Evaluation of Selected Potential MUTCD Signs

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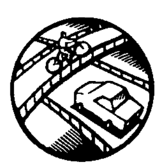

FOREWORD

The *Manual on Uniform Traffic Control Devices* (MUTCD) identifies appropriate design and application for traffic control devices on US roads. Signs proposed for inclusion in the MUTCD undergo an evaluation that includes assessing driver comprehension of the sign meaning and recognition distance. The evaluation forms an important component of the FHWA's decision-making process regarding signs' MUTCD status. This report documents the approach and findings of a study to evaluate the comprehension and recognition distance of a range of signs proposed for the MUTCD.

The study was laboratory based and included younger and older drivers in its subject pool. To assure that devices are designed to meet the needs of the ever-increasing proportion of people over 65 in the traffic stream, this population should be considered in all highway design and operational decisions. The report provides recommendations for specific signs, and identifies requirements for additional research. The information will be used by the FHWA and the National Committee on Uniform Traffic Control Devices in preparing the MUTCD 2000.

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Director, Office of Safety R&D

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16. Abstract

This report describes the findings of a study evaluating a variety of proposed signs for the *Manual on Uniform Traffic Control Devices* (MUTCD). The signs investigated included: a series of light rail signs, Lane Ends, Jogger, Cellular Phone Emergency Number, Rural Mail Delivery Route, Share the Road with Bikes, Electric Vehicle Charging Station and Scenic Byways Designation. The study included determination of comprehension and recognition distance for two versions of the signs under investigation, using 24 older (65+) and 24 young/middle-aged (21 - 45) licensed drivers. Recommendations are made for which signs should be considered for the MUTCD and for further research needed.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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INTRODUCTION

Traffic signs have long been used as a standard means of communicating regulatory, warning, and route guidance information to motorists. Sometimes, however, signs are not effective at communicating their intended messages. In particular, novel signs may appear and drivers may require considerable time to extract their meaning. Text messages have long been criticized as lacking standardization and being difficult to interpret (King, 1975). The growing dissatisfaction with text messages has resulted in an increasing frequency of symbol signs in the Manual on Uniform Traffic Control Devices (MUTCD). If the motorist is to successfully interpret their intended messages, signs must be legible and comprehensible.

BACKGROUND

The Older Driver

The graying of American society is clearly documented by demographic data. Each year the average age of Americans increases as the baby boom generation leaves middle age and heads toward older adulthood. In 1990, 12.6 percent of the U. S. population was 65 and over. This percentage is projected to increase to 21.1 percent by 2020 (Benekohal et al., 1994). Within this age group, the number of people aged 75 and over is expected to double by 2000 (Transportation Research Board, 1988). Because of the large variance in the effects of aging, chronological age is not necessarily a good indication of capabilities. It is, however, an easily measured and often used variable. For research purposes, older people are often categorized into separate groups: young-old (65 to 75), and old-old (75 and above) (Neugarten, 1975) in an attempt to account for the wide range of capabilities inherent in the older population. The older driver has been of concern to researchers for two basic reasons: mobility and safety. These issues are important as drivers age 65 and over are increasing both in number and in proportion at a faster rate than any other segment of the licensed population (Waller, 1991).

Demographic Changes

At the turn of the century, approximately 4.1 percent of the population (3 million people) was over 65. Currently, persons over 65 represent approximately 12.7 percent of the population (31 million people). Figures 1 and 2 (derived from data in Mattson, 1992) graphically represent this trend toward more older persons.

Figure 1: 1970 Population Distribution

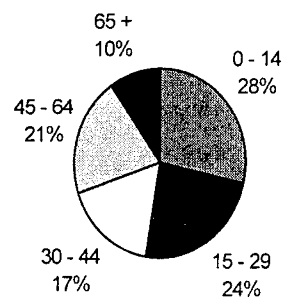
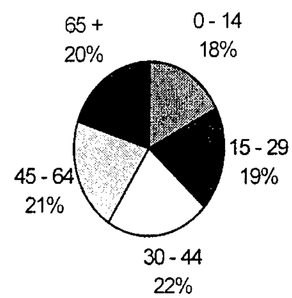


Figure 2: Projected 2020 Population Distribution



The large increase in the percentage of the population over 65 is due to two phenomena. The first is the ever-improving health care system in the United States, resulting in people living longer. The second is a cohort effect, due to the large number of children born after World War II. Commonly referred to as the baby boom generation, this cohort is largely responsible for the dramatic shifts in the population distribution.

Age-Related Changes that Affect Driving

Aging affects a wide variety of skills that are critical to safe driving. Studies have shown that older drivers have high rates of crashes, injuries, and fatalities on a per mile driven basis. Driving, however, allows older persons to maintain the same degree of travel freedom experienced by other Americans and can be a critical factor in maintaining an independent lifestyle.

In biological terms, aging is defined as the combination of changes in an organism that occur inevitably and irreversibly with the passage of time (Spence, 1989). These changes are manifested in deterioration in physical, sensory, and cognitive skills. Some changes are due strictly to aging itself, others are due to the propensity for certain diseases (arthritis, glaucoma, etc.) to strike at later ages. These losses are gradual and proceed at different rates for each person. Many people do not experience declines until very old age, and most learn to adjust to the limitations imposed by these changes.

Physical changes related to aging include reduced muscle mass and decreases in the efficiency of the circulatory, cardiac, and respiratory systems. Reductions in strength, flexibility, and range of motion caused by arthritis or other conditions can negatively impact driving. Difficulties in turning the head, resulting from reduced flexibility in the neck, for example, make merging into traffic and dealing with skewed intersections problematic for older drivers.

Sensory and perceptual changes affect all senses. Visual changes are the most critical to driving, which is considered to be a predominantly visual task, with up to 90 percent of the information required being obtained through the visual system (Dewar, 1992). As driving is a highly visual task, a number of studies (Kosnik et al., 1990; Shinar and Schieber, 1991; Klein, 1991; and Wood & Troutbeck, 1994) have attempted to identify the effects of various types of visual impairment on older driver performance. These studies have cited difficulties in visual acuity, contrast sensitivity, and visual field as adversely impacting older driver performance. Decreases in visual acuity can cause difficulty in reading signs. The current standard for sign legibility (50 feet of legibility distance for each inch of letter height (0.6 m/mm)) calculates back to a presumed visual acuity of 20/25. This is not only higher than the visual acuity standard in most states for licensing (usually 20/40) but exceeds the visual capabilities of 40 percent of drivers over 65. Reductions in contrast sensitivity start at around 40 years of age. Reduced contrast sensitivity can affect detection of pedestrians in low light situations, as well as detection of worn lane lines. Visual field changes may affect an older driver's ability to pick up a sign that is offset too far beyond their visual field.

Cognitive changes are perhaps the most varied with age. Working memory, selective attention, and processing speed are most often affected in normative aging. Deteriorating working memory functions make it difficult to process information if the density of signs is excessive. Memory issues also make phased variable message panels harder to interpret. Selective attention problems make it difficult for older drivers to pick out the most critical information when they are confronted with a wide array of signs. Processing speed affects perception-reaction time, particularly in situations where the response requires choosing between alternatives (i.e., brake or steer.)

A problem that persists in the study of age-related correlates of crashes is that of the compensatory driving strategies often employed by older drivers (Ball and Owsley, 1991). In a survey assessing the effects of aging on older driver travel characteristics, it was found that age was a factor in deciding when to drive during the day. Generally, as drivers aged, they were less likely to drive during peak hours. Additionally, they avoided whenever possible driving on icy roads, in the snow, during peak hours, at night, and in the rain (Benekohal et al., 1994). In attempts to build predictive models of accident involvement, this self-regulation has lessened the models' specificity by introducing into the equation samples whose actual behaviors are inconsistent with their predicted performance. Thus, any attempt to build successful models will have to include information regarding individual driver avoidance behaviors and habits (Ball and Owsley, 1991). Self-reports have suggested that, for the most part, drivers are aware of their own deficits, and this awareness influences driving decisions (Kosnik et al., 1990; Benekohal et al., 1994). However, the degree to which older drivers can successfully self-regulate their driving behavior remains to be seen.

Description of the Problem

Personal vehicles remain the transportation mode of choice for all Americans, including older people. As shown in figure 3, accident rates go down, on a per capita basis, with age. As shown in figure 4, however, fatality rates on a per mile driven basis, are highest for the youngest and oldest drivers.

Figure 3: Driver Involvement Rates in Fatal Crashes by Age and Sex (USDOT/NHTSA, 1997)

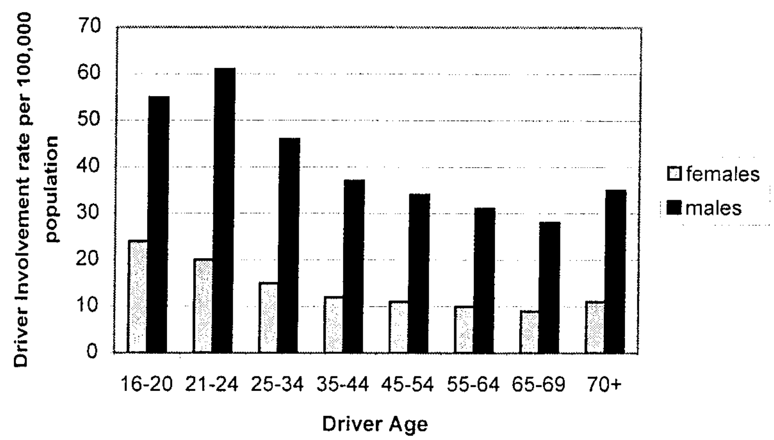
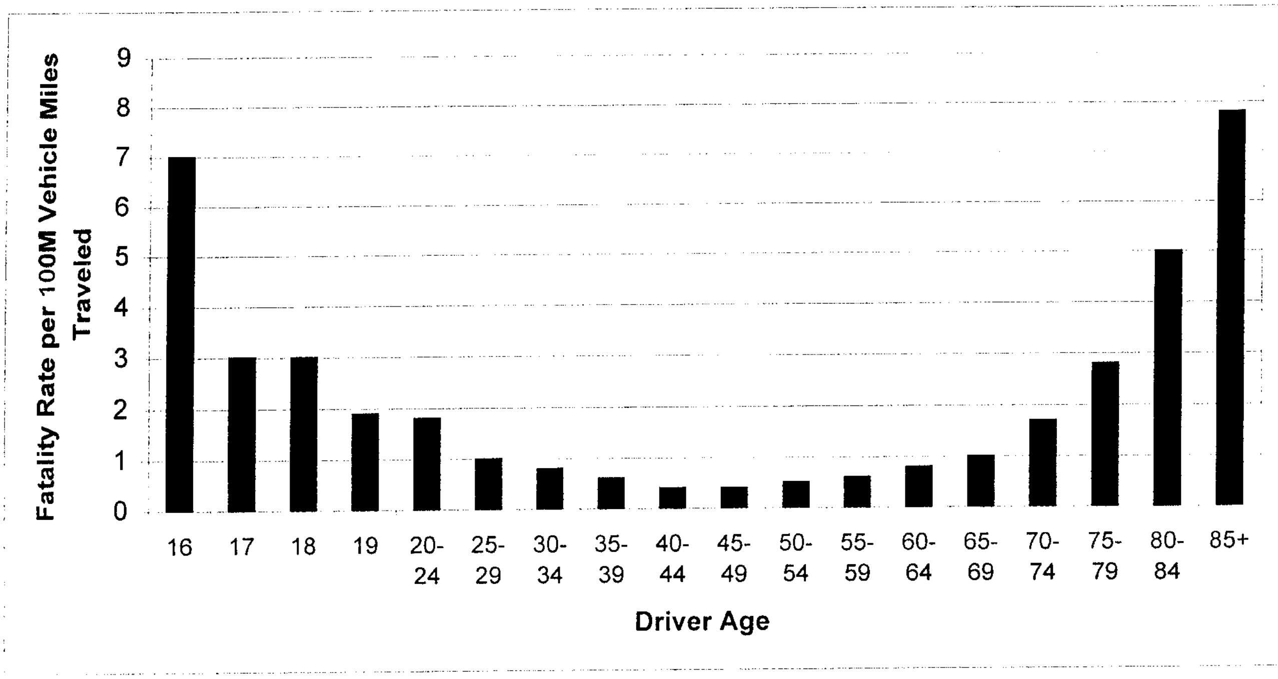


Figure 4: Driver Fatality Rates per 100 Million Vehicle Miles Traveled, by Age (USDOT/NHTSA, 1997)



In fact, adjusted for mileage, drivers over 85 have nine times the fatality rate of drivers 25 to 69 (USDOT/NHTSA, 1997). Although people limit their actual miles driven as they age, and even though those miles are often logged at the safest times, during the day and during non-rush-hour traffic (Planek and Overend, 1973) their rate of crashes per mile is extremely high. Older drivers have more traffic convictions and crashes per mile driven than any other age group and are more likely to be cited as being at fault (Benekohal et al., 1994). Because of the disproportionately large percentage of crashes attributed to older drivers, it has become essential that the correlates associated with those crashes be identified.

McKelvey, Maleck, Stamatiadis, and Hardy (1988) examined the relationship between age and highway crashes and found that drivers over age 50 were more likely to be involved in crashes than they were in earlier years. In addition, these crashes were likely to occur at intersections, suggesting diminished physical or mental capability as a causative factor. Stelmach and Nahom (1992) also cited diminished physical and mental capability, particularly cognitive-motor ability, as a contributor to the decline in the driving skills of older motorists.

Traffic Control Devices

According to the Manual on Uniform Traffic Control Devices (USDOT/FHWA, 1988), traffic control devices, including signs, help insure highway safety by providing orderly and predictable movement of traffic and insuring safe and informed operation of individual elements in the traffic stream. To be effective, traffic control devices should meet five basic requirements:

1. Fulfill a need.
2. Command attention.
3. Convey a clear, simple message.
4. Command respect of road users.
5. Give adequate time for proper response.

Items three and five are strongly related to sign comprehension and recognition distance. Traffic control devices fall into three categories: signs, markings, and signals. Although all traffic control devices are important, this review focuses on sign related issues only.

Traffic Sign Comprehension

According to Dewar and Ellis (1974), a number of criteria should be included in evaluating a traffic sign. In order of importance, these factors are: understandability, recognition time, conspicuity, legibility distance, glance legibility, and learnability. Traffic sign comprehension speaks to the first (understandability) and most critical of these factors. If the message on a sign cannot be understood by the users, clearly it will not be effective, even if it performs well on the other factors. A number of factors (e.g., conspicuity, glance legibility, recognition distance) have been investigated as possible determinants of traffic sign comprehension.

Sign comprehension studies have investigated a wide variety of topics. Much of the research includes direct comparisons between symbol and text signs (King, 1975; King & Tierney, 1970; Ellis & Dewar, 1979) to determine whether they performed differentially at conveying their intended messages. King (1975) pointed out that text signs had been frequently criticized as being ambiguous, lacking in standardization, and requiring considerable time to interpret. Given the importance of developing traffic signs that are clear, consistently -expressed, and easy to interpret, King and Tierney (1970) compared the glance legibility of symbol and text highway signs and found symbol signs to be generally superior to text signs in transmitting their message. King (1975) attempted to extend his previous findings (King & Tierney, 1970) by making the testing conditions more compatible with the true driving experience. He found that, even for brief exposure durations, symbol signs were superior to text signs at conveying their intended message.

Although the above studies provide evidence for the general superiority of symbols over text, some authors (Ellis & Dewar, 1979; Paniati, 1988) have suggested that their relative superiority should be determined for each sign under the expected environmental conditions in which they shall be perceived (i.e., daylight, darkness, glare, fog). Additionally, it has been suggested that for simple messages, the text may be processed more rapidly than the symbol version of the same message (Ellis & Dewar, 1979).

Kline and Beitel (1994) suggest that mixed-modality icons (information presented to more than one sense simultaneously) may have an advantage over single-modality icons in that they capitalize on the best aspects of both symbol-only and text-only messages. Guastello, Traut, and Korienek (1989) found mixed-modality icons to be significantly better than single-modality icons at conveying meaning. Similarly, Egido and Patterson (1988) found mixed-modality icons to be useful in making search and navigation tasks easier as subjects navigated through highly structured pictorial databases. Finally, Gittins (1986), in his attempt to recommend a systematic treatment of icon interfaces, noted that in icon interfaces, icons were often reinforced with text labels to facilitate learning as the user moved from one command-based system to the next. This research from the human computer interface world leads to the possibility of combining text and symbols in the same sign as a potential method of optimizing comprehension.

Consideration of redundancy issues may be a concern when a selected sign design is not intrinsically meaningful or its interpretation is open to considerable ambiguity. A specific example would be symbol signs that attempt to distinguish between vehicles that are "sharing the road" or "in the road" versus those that are simply "crossing the road" (Fox & Philips, 1995). Additionally, Collins and Lerner (1982), have stressed that confusion surrounding the symbol versions of some proposed building egress warning signs (i.e., "exit," "fire alarm call point," "not an exit," etc.) can lead to potentially hazardous consequences. Although these building signs are not directly related to traffic signs, information on human information processing crosses the domains.

Traffic Sign Recognition Distance

Recognition distance addresses the importance of a sign providing adequate time for a proper response. In particular, a sign that has adequate comprehension is of minimal value if drivers must be so close to the sign before making out the features that they do not have time to make the proper decision and response. Recognition distance, therefore, is a critical measure of sign effectiveness. When only text signs are being evaluated, the phrase "legibility distance" is often used for this concept.

Recognition distance is more difficult to evaluate than comprehension. In its most basic form, measuring comprehension requires representations of the signs being evaluated and a place to record subject responses. Recognition distance requires additional setups, including some technique for having subjects respond to when they can make out features of a sign on the basis of their distance from the sign.

Methods of evaluating recognition distance vary from real-time simulation (Allen et al., 1980) to road test with real signs (Dewar & Ellis, 1974) to test track situations (Garvey & Pietrucha, 1996) to dynamic laboratory evaluations (Paniati, 1988). Some researchers have used mixed methods including both simulator and field (Greene, et al., 1995) or multiple dynamic/semi-dynamic laboratory settings (Mahach, et al., 1999). All of these methods have advantages and disadvantages. Real-time simulation and road tests tap into dynamic visual acuity and include the other activities that drivers must perform while operating a motor vehicle, but are expensive and labor intensive and require very specific equipment. Test track evaluations can use full-size versions of signs, but also require access to specialized equipment. Laboratory evaluations are less expensive to set up and although some amount of specialized equipment is needed, significantly less is required than in the other techniques. Laboratory evaluations do not use full-size signs, but substituting visual angle and "apparent" distance allows the test to be generalized to the real world. Since a sign evaluation often compares two versions of the same sign, any of the inherent limitations in this approach are normally overcome by experimental design decisions.

Sign Optimization for Older Drivers

Improving text signs to accommodate the decreased visual capabilities of older drivers can be done relatively simply – by increasing the letter height. Khavanin & Schwab (1991) found, not surprisingly, that legibility distance increases with letter size. Other methods of improving legibility distance include modifications to the stroke width of the fonts used (Garvey & Pietrucha, 1996). Methods of improving symbols signs, however, are not as straightforward.

Although visual acuity tends to decline with age, many of these changes are identified by licensing agencies and can be corrected with lenses. Age-related contrast sensitivity changes, however, are less likely to be identified and no corrections are available. Given that the loss in contrast sensitivity is more pronounced in the higher frequency domain, it is logical to attempt to improve sign visibility distance through removal of high frequency elements.

Kline and Fuchs (1993) used a method that consisted of "filtering" high spatial frequency information from symbols using a sphere lens, and showed that such improved symbols had longer recognition distances than the standard symbols. A computerized method of filtering high spatial frequency information was later developed (Dewar, et al., 1997) and found to have similar promising results, with particular improvements in visibility distance of optimized symbols under less than optimal viewing conditions (nighttime legibility). The computerized version used 2D-Fourier analysis to filter out the high spatial frequencies. In both studies, the stimuli presentation for measurement of visibility distance was based on computer displays with progressively larger images (based on visual angle) representing varying real-world visibility distance.

METHOD

Subjects

Forty-eight subjects were drawn from the subject pool maintained by the Human Factors Laboratory at the Federal Highway Administration's Turner-Fairbank Highway Research Center in McLean, VA. Subjects were distributed equally between two age groups: young/middle aged (21-45) and older (65+), with an equal number of male and female subjects within each group. The average age of the young/middle-aged subjects was 32 years (range 25 to 45). The average age of the older subjects was 70 years (range 65 to 81). Subjects were required to possess a valid driver's license and pass a far visual acuity examination (20/40 minimum corrected far acuity -- the licensing requirement in this geographic area). Average far visual acuity for the young/middle aged subjects was 20/16, with a range from 20/13 to 20/40. Average far visual acuity for older subjects was 20/26, with a range from 20/13 to 20/40. Two subjects who agreed to participate in the study did not pass the far visual acuity screening and were paid $5.00. Subjects who participated in the full study were paid $ 35.00 for their participation.

Stimuli

Twelve experimental signs and 11 "distractor" standard signs were included in the evaluation. The Federal Highway Administration (FHWA) is currently reformatting and rewriting the MUTCD, and information on the utility of the 12 test signs is required for this activity. The distractor signs were chosen because they related, visually, to the test signs.

Test Signs

Twelve test signs were included in this evaluation. The signs are listed in Table 1 and are discussed in turn below. Figures depicting the two versions of each sign to be tested are included in Figures 5 to 16.

Table 1: Test Signs Included in the Evaluation

Sign	Sign Type	Figure Number
Light Rail: Lane Control	Regulatory	5
Light Rail: Do Not Pass	Regulatory	6
Light Rail: Do Not Drive on Tracks	Regulatory	7
Light Rail: Look Both Ways at Crossing	Warning	8
Lane Ends	Warning	9
Jogger	Warning	10
Cellular Phone Emergency Number	Information	11
Rural Mail Delivery Route	Warning	12
Share the Road with Bikes	Warning	13
Beach	Recreation	14
Electric Vehicle Charging Station	Information	15
Scenic Byways Designation	Guide	16

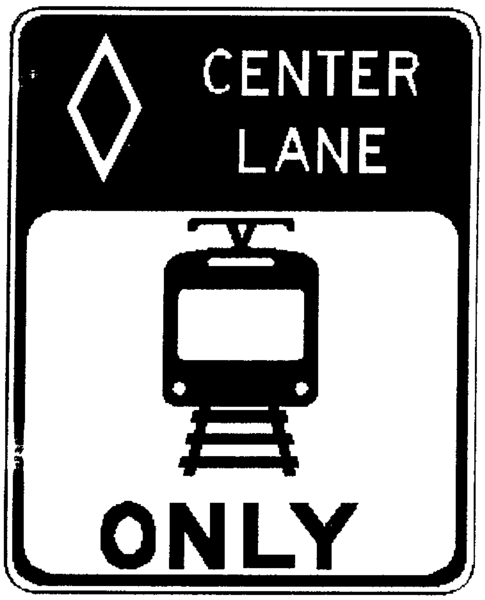
Light Rail Signing Series

The first four signs are all related to light rail issues. The National Committee on Uniform Traffic Control Devices submitted a new Part 10 to the MUTCD that would cover Traffic Control for Highway-Light Rail Crossings and is in the *Federal Register*. Light rail vehicles have particular characteristics that require a special series of signs. They are much quieter than traditional trains, making it easier for drivers to miss their presence. Furthermore, light rail vehicles operate in many different types of mixed-traffic environments and occasionally yield to cars. This series of signs would provide road users with warning and regulatory information in the presence of light rail vehicles.

For the three regulatory signs that were evaluated (Lane Control, Do Not Pass, and Do Not Drive on Tracks) the proposed signs were compared with versions optimized using the 2-D Fourier analysis method described previously. For the warning sign that was evaluated (Look Both Ways) a version with an educational plaque was compared with a version without the plaque.

Figure 5: Light Rail: Lane Control (black on white signs)

Proposed



Optimized

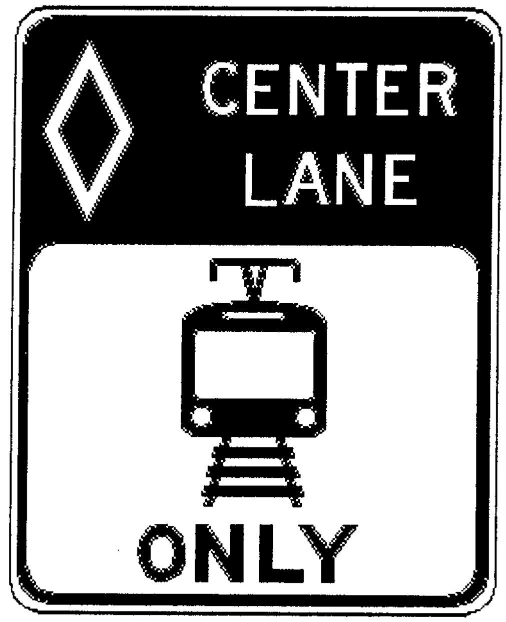


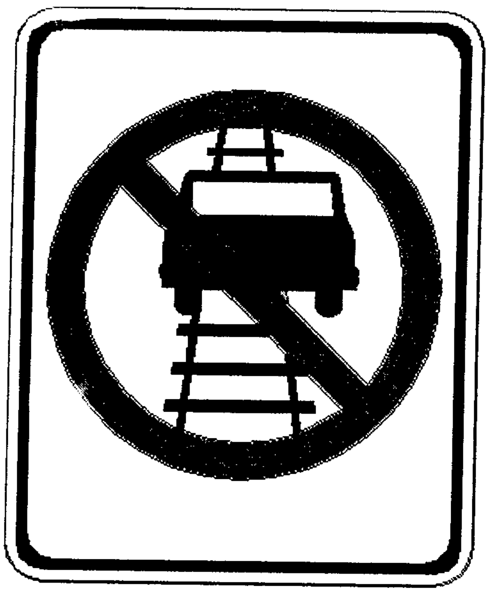
Figure 6: Light Rail: Do Not Pass (black on white signs)

Proposed

Optimized

Figure 7: Light Rail: Do Not Drive on Tracks (black on white signs)

Proposed (red circle and slash)



Optimized

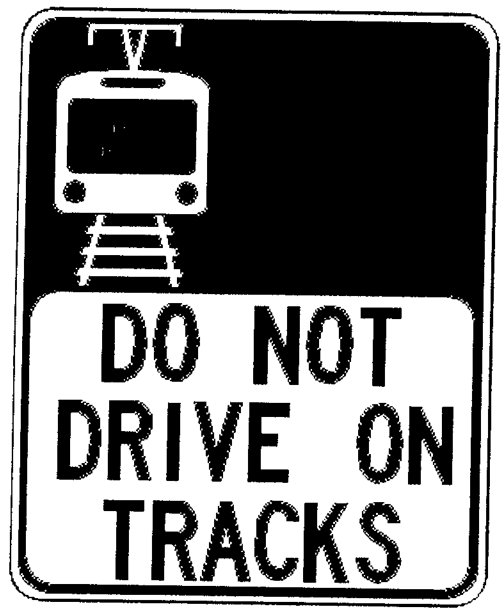
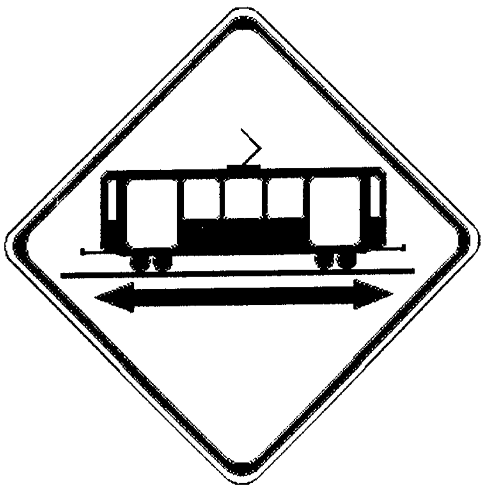
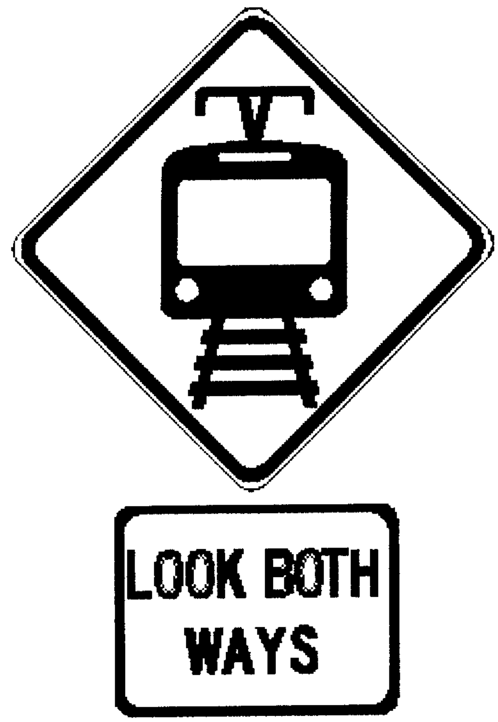


Figure 8: Light Rail: Look Both Ways at Crossing (black on yellow signs)

Proposed



Front View



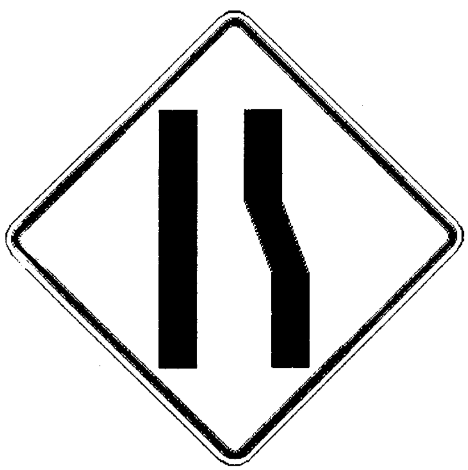
Lane Ends

Many evaluations of Lane Ends symbol signs have been performed over the years but few have been found to be very successful. Although it is possible that this concept is just too difficult to represent with a symbol, other more complex concepts are adequately conveyed symbolically.

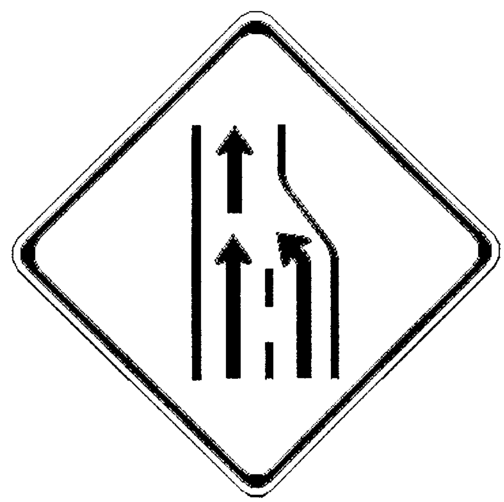
The signs tested in this evaluation included the current standard symbol sign (W4-2) and a modified version that might provide more positive information to drivers by including lane markings and directional arrows.

Figure 9: Lane Ends (black on yellow signs)

Standard



Proposed



Jogger

An evaluation of this sign to warn drivers of the presence of joggers along a route was requested by a local jurisdiction in New York State. Its application is intended for roadway sections that are regularly used by joggers.

A "jogger" figure was compared with a standard pedestrian figure, both with a plaque reading "JOGGER ROUTE" to see if a new symbol is needed, or if the current pedestrian symbol will serve adequately for this purpose.

Figure 10: Jogger (black on yellow signs)

Jogger

Pedestrian

Cellular Phone Emergency Number

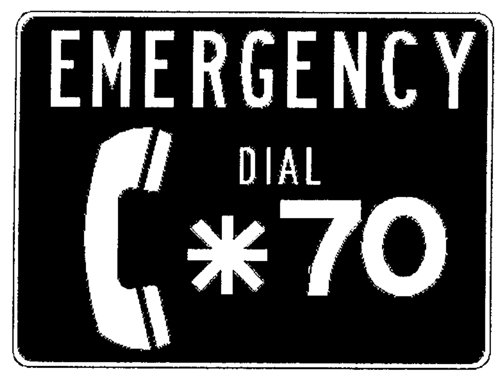
Incident management programs on many highways include a detection component that relies on information phoned in by drivers. With the advent of cellular phones, a sign is needed to inform motorists how to make these types of emergency contacts. Although many jurisdictions are using some version of the standard phone symbol (D9-1) for this means, the Massachusetts Highway Department has requested evaluation of a sign specifically for this purpose.

This evaluation compared a version of the sign with the word "cell" and an antenna with the standard emergency phone sign.

Figure 11: Cellular Phone Emergency Number (white on blue signs)

Cell/Antenna

No "Cell"/Antenna



Rural Mail Delivery Route

Rural mail delivery personnel drive slowly and make frequent stops. A sign could help alert drivers to this potentially hazardous situation. An evaluation of a sign warning motorists of the presence of rural mail delivery personnel was requested by a Postal worker team in Ohio.

This evaluation compared the sign developed by the Post Office working group with an optimized version of the sign.

Figure 12: Rural Mail Delivery Route (black on yellow signs)

Proposed

Optimized

Share the Road with Bikes

A previous evaluation (Fox & Philips, 1995) showed that a rear view of a bicyclist and a vehicle was appropriate for conveying the concept of bicyclists and cars "sharing the road." The symbol, however, had very poor recognition distance.

This evaluation compared the original symbol with an optimization of a symbol proposed by the Las Vegas Regional Transportation Commission to see if recognition distance can be improved without adversely impacting comprehension rate.

Figure 13: Share the Road with Bikes (black on yellow signs)

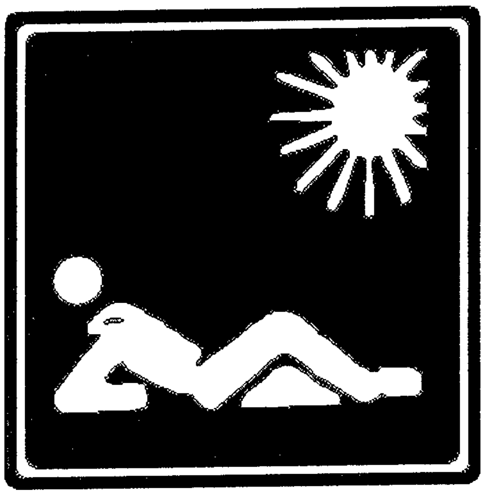
Proposed

Optimized

Beach

The Beach sign is intended as a Recreational and Cultural Interest Area sign. This series of signs is used to guide tourists and visitors to places of interest. There is no existing version of this sign, and only the proposed version was evaluated (for comprehension only).

Figure 14: Beach (white on brown sign)



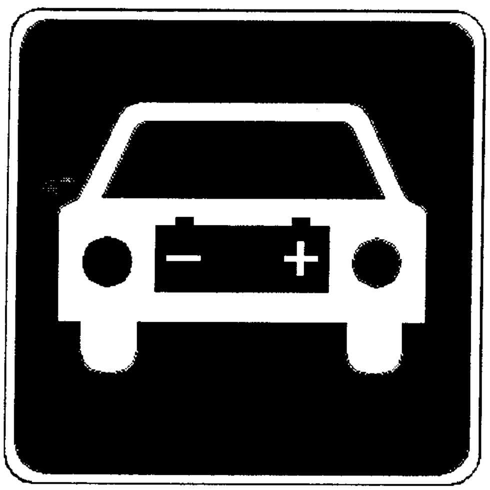
Electric Vehicle Charging Station

Commercial launch of electric vehicles is beginning in selected markets, and use of these vehicles is expected to increase over time. A highway sign to indicate the location of charging stations for such vehicles is needed as an addition to the current D9-11 series of "fueling" symbols addressed in the MUTCD.

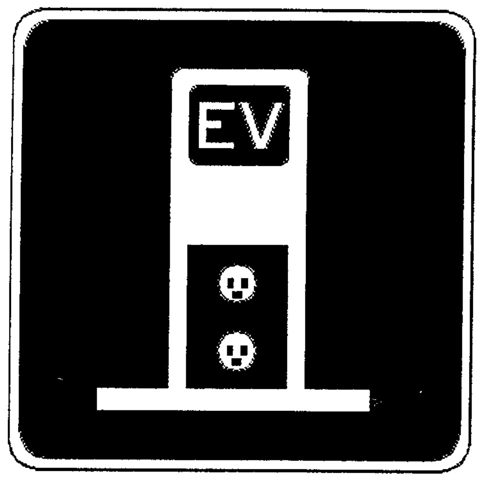
This evaluation included two symbols. The first symbol is the one designed by the Electric Vehicle Association of the Americas. The second symbol was designed at the FHWA and is a modified version of the standard D9-1 fuel pump symbol.

Figure 15: Electric Vehicle Charging Station (white on blue signs)

Car



Pump



Scenic Byways

The Scenic Byways sign is intended as an identifier and trailblazer for those roads designated as scenic byways or All-American Highways.

This evaluation compared the proposed symbol with an optimized version.

Figure 16: Scenic Byways Designation (blue, white, green, yellow, and black signs)

Proposed

Optimized

Distractor Signs

Eleven other signs were included in the study. These signs were selected to insure that subjects fully recognized the test signs before providing a recognition distance response. The distractor signs have some design characteristics that make them similar to the target signs. There is one distractor sign for each of the test signs, except for the Beach sign, which only has one version and was not evaluated for recognition distance.

Table 2 lists the signs (and MUTCD numbers) used as distractors in the study as well as a brief description of why the sign was included. Figures depicting these signs are included in Figures 17 to 27.

Table 2: Distractor Signs Included in the Evaluation

		MUTCD Number	**Size**	**Reason for Inclusion**
1	Train Station	I-7	24 X 24	similar to light rail
2	Bus Stop	R7-107a	30 X 12	similar to light rail
3	Truck Crossing	W11-10	30 X 30	similar to light rail
4	Advance Railroad Tracks	W10-4	30 X 30	similar to light rail
5	Added Lane	W4-3	30 X 30	similar to lane ends
6	Advance Pedestrian Crossing	W11-2	30 X 30	similar to Jogger
7	Phone	D9-1	24 X 24	similar to cell phone
8	Slippery When Wet	W8-5	30 X 30	similar to rural mail delivery
9	Bike Crossing	W11-1	30 X 30	similar to bike route
10	Fuel	D9-11	24 X 24	similar to EV charging
11	Evacuation Route	CD-1	18 diam	similar to scenic byways

Figure 17: Distractor: Train Station (I-7) (white on green sign)

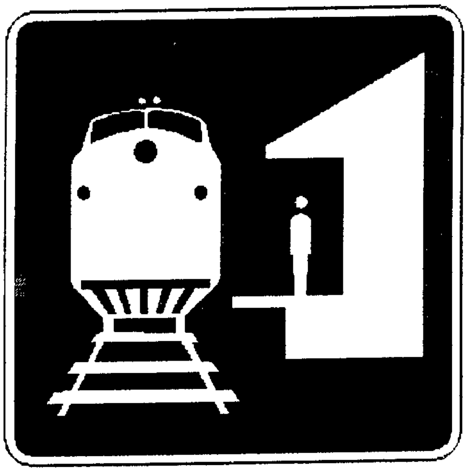


Figure 18: Distractor: Bus Stop (R7-107a) (black on white sign with red circle and slash)

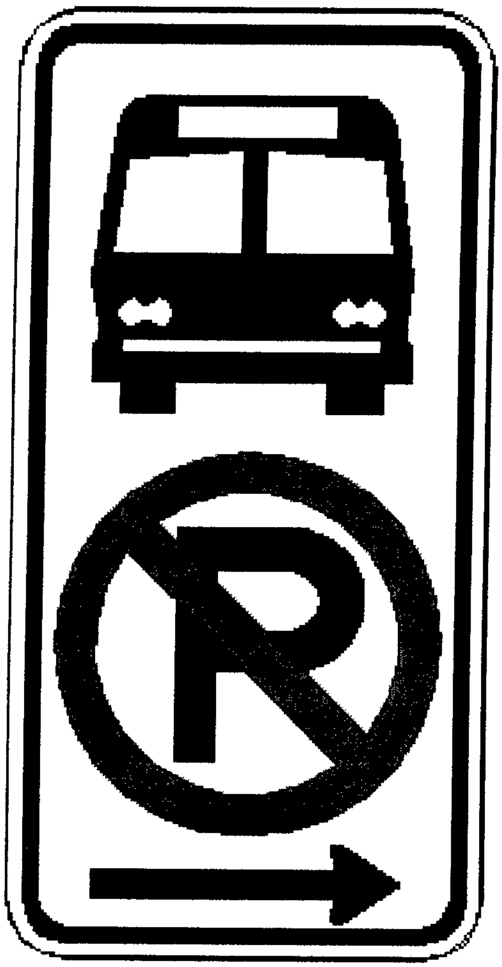


Figure 19: Distractor: Truck Crossing (W11-10) (black on yellow sign)

Figure 20: Distractor: Advance Railroad Tracks (W10-4) (black on yellow sign)

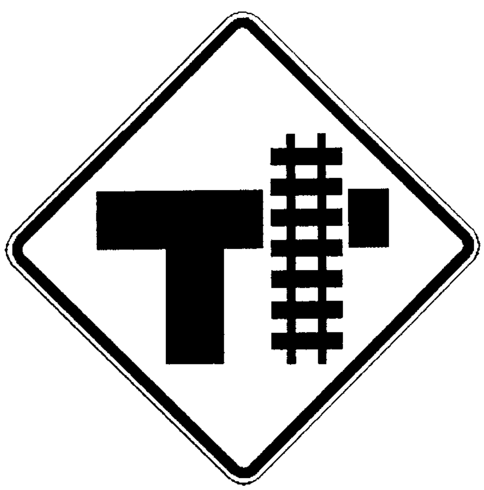


Figure 21: Distractor: Added Lane (W4-3) (black on yellow sign)

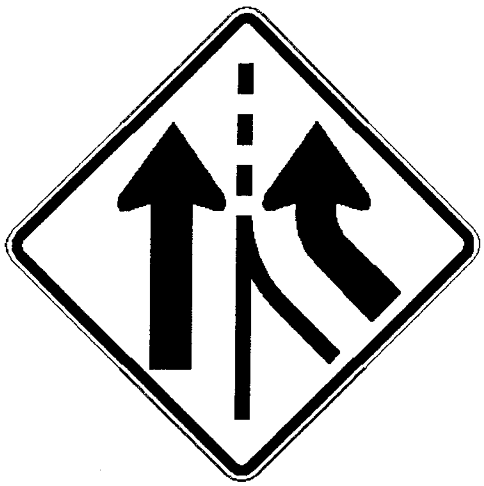


Figure 22: Distractor: Advance Pedestrian Crossing (W11-2) (black on yellow sign)

Figure 23: Distractor: Phone (D9-1) (white on blue sign)

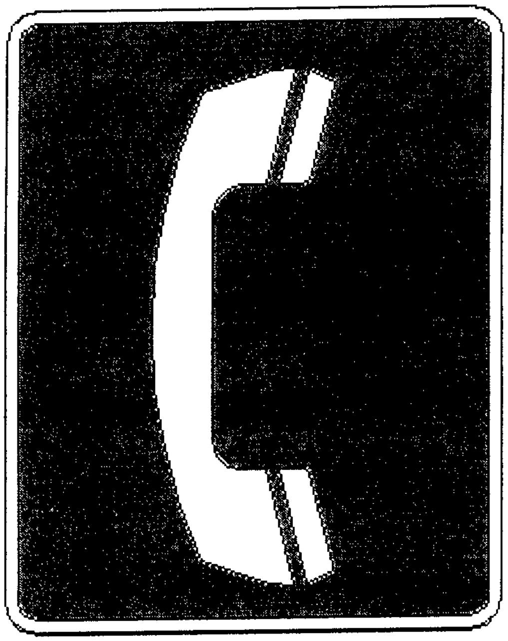


Figure 24: Distractor: Slippery When Wet (W8-5) (black on yellow sign)

Figure 25: Distractor: Bike Crossing (W11-1) (black on yellow sign)

Figure 26: Distractor: Fuel (D9-11) (white on blue sign)

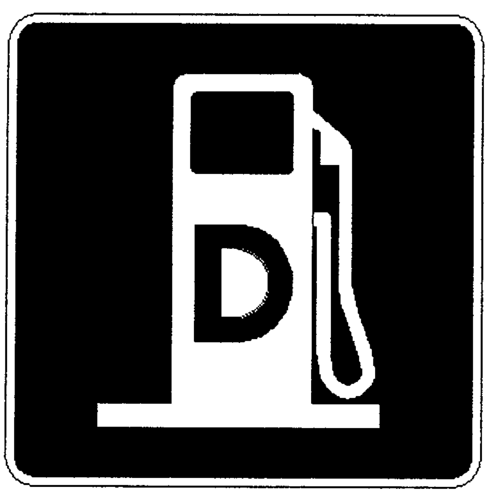


Figure 27: Distractor: Evacuation Route (CD-1) (white on blue sign)

Sign Optimization

The FHWA "Design-by-Blur Graphic Optimization Software" was used to redesign some of the signs in an attempt to improve their recognition distance. This package uses the "recursive blur" technique to shift critical symbol information from high spatial frequencies to low spatial frequencies. In this multi-step process, the designer constructs a symbol and then uses the software to "blur" the image. The effect of the blurring on the recognition of critical elements is evaluated, and those elements that are not clear under the blurred condition are redesigned. The redesigned symbol is subjected to the blurring process again and redesigned, if necessary, until all critical elements of the symbol are visible under blurred conditions.

In the blurring process, 2D Fourier computer analysis techniques generate an exact mathematical description of the image. These weighted functions are based on spatial frequency of the symbol. These functions are subjected to filtering that removes the high frequency elements of the symbol, and then the image is regenerated. In the resulting image, the high frequency elements appear blurred and are those that the designer attempts to remove in the iterative sign design passes.

Materials/Laboratory Setup

Comprehension

Color 8.5 by 11-inch (216 by 279 mm) prints of the signs were used in the comprehension portion of the evaluation. Subjects were seated at a desk in a quiet laboratory.

Recognition Distance

Scaled down versions of the signs were used in the recognition distance portion of the evaluation. The actual size of the signs ranged from 3.5 by 3.5 inches (89 by 89 mm) to 6.5 by 5 inches (165 by 127 mm). The signs were prepared in Autocad, cut from engineering grade sheeting using an Advanced Digital Cutting Systems Sign Cutter, and affixed to metal plates of the appropriate size and shape.

The FHWA Photometric and Visibility Laboratory was used for data collection for the recognition distance portion of the evaluation. The main portion of the laboratory is approximately 13 feet (4 m) wide and 120 feet (37 m) long. Walls, floors, and ceilings are painted flat black to minimize reflections. Overhead daylight fluorescent fixtures provide varying levels of illumination.

The scaled down signs were placed at one end of the laboratory, at 110 feet (33 m) from the subject's starting point. This combination of starting distance and sign scaling provides a maximum recognition distance that simulates 770 feet (235 m) in the real world. The lights were kept on in the laboratory, and the scaled down signs received additional spot illumination from a Xenon lamp to provide a luminance of 370 cd/m^2, approximating the amount of light on an overcast day. The signs were mounted on a flat black surface, 5 feet (1.5 m) above the floor, using Velcro tabs.

Every 5 feet (1.5 m), a piece of numbered blue electrical tape was place on the floor of the laboratory as a marker for the stations at which the subject was to stop. The experimenter stayed at the "sign" end of the laboratory, and the subject made a slow walking approach toward the sign, stopping at each station. After each trial, the subject returned to the starting point, and the experimenter mounted the next sign and the process was repeated.

Procedure

Overview

Comprehension

Subjects were given one version of each of the signs. They were then asked to write their interpretation of the signs' meanings and what actions they would take if they saw the signs along the roadway. Both of these measures (meaning and action) were used to evaluate comprehension of the signs.

Recognition Distance

Scaled down versions of each of the signs were made of actual sheeting materials. Subjects made a walking approach toward these scaled down signs in a long visual tunnel. The subject stopped at numbered stations along the way until he/she could identify the sign. If the identification was accurate, the distance was recorded, and the next trial began. If the identification was not accurate, the trial resumed. This process was repeated for each sign.

Intake Procedures

Upon arrival at FHWA's Turner-Fairbank Highway Research Center, the experimenter greeted the subject. The subject then read and signed an informed consent form (see Appendix A) that included minimal demographic information (date of birth, age, and gender). The experimenter then administered a visual acuity test (using a Titmus 2000) to ensure that the subjects met the minimum visual acuity requirements (20/40 minimum corrected far acuity).

Comprehension Procedure

Each subject was provided with a color, 8.5 by 11-inch (216 by 279 mm) copy of one version of each of the 12 test signs as well as the 11 distractor signs. Each subject saw a different randomized order of signs. The randomization was performed with the following rules:

1. None of the light rail signs could immediately follow each other;
2. None of the distractor signs could immediately follow its affiliated test sign, or vice versa; and

3. None of the light rail distractor signs could immediately follow another light rail sign, or vice versa.

Signs were individually presented to subjects in a three-ring binder. In the binder, a response sheet immediately followed each sign. Verbatim instructions that were read to each subject for all test procedures are included in Appendix B. Subjects noted the code for the sign at the top of the response sheet, wrote down their interpretation of the sign's meaning and what action they would take if they saw the sign along the roadway, and then went on to the next sign in the book. After the subject had completed this procedure for all 23 signs, the experimenter reviewed the signs and the subject's responses with the subject, and told the subject the intended meaning and action for each sign. Criteria for correct comprehension responses are included in Appendix C.

Recognition Distance Procedures

In the recognition distance procedure, each subject saw the signs in the reverse of the randomized order he/she had seen in the comprehension portion. These trials included 11 test signs (the Beach sign was not included), as well as the 11 distractor signs. The version of the target sign that the subject was exposed to in this portion of the study was the same version he/she was exposed to in the comprehension portion.

Each subject started at the far end of the visual tunnel. The subject walked slowly toward the sign until he/she could accurately identify the sign at the end. Subjects stopped every 5 feet (1.5 m) (equal to 35 feet (11 m) of recognition distance in the real world) to determine if they could accurately identify the sign. If the description was accurate, the "station" (tape mark) was recorded, the subject returned to the starting point, the experimenter mounted the next sign, and the next trial was started. A priori descriptions of elements that were required for an accurate response are included in Appendix D. If the description was insufficient, the trial resumed from the point of interruption. This process continued until the subject accurately identified the sign or reached the end of the laboratory.

Experimental Design

The study used a 2 (Age) x 2 (Versions of Sign) experimental design for each sign. Both Age and Version of Sign were between-group factors. Each subject only saw one of the two versions of the signs under investigation.

Hypotheses

The research hypotheses were:

1. Optimized signs would generally yield recognition distances superior to their non-optimized counterparts.
2. Younger/middle aged subjects would outperform older subjects on the recognition distance measure.

RESULTS

Data Reduction

Comprehension data were reduced into three categories: correct, partially correct, and incorrect for both meaning and action. The specific criteria used for this data reduction for each sign are listed in Appendix C.

Recognition data were multiplied by 35 (5 feet per station times a seven times scaling factor) to get a real-world recognition distance. This is the data set that was analyzed.

Comprehension Data Results

After coding, comprehension data were subjected to a two-sided, Pearson Chi-Square analysis to determine if there were significant differences between the two versions of the signs in terms of meaning or action. Results of the Chi-Square test are reported only if the difference reached significance.

Light Rail: Lane Control

There were no significant differences between the proposed and optimized version of this sign for either meaning or action comprehension. As seen in Tables 3 and 4, both signs had over 50 percent correct comprehension for both meaning and action.

Table 3: Percentage Distribution of Meaning Comprehension for Light Rail: Lane Control

	Proposed	Optimized
Correct	62	54
Partially Correct	4	4
Incorrect	33	42

Table 4: Percentage Distribution of Action Comprehension for Light Rail: Lane Control

	Proposed	Optimized
Correct	67	66
Partially Correct	0	4
Incorrect	33	29

Light Rail: Do Not Pass

There were no significant differences between the proposed and optimized versions of this sign for either meaning or action comprehension. As seen in Tables 5 and 6, both signs had rather low meaning comprehension, but action comprehension of over 50 percent correct.

Table 5: Percentage Distribution of Meaning Comprehension for Light Rail Do Not Pass

	Proposed	Optimized
Correct	37	42
Partially Correct	8	4
Incorrect	54	54

Table 6: Percentage distribution for action comprehension for Light Rail Do Not Pass

	Proposed	Optimized
Correct	54	79
Incorrect	46	21

Light Rail: Do Not Drive on Tracks

There were no significant differences between the proposed and optimized versions of this sign for either meaning or action comprehension. As seen in Tables 7 and 8, both signs had correct comprehension responses of at least 50 percent for each measure.

Table 7: Percentage Distribution of Meaning Comprehension for Light Rail Do Not Drive On Tracks

	Proposed	Optimized
Correct	50	54
Incorrect	50	46

Table 8: Percentage Distribution of Action Comprehension for Light Rail Do Not Drive On Tracks

	Proposed	Optimized
Correct	50	62
Incorrect	50	37

Light Rail: Look Both Ways at Crossing

There were no significant differences between the proposed and front view versions of this sign for either meaning or action comprehension. As seen in Tables 9 and 10, both signs had very high percentages of correct responses for both meaning and action comprehension.

Table 9: Percentage Distribution of Meaning Comprehension for Light Rail Look Both Ways

	Proposed	Front View
Correct	71	67
Partially Correct	8	4
Incorrect	12	29

Table 10: Percentage Distribution of Action Comprehension for Light Rail Look Both Ways

	Proposed	Front View
Correct	79	79
Incorrect	21	21

Lane Ends

The Chi-Square test indicated a significant difference in both the meaning and action comprehension rates for the standard and proposed versions of this sign. As seen in Tables 11 and 12, the proposed version of the sign has better comprehension for both meaning ($X^2 = 21.4$, $p = 0.0000$) and action ($X^2 = 5.40$, $p = 0.020$).

Table 11: Percentage Distribution of Meaning Comprehension for Lane Ends

	Standard	Proposed
Correct	17	83
Partially Correct	50	8
Incorrect	33	8

Table 12: Percentage Distribution of Action Comprehension for Lane Ends

	Standard	Proposed
Correct	71	96
Incorrect	29	4

Jogger

There were no significant differences between the jogger and pedestrian versions of this sign for either meaning or action comprehension. As seen in Tables 13 and 14, both signs had very high percentages of correct responses for both meaning and action comprehension.

Table 13: Percentage Distribution of Meaning Comprehension for Jogger

	Jogger	Pedestrian
Correct	92	75
Incorrect	8	25

Table 14: Percentage Distribution of Action Comprehension for Jogger

	Jogger	Pedestrian
Correct	92	87
Partially Correct	0	8
Incorrect	8	4

Cellular Phone Emergency Number

The Chi-Square test indicated a significant difference in both the meaning and action comprehension rates for the two versions of this sign. As seen in Tables 15 and 16, the sign with the additional text indicating "cell" and an antenna had better comprehension for both meaning ($X^2 = 6.454$, $p = 0.011$) and action ($X^2 = 9.375$, $p = 0.002$).

Table 15: Percentage Distribution of Meaning Comprehension for Cell Phone Emergency Number

	"Cell/antenna	No "cell"/antenna
Correct	87	54
Incorrect	12	46

Table 16: Percentage Distribution of Action Comprehension for Cell Phone Emergency Number

	"Cell/antenna	No "cell"/antenna
Correct	87	46
Incorrect	12	54

Rural Mail Delivery Route

There were no significant differences between the proposed and optimized versions of this sign for either meaning or action comprehension. As seen in Tables 17 and 18, both signs had very high percentages of correct responses for both meaning and action comprehension.

Table 17: Percentage Distribution of Meaning Comprehension for Rural Mail Delivery Route

	Proposed	Optimized
Correct	92	87
Partially Correct	4	4
Incorrect	4	8

Table 18: Percentage Distribution of Action Comprehension for Rural Mail Delivery Route

	Proposed	Optimized
Correct	92	83
Partially Correct	4	0
Incorrect	4	17

Share the Road with Bikes

There were no significant differences between the proposed and optimized versions of this sign for either meaning or action comprehension. Although the proposed version seemed to have better responses for both measures, as seen in Tables 19 and 20, this difference did not achieve significance for either. Even when the responses on these signs were re-coded to include only two categories (correct and incorrect), the differences between signs did not reach significance (although it was close to significance for the action measure, with a p value of 0.052).

Table 19: Percentage Distribution of Meaning Comprehension for Share the Road with Bikes

	Proposed	Optimized
Correct	67	42
Partially Correct	17	17
Incorrect	17	42

Table 20: Percentage Distribution of Action Comprehension for Share the Road with Bikes

	Proposed	Optimized
Correct	92	62
Partially Correct	0	4
Incorrect	8	33

Beach

Only one version of the Beach sign was evaluated. In terms of both meaning and comprehension, the sign performed poorly, as seen in Table 21, with less than one-third of the subjects providing a correct response. A Chi-Square test, comparing the observed response distribution to an expected (random) distribution of 50 percent correct and 50 percent incorrect produced a significant difference (meaning: $X^2 = 10.083$, $p = 0.001$; action: $X^2 = 8.333$, p =

0.004).

Table 21: Percentage of Correct and Incorrect Meaning and Action Comprehension for Beach

	Meaning	Action
Correct	27	29
Incorrect	71	71

Electric Vehicle Charging Station

There were no significant differences between the car and pump versions of this sign for either meaning or action comprehension. Although the pump seemed to have better responses for both measures, as seen in Tables 22 and 23, this difference did not achieve significance for either measure (although both were close to significance with p values of 0.066).

Table 22: Percentage Distribution of Meaning Comprehension for Electric Vehicle Charging Station

	Car	Pump
Correct	21	46
Incorrect	79	54

Table 23: Percentage Distribution of Action Comprehension for Electric Vehicle Charging Station

	Car	Pump
Correct	21	46
Incorrect	79	54

Scenic Byways Designation

There were no significant differences between the proposed and optimized versions of this sign for either meaning or action comprehension. As seen in Tables 24 and 25, both versions had very poor comprehension on both measures.

Table 24: Percentage Distribution of Meaning Comprehension for Scenic Byways.

	Proposed	Optimized
Correct	17	17
Incorrect	83	83

Table 25: Percentage Distribution of Action Comprehension for Scenic Byways

	Proposed	Optimized
Correct	17	8
Incorrect	83	92

Recognition Distance Data Results

Recognition distance data, coded into real-world distances as described above, were initially transformed to z-scores, to determine if there were outliers that might inappropriately affect the ANOVA. These z-scores were calculated separately for each sign type (across versions and age groups), and one outlier (recognition distance more than three standard deviations above or below the mean) was found for two signs: Light Rail Do Not Drive on Tracks and Light Rail Look Both Ways. In both cases, the outlier was the same subject, whose recognition distance was much higher than the mean on these signs. This outlier was removed from the analyses. A series of two-way ANOVAS were then performed, one for each of the test signs. Results of the ANOVA test are reported only if the difference reached significance.

Light Rail: Lane Control

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age ($F = 57.206$, $p = 0.000$), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 26). There were no interactions.

Table 26: Recognition Distance (in Feet) for Light Rail Lane Control, by Age and Sign Group

	Proposed	Optimized	Average
Younger	258.1	274.2	266.15
Older	154.6	137.1	145.83
Average	206.3	205.6	205.9

(1 ft = 0.305m)

Light Rail: Do Not Pass

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age ($F = 29.805$, $p = 0.000$), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 27). There were no interactions.

Table 27: Recognition Distance (in Feet) for Light Rail Do Not Pass, by Age and Sign Group

	Proposed	Optimized	Average
Younger	318.0	315.0	316.4
Older	187.0	226.0	206.3
Average	252.3	270.5	261.4

(1 ft = 0.305m)

Light Rail: Do Not Drive on Tracks

The ANOVA showed a significant difference in recognition distance for both sign group (F = 7.225, p = 0.010) and for age (F = 17.842, p = 0.000). The proposed version of the sign had a significantly better recognition distance than the optimized version, and younger drivers recognized the sign at a greater distance than older drivers (see Table 28). There were no interactions.

Table 28: Recognition Distance (in Feet) for Light Rail Do Not Drive on Tracks, by Age and Sign Group

	Proposed	Optimized	Average
Younger	295.0	216.0	255.2
Older	187.0	163.0	175.0
Average	240.6	189.6	215.1

(1 ft = 0.305m)

Light Rail: Look Both Ways at Crossing

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age (F = 15.462, p = 0.000), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 29). There were no interactions.

Table 29: Recognition Distance (in Feet) for Light Rail Look Both Ways, by Age and Sign Group

	Proposed	Front View	Average
Younger	338.3	306.3	322.9
Older	210.0	192.5	201.2
Average	274.2	249.4	261.8

(1 ft = 0.305m)

Lane Ends

The ANOVA showed a significant difference in recognition distance for both sign group (F = 56.390, p = 0.000) and for age (F = 24.799, p = 0.000). The standard version of the sign had a significantly better recognition distance than the proposed version, and younger drivers recognized the sign at a greater distance than older drivers (see Table 30). There were no interactions.

Table 30: Recognition Distance (in Feet) for Lane Ends, by Age and Sign Group

	Standard	Proposed	Average
Younger	723.0	405.0	564.4
Older	499.0	263.0	380.6
Average	611.0	333.9	472.5

(1 ft = 0.305m)

Jogger

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age ($F = 15.878$, $p = 0.000$), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 31). There were no interactions.

Table 31: Recognition Distance (in Feet) for Jogger, by Age and Sign Group

	Jogger	Ped	Average
Younger	440.4	367.5	403.9
Older	230.4	189.6	210.0
Average	335.4	278.5	306.9

(1 ft = 0.305m)

Cellular Phone Emergency Number

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age ($F = 10.065$, $p = 0.003$), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 32). There were no interactions.

Table 32: Recognition Distance (in Feet) for Cell Phone Emergency Number, by Age and Sign Group

	"Cell/antenna	No "cell"/antenna	Average
Younger	551.3	574.6	562.9
Older	431.7	360.2	395.9
Average	491.4	467.4	479.4

(1 ft = 0.305m)

Rural Mail Delivery Route

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age (F = 14.980, p = 0.000), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 33). There were no interactions.

Table 33: Recognition Distance (in Feet) for Rural Mail Delivery Route, by Age and Sign Group

	Proposed	Optimized	Average
Younger	268.3	259.6	263.9
Older	179.4	180.8	180.1
Average	223.8	220.2	222.0

(1 ft = 0.305m)

Share the Road with Bikes

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age (F = 20.044, p = 0.000), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 34). There were no interactions.

Table 34: Recognition Distance (in Feet) for Share the Road with Bikes, by Age and Sign Group

	Proposed	Optimized	Average
Younger	435.0	502.0	468.1
Older	293.0	235.0	263.0
Average	363.8	368.2	366.0

(1 ft = 0.305m)

Electric Vehicle Charging Station

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age (F = 6.992, p = 0.011), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 35). There were no interactions.

Table 35: Recognition Distance (in Feet) for Electric Vehicle Charging Station, by Age and Sign Group

	Car	Pump	Average
Younger	335.4	303.3	319.4
Older	188.1	186.7	187.4
Average	261.8	245.0	253.4

(1 ft = 0.305m)

Scenic Byways Designation

The ANOVA showed no significant difference in recognition distance between the two versions of this sign. There was a significant difference for age (F = 27.912, p = 0.000), with younger drivers recognizing the sign at a greater distance than older drivers (see Table 36). There were no interactions.

Table 36: Recognition Distance (in Feet) for Scenic Byways, by Age and Sign Group

	Proposed	Optimized	Average
Younger	387.9	411.3	399.6
Older	201.3	180.8	191.0
Average	294.6	296.0	295.3

(1 ft = 0.305m)

Summary of Results

Table 37 summarizes the results of the comprehension and recognition distance data for the test signs.

Table 37: Summary of Results

Sign	**Meaning Comprehension**	**Action Comprehension**	**Recognition Distance**
Light Rail Lane Control	No difference	No difference	No difference
Light Rail Do Not Pass	No difference	No difference	No difference
Light Rail Do Not Drive on Tracks	No difference	No difference	**Proposed better than optimized**
Light Rail Look Both Ways	No difference	No difference	No difference
Lane Ends	**Proposed better than standard**	**Proposed better than standard**	**Standard better than proposed**
Jogger	No difference	No difference	No difference
Cellular Phone Emergency	**With "cell" & antenna better than without**	**With "cell" & antenna better than without**	No difference
Rural Mail Delivery Route	No difference	No difference	No difference
Share the Road with Bikes	No difference	No difference	No difference
Beach	**Poor**	**Poor**	Not tested
Electric Vehicle Charging	No difference	No difference	No difference
Scenic Byway	No difference	No difference	No difference

DISCUSSION/RECOMMENDATIONS

Overall

For most of the signs, there were no significant differences between the two designs in the comprehension measures. This is not surprising, because, as seen in Figures 5 to 16, the difference between the versions was relatively subtle for six of the signs (Light Rail Lane Control, Light Rail Do Not Pass, Light Rail Do Not Drive on Tracks, Rural Mail Delivery Route, Share the Road with Bikes, Scenic Byways Designation). The two signs that did have a significant difference in comprehension, Lane Ends and Cell Phone Emergency Number, had noticeable differences in the two designs tested.

As expected, for all signs, younger participants had significantly longer recognition distances than older participants. Given the differences in the average visual acuity of the groups, with younger drivers averaging 20/16 and older drivers averaging 20/26, this is not surprising. In all of the signs, this would probably translate to a practical, as well as a statistical, difference.

The lack of significant difference between the two versions of the signs on the recognition distance measure is probably related to the criteria used for ending the recognition distance task as well as the fact that the subjects completed the comprehension task before the recognition distance task. Subjects could complete the recognition distance task by providing the meaning of the sign and did not have to describe each individual element on the sign. The optimization on the signs removed or modified high frequency elements, which may or may not have been critical to recognition of the sign. Furthermore, because they had seen large versions of each of the signs for an extended period of time during the comprehension portion of the evaluation, subjects had a good idea of what to look for to recognize each sign. In this evaluation, it was decided that if the distance-oriented task was to truly be a recognition distance task, there was no need to keep the subjects naïve as to what signs they were looking at. That is, it was a true "recognition" task, in that the subjects didn't have to describe the elements of the sign but could recognize it based on a wide range of features. This may have increased the recognition distance overall and may have also suppressed any subtle advantages that the optimization may have provided to the signs, but it more closely mimics the real-world task of sign recognition while driving.

Sign by Sign

Light Rail: Lane Control

The two versions of this sign showed no significant differences on any of the measures. There is no clear pattern in terms of the incorrect responses based on sign version, and both versions yielded correct comprehension of over 50 percent. Given that this is a novel sign, this is a reasonable comprehension rate, and furthermore, it will most likely be implemented with a significant educational campaign, potentially improving its comprehension. Most of the subjects participating in this study were from the DC Metro area, where there is no light rail system. It is feasible that higher rates of comprehension for this entire series of signs would have been achieved if it was tested with subjects more familiar with light rail systems. The older driver recognition distance, overall, was 145 feet (44 m). If this is a sufficient recognition distance for this sign, either version is acceptable.

Light Rail: Do Not Pass

The two versions of this sign showed no significant differences on any of the measures. There is no clear pattern in terms of the incorrect responses based on sign version. Neither version had a very good meaning comprehension (37 percent correct for the proposed and 42 percent for the optimized), although the action comprehension was adequate for a novel sign (54 percent correct for the proposed and 79 percent for the optimized). The sign will most likely be implemented with a significant educational campaign, potentially improving its comprehension. The older driver recognition distance, overall, was 206 feet (63 m). Either sign is acceptable.

Light Rail: Do Not Drive on Tracks

The two versions of this sign did not show a difference on the comprehension measures, but the proposed version had a better recognition distance than the optimized version. There is no clear pattern in terms of the incorrect responses based on sign version, but both versions had at least 50 percent correct comprehension on both meaning and action. Given that this is a novel sign, this is a reasonable comprehension rate, and furthermore, it will most likely be implemented with a significant educational campaign, potentially improving its comprehension. The proposed version had a significantly better recognition distance (240 feet (73 m) vs. 189 feet (58 m)) so it is recommended for implementation.

Light Rail: Look Both Ways at Crossing

The two versions of this sign showed no significant differences on any of the measures. Both versions yielded correct comprehension of over 65 percent. Given that this is a novel sign, this is a good comprehension rate, and furthermore, it will most likely be implemented with a significant educational campaign, potentially improving its comprehension The older driver recognition distance, overall, was 201 feet (61 m). Either sign is acceptable.

Lane Ends

The two versions of this sign showed significant differences on both measures. In the comprehension responses, the proposed version had better meaning comprehension (83 percent correct vs. 17 percent) and significantly better action comprehension (96 percent correct vs. 71 percent). The reason for the large difference in meaning and action comprehension for the standard sign is related to the acceptable correct responses. For the meaning comprehension to be correct, a subject had to identify that the right lane was ending; for the action comprehension, any response relating to being careful for vehicle entering their lane was considered correct. For the standard sign, all 12 of the partially correct responses were either “lanes merge ahead” or “lane narrows ahead.” The appropriate action for this incorrect meaning, and the appropriate action for the correct meaning (lane ends) are similar (watch for other vehicles entering your lane).

The distractor sign for Lane Ends was Added Lane (shown in Figure 21). This sign also had a very poor meaning comprehension (33 percent correct), with most of those incorrect responses (29 of 32 subjects) indicating the meaning as "merging traffic." In this case, however, the action response is quite different from the correct one with this interpretation. In fact, 35 percent of the subjects had an incorrect action for the Added Lane sign, and most of those incorrect responses (26 of 31 subjects) indicated the meaning as "merging traffic." In this case, the distractor sign and the test sign have similar symbols, but completely opposite meanings. Serious lack of understanding on the distractor sign leads to a recommendation that it be redesigned.

In terms of recognition distance, a different pattern emerged, with the standard sign showing a better recognition distance than the proposed sign (611 feet (186 m) vs. 333 feet (102 m)). Given the conflicting findings in the comprehension and recognition distance portions of the sign, and the confusion with a sign with an opposite meaning, more research is recommended.

Jogger

The two versions of this sign showed no significant differences on any of the measures. For the meaning comprehension, the pedestrian version showed more incorrect responses that included pedestrians than did the jogger version, but for the action comprehension, there is no clear pattern based on sign version. Both versions yielded correct meaning comprehension of at least 75 percent and correct action responses of over 85 percent. The older driver recognition distance, overall, was 210 feet (64 m). There was a significant difference in recognition distance of just the symbol (not including the text) with the pedestrian symbol being recognized at a greater distance then the jogger symbol, but as the pedestrian symbol does not convey the sign's intended meaning accurately, this was not considered sufficient. Given that an additional word plaque could be added to an existing symbol to convey the sign's intended message, rather than adding a new sign to inventories, the pedestrian sign with the plaque is recommended.

Cellular Phone Emergency Number

The two versions of this sign showed significant differences on both comprehension measures, with the version including the antenna and the word "cell" performing better than the other version. All of the incorrect meaning responses for the "non cell/antenna" version identified the sign as referring to a standard (land line) phone rather than a cell phone, and the action responses paralleled this pattern. There is no significant difference between the versions on recognition distance. The older driver recognition distance, overall, was 396 feet (121 m) . As the sign with "cell" and the antenna had significantly better comprehension and no deterioration in recognition distance, this version is recommended.

Rural Mail Delivery Route

The two versions of this sign showed no significant differences on any of the measures. There is no clear pattern in terms of the incorrect responses based on sign version, and both versions yielded correct comprehension of over 80 percent. Given that this is a novel sign, this is an excellent comprehension rate. The older driver recognition distance, overall, was 180 feet (55 m). Either version is acceptable.

Share the Road with Bikes

The two versions of this sign showed no significant differences on any of the measures. In the meaning comprehension, eight of the subjects giving incorrect responses to the optimized sign included motorcycles instead of or in addition to bicycles when referring to the vehicle depicted on the right of the sign. The action responses paralleled this pattern. The attempt to give the bicycle a better recognition distance by thickening its lines changed its perception for a small portion of the subjects (but the comprehension was not significantly different between the two versions). In terms of meaning both signs had adequate comprehension (67 percent correct for the proposed version, 42 percent for the optimized) and good comprehension on action (92 percent correct for the proposed version, 62 percent for the optimized version). The older driver recognition distance, overall, was 263 feet (80 m).

A previous study (Fox & Philips, 1995) had indicated that another version of this sign (standard bicycle symbol with plaque below reading "Share the Road" had better comprehension than the symbol sign, but poorer recognition distance. As the optimization technique did not improve the recognition distance of the sign, it is recommended that the current standard (standard bike with "Share the Road" plaque) be retained.

Beach

The Beach sign was very poorly comprehended, with over 70 percent incorrect responses for both meaning and action. The most common incorrect responses referred to sunbathing, rest areas, resort areas, or exercise areas. The sign is not recommended for implementation

Electric Vehicle Charging Station

The two versions of this sign showed no significant differences on any of the measures. In the meaning responses, a large number of the incorrect responses for the pump version included references to electrical outlets (five subjects), or subjects indicated they didn't know what the sign meant (five subjects). For the car version, seven of the incorrect responses referred to issues related to vehicle batteries. In the action comprehension, most of the incorrect responses for the pump version (7 of a total of 13 incorrect responses) were "don't know." For the car version the incorrect responses predominantly fell into two categories: five subjects responded "don't know" and five responded with something relating to charging their battery if necessary. Overall, neither version had adequate comprehension, with no measure reaching even 50 percent correct responses. The older driver recognition distance, overall, was 187 feet (57 m).

In an unpublished FHWA study, driver comprehension data were collected on a variety of Electric Vehicle Charging Station signs. In all cases, versions that included a pump had higher comprehension than those with just a car. Given the lack of significant difference in recognition distance between the car symbol and the pump symbol in the current study, the almost significant advantage of the pump over the car in terms of comprehension in the current study and the findings of the previous research, the pump symbol is recommended.

Scenic Byways Designation

The two versions of this sign showed no significant differences on any of the measures. There is no clear pattern in terms of the incorrect responses based on sign version, and both versions yielded very poor comprehension of less than 20 percent correct. The older driver recognition distance, overall, was 191 feet (58 m). Given the poor comprehension rate, neither version is recommended in isolation, although either might be acceptable if used as a symbol on a guide sign identifying the road in question.

Summary of Recommendations

Table 38 summarizes the recommendations as well as the comprehension and recognition distance results. Bolded items indicate places where the difference between versions were significant. In cells that do not have bolded text, there were no statistically significant differences between versions on that measure. For two of the signs (Share the Road with Bikes and Electric Vehicle Charging Station), the recommendation is based not only on results from this effort, but from other related research activities.

Table 38: Summary of Recommendations

Sign	Recommendation	Percent Correct Meaning	Percent Correct Action	Recognition Distance (feet)
Light Rail Lane Control	Either Version	62% proposed 54 % optimized	67 % proposed 66 % optimized	206.3 proposed 205.6 optimized
Light Rail Do Not Pass	Either Version	37% proposed 42 % optimized	54% proposed 79% optimized	252.3 proposed 270.5 optimized
Light Rail Do Not Drive on Tracks	Proposed Version	50% proposed 54% optimized	50% proposed 62% optimized	**240.6 proposed** **189.6 optimized**
Light Rail Look Both Ways at Crossing	Either Version	71% proposed 67% optimized	79% proposed 79% optimized	274.2 proposed 249.4 optimized
Lane Ends	Neither Version	**17% standard** **83% proposed**	**71% standard** **96% proposed**	**611.0 standard** **333.9 proposed**
Jogger	Pedestrian	92% jogger 75% pedestrian	92% jogger 87% pedestrian	335.4 jogger 278.5 pedestrian
Cell Phone Emergency Number	With "Cell" and Antenna	**87% with extra** **54% without**	**87% with extra** **46 % without**	491.4 with extra 467.4 without
Rural Mail Delivery Route	Either Version	92% proposed 87% optimized	92% proposed 83% optimized	223.8 proposed 220.2 optimized

Share the Road with Bikes	"Share the Road" Version	67% proposed 42% optimized	92% proposed 62% optimized	363.8 proposed 368.2 optimized
Beach	Not Recommended	27%	29%	
Electric Vehicle Charging Station	Pump Version	21% car 46% pump	21% car 46% pump	261.8 car 245.0 pump
Scenic Byways	Neither Version	17% proposed 17% optimized	17% proposed 8% optimized	294.6 proposed 296.0 optimized

(1 ft = 0.305m)

RECOMMENDED RESEARCH

Overall

In no case did the optimization technique improve the recognition distance of the symbols. This contradicts previous research in the area, which found significant improvements in legibility after optimization. There are a variety of possible reasons for this lack of consistency.

In the previous research, stimulus presentation was performed using a computer. It is possible that the optimization technique is useful for improving the legibility of images on a computer screen (whether they are traffic signs or something else) and that the improvements do not carry over to signs made of real materials.

In this study, one criterion for ending the recognition distance trial was for the subject to name the sign. In previous research on recognition distance and sign optimization, completion of recognition distance trials focused on individual elements of signs, rather than on overall recognition. Possibly the optimization technique, because of its emphasis on particular individual elements, is not as useful in improving recognition distance when the criterion is the overall symbol.

Finally, one reason for the lack of improvement in recognition distance because of optimization may have been related to sign designs. Although the recursive blur software will objectively point out where the high frequency elements are, the modifications to be made to the symbol are left to the discretion of the designer. Possibly, the elements that were chosen for improvement, or the way in which they were improved, removed the high spatial frequency portions but were not good designs.

Sign By Sign

Light Rail Signing Series

The remaining research needed on the light rail series relates to appropriate methods of road user education campaigns to improve driver comprehension of these signs.

Lane Ends

No recommendation was made for the Lane Ends sign. This symbol sign has been evaluated many times, and none of the versions has ever been found to be highly effective on a wide range of measures. Particularly given the confusion between this sign and the Added Lane sign, as well as the large number of incorrect responses that included "merge ahead," a research evaluation on just these signs is recommended. Such a study should include "pure" comprehension and recognition distance evaluation of symbol and word message, comprehension measures with the signs in context and, eventually, real-world field testing of the best candidates. It is possible that the signs are, in fact, encouraging appropriate driver behavior but that drivers are unable to articulate the correct response. Field research will help determine if this is true.

Cellular Phone Emergency Number

Follow-up research on the Cell Phone Emergency Number should include methods of optimizing the sign with the "cellular" plaque. In particular, investigations of which elements of the sign improved its comprehension (the antenna or the "cellular" plaque) should be conducted to see if the sign can be simplified. Furthermore, an evaluation should be conducted to determine if other elements of the sign (such as the word "dial") add to the comprehension of the sign.

Rural Mail Delivery Route

The remaining question on the Rural Mail Delivery Route sign concerns implementation. Direction will need to be provided on where and how this sign should be put on the roadways.

Beach

This sign had extremely poor comprehension. If it is determined that such a symbol is really required, another one should be developed and investigated.

Scenic Byways Designation

As neither sign was considered acceptable, a new symbol needs to be developed and evaluated. In future investigations, perhaps the sign should be evaluated in a context-appropriate setting rather than as a pure comprehension study. It is unlikely that any symbol developed for this purpose will have any intrinsic meaning.

APPENDIX A: INFORMED CONSENT FORM

RECORD OF INFORMED CONSENT

In accordance with 45 C.F.R., Section 46.116, relating to the Protection of Human Subjects in Research, your informed consent for participation in Federal Highway Administration Human Factors studies is required. Please consider the following elements of information in reaching your decision whether or not to consent:

Section I. General:

We are asking for your voluntary participation as a paid subject in a research study on sign design. Your participation will require approximately 1.5 to 2 hours. The results of this research will be useful to human factors researchers, engineers, and others concerned with improving the safety and operational efficiency of the nation's highway system.

Upon completion of this session, you will be paid $30.00 for your participation. You must complete the entire session to receive full remuneration, except as indicated in the sections below. You may stop at any time.

Section II. Study Procedures:

1. You will be asked for biographical information necessary to the study. All information you provide will remain confidential, and the source of information will not be disclosed to the public.

2. Prior to beginning the study, you will be given a visual acuity test. In order to proceed in the study, you must meet the minimum visual requirements with at least 20/40 corrected visual acuity (with glasses or contacts). If you do not meet these requirements you will be paid $5.00 for your time.

3. You will be asked to view a series of signs and provide information on what each means and what action you would take if you saw it on the roadway.

4. You will view a series of signs in a 100 foot darkened laboratory, walking toward each sign until you can describe it to an experimenter.

Section III. Risks:

With the exceptions listed below, the risks associated with this study are not greater than those ordinarily encountered in an office environment.

Section IV. Withdrawal of Consent:

You are free to decline consent, or to withdraw consent and discontinue participation in the study session at any time.

Section V. For Further Information:

If you have additional questions pertinent to this research, your rights as a subject, or any injury you believe to be related to this research, please contact:

Division Chief
Information and Behavioral Systems Division (HSR-30)
Federal Highway Administration
Office of Research
Washington, DC 20590

END OF INFORMATION

The basic elements of information have been presented and clearly understood by me, and I consent to participate as a subject.

NAME (Please print): ____

ADDRESS / APT. NO.: ____

CITY, STATE ZIP: ____

HOME PHONE NUMBER: (____) ______-________

WORK PHONE NUMBER: (____) ______-________

GENDER (Please circle one): M F

DATE OF BIRTH: ________, 19____ **AGE:** ______

SIGNATURE: ____________________________ **DATE:** _______

APPENDIX B: INSTRUCTIONS TO SUBJECTS

Comprehension

This book has color pictures of 23 signs. After each picture there is a response sheet. For each picture, please note on the top of the response sheet the code that appears in the upper left-hand corner of the picture of the sign Then, at the top of the response sheet (under "meaning") please write out what you think the sign means. On the lower half of the response sheet (under "action") please write out what action you would take if you saw the sign along the roadway. Please write neatly, and if you are unsure of the meaning or action, just provide the best response you can. Any questions?

Recognition

As perhaps you can see, at the end of this hall, is a small highway sign. If you can't make that out from here, that is ok. What you need to do is walk slowly toward that sign, stopping at each of the blue tape marks you see on the floor. At each stopping point, I will ask you if you can tell me what you see on the sign. If you can't make out the sign or if I tell you to provide more detail, please start walking again. Stop at the next piece of blue tape and once again tell me what you can see on the sign. When your response is accurate, I will ask you to tell me the number on the tape. At that point, please walk back to your starting point. I will change the sign, and we will begin the process again for the next sign. Any questions?

APPENDIX C: CRITERIA FOR COMPREHENSION CODING

Light Rail

For all the signs in the light rail series, correct identification of the vehicle included the following responses:

- Trolley
- Tram
- Cable Car
- Light Rail
- Electric Bus
- Electric Train

Light Rail: Lane Control

Correct Meaning: Subjects had to indicate that the correct vehicle type (as listed above) was the only vehicle permitted on the tracks in the center lane.

Partially Correct Meaning: Responses were coded as "partially correct" if the response indicated that the correct vehicle was using the center lane (neglected to state that other vehicles could not use the center lane).

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included: "road repair," "only center lane can cross the tracks," "drive in center lane only," and "HOV vehicles can use center lane."

Correct Action: Subjects had to indicate that if they were driving a car, they would not drive in the center lane.

Partially Correct Action: Responses were coded as "partially correct" if they indicated that they should avoid the center lane (rather than stating they were prohibited from the center lane).

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers paralleled the incorrect meaning responses and included: "stay in center lane only," "do not enter the roadway," "cross tracks at center lane," and "stay in center lane if in HOV." Responses such as "use caution" and "don't know" were coded as incorrect, as were non-responses.

Light Rail: Do Not Pass

Correct Meaning: Subjects had to indicate that they could not pass the correct vehicle type (as listed above).

Partially Correct Meaning: Responses were coded as "partially correct" if the response indicated that they could not pass the appropriate vehicle AND that there was a pedestrian crossing in the area.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included: "pedestrians crossing," "no passing" (not specific to the light rail vehicle), and "light rail stop ahead." Responses such as "don't know" were coded as incorrect, as were non-responses.

Correct Action: Subjects had to indicate that if they were driving a car, they would not pass the vehicle (as listed above).

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included: "slow down", "don't walk on tracks", and "stay in lane". Responses such as "don't know" were coded as incorrect, as were non-responses

Light Rail: Do Not Drive on Tracks

Correct Meaning: Subjects had to indicate that they could not drive on the vehicle tracks (as listed above).

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included "no stopping on tracks" and "do not enter." Responses such as "don't know" were coded as incorrect, as were non-responses.

Correct Action: Subjects had to indicate that if they were driving a car, they would not drive on the tracks.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included "no cars allowed" and "cross tracks carefully." Responses such as "don't know" were coded as incorrect, as were non-responses.

Light Rail: Look Both Ways

Correct Meaning: Subjects had to indicate that the correct vehicle (as listed above) was passing on the cross street and they should look both ways.

Partially Correct Meaning: Responses were coded as "partially correct" if they indicated that there was a trolley/tram line in the general area, but did not indicate it was on the cross street.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a subway or the tracks as railroad tracks.

Correct Action: Subjects had to indicate that if they were driving a car, they would look both ways and determine if a vehicle (as listed above) was approaching before they proceeded.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if the subject identified the vehicle as a train or the tracks as railroad tracks. Other incorrect answers included "slow down" and "stay to left or right of rail car."

Lane Ends

Correct Meaning: Subjects had to indicate that the right lane was ending ahead.

Partially Correct Meaning: Responses were coded as "partially correct" if they indicated that the lanes merged ahead or the roadway narrowed ahead.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include information as listed above. Other incorrect responses included :"jog in the road ahead," "road curves ahead," "road shifts ahead," and "a lane is added ahead."

Correct Action: Subjects had to indicate that they would stay in the left lane and watch for traffic entering or merging into their lane.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Other incorrect responses included "slow down for the upcoming curve" and "drive to accommodate the extra lane."

Jogger

Correct Meaning: Subjects had to indicate that there were likely to be joggers in the area.

Incorrect Meaning: Responses were coded as "incorrect" if they indicated that there were pedestrians in the area, or that there was a separate jogger and pedestrian path along the side of the road.

Correct Action: Subjects had to indicate that they would be alert to people jogging or running in or near the roadway.

Partially Correct Action: Responses were coded as "partially correct" if they indicated that the subject would be alert to people in or near the road, but did not specify if they meant joggers or pedestrians.

Incorrect Action: Responses were coded as "incorrect" if they indicated that the subject would be alert to pedestrians in or near the roadway. Other incorrect responses included "slow down and stop."

<u>**Cellular Phone Emergency Number**</u>

Correct Meaning: Subjects had to indicate that the number to dial on a cellular phone for an emergency was *70.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information indicated above. Incorrect responses included those that did not specify that the emergency call should be made from a cellular phone.

Correct Action: Subjects had to indicate that they would dial *70 from a cell phone in case of emergency, or do nothing because they did not have a cell phone, or remember the number for future reference to call from a cell phone in an emergency.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses included those that did not specify a cell phone. Responses of "don't know" were coded as incorrect, as were non-responses.

<u>**Rural Mail Delivery Route**</u>

Correct Meaning: Subjects had to indicate that mail was being delivered in the area. The rural aspect was not required for a response to be coded as correct.

Partially Correct Meaning: Two responses were coded as "partially correct." Both identified the presence of a mail vehicle, but attributed other characteristics (not delivering mail) to its actions.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses included "pull up mail drop ahead" and "mail truck stop ahead." Responses of "don't know" were coded as incorrect.

Correct Action: Subjects had to indicate that they would be alert to the presence of a vehicle delivering mail.

Partially Correct Action: One response was coded as "partially correct." This subject indicated that they could only pass the oncoming mail vehicle when it was safe to do so.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses included "don't park in front of mail boxes" and "watch for people dropping mail in the box."

Share the Road with Bikes

Correct Meaning: Subjects had to indicate that bicycles and cars shared the road or were both allowed on the road

Partially Correct Meaning: Responses were coded as "partially correct" if they indicated that certain vehicles (cars or bikes) had to stay in a particular lane, or if they included bikes and motorcycles in their response. Bike Lane and Bike Route responses were also coded as partially correct.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Answers were coded as incorrect if motorcycles but not bicycles were indicated, or if they indicated that this was a bike path or bike crossing.

Correct Action: Subjects had to indicate that, as a driver, they would be alert to bicyclists riding in the roadway.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Responses that only indicated a motorcycle (not a bicycle) as the vehicle to watch for were coded as incorrect. Other incorrect answers included "go slowly" and "stay left."

Beach

Correct Meaning: Subjects had to indicate that the sign showed the route to get to a beach.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses covered a wide range of areas, with the most frequent responses related to sunbathers, recreation, or rest areas. Responses of "don't know" were coded as incorrect, as were non-responses.

Correct Action: Subjects had to indicate that they would follow the sign if they wanted to get to the beach.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses paralleled the incorrect meaning responses, with the most frequent responses related to rest or recreation areas. Responses of "don't know" were coded as incorrect, as were non-responses.

Electric Vehicle Charging Station

Correct Meaning: Subjects had to indicate that the sign showed where an electric vehicle could be charged.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses covered a wide range of areas (from "Red Cross vehicle" to "car repair ahead"), with the most frequent being either no response or "don't know."

Correct Action: Subjects had to indicate that they would follow the sign if they were driving an electric vehicle that needed charging.

Incorrect Action: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses covered a wide range of areas (from "electricity available ahead" to "stop and reread sign"), with the most frequent response being either no response or "don't know."

Scenic Byways

Correct Meaning: Subjects had to indicate that the sign identified a scenic highway or route.

Incorrect Meaning: Responses were coded as "incorrect" if they did not include the information listed above. Incorrect responses covered a wide range of areas, from "glare" to "entering suburbs," with no particular incorrect response predominating. Responses of "don't know" were coded as incorrect, as were non-responses.

Correct Action: Subjects had to indicate that they should follow this sign if they wanted to be on a scenic highway or route.

Incorrect Action: Responses were coded as "incorrect" if they did not include the above information. Incorrect responses paralleled the meaning responses, covering a wide range of areas (from "slow down" to "ignore the sign") with no one response predominating. Responses of "don't know" were coded as incorrect, as were non-responses.

APPENDIX D: CRITERIA FOR COMPLETING RECOGNITION TRIAL

For the recognition distance trials, there were various types of responses that were acceptable to complete the trial. The subject could either name the sign, state its meaning (as described in the comprehension criteria in Appendix C), or identify all the critical elements of the sign. Critical elements are described below.

Light Rail: Lane Control

Both: Trolley, Tram, Cable Car, Light Rail, Electric Bus, Electric Train
"Center Lane Only"

Light Rail: Do Not Pass

Both: Trolley, Tram, Cable Car, Light Rail, Electric Bus, Electric Train
Pedestrian
"Do Not Pass"

Light Rail: Do Not Drive on Tracks

Proposed: Car
Tracks
"Do not" circle and slash

Optimized: Trolley, Tram, Cable Car, Light Rail, Electric Bus, Electric Train
"Do Not Drive on Tracks"

Light Rail: Look Both Ways at Crossing

Proposed: Trolley, Tram, Cable Car, Light Rail, Electric Bus, Electric Train
Arrow

Front View: Trolley, Tram, Cable Car, Light Rail, Electric Bus, Electric Train
Tracks
"Look Both Ways"

Lane Ends

Standard: Left line straight
Right line "jogs" left

Proposed: Left line straight
Right line "jogs" left
Arrows
Lane lines

Jogger

Both: Jogger, person, or pedestrian
"Jogger Route"

Cellular Phone Emergency Number

Cell/antenna: "Emergency"
Antenna
Phone
"Dial * 70"
"Cellular"

w/out cell: "Emergency"
Phone
"Dial * 70"

Rural Mail Delivery Route

Both: "Mail Delivery"
Vehicle
Mailbox

Share the Road with Bikes

Both: Vehicle
Person riding bicycle

Electric Vehicle Charging Station

Car: Car
Plus and minus symbol

Pump: Pump
"EV"
outlets

Scenic Byways Designation

Both: Mountains
Roadway
City

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