refl*font	dg3	c5wr		type4	c5wr		Tukey-Kramer	0.9935
refl*font	dg3	c5wr		type4	e		Tukey-Kramer	<.0001
refl*font	dg3	e		type1	c5w		Tukey-Kramer	0.8935
refl*font	dg3	e		type1	c5wr		Tukey-Kramer	0.9937
refl*font	dg3	e		type1	e		Tukey-Kramer	0.9725
refl*font	dg3	e		type4	c5w		Tukey-Kramer	0.9986
refl*font	dg3	e		type4	c5wr		Tukey-Kramer	0.1402
refl*font	dg3	e		type4	e		Tukey-Kramer	0.0038
refl*font	type1	c5w		type1	c5wr		Tukey-Kramer	0.9998
refl*font	type1	c5w		type1	e		Tukey-Kramer	1.0000
refl*font	type1	c5w		type4	c5w		Tukey-Kramer	0.4717
refl*font	type1	c5w		type4	c5wr		Tukey-Kramer	0.9128
refl*font	type1	c5w		type4	e		Tukey-Kramer	<.0001
refl*font	type1	c5wr		type1	e		Tukey-Kramer	1.0000
refl*font	type1	c5wr		type4	c5w		Tukey-Kramer	0.8121
refl*font	type1	c5wr		type4	c5wr		Tukey-Kramer	0.6289
refl*font	type1	c5wr		type4	e		Tukey-Kramer	0.0001
refl*font	type1	e		type4	c5w		Tukey-Kramer	0.6763
refl*font	type1	e		type4	c5wr		Tukey-Kramer	0.7728
refl*font	type1	e		type4	e		Tukey-Kramer	<.0001
refl*font	type4	c5w		type4	c5wr		Tukey-Kramer	0.0209
refl*font	type4	c5w		type4	e		Tukey-Kramer	0.0368
refl*font	type4	c5wr		type4	e		Tukey-Kramer	<.0001
refl*time	dg3		day	dg3		night	Tukey-Kramer	0.9622
refl*time	dg3		day	type1		day	Tukey-Kramer	0.0019
refl*time	dg3		day	type1		night	Tukey-Kramer	0.6099
refl*time	dg3		day	type4		day	Tukey-Kramer	0.4961
refl*time	dg3		day	type4		night	Tukey-Kramer	0.8852
refl*time	dg3		night	type1		day	Tukey-Kramer	0.2186
refl*time	dg3		night	type1		night	Tukey-Kramer	0.3026

refl*time	dg3	night	type4	day	Tukey-Kramer	1.0000
refl*time	dg3	night	type4	night	Tukey-Kramer	0.9791
refl*time	type1	day	type1	night	Tukey-Kramer	0.0359

The Mixed Procedure

Differences of Least Squares Means

Effect	refl	font	time	_refl	_font	_time	Estimate	Standard Error	DF	t Value	Pr > |t|
refl*time	type1		day	type4		day	65.6250	11.5102	112	5.70	<.0001
refl*time	type1		day	type4		night	79.7500	31.5919	16.8	2.52	0.0219
refl*time	type1		night	type4		day	-29.8333	31.5919	16.8	-0.94	0.3584
refl*time	type1		night	type4		night	-15.7083	11.5102	112	-1.36	0.1751
refl*time	type4		day	type4		night	14.1250	31.5919	16.8	0.45	0.6605

Differences of Least Squares Means

Effect	refl	font	time	_refl	_font	_time	Adjustment	Adj P
refl*time	type1		day	type4		day	Tukey-Kramer	<.0001
refl*time	type1		day	type4		night	Tukey-Kramer	0.1259
refl*time	type1		night	type4		day	Tukey-Kramer	0.9340
refl*time	type1		night	type4		night	Tukey-Kramer	0.7478
refl*time	type4		day	type4		night	Tukey-Kramer	0.9977