Delineation of Hazards for Older Drivers

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FOREWORD

The proportion of the driving population over age 65 is growing significantly. Older motorists can be expected to have problems in detecting and comprehending hazardous situations, given the known changes in their sensory, perceptual, cognitive, and psychomotor performances.

Object markers serve an important function and are intended to delineate obstructions within or adjacent to the roadway. They are applied to numerous situations where an object cannot be removed or protected, but could cause injury or damage to a vehicle if hit. Unfortunately, the exact meaning of object markers has become unclear over the years.

The research documented in this report identified drivers' problems with the conspicuity, recognizability, and comprehensibility of object markers. Through laboratory and field studies, a number of different static and dynamic markers were evaluated for their effectiveness and a cost-benefit analysis was conducted.

The information contained in this report should be of interest to highway designers, traffic engineers, and highway safety specialists involved in the design and operation of highway facilities.

A. George Ostensen, Director
Office of Safety and Traffic Operations,
Research and Development

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16. Abstract

The objective of this research project was to identify conspicuity, recognizability, and comprehensibility problems with object markers, particularly as they relate to the needs and capabilities of the older driver. This was accomplished through a series of tasks and three sets of experiments (problem identification, laboratory and field studies) which determined through empirical research the effect of selected enhancements on the design and implementation of current object markers. Specifically, emphasis was placed on optimizing the design and implementation of Type 1, Type 2, and Type 3 object markers in order to increase conspicuity, recognizability, and comprehension, while eliminating confusion with other devices. Changes including size, color, shape, placement, and symbology were investigated under daytime and nighttime conditions for various roadway geometries. Additionally, object markers employing active technology (e.g., flashing beacons) were evaluated for comprehension and conspicuity in a field setting. While the specific meanings of current markers were not necessarily well understood by subjects, the general message of caution, general hazard, or general warning was typically conveyed in a field setting. Findings from the studies of static markers did not produce results that strongly support the adoption of new markers over existing object markers. While novel markings generally led to higher conspicuity, the magnitude of this improvement was small and generally not statistically significant. Using the findings from the lab and field studies, a cost-benefit analysis found that for the passive markers, two of the new, novel markers (Double Modified Chevron and cone symbol) demonstrated good results when a high weight was placed on conspicuity. The device with the lowest benefit-cost payoff was the painted pavement hash marks. None of the additional costs of the active device applications were justified on the basis of the cost-benefit analysis. Recommendations for changes to the MUTCD were discussed and suggestions were made for future research.

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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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CHAPTER 1. INTRODUCTION

PROJECT OBJECTIVES

The objectives of this research project were to identity conspicuity, recognizability, and comprehensibility problems with object markers, particularly as they relate to the needs and capabilities of the older driver. This was accomplished through a series of tasks which determined through empirical research the effect of selected enhancements on the design and implementation of current object markers.

SCOPE

The Delineation of Hazards for Older Drivers Project investigated the effects of changes in the design and implementation of object markers on driver performance, particularly older drivers. Emphasis was placed on optimizing the design and implementation of Type 1, Type 2, and Type 3 object markers in order to increase conspicuity, recognizability, and comprehension, while eliminating confusion with other devices such as post-mounted delineators, end of road markers, Type I and Type II barricades, drums, vertical panels, and chevron signs. Changes including size, color, shape, placement, and symbology were investigated under daytime and nighttime conditions for various roadway geometries. Additionally, object markers employing active technology (e.g., flashing beacons) were evaluated for comprehension and conspicuity in a field setting. Both the laboratory and field research studies used young/middle-aged and older drivers.

BACKGROUND

Over the years the exact meaning of object markers has become unclear. There has been some disagreement on whether object markers should convey the presence of something or a sense of hazard. There has also been confusion between the use of object markers and standard delineation and marking treatments.

Object markers are intended to delineate obstructions within or adjacent to the roadway. They are applied to numerous situations where an object cannot be removed or protected, but could cause injury or damage to a vehicle if hit. Examples include the marking of bridge rails, abutments, and piers; culvert ends; median noses; utility poles; and natural obstacles such as trees, shrubs, and rocks. The name object marker implies a single object. However, object markers have been used as a series of signs by highway engineers, in fact their use is implied in the following quotation from the *Manual on Uniform Control Devices for Streets and Highways* (MUTCD):[1]

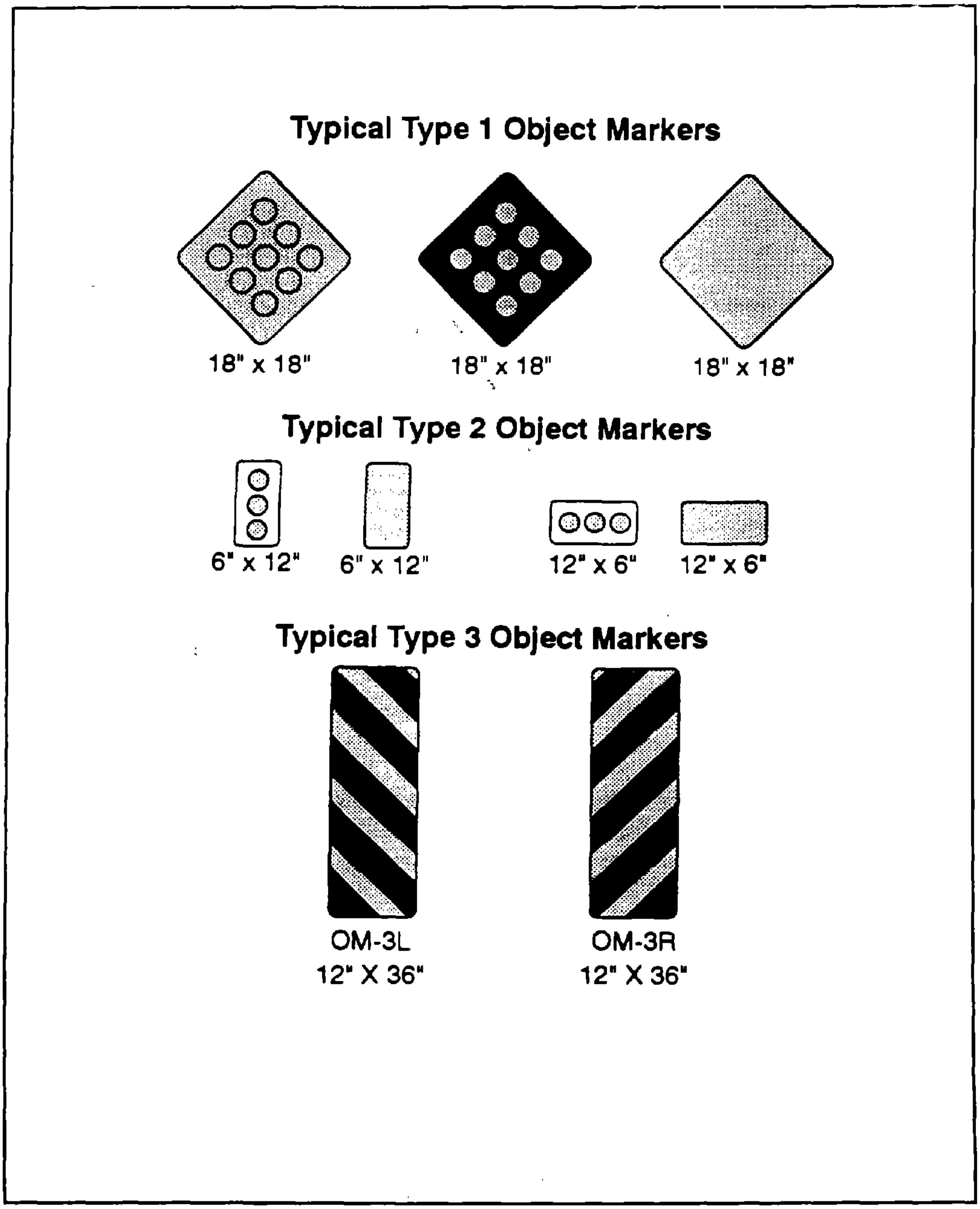
In some cases there may not be a physical object involved, but other roadside conditions such as *narrow shoulder drop-offs*, gores, small islands and *abrupt changes in the roadway* *alignment* may make it undesirable for a driver to leave the roadway. (Emphasis added. Page 3C-2.)

On the other hand, signs designed for other purposes, such as the chevron alignment marker, have been used as object markers. Thus there is some overlap in both specifications and practice. Another example of confusion occurs in the *Traffic Control Device Handbook* (TCDH), a supplement to the MUTCD.[2] Unfortunately, in Part V, Islands, it specifies that Type 1 or 2 object markers should be used on median islands (reinforcing this with an illustration) and gives no mention of uses for Type 3 markers in such areas. This would appear to conflict with the guidance of the MUTCD, and its own specifications on page 3-25, both of which specify that Type 1 or Type 3 markers should be employed for this use.

There are three types of markers outlined in the MUTCD (see pp. 3C-1 to 3C-4).[1] These markers are categorized as Type 1, Type 2, and Type 3 (See figure 1 on the following page). The following section defines their form and use according to the MUTCD. Type 1 markers incorporate nine yellow reflectors, each with a minimum diameter of 7.6 cm (3 in), symmetrically mounted on a 45.7 cm (18 in) yellow (reflective or non-reflective) or black diamond panel. Type 2 markers may contain either three yellow reflectors, 7.6 cm (3 in) minimum diameter, mounted vertically or horizontally, or an all yellow reflective panel, 15.2 cm by 30.5 cm (6 in by 12 in). Type 1 and 2 markers may be larger if conditions warrant. The Type 1 object marker has three to four times the reflective power of the Type 2 marker, providing more warning to approaching vehicles.[2] The Type 3 marker is a vertical rectangle, 30.5 cm by 91.4 cm (12 in by 36 in) in size, with alternating black and yellow reflectorized stripes approximately 7.62 cm (3 in) in width. These stripes are sloped downward at an angle of 45 degrees toward the side of the obstruction on which traffic is supposed to pass. Better effects can be achieved if wider black stripes are used.[1]

When used to denote objects in the roadway, or less than 2.4 m (8 ft) from the shoulder or curb, these markers are to be mounted 1.2 m (4 ft) above the nearest travel lane. When marking objects that are more than 2.4 m (8 ft) from the shoulder or curb, the bottom of the marker should be mounted 1.2 m (4 ft) above the ground level. These heights may be varied according to need.[1]

The location of the hazard plays a major role in the determination of the type of object marker used. When an obstruction is encountered in the roadway, it should be denoted by a Type 1 or Type 3 marker. To emphasize larger fixed objects, such as bridge abutments, to the driver, these objects can be painted with a diagonal stripe pattern, each stripe being 30.5 cm (12 in) wide, similar to those used for Type 3 markers above.[1] Other objects may not be in the roadway but may be close enough to merit a marker. For cases such as these, Type 2 or 3 markers should be used. Examples of these would be underpass piers, bridge abutments, culvert headwalls, and handrails. Also, other conditions such as gores, islands, shoulder drop-offs, and abrupt roadway changes would also warrant markers.



1 in = 2.54 cm

Figure 1. Illustration of object markers reproduced from page 3C-3 of the MUTCD.

In the case of islands, object markers are used to warn drivers of the presence of an island. Generally, object markers are used on islands that are narrower than 0.92 m (3 ft). In cases where islands are wider than 0.92 m (3 ft), signing such as Keep Right (R4-7, 7a, 7b), Keep Left (R4-8), or a Double Arrow warning sign (W12-1) should be used. One particular use of object markers on islands is at intersections with multiple islands or at intermediate ends of divisional islands and medians.[1] Object markers are beneficial in these situations because they are small but still emphasize the end of the islands without cluttering the area with other larger signs. They should be used to indicate the presence of raised curbs or other such obstructions and should be used even if another sign (e.g., Keep Right) is used (see p. 5F-1).[1]

PROJECT APPROACH

The project objectives were accomplished through a research program which included the following tasks:

Background Review and Problem Identification Workplans - A review of the technical literature and current standards and practice related to the effects of (1) older driver ability to see and comprehend object markers, (2) methods used in previous studies to evaluate the utility of the design and implementations of TCD, and (3) methods of increasing the conspicuity, recognizability, and comprehensibility of object markers to older drivers was accomplished during this activity.

Problem Identification Studies - This effort consisted of studies that were designed to investigate issues that surfaced during the background review and survey. The conclusions of the literature review found that experts have varying opinions regarding the marking of roadside hazards, and in fact a wide variety of choices is offered by the MUTCD. The laboratory studies focused on identifying problems with object markers, particularly for older drivers. Specifically, the studies looked at conspicuity, comprehension, recognizability, and stereotyping issues in hazard marking.

Alternative Design and Implementation Strategies - Based on the background review and problem identification studies this task developed alternative concepts for hazard markings which included pavement markings, as well as post-mounted markers. The goal of the redesigned markers was to emphasize increased conspicuity, recognizability, and comprehension.

Laboratory Investigations - This task included a series of three experiments to investigate the responses of younger and older drivers to the current and redesigned markers related to conspicuity, recognizability, and comprehension.

Field Verification Studies - A field study was conducted to verify laboratory study findings and investigate the use of active technology such as flashing beacons as object markings.

In chapter 2, the key findings of the literature review will be summarized. Chapter 3 presents an overview of the problem identification experiments. Methods and results of the three problem identification experiments are presented in chapters 4 to 6. Chapter 7 presents the rationale for the alternative object markers used in the laboratory and field studies. An overview of the laboratory investigations is presented in Chapter 8. Following that, the methods and results of the laboratory and field experiment conducted under this project will be reported (chapters 9 to 13). Chapter 14 presents a cost-benefit analysis of the markers used in the field studies. Chapter 15 discusses the findings of the projects and considers the implications for changes to the MUTCD.

CHAPTER 2. LITERATURE REVIEW

Object markers are intended to delineate obstructions within or adjacent to the roadway. They are applied to numerous situations where an object cannot be removed or protected, but could cause injury or damage to a vehicle if hit. Examples include the marking of bridge rails, abutments, and piers; culvert ends; median noses; utility poles; and natural obstacles such as trees, shrubs, and rocks. The name "object marker" implies a single object. However, object markers have been used as a series of signs by highway engineers, and signs designed for other purposes, such as the chevron alignment marker, have been used as object markers.

The first part of this chapter reviews the published standards for the treatment of roadside hazards and hazards within the roadway. The second part reports on conversations with nine State highway officials who deal with signage and delineation. Next, the abilities of the older driver is discussed relative to object markers, roadside hazards, and other signing and marking related to object markers. The fourth section reviews the various methodologies for assessing signage and object markers for streets and roads. Lastly, a summary is given and recommendations are made for improved object markers.

REVIEW OF CURRENT PRACTICES IN DEFINITION AND TREATMENT OF ROADSIDE HAZARDS

Object markers are used to delineate obstructions within or adjacent to the roadway. Over the years the exact meaning of these markers has become unclear. There has been some disagreement on whether object markers should convey the presence of something or a sense of hazard. There has also been confusion between the use of object markers and standard delineation and marking treatments.

Relationship of Object Markers to Path Delineation. To be consistent, pavement striping and associated markers (curb markings, raised pavement markers, and post-mounted delineators) should define the proper path for the vehicle while object markers should warn of exceptions or near exceptions to the path.

According to the recommendations of Institute of Transportation Engineers' (ITE) *Traffic Engineering Handbook*, delineation devices are to be used as guide markings (providing moment to moment vehicle control and alignment preview) rather than warning devices.[3] Many times, however, these devices are used to mark objects within the roadway environment. This may lead to some confusion among drivers who are looking to these markers for directional guidance.

In practice, white post-mounted delineators (PMD) are placed to delineate the right edge and yellow PMD are used to delineate the left edge of roadways with traffic traveling in one direction. This convention precludes the use of a left edge delineation device on a roadway with undivided, bi-directional traffic. This is because it might influence the driver to travel just to the right of the delineators, which would be in the lane for on-coming traffic.

Additionally, object markers also are used as a treatment for certain types of high accident locations or in response to citizen requests for delineation of a perceived hazard.

Review of Selected Publications. Several publications related to highway design and operations were reviewed to find information on policies, guidelines, or standards related to marking in-road and roadside hazards. It was expected that the American Association of State Highway and Transportation Officials (AASHTO) *Policy on Geometric Design of Highways and Streets* would contain many details regarding the use of object makers.[4] However, the *Policy* refers the reader "to the *Manual on Uniform Control Devices* (MUTCD) for criteria, methods, and standards of markings."[1]

Similarly, the *Roadway Delineation Practices Handbook*, when addressing object markers, reiterates the contents of the MUTCD.[5]

The Clear Zone. A well-designed roadway will have lanes wide enough for normal driving, plus shoulders wide enough to accommodate vehicles with emergency break-downs such as flat tires and overheating engines. Since the publication of the 1967 *AASHTO–Geometric Design of Highways and Streets*, a well-designed highway also includes a 'clear' zone.[4]

The AASHTO *Roadside Design Guide* defines the clear zone as "the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles."[6] This area should be free from obstructions. The width of the clear zone is dependent upon traffic volumes, speed, and side slopes. It is recommended that a width of 9.2 m (30 ft) be used for clear zones associated with high speed facilities. This value is somewhat excessive for low-speed and low-volume facilities. The AASHTO Policy advises the practitioner to refer to the *Roadside Design Guide* for more detailed information on clear zones. It does however, provide some guidelines for clear zones on urban and rural local roads. For rural roads, a clear zone of 3.1 m (10 ft) is preferred. This should be adjusted accordingly if guiderail is provided to protect vehicles from unyielding obstructions. Urban roadways of the same classification require a minimum clearance of 0.5 m (1.5 ft) beyond the curb face unless parking is provided. In this case, no clear zone is required but a setback of 0.6 m (2 ft) is desired.

While there are guidelines for clear zone widths, the designer must also take into consideration site-specific information such as functional class and design speed. The point of this concept is to provide drivers, who have left the roadway due to loss of vehicle control or other reasons, an area in which they should be able to recover control of their vehicle before encountering a fixed obstacle. If removal of these fixed objects is not feasible, there are other alternatives. These include relocation of the obstacle to a safer location, redesign of the object to have breakaway supports if possible, or shielding from the traffic flow by some type of positive barrier. Obstructions that may be hazardous to motorists leaving the roadway should also be clearly marked in an effort to call attention to them. Object markers can be used by roadway designers to indicate the existence of hazards. It is notable that the marking of hazards is placed last in the list of ways of dealing with them. Unfortunately, this last resort is the only option when there is not the money or space to effect the more desirable methods.

Specification of Object Markers. There are three types of markers outlined in the MUTCD (see pp. 3C-1 to 3C-4).[1] These markers are categorized as Type 1, Type 2, and Type 3 (See figure 1 in chapter 1). Type 1 markers incorporate nine yellow reflectors, each with a minimum diameter of 7.6 cm (3 in), symmetrically mounted on an 45.7 cm (18 in) yellow (reflective or non-reflective) or black diamond panel. Type 2 markers may contain either three yellow reflectors, three inch minimum diameter, mounted vertically or horizontally, or an all yellow reflective panel, 15.2 cm by 30.5 cm (6 in by 12 in). Type 1 and 2 markers may be larger if conditions warrant. The Type 1 object marker has three to four times the reflective power of the Type 2 marker, providing more warning to approaching vehicles.[2] The Type 3 marker is a vertical rectangle, 30.5 cm by 91.4 cm (12 in by 36 in) in size, with alternating black and yellow reflectorized stripes approximately 7.5 cm (3 in) in width. These stripes are sloped downward at an angle of 45 degrees toward the side of the obstruction on which traffic is supposed to pass. Better effects can be achieved if wider black stripes are used.[1]

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The location of the hazard plays a major role in the determination of the type of object marker used. When an obstruction is encountered in the roadway, it should be denoted by a Type 1 or Type 3 marker. To emphasize larger fixed objects, such as bridge abutments, to the driver, these objects can be painted with a diagonal stripe pattern, each stripe being 30.5 cm (12 in) wide, similar to those used for Type 3 markers above.[1] Other objects may not be in the roadway but may be close enough to merit a marker. For cases such as these, Type 2 or 3 markers should be used. Examples of these would be underpass piers, bridge abutments, culvert headwalls, and handrails. Also, other conditions such as gores, islands, shoulder drop-offs, and abrupt roadway changes would also warrant markers.

Comparison of Object Markers to Warning Signs. Object markers are similar to warning signs in several ways. They share the same colors, and the Type 1 object marker shares the same shape. However, there are some differences.

First, object markers are placed at the hazardous object, whereas most warning signs are placed far enough in front of the condition to allow the driver to respond to the sign (See table II-1 on p. 2C-2a in the MUTCD). There are a few other warning signs which are placed at the situation to be warned, (Large Arrow Sign [W1-6, W1-7], Chevron Alignment Sign [W1-8], Double arrow sign [W12-1], and No Passing Zone Sign [W14-3]), most of which are among those likely to be used instead of, and possibly confused with, object markers.

Second, Type 2 and Type 3 object markers are rectangular, whereas the large majority of warning signs are diamond shaped. Most of the other rectangular warning signs are usually small supplemental plaques to a larger diamond sign. The largest exception (in surface area) is the runaway truck ramp signs [W7-4 and -4a]. The other two rectangular warning signs, (Large Arrow Sign [W1-6, W1-7], and Chevron Alignment Sign [W1-8]), are likely to be confused with object markers, as mentioned above.

Third, although the Type 1 object marker is diamond shaped, it is the only one not required to have a black border, which may reduce its conspicuity through a lack of contrast.

Positive Guidance. The interaction of positive guidance and object markers was also investigated. The concept of positive guidance is based on the assumption that if competent drivers are given suitable information on hazards, they will be able to take the appropriate actions to avoid them.[7] The intent is to reduce the amount of failures related to information obtained from the roadway environment and increase safe driver performance.

Of the three main levels of the driving task described in this concept, the one which is applicable to marking hazards is guidance. At the guidance level drivers focus on "the maintenance of a safe speed and proper path relative to roadway and traffic elements" (see pp. 1-4).[7] Drivers must see objects in the roadway in order for them to react. Following on these concepts, the placement of object markers should provide drivers with adequate decision sight distance. The detectability of a hazard depends upon its visibility, conspicuity, primacy, and the extent to which the surrounding environment is cluttered with other objects competing for the driver's attention. For roadway hazards, increasing the driver expectancy with the appropriate signing will aid in improving the detectability of the hazards. The objects must also be visible from a distance that allows the driver to take suitable actions to avoid it. Table 1 gives examples of roadside hazards.

Table 1. Fixed object hazards (modified from table 3-2).[7]

• Barriers	• Fences	• Retaining Walls
• Bridge Abutments	• Guardrail	• Signposts
• Bridge Rails	• Guardrail Ends	• Trees, Shrubs
• Bridge Rails Ends	• Inlets	• Tree Stumps
• Bridge Piers	• Light Poles	• Utility Poles
• Culverts	• Mailboxes	• Walls
• Curbs	• Parked Vehicles	

Considering the present project, parked vehicles can be ignored because they are movable, and signposts can be ignored because object markers for them would be redundant (although examples of such exist on the roadways, such as a guide sign with a Type 1 Object Marker on each post). For all other objects, the decision to attach a object marker depends on a number of factors:

1. Size: Size *per se* is not a sufficient factor. A very small object is not dangerous, and a very large object will be easily seen unless it blends into the background.

2. Conspicuity: More important is whether the object can be easily seen. A hole, culvert head, rock, or ditch can be easily screened by grass. A wall or fence can be hard to see if there are many advertising signs nearby. At night the glare from lighted signs or security lights can make invisible an object that is easily seen during the day.

3. Location: A telephone pole in the middle of a curve is more dangerous than one along a straight section of road.

4. Expectancy: A large rock next to the road following kilometers of a road with a wide clear zone might be more dangerous than rocks every few meters.

5. Lethality: A 1.8 t (2 T) rock is obviously more dangerous than a bush, but more subtle gradations exist. For example, striking a single mail box on a steel tube is unlikely to cause injury, but a row of mailboxes mounted on a board and two posts can enter the passenger compartment of a car like a spear when struck.

6. Proximity: The closer the object is to the travel lane, the more a marker is needed.

7. Exposure: A bridge pier without a longitudinal barrier in front of it needs a marker more than a pier behind one.

Other Sources. Investigation of other sources has yielded similar findings. The *Traffic Control Device Handbook* (TCDH), a supplement to the MUTCD, identifies the MUTCD as the manual in which object markers are defined.[2,1] The TCDH gives uses for these markers on pages 3-25 and 5-18. The former page, in Part III, Markings, reiterates the MUTCD and adds that the older method of marking trees with whitewash is insufficient. Unfortunately, in Part V, Islands, it specifies that Type 1 or 2 object markers should be used on median islands (reinforcing this with an illustration) and gives no mention of uses for Type 3 markers in such areas. This would appear to conflict with the guidance of the MUTCD, and its own specifications on page 3-25, both of which specify that Type 1 or Type 3 markers should be employed for this use.

Further sources of information, such as the AASHTO *Roadside Design Guide* and the State of New Jersey *Roadway Design Manual*, offer no direction concerning the placement or use of hazardous object markers.[4,8]

STATE INTERVIEWS

A series of nine telephone interviews with representatives of State highway agencies, knowledgeable in the use of object markers, was conducted to determine how these agencies identify hazards and implement the appropriate marker treatments. Each State was from a separate FHWA region. Specifically, they were: Oregon, California, Wyoming, Nebraska, Texas, Illinois, North Carolina, West Virginia, and New Jersey. It should be noted that a reference is made in the following to practices in Virginia, but these stem from observations of the project team rather that an interview with a Virginia State highway agent. Questions dealt with hazardous roadside conditions, current usage of markers, and their effect on improving roadway safety (see appendix A).

Conditions that highway officials consider hazardous (undesirable) were predominantly any fixed object near the roadway. The most common responses dealt with bridge structures such as railings, approaches, piers, abutments, columns, parapets and narrow bridges. Other responses included drainage structures above the road surface, ditches, guide-rail, sign posts, curbing, median islands and narrowing roadway sections. California also includes object markers in the design of their truck escape ramps.

All States use the markers specified in the MUTCD as their standards. Some States surveyed (New Jersey, and Wyoming) include the Chevron Alignment sign (W1-8) in their inventory of object markers, although they are not contained as such in the MUTCD. These are normally used on sharp curves and will occasionally be accompanied by additional object markers. Many States also use chevrons to delineate pavement width transition areas.

California, New Jersey, West Virginia, and Wyoming use other markers in addition to the ones specified in the MUTCD. While all States include utility poles as roadside hazards, little has been done to delineate them. California, however, has an object marker specifically for poles, consisting of three 30-cm (12-in) strips of yellow reflective sheeting placed horizontally at 0.9, 1.2, and 1.5 m (3, 4, and 5 ft) from the ground. Another non-standard marker type used in California is a combination of the OM-3L and OM-3R, sometimes referred to as "Sergeant's Stripes." This is used where traffic is to proceed on either side of the hazard. It is also used on the noses of crash-attenuators in the Washington, DC area. Other States have used the basic OM-3 pattern in non-standard signs, sometimes enlarging them, sometimes incorporating them with the large arrow signs.

Although no scientific studies had been performed, it was the opinion of seven of the nine highway officials that the object markers currently in use do have a positive effect on improving roadway safety. In instances where improvements have been necessary to reduce the accidents at a particular site, the officials believe the installation of object markers has reduced the accidents to a degree that no further improvements appeared to be necessary. Since these are uncontrolled studies, the positive results might be a regression-to-the-mean effect.[1] In essence, many practitioners use object markers as post-hoc treatments for areas with high accident histories. Frequently, they are not incorporated as part of the original design of roadways.

On the other hand, only four of the nine unreservedly felt the average driver understood object markers. One other official stated he felt that drivers would understand the meaning if the obstruction was obvious.

The final question of the interview was to determine the types of changes officials would like to see in relation to object markers and the standards that govern their usage. One suggestion was the use of barrels to direct traffic away from hazards.

It was also recommended that there should also be some mention about the use of markers on both sides of supports to delineate hazards for traffic in both directions. However, there is a color coding confusion here which can occur on both sides of the roadway but is more dangerous on the left. It has to do with white post-mounted delineators and yellow Type 2 object markers. Edge lines of roads with two-way traffic are white, and post-mounted delineators along them should also be white. Yellow post-mounted delineators are only found on the left where there is one-way traffic, such as a separated highway or an entrance ramp. Placing yellow Type 2 object markers on the left side would make it more likely that drivers would drive next to them when pavement marking was covered with rain or snow. This would place those drivers in the lane of on-coming traffic.

Another proposal was to alter the shape of the Type 1 marker to increase its conspicuity. Also, alternative posts, such as the flexible posts used with some PMD, might be introduced to reduce maintenance costs.

<u>**European Practice**</u>. Information was received from France, Switzerland, and the Netherlands. The International Road Federation lists a warning sign ("Other Dangers") which consists of an upright white triangle with a red border and a black exclamation point (!) inside. In France, at choice points, such as gores or islands, two white triangles pointing left and right on a green background are used. See figure 2. No dimensions are given, but the freeway picture shows the entire panel as approximately 150 percent to 200 percent the

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[1]Statistically, this means "the tendancy for the expected value of one of two jointly correlated random variables to approach more closely the mean value of its set than the other."[(9)] In this case it means the individual <u>predicted</u> accident rates for the 'after' data will be closer to their mean than the individual accident rates for the 'before' data will be to their mean. In a looser sense, it means very poor accident sites one year will likely fare better the next, even if nothing is done. Part of this is due to the statistical model of linear regression, part of it is explained as 'natural law.'

size of the yellow and black chevron nose panel used at the freeway gores in the United States.

The Swiss use a black and white version of the Type 3 object marker at bridge rail ends, abutments, and buildings close to the pavement. This is also used in the Netherlands, specified as 50 cm (20 in) wide and 165 cm (65 in) high with 15-cm (6-in) wide stripes. For medians the Dutch use a blue circle 40 cm (16 in) in diameter with a white border and a white arrow facing diagonally downward, as shown in figure 3. In rural areas the diameter is 60 cm (24 in). In urban areas the post (90 cm or 35 in to the bottom of the sign) is covered with a yellow, 'circular,' reflective panel. (This may mean a reflective tube, which would be visible from all directions and eliminate the 'detached' sign perception that can occur at night.

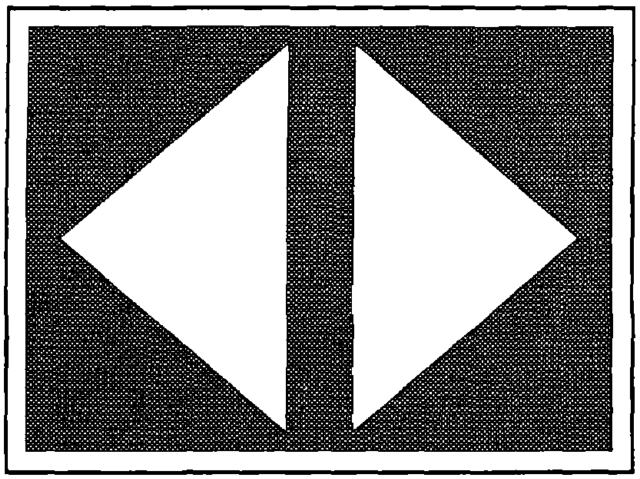


Figure 2. French sign used at gores and choice points. White arrows on green background.

AGE-RELATED CHANGES IN PERCEPTION OF ROADSIDE HAZARDS

There are several factors relating to the difference between older and younger drivers which are of significance to object markers. Markers are intended as an enhancement of the visibility and identifiability of roadside hazards, and the effects of aging change the ability of older drivers to see and identify them. There is an extensive body of research on the changes in ability that result from aging as they relate to driving, much of it specific to perception and cognition.[10,11,12] Most of the studies are not concerned with the specific issue of object markers, but contain many useful insights.

Physiological Changes in the Eye. As the eye itself ages, several changes occur which could affect detection of object markers.[11] The cornea, the major refractive organ of the eye, can become damaged through disease or injury, reducing acuity if it becomes cloudy or scratched. However, these conditions are relatively rare and not part of normal aging.

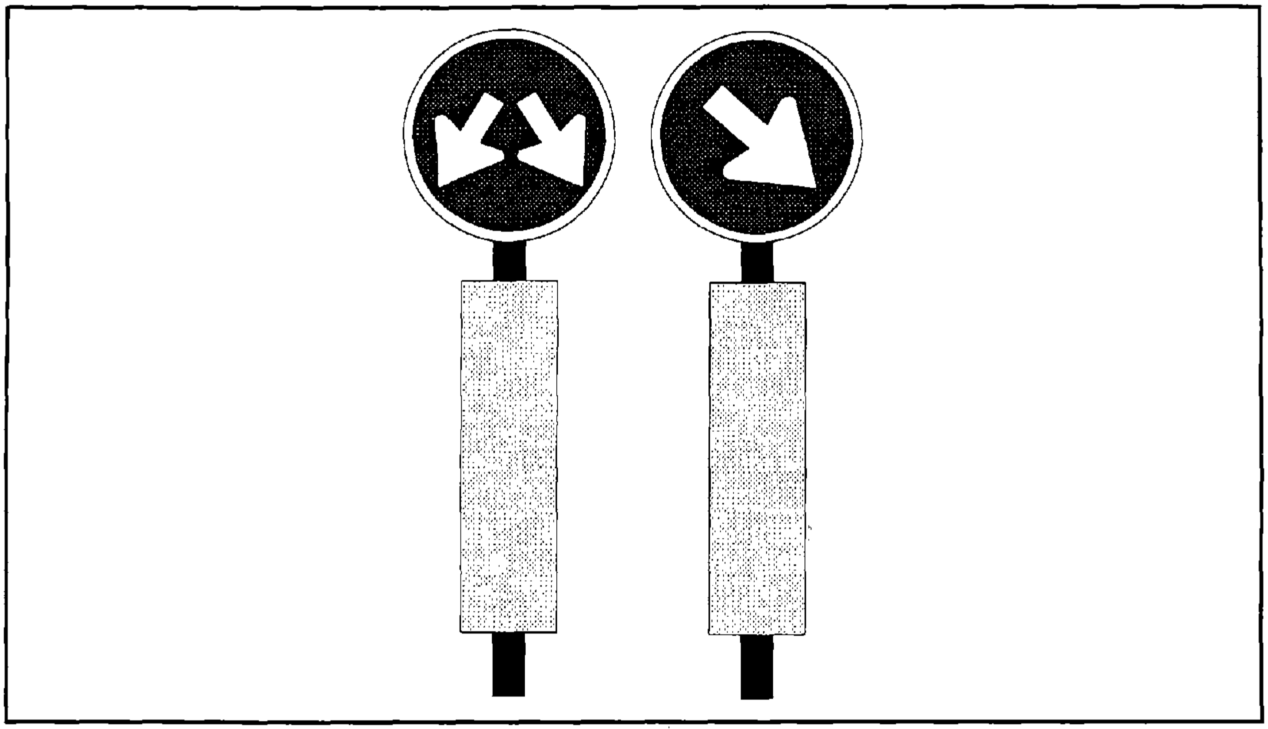


Figure 3. Dutch signs used at choice points such as medians and gores.

Between the cornea and the lens is the anterior chamber, filled with aqueous humor. Abnormally high pressure in this fluid is called glaucoma, and indirectly causes damage to the retina by cutting off the blood supply. Once again, this is a disease rather than normal aging, but is noted here because it is insidious in its progression, such that a number of older drivers may be suffering the beginning symptoms, a loss of peripheral vision, without being aware of it.

In front of the lens is the pupil, which loses its ability to dilate fully as it ages, a condition known as senile miosis. This has its main effect at night, reducing the useful tunnel of vision from headlights below that of younger drivers and making objects in the near periphery impossible to see.

The lens itself loses its elasticity and its clearness with age. The effect of the former is termed presbyopia, and reduces the near-point of the eye. Between the ages of 40 and 50 the main effect is the addition of reading glasses, but by age 70 the average near-point is at 400 cm (160 in), which might affect the time taken to look at the instrument panel, if it could be seen at all.[13] The opacity of the lens, and its accompanying yellowing, reduces both the quantity and quality of light reaching the retina. Cataract, a relatively quicker and much more profound opacity of the lens, can change relatively normal vision to functional blindness in 1 to 5 years.

The vitreous humor of the eye is relatively stable in its effect on functional vision. Although changes do occur, the usual effect is a gradual increase in *muscae volantes*, commonly known as 'floaters,' which are generally ignored by the viewer.

Changes in the retina can be more serious. Aside from the many diseases, mostly circulation related, that can cause damage, Kline and Schieber summarize changes that seem to be age-only related: the accumulation of 'aging pigment,' loss of photoreceptors, misalignment of cone cells (contributing to glare problems), atrophy of the bipolar and ganglion cells (between the photoreceptors and the optic nerve), and atrophy of the retinal capillaries (see p. 301).[14] The functional results of these changes are loss of acuity, lessening of motion detection, and increased susceptibility to glare.

Perception. Many of the issues relating to older drivers concern aspects of perception, including the following:

Field of Vision. Older drivers differ from the general population in field of vision. Older drivers have less peripheral vision than the general population, and often have difficulties, under high task loading, perceiving activity in the periphery of their field of vision.[15,16] Object markers, by definition, are placed on roadside hazards in the periphery of the field of vision of drivers looking forward. When an unplanned diversion such as an encroaching vehicle forces the car off the road, the object markers must be immediately visible to the driver to permit the appropriate avoidance behavior. Therefore, the ability of older drivers to perceive hazards in their periphery must be considered.

Acuity. Older drivers have a decline in their visual acuity, especially when diseases affect their eyes. These declines have also been well documented in the literature, without specific reference to object markers, but sufficiently that appropriate conclusions can be drawn.[14,17] Age-related changes in static acuity and the higher frequencies of spatial vision may not be relatively important in the perception of object markers because they contain no words and no features, save the stripes on the Type 3 object marker. However, most Type 1 and all Type 2 Object markers are small, much smaller than the average road sign, and the age-related reductions in the spatial frequencies between 2 and 8 cycles per degree may reduce the probability of seeing the markers at all.

Conspicuity. Conspicuity appears in the vision and driving safety literature under several definitions. It is often synonymous to detectability.[18] However, a more exact definition includes the concept drawing the observer's attention. Engel regards conspicuity as "an object property in relation to its background."[19] Mace notes that "driver motivation and expectancy should also be considered in any definition of a conspicuous object."[20] These two points of view are both considered by Cole and Hughes.[21] Attention conspicuity is the quality of an object to attract the attention of a subject in the absence of specific instructions to look for the object. A solitary flashing light at night is a prime example. Search conspicuity is the quality of an object to be seen when the subject is actively searching for it. Attention conspicuity is more appropriate in case of object markers because they are low in the driver's hierarchy of what to look for. (Traffic lights and stop signs would be high on the list, perhaps underneath the appearance of brake lights on a leading vehicle).

Search conspicuity is a greater problem for older drivers than for the general population, a phenomenon that has been well documented. Attention conspicuity has received less attention, although Lerner and Dudek found a significant effect in an experiment on crash cushion delineation, even with a fairly young 'older' group (age 51-78).[22] This is to be expected given the acuity and visual field decrements found in older drivers.

Object markers are expected to be even more inconspicuous, since they are small, peripheral, and placed against a jumbled background of roadside vegetation and development. Nighttime conspicuity is enhanced by reflectorized material, and object markers are more conspicuous at night when the headlights hit them, but they may be a problem in daytime.

Legibility. Older drivers have difficulty with small letters, arrows and complex messages which cannot be easily read at driving speeds. Mace recommends increasing the letter legibility standard for highway signs to 4.8 m/cm (40 ft/in).[20] Some of the alternatives to object markers contain arrows and words, but none of the standard markers do. Type 3 markers are angled to indicate the direction to avoid the hazard, a distinction the public is not generally aware of, but that is not an issue of legibility as much as comprehension.

Luminance. Older drivers have more difficulty adjusting to changes in brightness, and will not perceive signs when they have just been approached by oncoming headlights. This could affect their ability to see object markers when they are having difficulty adjusting to the night driving environment and its changes, an issue which should be addressed. Luminance is not an issue in the day driving environment.

Comprehension. There is little evidence in the literature that the public, at any age, fully comprehends the meaning of object markers, even though their behavior is appropriate. Older drivers are less likely to comprehend the meaning of a symbolic sign than a verbal sign. Object markers are non-verbal, but they are also not symbolic.[23] None of the literature reviewed addressed the issue of comprehension of non-symbolic cues.

REVIEW OF METHODOLOGIES IN SIGNING RESEARCH

Several research methodologies have been used to evaluate TCD both in the laboratory and in the field. A representative sample of these studies are tabled in appendix B. Laboratory methods most commonly used include paper and pencil studies, presentations of slides, photographs, and miniature scaled-down versions of TCD, part-task simulator studies, and more realistic interactive simulator studies. Field methods may consist of either controlled studies or observational studies.

SUMMARY AND IMPLICATIONS

Current guidelines recommend a 9.15-m (30-ft) clear zone on the side of high-speed roadways, a 3.1-m (10-ft) zone on rural roads, and a 0.46-m (1.5-ft) clear zone on city streets without parking, but this recommendation is frequently not followed. In many cases, governments do not have the resources to upgrade older roads that are not up to this present standard. The preferred actions are to clear the hazard, move the hazard, protect the traveler from the hazard with a guiderail or a crash cushion, or make the hazard less dangerous, such as with breakaway sign posts. When none of these can be accomplished, the hazard should be marked to help the driver avoid it.

Granted the above, two major questions remain: 1) Do **all** hazards in clear zones have to be marked if they are in the clear zone, and 2) What is the most appropriate marking?

For example, should all telephone poles be marked? All mailboxes? All trees? Or is it reasonable only to sign those hazards which deviate from the norm by being closer to the roadway than the rest? If this is accepted as reasonable, how does the traffic engineer decide which hazards are too close? The most common practice at the present time seems to be based on accident history. If an object has been struck more than once, it is considered a candidate for an object marker. This practice leaves both the public and the engineer with a sense that something has been done, but the effect may be due to regression to the mean, and no rigorous accident studies concerning object-marker use were uncovered in the literature review.

Although an accident analysis was not formally undertaken, the literature that was searched did not imply that older drivers were more liable to strike roadside objects. In fact, older drivers are under-represented in the type of accident most often associated with roadside hazards: single-vehicle, off-the-road, collision-with-fixed-object accidents. However, the low percentage of these accidents among older drivers could be partially explained by the lower tendency of older drivers to drive at night. Also, even if they are under-represented, there are still a sizeable number of deaths associated with older drivers and this type of accident. Data from the 1994 Fatal Accident Reporting System revealed that of all single-vehicle, collision-with-fixed-object, fatal accidents, 9.5 percent of the drivers were 65 or over.[24] This amounted to 978 deaths in 1994.

The findings cited above that older drivers have lower visual acuity, narrower field of view, increased reaction time, and increased processing time suggest that they may be less likely to perceive and consequently react appropriately to object markers.

Perhaps better positive delineation would be more useful than object markers. This opinion recurred several times among the State highway officials and other experts contacted. These engineers felt that it was better to show the driver the proper path rather than the improper path.

There is also a possible confusion among white post-mounted delineators on the left side of the roadway, yellow post-mounted delineators on the right side of the roadway, and yellow Type 2 object markers which can be mounted on the right or left side of the roadway. Granted that post-mounted delineators (PMD) are either one-third or two-thirds the height of a vertically-oriented Type 2 object marker, and granted that delineators always occur in a series whereas an object marker usually stands separately, there is still the possibility that a driver may keep to the right of the object marker under conditions where the road and its striping are obscured, since the general rule for yellow striping and delineation is to keep to the right. If the object marker had been placed on the right, this could result in an accident.

CHAPTER 3. OVERVIEW OF PROBLEM IDENTIFICATION EXPERIMENTS

RATIONALE

The conclusions of the literature review found that experts have varying opinions regarding the marking of roadside hazards, and in fact a wide variety of choices is offered by the MUTCD.[1] The following laboratory studies focused on identifying problems with object markers, particularly for older drivers.

The first study examined the conspicuity of object markers. Many of the objects mentioned in the MUTCD are partially hidden, so one of the uses of object markers is to make the danger more visible; to make the driver aware that there is something to avoid.[1] Experiment 1 measured the conspicuity value of object markers and other signs. Participants looked at a slide of a roadway scene for 2 s, then answered a list of questions about the scene. Detection of a hazardous object was placed near the bottom of a list of questions so the task would be more like attention conspicuity than search conspicuity. Each scene was observed by four groups, each seeing either no marker or one of the three MUTCD object markers.

The second study focused on comprehension of object markers. There are many signs with which object makers could be confused, in fact it could be argued that there are more differences <u>among</u> the object markers than between specific object markers and other signs. The greatest similarity is between the Type 2 object marker and the yellow post-mounted delineator. Participants saw colored scenes with a sign or marker in a booklet. Half of the scenes had object markers. On the facing page was a black-and-white enlargement of the sign/marker and questions on the meaning of the sign/marker and the action required by the driver. Participants also rated the familiarity of the sign and the danger of the scene.

The third study used small groups to explore the possibility of stereotypes in object markers. Small groups of drivers were asked to design and discuss object markers to uncover any general principles about roadside objects and their markers that may exist among drivers, especially older drivers. These designs were then incorporated into the laboratory and field experiments.

ISSUES APPLYING TO ALL EXPERIMENTS

1. When the word 'marker' is used without a qualifier, it refers to post-mounted markers (such as all three types of object markers and post-mounted delineators), not to pavement striping or raised pavement markers.

2. No participants were allowed in more than one experiment, to avoid information from one experiment influencing another.

3. Any driver had to be driving at least three times every week to be allowed as a participant in any of the experiments under this contract. Potential participants

were screened on this point during the first telephone contact. Other than this, drivers were not asked how much they drove.

4. Although each experiment was balanced for gender, no significant sex effects, or interactions involving sex, were expected.

CHAPTER 4. PROBLEM IDENTIFICATION EXPERIMENT 1: CONSPICUITY OF OBJECT MARKERS

The MUTCD implies that all dangerous objects within roadways and any objects too close to the edge of the roadway require signage to aid the driver in avoiding the object.[1] The markers or signs should make the object, or at least the situation, more conspicuous, or 'attention-getting.' Since they are in or near the roadway, they will already be close to the driver's line of sight but may blend into the background or may be less visible due to 'visual clutter' as on urban streets and highways. Highway departments clear these objects as often as is practical, so unless the driver is familiar with the road, they will be unexpected.

Thus, the most important quality of these markers is that they attract the attention of the driver. In keeping with the distinction proffered by Cole and Hughes, this defines 'attention conspicuity,' as opposed to 'search conspicuity.' (The latter means the participant is actively looking for something).[21] Thus it is important that the participant not realize that conspicuity is the main object of the experiment. The instructions to the participant were carefully written to keep the experiment from turning into a search for signs.

To do this, the experiment was introduced as a study of "how drivers presently perceive roadway situations." Participants in a group setting watched a slide of a roadway scene for 2 s, then answered six questions about it. The fifth was, "Were there any immovable objects that should not be hit?" Twenty of the sixty scenes had objects with no marker, or one of the three MUTCD object markers.[1] A participant saw only one version of each scene. Thus for each scene there were four independent groups to compare the effect of the MUTCD object markers on conspicuity.

Objectives. To covertly assess the attention conspicuity of the present set of object markers in a variety of situations.

Methodology. The method was similar to that of Lerner and Dudek's study of crash cushion delineation.[22] Participants, in small groups, viewed 35-mm slides of roadway scenes, presented tachistoscopically, in which an object marker or other sign may have been placed. The tachistoscope was a standard Kodak ™ slide projector with a modified remote control that presented each slide for a 2 s duration, then advanced to a neutral position in the slide tray, which contained a numbered slide corresponding to the page in their answer booklets. This helped ensure accuracy with the data collection.

Half of the scenes were foils and thus did not include an object marker or sign. Participants were told this was a study of how people see and interpret roadway scenes. All scenes were digitized so that those with roadside hazards could be given differing object markers (Although no one person saw the same scene twice). Participants answered a series of multiple-choice and true-false questions about each scene:

1. What type of surroundings were in the scene?
2. How many vehicles were in the lane in front of you?
3. Were there any intersecting streets, roads or ramps?
4. Were there any vehicles at the intersection?
5. Were there any immovable objects that should not be hit?
6. Were there any pedestrians anywhere in the scene?

They were told that the questions were arranged in order of importance to the experiment. After the entire series of slides was shown, the participants were debriefed and informally asked about their experiences with roadside hazards and their opinions about object markers.

Variables.

1. Independent. Markers and signs; age; objects being marked; and road type.

Markers and signs. The only object markers used were Types 1, 2, and 3. None of the 'experimental' object markers identified in the survey of practices were investigated in any of the experiments. However, some warning signs and one regulatory sign that the MUTCD allows as substitutions for object markers in particular locations were included.(1) Additionally, other signs were included that were thought to be easily confused with the object markers (see table 3).

Objects being marked and road type. For the scenes with object markers, twelve situations were selected out of the many possible: bridge piers, abutments, or rail ends; culverts and inlets; utility and light poles; median noses or islands; trees; guide-rail ends; and gores. Examples of each situation were drawn from three different types of roads: Rural, freeway, and urban. The 20 combinations of these situations and road types that were selected for the experiment are some of the most frequently found. However, situation and road type are not fully crossed (see table 2) because some situations do not often appear on some road types. For example, utility poles are not found on freeways, and overhead streetlights are not found on rural roads.

To compare marker types, digitized photographs allowed markers to be added, changed, or removed altogether. This gave excellent experimental control over nuisance variables. If the markers had been changed in the field, the traffic and lighting would not be identical in all four versions. On the other hand, if a participant saw the same scene four times, each with a different treatment, suspicions would be raised regarding the underlying purpose of the experiment. To avoid this the participants were split into four groups, making marker-type a between-groups factor. There were 4 sets of slides of the 20 combinations of object and road type, such that each type of object marker (including no object marker) appeared on each combination of hazard and road type. In each set, a participant saw five scenes with no marker, five scenes with OM-1, five with OM-2, and five with OM-3. Thus a participant saw a mixture of object markers, but when all the data was joined, each combination of object marker, road type, and situation was seen by 15 to 17 participants.

2. Dependent. Conspicuity was initially defined as the percentage of trials where a scene with a particular marker was identified as 'any immovable objects that should not be hit,' *relative* to the same percentage in the same scene when *no* marker was present. [Conspicuity = δP = P(marker) - P(no marker)]. After the fact, however, percentages were so small that this relative percentage had to be discarded.

This changed the dependent variable to nominal-scale variable, i.e., one that only classifies things in groups. Generally, X^2 tests are used to analyze such data, but one of the assumptions is that the observations be independent. In this study, this is only true within each specific scene. When any data involve more than one scene, repeated measures from the participants are involved, and participant patterns that develop in the beginning of the experiment may affect later scenes.

Therefore, although these suspect X^2 tests are still reported in the results section for the sake of the percentages, two other scales were computed which could be more correctly analyzed. A mixed-model analysis of variance was used (between-subjects for age, within-subjects for type of roadway or type of marker). The first scale was the probability of a participant seeing a hazardous object on a particular type of roadway: Urban, Rural, or Freeway. Of the 20 manipulated scenes, 6 were urban, 7 were rural, and 7 were freeway. For each participant and each type of road, the number of objects seen was divided by the total number possible, giving a 'probability seen' score. This allows direct comparison of type of roadway even though the participants saw one less urban scene than rural or freeway scenes. This scale was used to test for age differences, roadway differences, and the interaction of the two.

The second scale tallied the number of the 20 manipulated scenes in which a participant saw a hazardous object. This scale was done for each marker type (none, Type 1, Type 2, or Type 3). Each participant was shown exactly five scenes for each marker type, so 'total seen' was used instead of averages. This scale was used to test for age differences, marker differences, and the interaction of the two.

Unfortunately, there was no way to properly analyze differences among individual scenes. An attempt was made through the CatMod (categorical modeling) Procedure in SAS to use log-linear modeling to directly analyze the counts. However, the number of permutations involved with 20 scenes was too large for any computer, not to mention the enormous number of participants that would be required for such an analysis.

Stimulus materials. Sixty digitized slides of a driver's-eye view of roadways with and without object markers were presented to each participant, although not every participant saw exactly the same set. Object markers were manipulated in 20 of the scenes (33 percent). Signs and markers that are sometimes used instead of object markers, and signs and post-mounted delineator that may be confused with object markers were in 10 scenes (17 percent). Thirty other scenes (50 percent) were included to distract the participants from the real intent of the study.

Before the scenes were digitized, photographs were taken from several distances. Distances between 30.5 and 91.5 m (100 and 300 ft) were used in a similar study on crash cushion delineators.[22] In the present study, 30.5 m (100 ft) was selected to minimize the possibility of a 'ceiling' or 'basement' effect (where everyone sees the sign or no one sees the sign, respectively). This distance was also the closest point at which hazards on both sides of the road could fit in the picture, and even then, two scenes (freeway bridge columns and freeway bridge rail ends) were probably narrower than average for their situations. But had a longer distance been used, Type 2 markers would have been too hard to see, especially for the older participants.

Object marker slides (20). Combinations of road and situation used are indicated by an 'X' in table 2. These combinations are thought as being fairly common while still exploring the wide range of possible in-road and roadside objects. However, some exceptions to this general principle were made. The freeway inlet and the urban culvert were not as common as other situations but were included to have a low-lying hazard for each roadway type. Utility poles, street light poles, and trees are rarely marked outside of high accident locations but were included because of the large number of collisions involving them.

Four slides were made of each combination, one for each type of object marker, and one with no marker. These were mixed into 4 sets of slides, each set having all 20 combinations, with 5 of each type of object marker and 5 with no marker. These slide groups are labelled by color names in table 5 and elsewhere. These combinations allow comparisons of object markers in the same scene without any participant seeing the same scene more than once.

The markers were positioned on the object or post according to the MUTCD (pages 3C-1 and 3C-2).[1] Mounting height was 1.22 m (4 ft) above the surface of the nearest traffic lane. For roadside objects, the near edge of the marker was aligned with the near edge of the object. Even though Type 1 object markers are not supposed to be used on the side of the road, and Type 2 object markers are not supposed to be used in the middle of the road, these situations were included. Markers on islands were centered in the island as pictured on page 5-20 of the TCD Handbook.[2] All Type 1 and 2 markers were represented as covered with sheeting rather than reflective buttons. Experiment 2 investigated sheeting versus button effects.

The lateral offset of roadside objects that are regularly marked varies greatly between freeways and rural roads. Piers and abutments on interstate highways may be 6.1 m (20 ft) or more from the roadway and still be marked, whereas mailboxes, trees, and utility poles within 0.61 m (2 ft) may remain unmarked on rural roads. In order to minimize the differences in the size (visual angle) of the markers in the slides, freeway sites were chosen where the offset was 4.6 m (15 ft) or less.

Table 2. Combinations of hazards and roadway type used in the conspicuity study. An 'X' indicates the combination was used.

Hazard Situation	Side	Freeway	Rural	Urban
Bridge Pier	Both	X		
Bridge Abutment	Both		X	X
Bridge Rail End	Both	X	X	
Inlet	Right	X		
Culvert	Both		X	X
Street Light Pole	Right	X		
Utility Pole	Right		X	X
Median Nose or Island	Left		X	X
Tree	Right		X	X
Guide-rail End	Right	X		
Guide-rail End	Left	X	X	
Gore	Left	X		X

Substitute signs or markers. Signs or markers allowed as substitutes for object markers, or possibly confused with object markers were included in the stimuli. Each participant saw all of the signs. Only the delineators appeared in series. The two construction devices, vertical panel and Type II barricade, were next to a single object. It was decided not to use drums as they are almost always used as channelizers, and are so much larger than object markers that it would be unlikely the two would be confused. See table 3.

Foils (Distractor Slides). Thirty foils were included, three of each combination in table 4 below. Each scene was different, with a variety of other vehicles and pedestrians in some of them to maintain the distractor task given to the participants.

Table 3. Selected signs or markers that are allowed as substitutes for object markers, or possibly confused with object markers.

Sign or delineator	Situation	Road Type
Keep Right (R4-7 in MUTCD)	Median	Rural
Large Arrow (W1-6)	Right Turn	Urban
Large Arrow (W1-7)	T-intersection	Rural
Chevron Alignment (W1-8)	Left Turn	Rural
Divided Highway (W6-1)	Median	Urban
Double Arrow (W12-1)	Median	Urban
Type II Barricade (§6C-8) (Orange/White)	Construction	Urban
Vertical Panel (§6C-5) (Orange/White)	Construction	Freeway
Delineators (§3C-4) (Yellow-left)	Lane Reduction	Freeway
Delineators (§3C-4) (White-right)	Left Curve	Rural

Table 4. Classifications of distractor slides (foils). (There were 3 slides for each category in the table, for a total of 30 separate scenes.)

Road Type	Intersection/Exit/Entrance present?
Freeway	Yes
Freeway	No
Rural	Yes
Rural	No
Urban	Yes
Urban	No
Arterial	Yes
Arterial	No
Residential	Yes
Residential	No

Recruitment procedures for test participants. Participants were recruited from the participant pool, from organizations involved with older adults and through bulletins at meeting places of older adults. All groups in this experiment met at a site mutually convenient to its older members.

Number and age grouping of participants. There were 63 participants in all, 15 in the 20 to 40 year-old comparison group, 24 in the 65 to 69 year-old group, and 24 in the 70 and older group. This concentrated resources in the age ranges of greatest interest. Each age group was balanced by gender. In a typical session, a group contained eight people, made up of six older people and two younger people from the control group.

Table 5. Age, gender, and slide group of the 63 participants. (Slide group refers to the mix of scene and type of marker).

N	Age Group	Gender	Slide Group
4	20 - 40	2 males, 2 females	Blue
3	20 - 40	1 male, 2 females	Red
3	20 - 40	1 male, 2 females	Yellow
5	20 - 40	3 males, 2 females	Green
6	65 - 69	3 males, 3 females	Blue
6	65 - 69	3 males, 3 females	Red
6	65 - 69	3 males, 3 females	Yellow
6	65 - 69	3 males, 3 females	Green
6	70 plus	3 males, 3 females	Blue
6	70 Plus	3 males, 3 females	Red
6	70 plus	3 males, 3 females	Yellow
6	70 plus	3 males, 3 females	Green

Experimental protocol. Once the group had gathered, the experimenters introduced themselves and explained that they were studying how people see and interpret roadway scenes. They then handed out the answer booklets which had an informed consent as a cover sheet. They read over the consent form, had the participants sign, address, and date it, then gave the detailed instructions (see appendix C).

Participants were presented with roadway scenes in slide format. Each scene was shown for 2 s. After each slide was shown the participants were to answer six questions about its content (see appendix C). However, the answers to question number 5, "Were there any immovable objects that should not be hit; if yes, what were they?" were most important. The additional questions were necessary to provide realism to the task. The experimenter read through each question explaining what type of information to include. Although each slide was only shown for a duration of 2 s, participants were given as much time as needed to complete the six questions about each slide. They usually finished in 50 to 60 s.

After the instructions and a chance for questions, 20 example slides were shown twice, first slowly for the examples and second in real time for practice.

After the practice slides were presented, the actual data slides were shown in their entirety with a slight pause after slide 40 to change slide trays and provide participants with a short break.

At the end of the slide presentation, participants were given a single sheet containing a solidary OM-3 and asked in which direction would they travel if they could see only the sign and no roadway clues. The rationale for and results of these data are presented in Problem Identification Experiment 2. Last there was a debriefing, along with a short discussion with all the participants about the problems of marking hazards.

PROBLEM IDENTIFICATION EXPERIMENT 1 RESULTS: CONSPICUITY OF OBJECT MARKERS

Scenes with selected hazards. Twenty scenes contained selected hazards that were treated either without a marker (condition 0), or with a Type-1, Type-2, or Type-3 MUTCD-approved marker (conditions 1, 2, and 3 respectively).

Marker effects. The markers made small and insignificant differences in hazard identification, as shown in table 6. Of the 1,260 exposures (63 participants times 20 scenes per participant), there were 456 correct answers. Although the no-marker condition was worst and the largest marker (Type 3) was best, the other two markers were not in the expected order. The smallest (Type 2) had more correct than the diamond (Type 1).

Table 6. Overall marker effects for the question, "Were there any immovable objects that should not be hit?"

	Type of Marker[1]				
	No marker	Type 1	Type 2	Type 3	Total
Number Correct	100	113	114	129	456
Percent Correct	33%	33%	38%	40%	36%
Number Incorrect	200	227	186	191	804
Percent Incorrect	67%	67%	62%	60%	64%
Total	300	340	300	320	1,260

[1]There were no significant differences among marker conditions (X^2= 5.13, *df*= 3, $p > 0.05$).

Age effects. As seen in table 7, age effects were much larger, and in the expected direction. Tests on the next page show the youngest group was significantly better than either of the older groups, which were not different from each other.

An analysis of variance on the 'total seen' score revealed significant age effects (F= 7.95, *df*= 2/60, p= .0009), but a barely significant marker effect (F= 2.71, *df*= 3/180, p= .0466), and no interaction between the two factors. Since figure 4 shows some decrease from the younger old group to the older old group, another analysis was run with just those two groups. There were no significant effects, even for type of marker.

Scene Effects. As expected, the hazard in the scene had major effects on perception, with larger, closer objects more easily perceived as something that should not be hit, compared to low objects. When strictly scored, percentage correctly seen ranged from 0 (freeway inlet, urban culvert) to 82 (rural bridge abutment). The percentages given in tables 6, 7, and 8 are based on a looser definition. A marker perceived as a hazard was sufficient because it alerted the driver to a danger. Therefore, a person was given credit for the answer 'sign' if there was a Type 1, 2, or 3 marker present in the version of the scene she or he saw, and there was no other sign in the scene. For instance, in the rural culvert scene there was a 40 mi/h (64.4 km/h) sign, so credit for a 'sign' answer could not be given since the participant might have been referring to the speed limit sign, not the marker.

Table 7. Overall age effects for the question, "Were there any immovable objects that should not be hit?"

	Age Group[1]			
	20-40	65-69	70+	Total
Number Correct	157	159	140	456
Percent Correct	52%	33%	29%	36%
Number Incorrect	143	321	340	804
Percent Incorrect	48%	67%	71%	64%
Total	300	480	480	1260

[1]There were significant differences among age groups ($X^2 = 46.06$, $df = 2$, $p < 0.001$).

In table 8, scenes are listed in "percent correct" order, highest first. Slide number refers to order within the session. It is included to show there are no obvious order effects. 'Best marker' columns show which marker (0 means no marker) was identified most as a hazard. Multiple numbers, i.e. 1/2/3, indicate ties. Any statistical significance is given in the 'Notes' column. References to City (Urban), Country (Rural), Freeway, Arterial, and Residential refer to answers to question 1, "What type of surroundings were in the scene?" They are included to show that the concepts of Freeway and Arterial were not successfully taught, and that the 'Urban' culvert was not accepted as urban. The X^2 analyses within each scene are appropriate because each is based on 63 independent observations. However, note that among 20 separate tests, on the average one test would commit a Type 1 error, i.e. indicate spurious differences.

Marker effects within scenes. Of the 20 scenes, only 4 had significant effects where a marker was better than no marker (Rural Bridge Abutment, Urban Culvert, Freeway Inlet, and Rural Median Nose). On the other hand, in the Freeway Bridge Piers scene, the hazard was correctly identified with no marker significantly more than with any marker.

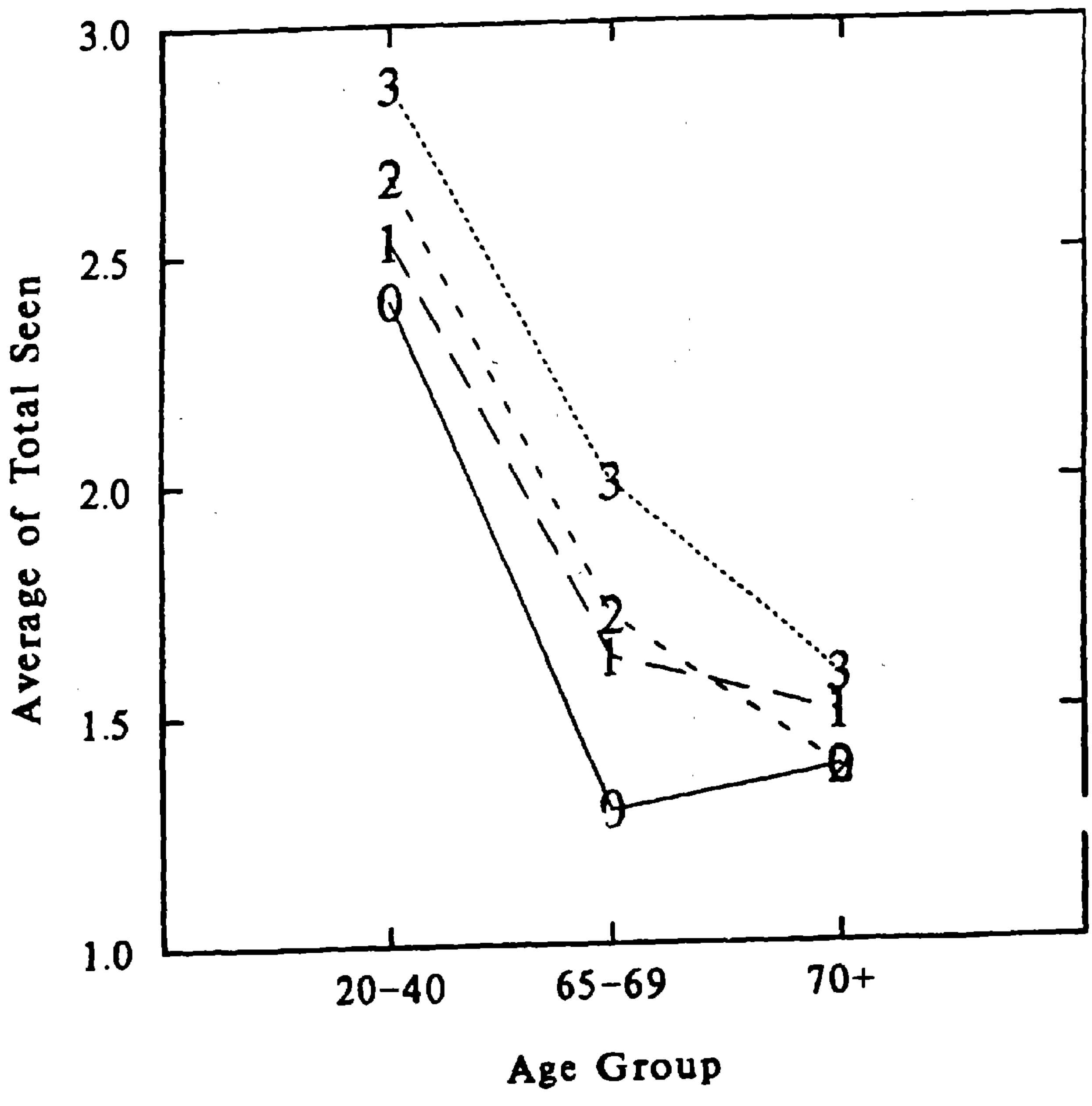


Figure 4. Averages of 'total seen' scores, broken down by age and marker type. (No marker is symbolized by 0, and 1, 2, or 3 refer to MUTCD(1) object marker type).

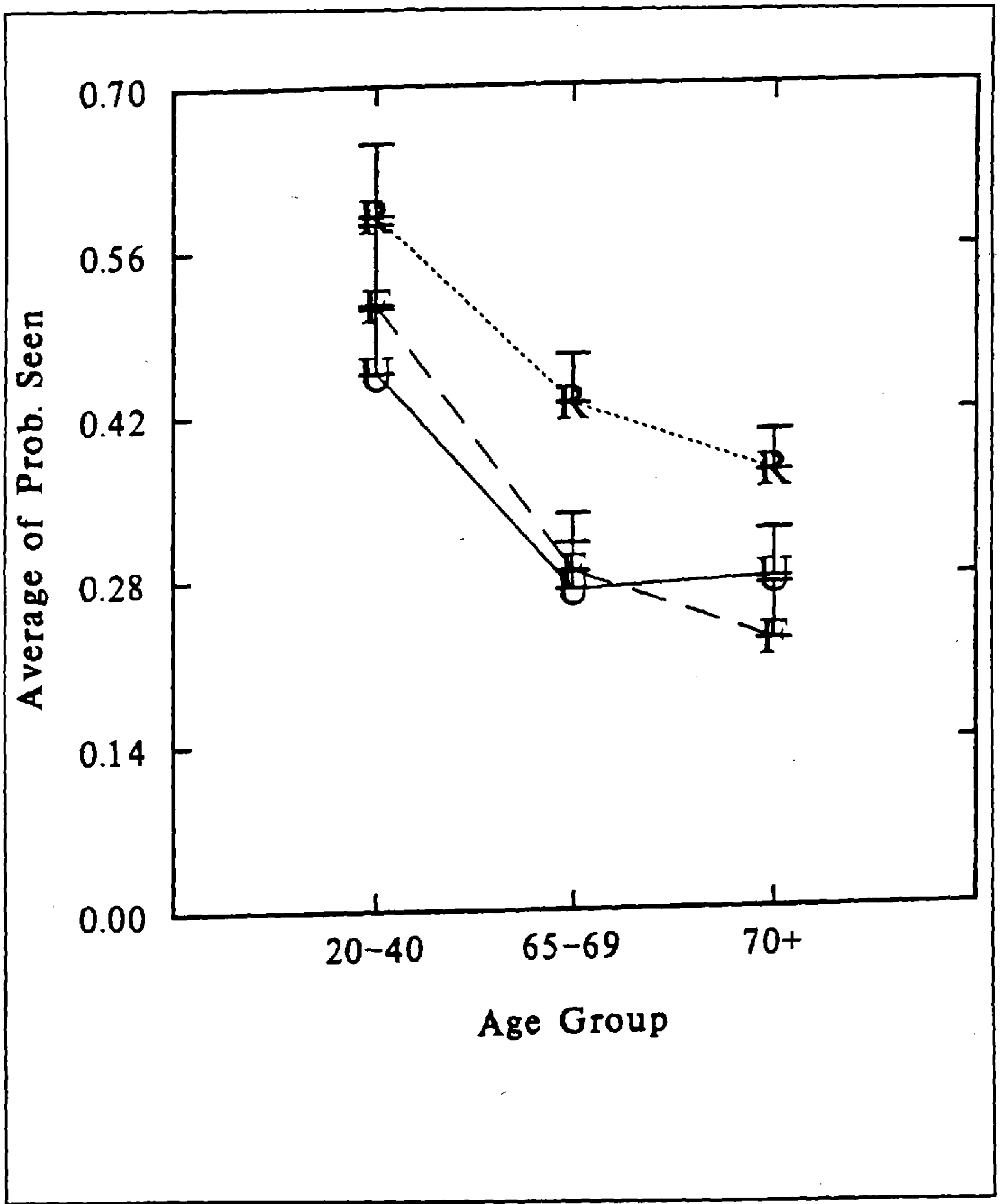


Figure 5. Probability of identifying a hazardous object, by type of roadway and age group. (R, U, and F mean rural, urban, and freeway respectively. One-sided error bars are 1.0 standard error of the mean wide).

Table 8. Breakdown of the 20 manipulated scenes.

Scene description	**Percent Correct**	Slide Num.	Best marker, by age 20-40	65-69	70+	Notes
Rural Bridge Abutment (both sides)	**83**	24	1/2/3	1/3	1	"Country" selected by 94%. This was the only scene where each marker was significantly better than no marker (X^2= 14.99, *df*= 3, *p*= 0.002).
Rural Tree (right)	**78**	9	1/2/3	1	0	"Country" selected by 95%.
Rural Utility Poles (both sides)	**73**	54	2/3	0/2	2	"Country" selected by 95%. For 65-69, Type 2 sig. worse than nothing. Over all age groups, Types 2 and 3 were significantly better than Type 1 (X^2= 9.51, *df*= 3, *p*= 0.023).
Urban Bridge Abutment (both sides)	**65**	1	3	0	1	"City" selected by 49%, "Arterial" by 35% The 65-69 group which saw the Type 1 diamond missed 5 of 6 (X^2= 11.90, *df*= 3, *p*= 0.008).
Freeway Bridge Piers (both sides)	**63**	47	0/1	0	0	48% said "Freeway," 38% said "Arterial." Over all ages, No marker (0) was significantly best (X^2= 8.42, *df*= 3, *p*= 0.038).
Urban Median Nose (Left)	**46**	18	3	3	3	25% said "City," 29% said "Arterial," but another 41% said "Residential". In this scene and all those below, over half of the participants saw no hazard.
Freeway Street Light Pole (Right)	**40**	38	0	1/3	1/3	60% said "Freeway," 37% said "Country."
Freeway Guide Rail End (Right)	**38**	34	2/3	2	3	63% said "Freeway," 24% said "Country." Over all ages, Type 2 was better than Type 1 (X^2= 10.22, *df*= 3, *p*= 0.017).
Rural Bridge Rail End (Both)	**33**	29	3	0	0	95% said "Country." No marker was as good or better than any marker.
Rural Guide Rail End (Left)	**33**	15	3	1	0/3	98% said "Country." Type 2 was significantly better for the 65 to 69 year-old group (X^2= 9.78, *df*= 3, *p*= 0.021). Many participants also appropriately identified trees as hazards.
Freeway Bridge Rail End (Both)	**30**	11	1/2	3	1	76% said "Freeway," 16% said "Arterial."
Urban Tree (Left)	**29**	26	2	2	3	75% said "City," 13% said "Residential."

Table 8. Breakdown of the 20 manipulated scenes (continued).

Scene description	Percent Correct	Slide Num.	Best marker, by age: 20-40	65-69	70+	Notes
Freeway Guide Rail End (Left)	**25**	22	1	2	1/2	92% said "Freeway," 6% said "Arterial."
Urban Utility Pole (Right)	**25**	3	3	1	0/2	62% said "City," 27% said "Arterial." The Type 1 marker worked best for the 65 to 69 year-old group (X^2= 10.86, *df*= 3, *p*= 0.012).
Freeway Gore (Left)	**16**	6	2	3	2	62% said "Freeway," 22% said "Arterial." Since the gore had an EXIT sign on a large post, "pole" was also accepted as correct. Otherwise, only one participant gave the correct answer. Type 3 was significantly better for the 65-69 group (X^2= 8.00, *df*= 3, *p*= 0.046).
Urban Gore (Left)	**14**	41	1	1	1	97% said "City." Bridge abutment (1 case) or median nose (3 cases) were also accepted as correct. Over all age groups, Type 1 was significantly better than Type 2 (X^2= 10.34, *df*= 3, *p*= 0.016).
Urban Culvert (Both)	**11**	58	1/2	1	1/2	Only 6% said "City." 48% said "Residential" and 40% said "Country." Over all age groups, Type 1 was significantly better than no marker (X^2= 8.32, *df*= 3, *p*= 0.040).
Freeway Inlet (Both)	**10**	50	2/3	3	2/3	71% said "Freeway," 13% said "Arterial," and 16% said "Country." Over all age groups, Type 3 was significantly better than Type 1 or no marker (X^2= 8.48, *df*= 3, *p*= 0.037).
Rural Median Nose (Right)	**8**	31	3	3	3	73% said "Country." As above, Type 3 was significantly better than Type 1 or no marker (X^2= 9.97, *df*= 3, *p*= 0.019).
Rural Culvert (Both)	**3**	43	0	2	--	No one in the oldest group saw the hazard or the markers, so no marker was best. 97% said "Country."

Also, where the marker could have been said to be useful in the four scenes listed above, in the three of the four the markers did not do the job well. The <u>best</u> marker in Urban Culvert, Freeway Inlet, or Rural Median Nose only identified an object 38 percent of the time. The type of <u>hazard</u> (one which is large, solid, or tall) was most important in identifying a scene as containing a hazard. The markers themselves have small effects at best.

Scene and age effects. Objects in freeway scenes were much better identified by the 20 to 40 group than either older group. The younger group was usually well over 50 percent while the older groups were around 20 percent. This was also true for the rural guide rail end, rural bridge rail end, urban median nose, and urban tree. Exceptions were the freeway bridge piers, which over half of every group identified, and the freeway inlet, which was next to the lowest overall. Table 8 also shows scene-specific marker differences for the 65 to 69 age group. These results cannot be trusted. It was suspected that a "good" group (more likely to identify a hazard) was showing up in different situations because in one scene the Type 1 marker would be best, in another the Type 2, and so on. An analysis of variance using number correct per scene by color group rather than by marker was highly significant for this age group, revealing two good groups that were identifying many hazards regardless of which marker they saw, and one bad group that was identifying few hazards, regardless of which marker they saw. Thus age-group by scene by marker interactions in table 8 (all of which involved the 65 to 69 year-old group) should be ignored.

Comparisons between similar scenes. Where there were rural and urban versions of the same hazard, the rural one sometimes was seen more often, such as the rural tree (49 of 63 participants identified it) versus urban tree (18 of 63), $Z= 5.59$, $p_{(two\text{-}tailed)} < .001$, and the rural utility poles (both sides) (46 of 63) versus urban utility pole (right side) (16 of 63), $Z= 5.39$, $p_{(two\text{-}tailed)} < .001$), but it was sometimes seen less often, such as the rural median (5 of 63) versus the urban median (29 of 63) $Z=-4.83$, $p_{(two\text{-}tailed)} < .001$). Note that the Z tests in this paragraph are based on data that are not completely independent. Some of the counts come from repeated measures on the same participant. If the repeated measures had the effect of making successive answers similar to previous answers, it would follow that the comparisons in this paragraph would be less likely to show differences.

Looking at the bridge-rail ends and guard-rail ends (five in all), which ranged from 16 of 63 for the freeway guard rail end (left) to 24 of 63 for the freeway guard rail end (right), there were no significant differences at all. Finally, the freeway light pole (right) (25 of 63) was not significantly better than the urban utility pole, but was significantly worse than the rural utility poles (both sides) (46 of 63), $Z= 3.81$, $p_{(two\text{-}tailed)} < .001$. Not only the extra pole but also the uncomplicated background helped the conspicuity in the rural scene.

Type of road and age effects. Scene effects are admittedly idiosyncratic. The 'probability seen' score groups data by roadway and acts as a counterpoint to the 'total seen' scores which showed no marker effects. If marker effects and roadway effects were both insignificant, the argument could be made that the method used was insensitive. However, as can be seen in figure 5, there were significant roadway effects ($F= 15.06$, $df= 2/120$, $p= .0001$). Visual inspection of the means leads to the conclusion that hazards are easier to see in rural scenes, compared to urban or freeway scenes. The age effect ($F= 7.92$, $df= 2/60$, $p= .0009$) is almost identical to that seen for the 'total seen' scores. This is to be expected because both sets of scores are different views of the same data. There was no interaction between the age factor and the roadway factor. Thus the specific interaction regarding older drivers and freeway hazards was not supported.

As with the 'total seen' scores, the two older groups were compared alone. As before, they were not different, but there was still a roadway effect ($F = 15.36$, $df = 2/92$, $p = .0001$).

Example effects. Participants saw a tree, a median, bridge piers, a culvert, and a building as examples of roadside hazards before seeing the slides they were to rate. Were participants more likely to identify those examples? Evidence says not. Bridge piers were detected 63 percent of the time, but bridge abutments, not given as an example, were detected 74 percent of the time. They detected trees 48 percent of the time, not significantly different from 42 percent for poles. Culverts, even though given as an example, were detected (as culverts) less than 1 percent of the time.

Supplemental analyses. The lack of effect for 'type of marker' was unexpected, given the large size and shape differences among the markers, not to mention the lack of a difference between any marker and no marker. To insure that the participants were giving reasonable answers in other areas, several other aspects of the data were investigated.

Gender effects. Male/female differences varied. There were no differences for answers to the surroundings-question (1), the number-of-vehicles-in-lane question (2), or the intersecting-streets question (3), but females were more likely to see a vehicle, given they saw an intersection (question 4; $X^2 = 5.6$, $df = 1$, $p < .05$). On the most important question, (5, "Were there any immovable objects..."), there were no differences on answers to slides that contained the selected hazards, but on the foils and confusions, there were several very significant differences, as shown in table 9 (overall $X^2 = 111$, $df = 14$, $p < 0.001$). It must be noted that the repeated measures here tend to accentuate statistical errors of Type I. A participant seeing a fence in one scene may be more likely to see one in a later scene. Thus the gender differences presented here should be independently corroborated to insure their validity. Women were more likely to identify a hazard in general, and more likely to identify signs, sign posts, mail boxes, curbs, and guard rail ends as hazards in particular. Men, as opposed to women, were more likely to identify poles or a bridge abutment as a hazard. Concerning the pedestrian question (6), there were also no gender effects.

The pedestrian question. Overall, the answers to question 6 were quite reasonable and within the range expected. One of the reasons this question was chosen for further investigation was it was a simple yes-no question. Also, pedestrians occurred in a large number of scenes, but not so many that participants would guess one was there when one was not. Of the 60 scenes, 14 had pedestrians, 2 of which were also selected hazard scenes. They were distributed realistically across the type of surrounding: 8 Urban, 4 Residential, 1 Arterial, 1 Rural, and 0 Freeway. The percentage of hits was reasonable given it was presented as the least important question, and the number of false alarms was very low, indicating the participants were conservative in saying they saw something (see table 9). The few false alarms were concentrated in four scenes. One had a mailbox that could have been interpreted as a pedestrian, one had an advertisement that resembled a pedestrian, and the other two had some dark shadows and immediately followed scenes with conspicuous pedestrians. As mentioned previously, there were no gender effects on this question.

Table 9. Gender differences in hazards seen in confusion and foil scenes.[1]

Hazard	No answer	Trees	Poles	Guard Rail Ends	Bridge Abutments	Bridge Piers	Medians	Sign or Sign Post
N Female	759	123	93	15	6	14	41	253
N Male	839	108	131	5	22	17	27	110
Z-score[2]	2.30	ns	2.70	-2.14	3.11	ns	ns	-6.83
Total	1,598	231	224	20	28	31	68	363
Hazard	**Buildings**	**Mail Boxes**	**Guard Rails**	**Fences**	**Walls**	**Curbs**	**Missing**	**Total**
N Female	22	46	23	44	21	51	392	1905
N Male	17	19	35	30	16	28	431	1835
Z-score[2]	ns	-3.36	ns	ns	ns	-2.40	ns	$X^2=111$
Total	39	67	58	74	37	79	823	3,740

[1]Counts from the 20 manipulated hazard scenes are not included here. Items with less than five occurrences have been omitted. Z-scores are from the test for differences between two proportions. See statistical note in text. Negative Z-scores mean women identified the hazard more than men.
[2]A Z-score of ± 1.96 is significant at $p=.05$, one of ± 2.58 is significant at $p=.01$ (two-tailed tests).

Table 10. Responses to pedestrian question

	Participant said		
Pedestrians were:	Present	Absent	Total
Present	Hits 367 41.6%	Misses 515 58.4%	 882 23.3%
Absent	False Alarms 43 1.5%	Correct Rejections 2,885 98.5%	 2,898 76.7%
Total	410 10.8%	3,370 89.2%	3,780 100%

Age-group effects. The 20 to 40 age group saw 60 percent of the pedestrians, the 65 to 69 group saw 40 percent, and the 70 and older group saw 32 percent. Overall this was highly statistically significant ($X^2 = 39.93$, $df = 2$, $p < 0.001$). These effects were to be expected from the literature.

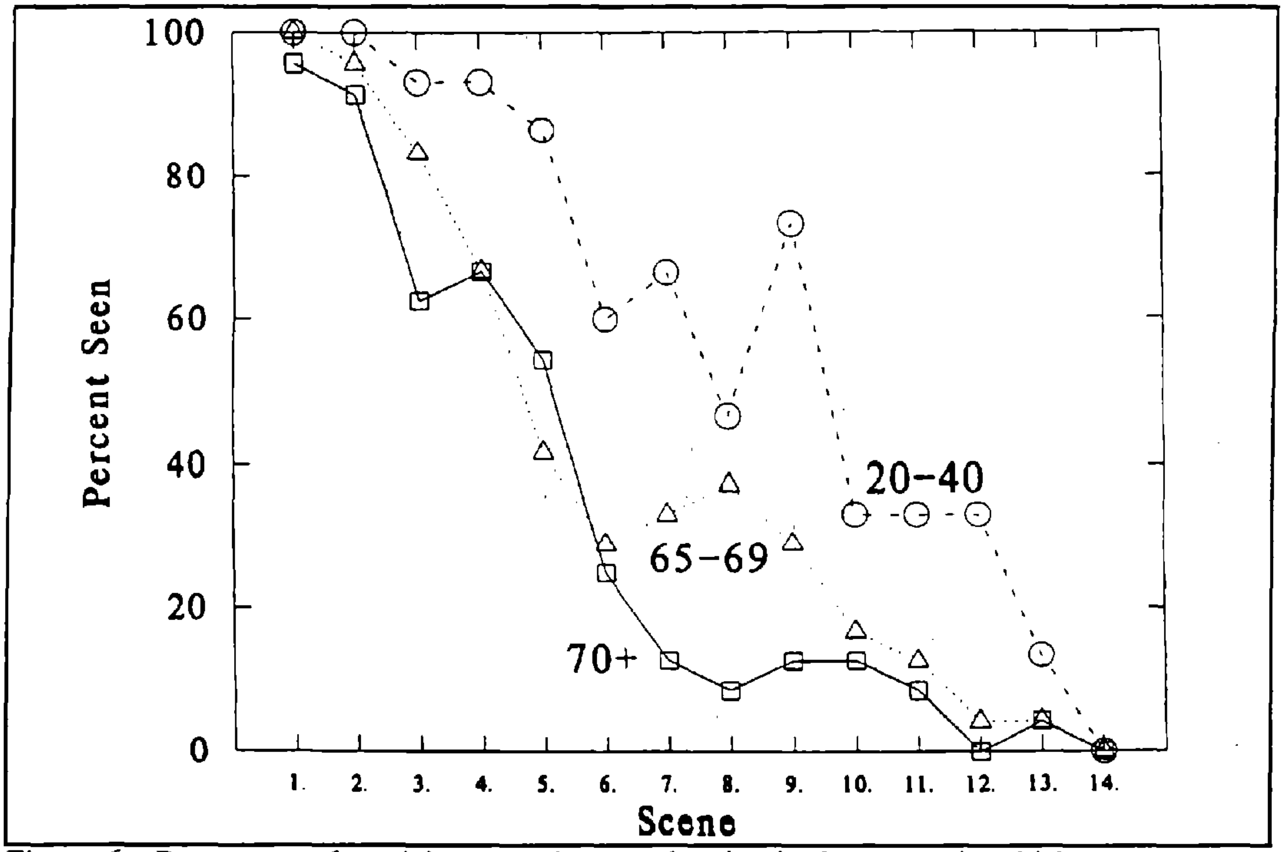


Figure 6. Percentage of participants seeing a pedestrian in the scenes in which one was pictured. (The scenes are ordered by the overall percentage seen and the data are broken down by age group).

Scene effects. Scene effects were large, because no attempt was made to regulate the pedestrians in the scene ($X^2 = 367.32$, $df = 14$, $p < 0.001$). They occurred in varying numbers, at varying distances, illumination, and peripheral angles, and against differing backgrounds, which sometimes showed only parts of them. The easiest scene was an urban intersection with two women crossing in the center of the picture with good contrast to the background. Everyone but one participant in the 70 and older group saw them. The hardest scene was a rural scene with a single pedestrian far to the right, back to camera, and in shadow. No one saw her. Expectancy may have played a part here since this was the only rural scene with a pedestrian. Differences across scenes and age groups are shown in figure 6.

Scene by Age interactions. Generally, age-group effects were constant over the different scenes, although there are some differences. Scene 3, with three small boys on bikes, may have been relatively harder for the 70 and older group due to the figure/ground effect. The boys are not as easy to pull out of the background as the two adults in scene 2. The same effect may account for the differences in scene 9, where a man is fully visible, but is standing at the point where one car ends and another begins.

Other hazards identified. Since question 5 was open-ended, once the participants decided they had seen a hazard, they gave a representative sample of other objects beside the tree, median, bridge piers, culvert, and building used as examples. Sign or sign post was the most common category with 363, even more common than trees (231, or 294 including the two object marker scenes with trees) or poles (224, or 307 including the three object marker scenes with poles). Mailboxes were frequently identified as dangerous in rural and residential foils (72 times).

Median noses were identified 36 times in the foils and 24 times in the confusions. Looking at the number of times 'median nose was' identified as a hazard, the KEEP RIGHT sign and the DOUBLE ARROW signs fell between the rural and urban object-marker/median scenes, showing there are reasonable alternates to object markers for treating median noses.

Longitudinal hazards were often identified: Curbs, 79 times plus an additional 17 times in the manipulated scenes; fences, 74 times plus an additional 41 times in the manipulated scenes; guide rails or bridge rails (not ends), 58 times plus an additional 10 in the manipulated scenes; and walls or barriers, 37 times plus an additional 6 times in the manipulated scenes. Thus even though they were placed near the road to protect the driver from a greater danger (in the case of guide rails and New Jersey walls) longitudinal barriers were still perceived as dangerous by the participant.

Discussion. In general, hazard markers seem to have very little effect on participants' perception of hazards. They have their greatest effect, if any, on objects that are already conspicuous, such as trees, poles, and bridge abutments or piers. They have little or no effect on objects where they are most needed, such as culverts.

Was the methodology faulty? The evidence in the pedestrian question refutes that. The order of the various pedestrian scenes fit with what is known about conspicuity (large objects with good illumination and contrast in the central field with an uncluttered background are easiest to see), and the age differences found in the pedestrian question are also found in the 'immovable object' question. Aside from the lack of effect of the markers, the data seem very reasonable.

CHAPTER 5. PROBLEM IDENTIFICATION EXPERIMENT 2: COMPREHENSION OF PRESENT OBJECT MARKERS AND CONFUSION WITH OTHER WARNING SIGNS, POST-MOUNTED DELINEATORS, AND CONSTRUCTION SIGNS

Rationale. As discussed in the literature survey, object markers may be useful to drivers even though the drivers cannot identify specifically what the purposes of the object markers are. Even so, confusion among the present object markers and confusion between them and other warning signs or post-mounted delineators should be studied. If confusions exist and different actions are required, then redesign is essential. On the other hand, if confusions exist and different driver actions are not required, perhaps the sign that conflicts and is less useful could be eliminated.

Objectives.

1. To identify what the present signs mean to drivers, and how they affect their driving;

2. To uncover confusions among signs, especially the following:
   a) Orange and white striped vertical construction panel (p 6C-6, figure 6-14 in MUTCD);[1]
   b) Orange and white striped Type II barricade (p 6C-6, figure 6-14 in MUTCD);
   c) The double-arrow sign (W12-1);
   d) The large arrow signs (W1-6, W1-7);
   e) Chevron alignment sign (W1-8);
   f) Post-mounted delineators (pages 3D-1 through 3D-3 in MUTCD);
   g) Divided highway (road) sign (W6-1); and
   h) The related symbolic regulatory sign 'keep right' (R4-7).

3. To compare differences between the appearance of reflective buttons and sheeting for Types 1 and 2 object markers.

4. To see if participants understood the directional information on the Type 3 object marker when no context was available.

Methodology. The data for this experiment was collected at the Pennsylvania Transportation Institute.

Participants completed questions on meaning and action for a set of traffic control devices (TCD's), presented in a booklet. Each TCD was shown in context, using many of the same digitized photos from experiment 1. The answers were then coded 5: 'correct', 4: 'partially correct', 3: 'incorrect but not dangerous', 2: 'confusion, possible danger', 1: 'dangerously wrong, dangerous confusion', or 0: 'no answer' according to experimental protocols. Two researchers coded each answer booklet. In addition, one (randomly selected) out of every six was checked by an additional researcher as the coding progressed to insure reliability. The 10 'additional foils' were not coded for meaning and action, but danger ratings were used from all scenes.

Variables.

1. Independent. Age-group, sign, sign material (for Types 1 and 2), and situation.

2. Dependent. a) Correctness of answers to two questions, "Exactly what do you think this marking means?" and "What action, if any, would you take as a driver if you saw this marking?" b) Confusions with other TCD's, c) Familiarity ratings of signs/markers, and d) Danger ratings of situations. For more detailed descriptions, see appendix C, instructions for Problem Identification Experiment 2.

Stimulus materials. Participants saw 40 scenes, each in full color. Twenty were foils, of which ten were the same substitution/confusion TCDs selected for experiment 1. The additional 10 foils are listed below:

1. No right turn (R3-1).
2. Two way left turn only (R3-9a).
3. Restricted lane ahead (R3-13).
4. Narrow bridge (W5-2a).
5. Playground (W15-1).
6. Campground ahead (D9-3).
7. Gas ahead (D9-7).
8. Deer Crossing (W11-3).
9. Two-way Traffic (W6-3).
10. No Hazardous Cargo (R14-3).

Color samples from FHWA were used to verify that the final prints would be within their standards. In the booklets, pictures appeared on the left page and participants had several lines on the facing page in which to write their answers. Aside from the first 3 practice scenes, each of the 10 booklets had a different order, to randomize order effects.

Twenty of the pictures contained object markers, using the situations from Experiment 1. This time however, only one type of marker was used for a particular scene (see table 11). Type was selected from prevailing usage in Pennsylvania, with the qualification that trees and poles are not usually marked unless the location has a high accident history.

The sign material factor was an independent-group factor. Half of the participants saw all Type 1 and 2 object markers represented with reflective buttons. The other half saw them represented as having sheeting. Type 2 button copy appeared as three circles, 7.5 cm (3 in) in diameter, with no background. Type 1 button copy appeared as nine orange circles, also 7.5 cm (3 in) in diameter, on a darker yellow background. Orange on yellow was used over yellow on yellow, as proposed in the work plan, because not enough contrast could be achieved. Yellow on black was not used because few examples of this version were seen by the researchers and none were explicitly mentioned by the State highway officials.

Table 11. Description of scenes with MUTCD object markers.

Hazard Situation	Type	Side	Freeway	Rural	Urban
Bridge Pier	3	Both	X		
Bridge Abutment	3	Both		X	X
Bridge Rail End	3	Both	X		
Bridge Rail End	2	Both		X	
Inlet	2	Right	X		
Culvert	2	Both		X	X
Street Light Pole	2	Right	X		
Utility Pole	2	Right		X	X
Median Nose or Island	1	Left		X	X
Tree	2	Right		X	X
Guide-rail End	3	Right	X		
Guide-rail End	3	Left	X		
Guide-rail End	2	Left		X	
Gore	1	Left	X		X

<u>Recruitment procedures for research participants.</u> Participants in this experiment were recruited from the University Park, PA, area. To guard against a control group with predominantly unexperienced drivers, as could happen in a university town, drivers in the 20 to 40 age group were required to have a minimum of 6 years driving experience. To guard against self-selection of the best drivers, participants were explicitly told no driving would be necessary.

<u>Number and age grouping of participants.</u> There were 56 participants in all, 15 in the 20 to 40-year-old group, 20 in the 65 to 69 year-old group, and 21 in the 70 and older group. This concentrated resources in the age ranges of greatest interest. The booklet format allowed experimenters to vary group size and to intermix age groups since each participant

worked independently.

Experimental protocol. Once the group had gathered, the experimenters introduced themselves and explained that they were studying how well drivers understand traffic signs and situations. They then handed out the booklets which had an informed consent as a cover sheet. They read over the consent form, had participants sign, address, and date it, then gave the detailed instructions (see appendix C).

Participants were given booklets with color scenes and asked to write the meaning of each sign identified along with what action they would take as a driver if they came upon this situation. Participants were given as much time as they needed to complete the booklet. The average completion time was 90 min.

When participants completed all scenes in their booklets they were given a single sheet containing a solitary OM-3 and asked in which direction would they travel if they could see only the sign and no roadway clues. Last they were given instructions on rating the 'danger' of the situation and 'familiarity' of the sign in each scene.

Scoring. The open-ended responses were scored on a 5-point scale according to pretested protocols.

To be 'correct' (5) for an object marker, a response had to state that it warned of a hazard and give its location. The 'correct' action was to drive to the proper side of the hazard, or between the hazards if they were on both sides of the road, or in the case of the Type 1 marker, to drive to either side.

To be 'partially correct' (4), any answer involving caution, general warning, or general hazard was accepted. The 'partially correct' action was to be cautious, or generally avoid the hazard.

An 'incorrect but not dangerous' (3) answer was any reference to the situation that did not involve the hazard or an aspect of caution, such as "I am coming to a signal light" in response to the Type 2 marker in button copy.

Answers scored as 'confusion, possible danger' (2) were site specific. For example, if the participant saw a freeway scene and said he would slow for a signal ahead it would be dangerous.

Likewise, answers scored as 'dangerously wrong, dangerous confusion' (1) were also site specific. An example would be interpreting the markers as 'Do Not Enter' at the mouth of an underpass.

Blank answers were coded 'no answer' and scored 0. Fortunately, less than 0.5 percent of the answers were blank.

PROBLEM IDENTIFICATION EXPERIMENT 2 RESULTS: MEANING & COMPREHENSION

__Summary of marker results.__ Figures 7 and 8 show the averages of the meaning scores for each scene or scene/material combination. That is, each point is the average, over all ages, for a particular scene/sign/material combination. In figure 7, the "Button" and "Sheeting" categories are consolidated in the Type 1 and Type 2 marker categories. In figure 8, the Type 1 and Type 2 markers are consolidated in the "Button" and "Sheeting" categories. The same pattern is followed in figures 9 and 10, which picture the average familiarity ratings, and figures 11 and 12, which illustrate the danger ratings. Although each type of marker is discussed in detail in the following pages, these figures give a broad overview of the results.

Meaning scores for the confusion signs were best, followed by the Type 3 object markers, then the Type 2, and last the Type 1. Several analyses of variance were performed, using the averages plotted in the figures as data. The results were significant for all measures: For meaning, (F= 14.035, df= 3/40, p= .000); for familiarity, (F= 46.880, df= 3/40, p= .000); and for danger, (F= 3.822, df= 3/40, p= .017). (Note that the pattern of averages for familiarity and danger are different than the pattern for meaning. These differences are discussed later.) Because the average of the confusions signs was so much higher than the object markers, the analyses were recomputed without the confusion data. The results were still significant: Meaning (F= 12.648, df= 2/31, p= .000), action (F= 41.580, df= 2/31, p= .000), and danger (F= 3.900, df= 2/31, p= .031).

However, it cannot be over emphasized that scene effects are confounded with marker effects. Scenes were assigned the marker most likely to be used in current practice, which means Type 3 markers were assigned to the most obvious hazards, making it easier to guess the correct meaning.

More importantly, the average meaning score for **every** object marker was lower than the combined average meaning score for the confusion signs. If not for the lowest confusion average, the yellow post-mounted delineators (average = 3.14), the differences between the confusions signs and the markers would have been greater.

As expected, the meaning scores for the object markers were highest for the younger group and lowest for the 70 and older group. However, these results were not statistically significant. Scene differences are similar to the conspicuity experiment: Those scenes with a prominent hazard had higher scores than those that did not, or scenes with dangerous features aside from the hazard itself tended to have higher meaning scores.

Original pilot testing revealed that meaning and action scores were redundant. However, in this experiment, the answers were rated separately for meaning and action anyway. The action scores were found to be highly correlated to meaning scores (r= 0.803, p= .000) as illustrated in figure 13, and it was felt to be unnecessary to duplicate all the analyses found on the following pages. However, for the sake of completeness, an analysis of variance paralleling that above was performed on the action averages. The figures were almost identical: (F= 13.506, df= 3/40, p= .000). For the Type 3 markers, both meaning and action were identical: 3.72.

For the Type 2 markers, they were within 0.04 of a point: 3.43 for action and 3.39 for meaning. For the Type 1 markers, they were within 0.15: 3.30 for action and 3.15 for meaning. The averages of the confusion signs were the same distance apart: 4.02 for action and 3.87 for meaning.

Comparing the button-copy to sheeting (remember that the participants only saw color reproductions, not the actual markers, and all reproductions were day scenes), there was a suggestion that button copy may have higher meaning scores, but this also was not significant.

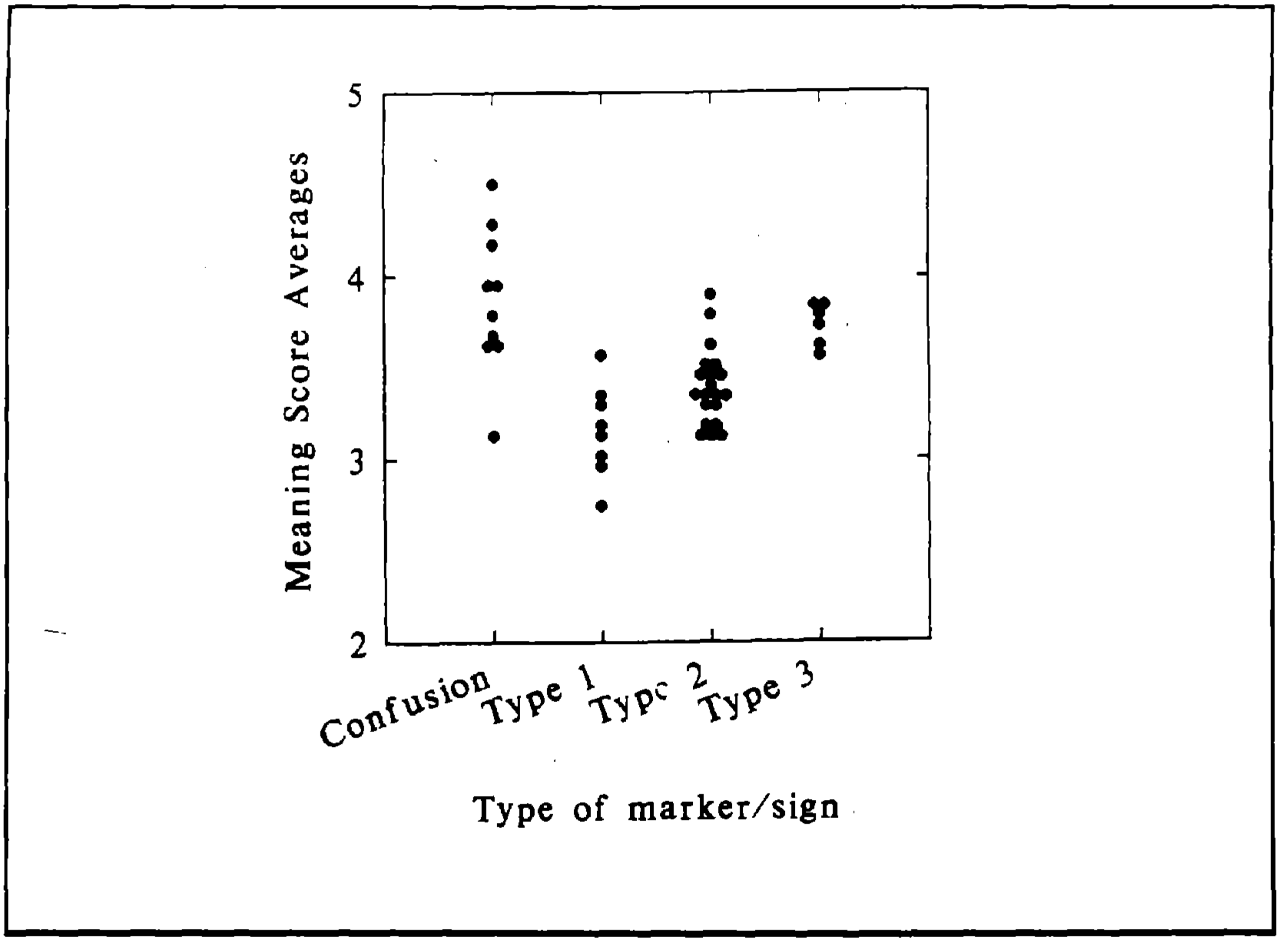


Figure 7. Average meaning scores for all scene/sign/material combinations. (Half of the Type 1 and Type 2 averages represented button copy, half represented sheeting. Scores could range from 0 (missing) to 5 (correct)).

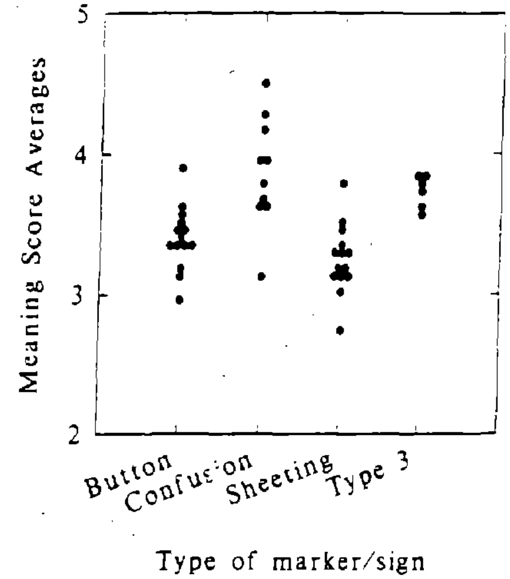


Figure 8. Average meaning scores for each combination by material type. (This figure separates all the Type 1 and 2 averages by type of material: button versus sheeting. Scores could range from 0 (missing) to 5 (correct)).

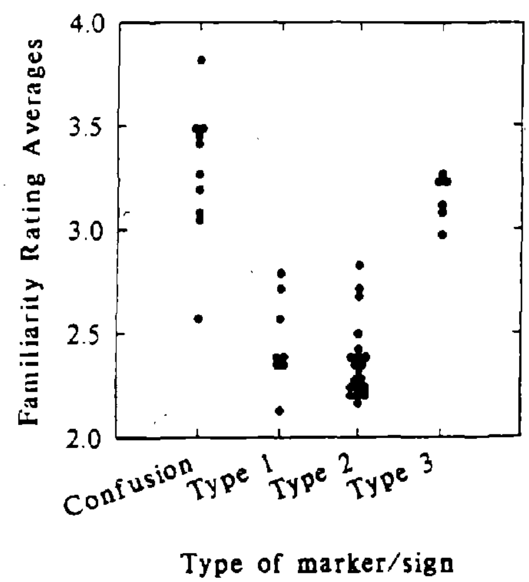


Figure 9. Average familiarity scores for all scene/sign/material combinations. (Button copy and sheeting materials are consolidated in Type 1 and Type 2 categories. The scale ranged from 1 (I have never seen this sign) to 5 (I see this sign every time I drive)).

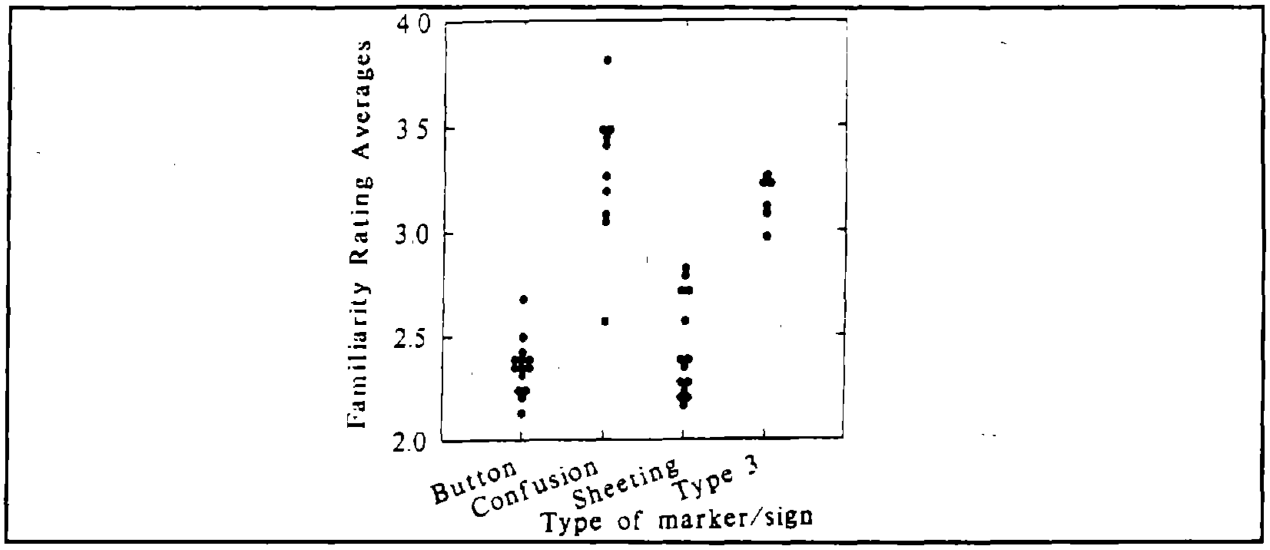


Figure 10. Average familiarity scores for each combination by material type. (Type 1 and Type 2 averages are consolidated in the button copy and sheeting materials categories. The scale ranged from 1 (I have never seen this sign) to 5 (I see this sign every time I drive)).

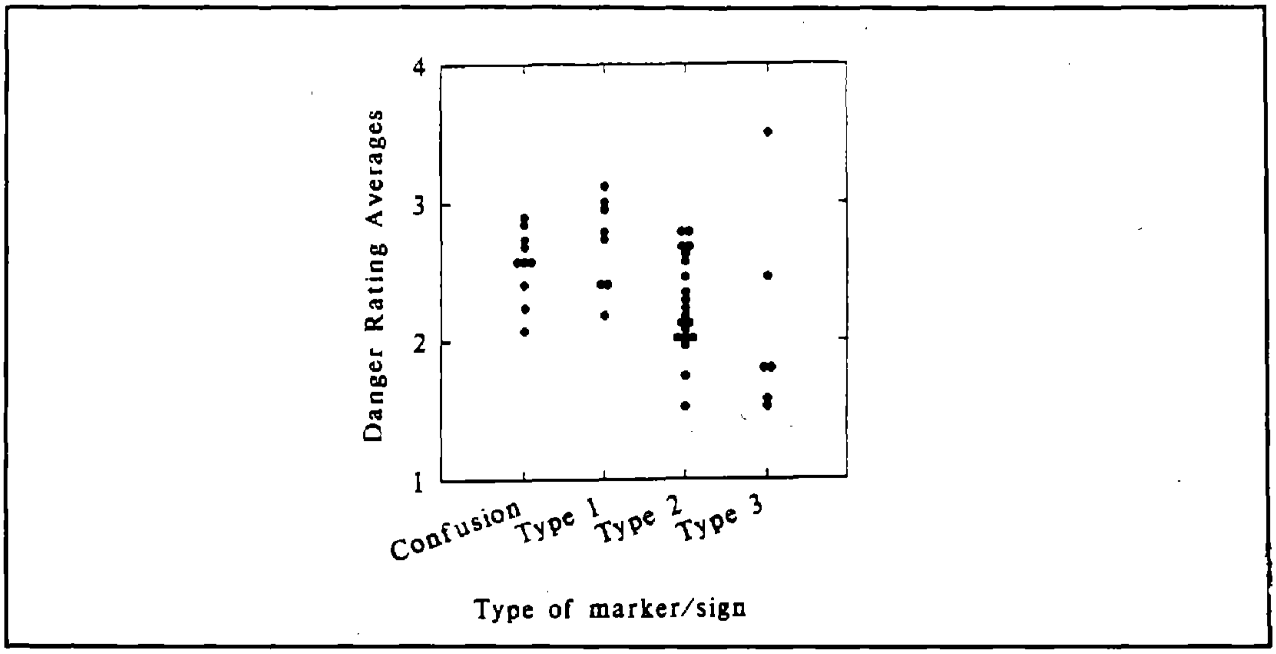


Figure 11. Average danger scores for all scene/sign/material combinations. (Button and sheeting averages are consolidated in the Type 1 and Type 2 categories. The scale ranged from 1 (This is a safe situation) to 5 (This is a very dangerous situation)).

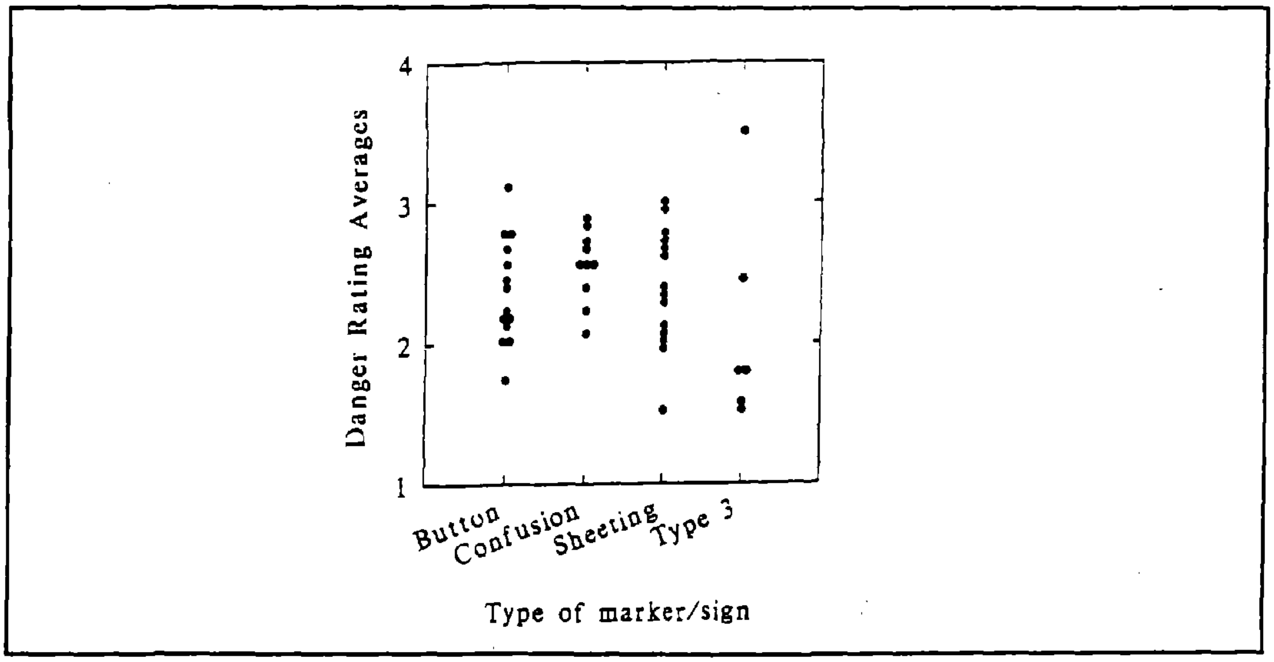


Figure 12. Average danger scores for each combination by material type. (Type 1 and Type 2 averages are consolidated in the button and sheeting categories. The scale ranged from 1 (This is a safe situation) to 5 (This is a very dangerous situation)).

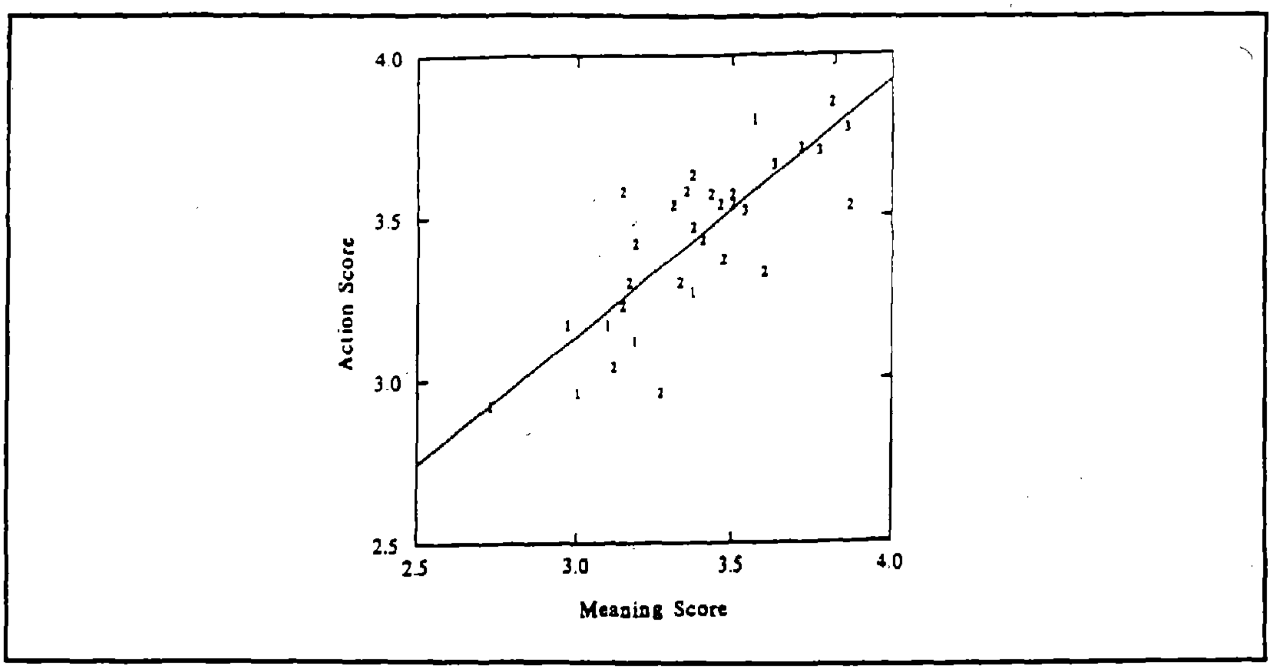


Figure 13. Scatter plot of averages for meaning and action. (Numbers in the figure indicate the object marker type. Line is regression of action on meaning. Pearson $r = 0.80$).

Type 1 Markers. Meaning, familiarity, and danger scores for Type 1 Markers are presented below.

Meaning Data. Tables 12 and 13, below, show the average meaning scores for the two Type 1 marker designs. As shown, the younger participant group exhibited somewhat greater understanding of the meaning of the markers, but the analysis showed that the age group differences were not significant. All six age group averages fell in the range of 3 to 4 (Incorrect, but not dangerous) to (Partially correct). The two older groups were closer to the former. Generally speaking, lower levels of understanding were shown for the markers that were placed on the left side of the roadway, in conjunction with a median nose or island, as compared with those used at gores. This is supported by the statistical analysis which indicated significant scene effects.

Table 12. Average meaning scores, Type 1 button markers.[1]

		TYPE 1 BUTTON MARKERS				
AGE GROUP	SCENE →	r med	u med	f gore	u gore	AVG
20-40		3.3	3.9	3.4	3.9	3.6
65-69		2.5	3.1	2.9	3.5	3.0
70+		3.2	3.3	3.1	3.5	3.3

[1]In all tables, r=rural, u=urban, f=freeway, med=median nose.

Table 13. Average meaning scores, Type 1 sheeting markers.

		TYPE 1 SHEETING MARKERS				
AGE GROUP	SCENE →	r med	u med	f gore	u gore	AVG
20-40		3.3	3.0	2.6	3.6	3.4
65-69		2.8	3.6	3.3	3.2	3.1
70+		2.2	3.0	3.0	3.1	3.1

The statistical analysis of meaning data for the Type 1 markers showed that there were statistically significant scene effects. The age effect was not significant. Also, differences associated with the design of the Type 1 markers (i.e., markers using sheeting only versus those using reflective buttons) were not significant. Table 14 shows the ANOVA table for this data set.

Table 14. ANOVA, Type 1 markers meaning data.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*3.68331*	*1.84166*	*0.66785*	*0.5173*
Design1[1]	*1*	*2.92867*	*2.92867*	*1.062*	*0.3077*
Age x Design	*2*	*5.86902*	*2.93451*	*1.0642*	*0.3527*
Participant (A x D)	*50*	*137.88*	*2.7576*		
Scene	*3*	*11.25*	*3.75*	*6.283*	*0.0005*
Age x Scene	*6*	*2.7608*	*0.460134*	*0.77094*	*0.5939*
Design x Scene	*3*	*0.124602*	*0.041534*	*0.06959*	*0.9761*
Age x Design x Scene	*6*	*5.10104*	*0.850173*	*1.4244*	*0.2088*
Subj (A x D) x Scene	*150*	*89.5277*	*0.596851*		
Total	*223*	*258.214*			

[1] Refers to button vs. sheeting version of markers

The statistically significant effects of the scene indicate that the context influences the manner in which drivers interpret the meaning. To the extent that contextual patterns are found to be associated with lower levels of understanding, it may be possible to derive more definitive guidelines for the use/location of Type 1 markers to reduce driver misunderstanding. It appears, as in the conspicuity experiment, that more obvious hazards promote understanding of the associated markers.

Familiarity Data. The results of the Familiarity ratings, shown in tables 15 and 16, below, indicate that there are average difference in familiarity with the two Type 1 marker designs. The younger participant group showed a greater familiarity with the button design, while the older group was more familiar with the "sheeting" design. Further, the marker is not, on the average, judged to be commonly seen.

Table 15. Average familiarity scores, Type 1 button markers.

		TYPE 1 BUTTON MARKERS				
AGE GROUP	***SCENE →***	***r med***	***u med***	***f gore***	***u gore***	***AVG***
20-40		*2.6*	*2.7*	*3.4*	*3.3*	*3.0*
65-69		*2.0*	*2.5*	*2.0*	*2.2*	*2.2*
70+		*2.0*	*1.9*	*2.0*	*2.0*	*2.0*

Table 16. Average familiarity scores, Type 1 sheeting markers.

		TYPE 1 SHEETING MARKERS				
AGE GROUP	***SCENE →***	***r med***	***u med***	***f gore***	***u gore***	***AVG***
20-40		*2.3*	*2.0*	*2.0*	*2.4*	*2.2*
65-69		*2.8*	*2.1*	*3.0*	*2.3*	*2.6*
70+		*3.1*	*3.0*	*3.2*	*3.0*	*3.1*

The statistical analysis of familiarity data for the Type 1 markers showed that neither the differences between marker design or the age differences observed were statistically significant. As shown in the ANOVA table below (table 17), none of the main effects were significant. The age group and marker design differences noted above are reflected in the significant age/design interaction. The relatively low average familiarity with Type 1 markers probably accounts for the absence of a significant scene effect.

Table 17. ANOVA, Type 1 markers familiarity data.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	2	1.7654	0.882702	0.21308	0.8088
Design[1]	1	2.42142	2.42142	0.58451	0.4481
Age x Design	2	32.9307	16.4654	3.9746	0.025
Participant (A x D)	50	207.132	4.14265		
Scene	3	0.977679	0.325893	0.67243	0.5702
Age x Scene	6	1.93278	0.322129	0.66466	0.6783
Design x Scene	3	2.31884	0.772947	1.5949	0.193
Age x Design x Scene	6	6.20703	1.03451	2.1345	0.0526
Subj (A x D) x Scene	150	72.6976	0.484651		
Total	223	331.246			

[1] Refers to button vs. sheeting version of markers

Danger Data. As with the familiarity ratings, the danger ratings also show some age-related differences between the two Type 1 marker designs. As seen on tables 18 and 19, below, for the button markers, the younger group, on the average, judged the scenes/situations including button copy to be slightly dangerous, while the older group judged them to be relatively safer. However, the reverse was true for the same scenes/situations in which the sheeting-only marker was used. As will be shown by the statistical analysis, the observed differences were not significant.

Table 18. Average danger ratings, Type 1 button markers.

AGE GROUP	SCENE →	*TYPE 1 BUTTON MARKERS* r med	u med	f gore	u gore	AVG
20-40		3.0	2.3	2.3	3.3	2.7
65-69		2.6	2.5	1.9	3.1	2.5
70+		2.8	2.4	2.3	3.0	2.6

Table 19. Average danger ratings, Type 1 sheeting markers.

AGE GROUP	SCENE →	*TYPE 1 BUTTON MARKERS* r med	u med	f gore	u gore	AVG
20-40		2.5	2.3	2.5	2.8	2.6
65-69		3.1	2.8	2.3	3.1	2.9
70+		3.1	2.8	2.4	3.1	2.9

Table 20. ANOVA, Type 1 markers danger ratings.

Source	df	Sums of Squares	Mean Square	F-ratio	Prob
Age	2	0.614105	0.307052	0.14423	0.866
Design[1]	1	1.09363	1.09363	0.51371	0.4769
Age x Design	2	2.89617	1.44808	0.6802	0.5111
Participant (A x D)	50	106.445	2.1289		
Scene	3	19.5134	6.50446	10.928	≤0.0001
Age x Scene	6	2.8756	0.479266	0.80523	0.5673
Design x Scene	3	1.66448	0.554828	0.93218	0.4268
Age x Design x Scene	6	1.0156	0.169267	0.28439	0.9436
Subj (A x D) x Scene	150	89.2788	0.595192		
Total	223	225.746			

[1]Refers to button vs. sheeting version of markers

The ANOVA (see table 20) indicated that the only statistically significant effects were those associated with variation across participants and those associated with scene. The differences discussed above were not significant, nor were any of the interactions.

Type 2 Markers. Meaning, familiarity, and danger scores for Type 2 Markers are presented below.

Meaning Data. As indicated in the averages shown in tables 21 and 22 below, the younger participants scored slightly higher than the older groups in identification of the meaning of the Type 2 markers. Unlike the age group reversals in the Type 1 marker data, higher scores were observed for the younger group with both marker designs. The higher scores for the younger group were also generally consistently observed across scenes.

Table 21. Average meaning scores, Type 2 button markers.

		TYPE 2 BUTTON MARKERS										
AGE GROUP	SCENE →	r br end	f inlet	r culv	u culv	f pole	r pole	u pole	r tree	u tree	r gr end	AVG
20-40		4	3.3	4.3	3.4	4.3	4.1	3.9	4	3.7	3.7	3.9
65-69		3.7	3.1	3.2	3.5	3.7	2.8	3.1	3.3	3.4	3.4	3.3
70+		3.9	3.2	2.9	3.3	3.1	3.4	3.3	3.4	3.4	3.3	3.3

Table 22. Average meaning scores, Type 2 sheeting markers.

		TYPE 2 SHEETING MARKERS										
AGE GROUP	SCENE →	r br end	f inlet	r culv	u culv	f pole	r pole	u pole	r tree	u tree	r gr end	AVG
20-40		4	3.4	3.6	3.3	4	3.9	3.1	4	3.6	3.5	3.7
65-69		3.1	3	3.4	3.3	3.3	3.4	3.4	3.9	3.4	3.3	3.3
70+		3.4	3	3	2.9	2.6	3.1	2.9	3.6	2.6	3.1	3.2

With regard to statistical significance, however, the age-related differences failed to reach significance. Of the main effects in the analysis (see table 23 below), only participant and scene were significant. Further, none of the interactions were significant. The safest interpretation of the scene effect is that the freeway inlet scene was harder to interpret than the other scenes, but even this statement is not perfectly consistent with all the sub-group means.

Familiarity Data. The familiarity results for the Type 2 markers exhibits the same trends as the Type 1 marker data. That is, the younger participant group indicated a greater familiarity with the button design, while the older group was more familiar with the sheeting design . This is counter-intuitive, since the sheeting versions of these markers are newer than the button copy. One would expect older drivers to be more familiar button copy. Further, like the Type 1 markers, the Type 2 markers are not, on the average, judged to be commonly seen. As shown in tables 24 and 25 below, the average familiarity ratings fall between rating categories 2 and 3 ('I have seen this sign only a few times in my life') and ('I have seen this sign several times but it is not a common sign'). The lack of familiarity cannot be ascribed to a lack of signage on the Pennsylvania roads, as all three types are common, although as stated earlier, some objects such as trees, poles, and inlets may not be always marked.

Table 23. ANOVA, Type 2 markers meaning scores.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*29.3317*	*14.6659*	*2.376*	*0.1029*
Design[1]	*1*	*3.47715*	*3.47715*	*0.56333*	*0.4563*
Participant (A x D)	*52*	*320.972*	*6.17254*		
Scene	*9*	*14.1946*	*1.57718*	*2.4763*	*0.0091*
Age x Scene	*18*	*15.5882*	*0.866012*	*1.3597*	*0.1467*
Design x Scene	*9*	*5.61182*	*0.623536*	*0.979*	*0.4565*
Subj (A x D) x Scene	*468*	*298.075*	*0.636912*		
Total	*559*	*685.784*			

[1] Refers to button vs. sheeting version of markers

Table 24. Average familiarity ratings, Type 2 button markers.

		TYPE 2 BUTTON MARKERS										
AGE GROUP	***SCENE →***	***r br end***	***f inlet***	***r culv***	***u culv***	***f pole***	***r pole***	***u pole***	***r tree***	***u tree***	***r gr end***	***AVG***
20-40		*2.6*	*2.9*	*2.9*	*2.9*	*2.9*	*2.9*	*2.7*	*2.7*	*2.7*	*3.0*	*2.8*
65-69		*2.6*	*2.6*	*2.4*	*2.0*	*2.2*	*1.9*	*2.1*	*2.3*	*2.4*	*2.2*	*2.3*
70+		*2.8*	*1.9*	*2.4*	*2.1*	*2.4*	*2.1*	*2.3*	*2.2*	*1.8*	*2.2*	*2.2*

Table 25. Average familiarity ratings, Type 2 sheeting markers.

AGE GROUP	SCENE →	*TYPE 2 SHEETING MARKERS* r br end	f inlet	r culv	u culv	f pole	r pole	u pole	r tree	u tree	r gr end	AVG
20-40		2.3	2.1	1.8	1.9	1.9	2.1	1.9	2.1	1.9	2.0	2.0
65-69		2.1	3.1	2.7	2.6	2.3	2.6	2.2	2.2	2.4	2.3	2.5
70+		2.3	3.1	3.3	2.3	2.6	2.4	2.4	2.1	2.2	2.7	2.5

The statistics showed the pattern of significance observed for many of the other data sets. That is, participant and scene were the only significant main effects. Further, none of the interactions were statistically significant. As in the other results, the context in which a marker is placed, seems to produce more variation in responses than other factors. Collapsed over type of design, the tree scenes are least familiar and the freeway inlet and rural culvert are most familiar. However, even though there must be a difference between the most familiar scene and the least familiar scene, it still is less than half a unit on the scale, and may not be meaningful.

Table 26. ANOVA, Type 2 markers familiarity scores.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	2	1.09918	0.549588	0.03516	0.9655
Design[1]	1	0.204116	0.204116	0.01306	0.9095
Age x Design	2	22.9982	11.4991	0.73562	0.4844
Participant (A x D)	49	765.962	15.6319		
Scene	9	9.76182	1.08465	2.0593	0.0319
Age x Scene	18	8.82876	0.490487	0.93125	0.5405
Design x Scene	9	5.0236	0.558178	1.0598	0.3915
Age x Design x Scene	18	9.47539	0.526411	0.99945	0.4589
Subj (A x D) x Scene	441	232.274	0.526699		
Total	549	1058.05			

[1] Refers to button vs. sheeting version of markers

Danger Data. The danger ratings for the Type 2 markers revealed very little. As can be seen in the tables of averages below, there was little difference between the age groups and very little difference between the two marker designs. As one might expect after viewing the tables, neither of these two factors produced statistically significant differences. Generally speaking, participants of both age groups judged most of the situations in which Type 2 markers were used to be relatively safe. Based on the average ratings, the Type 2 marker does not appear to be interpreted as one used in situations where an accident is likely. Rather, it appears to serve the intended alerting function.

Table 27. Average danger ratings, Type 2 button markers.

AGE GROUP	SCENE →	TYPE 2 BUTTON MARKERS										
		r br end	f inlet	r culv	u culv	f pole	r pole	u pole	r tree	u tree	r gr end	AVG
20-40		1.9	2.1	2.0	2.3	2.0	3.0	2.1	2.9	2.6	2.4	2.3
65-69		2.1	2.1	1.9	2.0	1.8	2.5	2.4	2.7	2.4	2.6	2.3
70+		2.1	1.8	2.3	2.3	1.5	2.3	2.7	2.8	1.9	2.9	2.3

Table 28. Average danger ratings, Type 2 sheeting markers.

AGE GROUP	SCENE →	TYPE 2 SHEETING MARKERS										
		r br end	f inlet	r culv	u culv	f pole	r pole	u pole	r tree	u tree	r gr end	AVG
20-40		1.8	2.3	1.8	2.0	1.4	1.8	2.1	2.6	2.5	3.0	2.1
65-69		2.4	2.3	2.9	1.9	1.8	2.1	2.3	2.7	2.7	3.1	2.4
70+		2.0	2.2	2.0	2.0	1.4	2.1	2.0	2.7	2.7	2.2	2.1

With regard to the statistical analysis, the ANOVA again shows participant and scene to be the only significant main effect. Additionally, as shown in table 29, the scene/design interaction is marginally significant. It is probably due to higher averages for rural pole/button copy and rural guide-rail end/sheeting copy, but is felt to be of negligible importance.

Type 3 Markers. Meaning, familiarity, and danger scores for Type 3 markers are presented below.

Meaning Data. The Type 3 markers appear to be understood to a slightly greater degree than the other markers evaluated, in terms of the average scores across scenes (see table 30). The overall average for Type 1 was 3.25, for Type 2 was 3.45, and for Type 3 was 3.73. Type 3 was the only marker for which more people got the answer at least partially right than incorrect. Certainly, there were fewer definitions that were classified as those that might result in 'dangerous' or 'possibly dangerous' actions. The small differences between age groups and across scenes were not statistically significant, as shown in the ANOVA table (table 31). The only significant effect was the variation across participants.

Table 29. ANOVA, Type 2 markers danger ratings.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*2.84017*	*1.42008*	*0.40882*	*0.6667*
Design[1]	*1*	*0.970643*	*0.970643*	*0.27944*	*0.5995*
Age x Design	*2*	*4.79756*	*2.39878*	*0.69058*	*0.5061*
Participant (A x D)	*49*	*170.206*	*3.47358*		
Scene	*9*	*53.3164*	*5.92404*	*9.5385*	*≤0.0001*
Age x Scene	*18*	*5.24774*	*0.291541*	*0.46942*	*0.9698*
Design x Scene	*9*	*11.5459*	*1.28288*	*2.0656*	*0.0313*
Age x Design x Scene	*18*	*13.865*	*0.770277*	*1.2403*	*0.2245*
Subj (A x D) x Scene	*441*	*273.89*	*0.621066*		
Total	*549*	*535.353*			

[1] Refers to button vs. sheeting version of markers

Table 30. Average meaning scores, Type 3 markers.

		TYPE 3 MARKERS						
AGE GROUP	*SCENE →*	*f br col*	*r br abut*	*u br abut*	*f br end*	*fr gr end*	*fl gr end*	*AVG*
20-40		*4.1*	*3.9*	*3.9*	*3.7*	*4*	*3.8*	*3.9*
65-69		*4*	*3.6*	*3.8*	*3.6*	*3.4*	*3.9*	*3.7*
70+		*3.6*	*4*	*3.5*	*3.4*	*3.6*	*3.7*	*3.6*

Table 31. ANOVA, Type 3 markers meaning scores.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*3.69276*	*1.84638*	*0.32736*	*0.7236*
Participant (Age)	*27*	*152.288*	*5.6403*		
Scene	*6*	*1.59048*	*0.265079*	*0.52879*	*0.7859*
Age x Scene	*12*	*4.34273*	*0.361894*	*0.72192*	*0.7286*
Participant (Age) x Scene	*162*	*81.2096*	*0.501294*		
Total	*209*	*243.124*			

The higher meaning scores cannot be taken at face value. This group of scenes includes bridge abutments and columns, which may have helped the participants interpret the markers.

Solitary OM-3. The isolated OM-3, with no background or other cues, was tested for direction information. Data from all three experiments are presented together here. The Pennsylvania sample (56) had 27 correct (48 percent), and the Washington, DC, area (102) had 35 correct (34 percent). The latter is significantly worse than chance ($Z = 4.48$, $p < .01$). Combined, the participants were correct only 39 percent of the time, which is also significantly worse than chance. It should be noted that participants were forced to make a choice. Many participants stated they did not realize the direction of the stripes meant anything, a point confirmed in the markers participants designed in Experiment 3. When stripes were used on both sides of the road, sometimes they were drawn in the same direction for right and left sides. Overall, use of direction of stripes in the drawings was correct approximately half of the time. All this confirms previous research.[25,26,27] It should be noted that the investigators found no installations in the field that were installed incorrectly, so the participants were not confused by inconsistencies on the road.

Familiarity Data. For the Type 3 markers, younger drivers were generally more familiar than were either of the older groups (see table 32). Further, this data set was one of the few for which the age group differences were statistically significant (see table 33). Also, unlike most of the other data sets, there were no significant scene effects. This is most likely due to the relative size and conspicuity of the Type 3 markers.

Table 32. Average familiarity ratings, Type 3 markers.

		TYPE 3 MARKERS						
AGE GROUP	***SCENE →***	***f br col***	***r br abut***	***u br abut***	***f br end***	***fr gr end***	***fl gr end***	***AVG***
20-40		*3.5*	*3.9*	*3.5*	*3.8*	*3.7*	*3.7*	*3.7*
65-69		*3.0*	*2.6*	*2.7*	*2.8*	*2.9*	*4.5*	*3.1*
70+		*3.2*	*3*	*2.9*	*3.3*	*3.2*	*3.3*	*3.2*

The familiarity ratings were generally higher for Type 3 markers than they were for the other types. Given the nature of the hazards typically marked with these markers, the higher overall familiarity may be a positive finding in terms of safety. On the other hand, it may only mean that these objects are more likely to be marked.

Danger Data. While the general trend was for the older participant groups to use higher danger ratings for the situations in which Type 3 markers were used, the differences are relatively small and are not statistically significant. With the exception of Scene 5 (a bridge abutment in a rural setting), few of the situations in which Type 3 markers were portrayed were judged to be dangerous (see table 34).

Table 33. ANOVA, Type 3 markers familiarity ratings.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*45.6752*	*22.8376*	*4.5979*	*0.0144*
Participant (Age)	*53*	*263.25*	*4.96699*		
Scene	*5*	*3.51488*	*0.702976*	*1.7474*	*0.1241*
Age x Scene	*10*	*5.37599*	*0.537599*	*1.3363*	*0.211*
Participant (Age) x Scene	*265*	*106.609*	*0.402299*		
Total	*335*	*424.426*			

Table 34. Average danger ratings, Type 3 markers.

		TYPE 3 MARKERS						
AGE GROUP	*SCENE →*	*f br col*	*r br abut*	*u br abut*	*f br end*	*fr gr end*	*fl gr end*	*AVG*
20-40		*1.6*	*3.5*	*2.1*	*1.4*	*1.5*	*1.5*	*1.9*
65-69		*2.0*	*3.5*	*2.4*	*1.8*	*1.6*	*1.7*	*2.1*
70+		*1.7*	*3.6*	*2.8*	*2.0*	*1.4*	*1.6*	*2.2*

With regard to the statistical analysis, Scene was significant (see table 35). The significance probably resulted from the considerable higher ranking of the rural bridge abutment as compared to the other scenes.

Table 35. ANOVA-Type 3 markers, danger ratings.

Source	*df*	*Sums of Squares*	*Mean Square*	*F-ratio*	*Prob*
Age	*2*	*4.00813*	*2.00407*	*1.0811*	*0.3466*
Participant (Age)	*53*	*98.2508*	*1.85379*	*3.6024*	*≤0.0001*
Scene	*5*	*165.098*	*33.0196*	*64.166*	*≤0.0001*
Age x Scene	*10*	*6.03353*	*0.603353*	*1.1725*	*0.3095*
Participant (Age) x Scene	*265*	*136.368*	*0.514597*		
Total	*335*	*409.759*			

Discussion. The data from the meaning experiment suggest that object markers are understood poorly, with the possible exception of the Type 3 markers. There is a tendency for younger drivers to understand better, but it is not statistically significant. As in the conspicuity experiment, the scenes with the largest effect were those that had the most salient obstacles, which may explain why the Type 3 markers tend to be understood the best of the three.

The other finding of this experiment is the lack of understanding of direction in the Type 3 object marker, which corroborates previous research on that subject. In fact, the data gathered in the Washington, DC area resulted in significantly more people making the **wrong** decision when pressed for a direction.

CHAPTER 6. PROBLEM IDENTIFICATION EXPERIMENT 3: POPULATION STEREOTYPES OF OBJECT MARKER APPEARANCE AND LOCATION

Rationale. Technology in general, and traffic control devices in particular, should take advantage of stereotypes held by the general population regarding how a system should operate. Some are natural stereotypes, such as an arrow curving to the right to warn of a right curve ahead, while others are traditional, such as the octagon shape for a stop sign, or the American stereotype for flipping a wall switch up to turn on a light. This experiment investigated stereotypes in the design and implementation of object markers.

Objectives. To find any existing stereotypes for the design and implementation of object markers.

Methodology.. Five sessions were run. Each session was made up of members of the same age group, to keep age effects separate during the focus-group part of the session. Each group met at a site mutually convenient to its members.

Each session was divided into two halves: a creation and focus group. In the creation half, the intended message of object markers was explained to the group and each member independently created a design or designs to communicate the presence of the object(s) to other drivers, for each of 12 scenes. Then, in the focus group, the same participants discussed current and future designs and practices.

Variables.

1. Independent. Age groups, type of road, and type of object.

2. Dependent. Design and implementation guidelines. These variables are admittedly qualitative rather than quantitative. The following qualities were coded from the participants' designs and annotations: 1) Graphic elements of their designs, 2) Location of object marker relative to the object, 3) Location of object marker relative to the edge of the roadway, 4) Frequency of usage of the object marker, i.e., in the woods, how many and which trees should be marked, 5) Colors used on the object marker, 6) Size of the object marker, and 7) Presence or absence of directional information on the object marker. Idiosyncratic designs and information were recorded for possible additional categories.

Stimulus materials. For the creation half, participants used a booklet with 12 pages of photographs of actual hazard situations. The scene was pictured on the left-hand page, and the right-hand page was blank for a large-scale picture of their design. They indicated the position of the object marker in the scene by drawing an outline of their design (rectangle, square, triangle, circle, etc.) exactly where they thought it should be. They were given the option of putting the object marker on the object itself, or putting it on a post by drawing a black line down to the ground.

Although the MUTCD gives rigid color restrictions (Section 2A-11, pages 2A-5 and -6), the contract specifically states that other colors be investigated. Thus, the participants were given felt-tip pens in the full range of the 12 FHWA colors listed on pages 1A-8 and -9 of the MUTCD.[1]

The situations included the following: Hazards on freeways/arterials, rural roads, and city streets; elevated, near-ground, and below-ground hazards; and hazards on the side and in the middle of the roadway. The photographs covered representative combinations of road type, hazard elevation, and hazard position.

Number and age grouping of participants. There were 39 participants: 7 in one 20 to 40 year-old group (3 females, 4 males), 16 in two 65 to 69 year-old groups, and 16 in two 70 and older groups (16 females, 16 males).

Experimental protocols. Participants gathered in the meeting place, read the informed consent, signed it, and filled out the minimal biographical information.

Participants received a booklet containing various roadway scenes with hazards. They were asked to design a warning for motorists and place the warning in its most appropriate or effective location. After the instructions were read (See appendix C) and questions answered, participants completed an initial practice scene and received individual feedback from an experimenter. Following successful comprehension of the procedure participants were allowed approximately 60 min to design and locate the object markers for each scene.

The focus group portion of the session began when all participants had finished, following a short break. Group size was eight people for all four older groups and seven for the younger group. The moderator's responsibility was to insure that: 1) The question path was followed; 2) Each person had a chance to express his or her opinion; and 3) No particular member dominated the discussion.

The moderator's question path is listed in appendix C. Participants also received a single sheet containing a solitary OM-3 and were asked in which direction would they travel if they could see only the sign and no roadway clues.

PROBLEM IDENTIFICATION EXPERIMENT 3 RESULTS: POPULATION STEREOTYPES OF OBJECT MARKER APPEARANCE AND LOCATION

Sign creation. After the experimental sessions, each participant's drawing and placements were reviewed as a set to discern any patterns within the individual participant. A few participants would devise a general warning sign and use it frequently throughout the 12 scenes. These are referred to as "generic" signs in the results. Unfortunately, they were "generic" only within a participant, for there was no design agreement among those who took this direction. Another problem were blank answer sheets, even though the experimenter went from participant to participant urging them, among other things, to make a design for each scene. One explanation is that the scenes left blank most often were the ones rated least dangerous and vice versa. The blank scenes were probably the participants' way of stating they did not think the hazard required a marker.

Marker design. The participant's designs were scored for shape of sign, figure colors, background color, border color, and type of design (representational or picture-like, overhead view similar to the crossroads warning sign, arrows, generic symbols, reflectors/reflective paint, or generic symbols).

Shape. The most popular shape was the square (26 percent), followed by the vertical rectangle (21 percent), the horizontal rectangle (11 percent), and the circle (9 percent). Seventeen other shapes were spread among 69 responses. Looking at scene differences for shape, the shapes were spread fairly evenly among the scenes. The square was most popular in seven, and the vertical rectangle was most popular in five, the latter group generally being taller objects: freeway light pole, rural tree, rural utility poles, and urban bridge abutment. Comparing, in each scene, the most popular shape to the next most popular, there were only two significant differences: In the freeway pole scene the vertical rectangle (42 percent) was significantly more popular than the diamond or horizontal rectangle (11 percent each) ($Z = 3.14$, $p < .01$); and in the urban tree scene the square (39 percent) was significantly more popular than the vertical rectangle ($Z = 2.03$, $p < .05$).

There were some age-specific patterns in the results: The choices of the 20 to 40 group did not deviate from the overall pattern described above, but the 65 to 69 group was over-represented in the choice of the diamond and the vertical rectangle, whereas the 70 and older group was over-represented in the choice of the circle and the horizontal rectangle.

Design. Designs were classified (in descending popularity) as 1) representational (21 percent), i.e. the tree hazard marker had a tree on it (in two cases, the shape was specified as a tree); 2) geometric (19 percent), usually slanted stripes; 3) arrows or chevrons (19 percent); 4) reflectors or reflective paint (17 percent); 5) overhead views (14 percent) (as 'curve' and 'crossroad' warning signs are overhead views); and various others making up the remaining 12 percent of the markers. There were significant age-group differences among these most popular designs ($X^2 = 18.71$, $df = 8$, $p = 0.016$). The 70 and older group was less likely to use geometric designs, the 65 to 69 group was more likely to use arrows and less likely to use overhead views, and the 20 to 40 group rarely used arrows but was more likely to use overhead views or reflectors.

Scene was highly related to type of design chosen ($X^2 = 105.89$, $df = 44$, $p = 0.000$). Representational designs were used in both poles and both trees, and for some reason, for the freeway guide-rail end but not for the rural guide-rail end. The geometric design was slightly more popular for that situation, perhaps because of the curve in the scene. Geometric designs were also most popular design for the freeway bridge column and the rural culvert. Arrow designs were most popular where there were choice points, such as the urban gore and the urban median. Finally, reflective treatments were most popular on the urban bridge abutment.

Colors. The most popular background color by far for the two older groups was white, but that may have been by default. It was easier not to fill in the white paper with some color. In the 20 to 40 group white was still the most popular, but orange and strong yellow-green were also frequently used. These differences were significant ($X^2 = 72.28$, $df = 6$, $p = 0.000$). There were no significant scene differences. For the figure color, orange (29 percent) was most popular, followed by red (25 percent), yellow (11 percent), black (11 percent), yellow-green (7 percent), and brown (5 percent). Although the data were too spread out to trust any scene differences, there were significant age-group differences ($X^2 = 57.06$, $df = 12$, $p = 0.000$). The 20 to 40 group was more likely to use yellow or yellow-green, while the 65 to 69 group preferred orange and the 70 and older group preferred red more than the other two age-groups.

Marker size and placement. The participant's placement of the marker in the scene was scored on several variables. Unfortunately, this process was complicated by the participant's insistence on placing the marker or markers in front of the hazard even though the instructions emphasized explicitly that it should be on or at the hazard. Therefore, the size, mounting height, and position relative to the edge of the pavement could not be measured as exactly as had been expected. The principal investigator drew lines on two sets of the scenes to aid the raters. One was to help with lateral offset, measured from the edge of the pavement (on freeways this meant the edge of the paved shoulder), and the other was to measure height. Even with this aids, however, the task was difficult because the participants were neither precise or consistent. Their variety of markers added to the analysis problem. In two scenes, the urban bridge abutment and the freeway bridge columns, they sometimes put the marker overhead, as guide signs are placed.

Size. Given the problems stated above, it was impossible to measure the signs with a ruler. As a substitute, the scorers were given a relative scale where '1' was 'about the same size as a Type 2 marker,' 15 cm by 30 cm (6 in by 12 in), '3' was 'about the same as a Type 1 marker, 46 cm by 46 cm (18 in by 18 in), and '5' was 'about the same as a Type 3 marker, 30 cm by 91 cm (12 in by 36 in). Extrapolation and interpolation were allowed, so the scale ranged from 0 to 6.

All scenes averaged a rating of 3 or larger, which implies these participants would consider the present Type 2 too small and the Type 3 too large. The age-group averages range from 3.2 for the 65 to 69 group to 3.9 for the 70 and older group. Inspection of the distributions lead to the conclusion that these differences are probably not significant. The proper analysis of variance (ANOVA) could not be run for any of the scaled measurements (size, offset, and height) because there were not enough complete cases of data. When a participant decided that any scene required reflectors, or pavement marking rather that a marker on a post, there was no sign to size and that participant's data could not be used in a repeated-measures ANOVA.

The urban bridge abutment scene had the largest average and the urban gore scene had the next largest. These two may be significantly larger than the others, which fell into one large cluster.

Offset. Participants were quite unrealistic in their lateral placement of the markers. Rather than place them at the near edge of the hazard, as specified in the MUTCD, they generally placed them on the edge of the pavement, or sometimes in the pavement. This is most prevalent in the three freeway scenes that had a paved shoulder (light pole, inlet, and right guide-rail end). The average for the light pole was 0.52 m (1.7 ft) into the shoulder. The urban median was the furthest off the pavement, but this was only because it seemed natural for the participants to center the marker in the median. It may be significantly further off than all others. The four rural scenes had the next largest offsets, but even the greatest of these averages was less than 0.3 m (1 ft). Among the age-groups, the 70 and older group may have been significantly worst, with an average over all scenes of -.1 m (-.4 ft).

Height. Participants were also unrealistic in mounting height. There were many instance where the bottom of the sign was on the surface of the road. (Remember that these data do not include any pavement marking designs. The overall average, not counting overhead signs, was 0.7 m (2.3 ft).

Danger ratings. At the bottom of each sheet was the question, "How would you rate the danger of this hazard? SLIGHT, MODERATE, EXTREME." These were converted into 1, 2, and 3. Anyone who did not rate the scene was assigned 0, since these were participants who left the page blank when they felt the hazard did not require any marker at all. This also allowed a complete set of data for a repeated-measures ANOVA.

Although the 70 and older group had the highest average danger rating (2.0), there were no significant age-group differences ($F = 1.380$, $df = 2/36$, $p = .265$). However, there were very significant scene differences ($F = 6.811$, $df = 11/396$, $p = .000$). The rural tree (2.39) and the urban gore (2.33) were rated first and second, respectively, and the freeway light pole was rated least dangerous (1.33). The differences are illustrated in figure 14. The interpretation of the differences is problematic. There are no consistent differences by size of object or type of road. The rural tree is highest, but the urban tree is much lower. The rural utility poles are rated quite dangerous, but the freeway pole is much lower. It is possible that participants are responding to other aspects of the scene than the hazard itself. This is best illustrated by the urban gore. The fence is indistinct and rather low, so the participants may be basing their ratings on the underpass/tunnel on the left side of the scene. In the rural guide-rail end, participants mentioned the curve beyond the hazard more often that the identified hazard, and wanted to incorporate 'curve ahead' into their marker. The rural tree may be identified as more dangerous than the urban tree for three reasons: It is on the right side of the road, the road curves to the right after the tree, and there are fewer distractors in

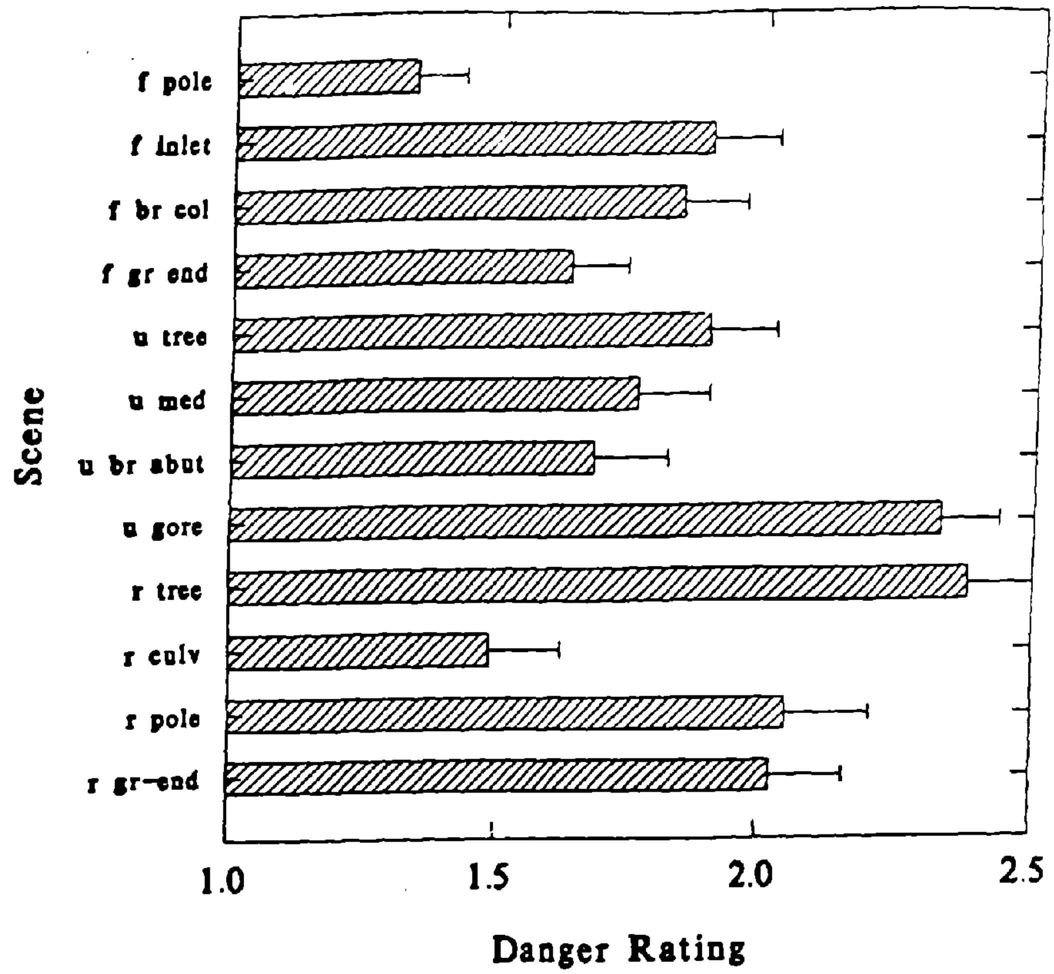


Figure 14. Average danger rating by scene. (Error bars are +1 standard error of the mean. f=freeway, u=urban, br=bridge, col=column, gr=guide rail, med=median, abut=abutment, and cul=culvert.)

the picture, making it more salient than the urban tree. Interpreted in this light, the data reinforce the conclusion in the other experiments, that is, drivers do not have a clear perception of how dangerous a roadside hazard is, even though they are fairly consistent among themselves.

FOCUS GROUPS

The same five groups held a focus group discussion after making their designs. Although participants were instructed to discuss conspicuity of specific objects and markers for those objects, many references were made to improving the lane stripes and raised pavement markers. These experienced drivers felt that many accidents are caused by motorists straying from their lane or not maneuvering correctly into the desired lane. Drivers of all ages felt that many accidents could be avoided if motorists were better able to see where they should be going. The drivers suggested yellow, red, and white reflective buttons or paint to mark each lane more clearly. They felt the benefit would be greatest during night driving and inclement weather.

There were more similarities among age groups then there were differences in ideas and opinions. Aside from the overwhelming mention of increasing conspicuity of lane markers, several other issues were in agreement. All age groups mentioned a desire for standardization among object markers. They felt this would assist driver education as well as increase compliance. The majority of participants felt strongly that color was much more important in relaying a message to drivers than the shape of the sign. The colors suggested to all participants were the 12 recommended by MUTCD: yellow, red, blue, green, brown, orange, black, white, purple, strong yellow-green, light blue, and coral. They felt yellow was the best color to indicate warning, danger, or caution. Red was the second most popular color usually indicating extreme danger or stop, followed by white which was thought to be very attention-getting. Regarding the shape of signs, all groups disliked the rectangle, even though it was the most popular in the drawings they had just completed. Many participants stated that they "ignore" rectangular signs, and because they are so common they "would not capture the attention" of drivers.

There were also similarities noted when listing which hazards should be considered. All groups felt poles, signs, curbs, islands, driveway entrances, and trees were most prominent. They also mentioned with the same emphasis, several types of object markers. They preferred reflectors, reflective paint and word signs posted ahead of the hazard.

Although slight, there were some differences between the 20 to 40 year-old drivers and the two older driver groups. For instance, although the young drivers mentioned the same hazards, they mentioned them with far less frequency. The young drivers also felt less danger was associated with each hazard. Senior drivers were concerned with night driving, while the young drivers did not mention night driving at all. The senior drivers were also more concerned with simplifying signs and markers. This may be attributed to their appreciation of declining driving abilities and an awareness to compensate for this natural aging process. Simplifying signs was again not mentioned by the younger group.

Two differences emerged between the 65 to 69 year-olds and the drivers 70 and older. Mainly the 65 to 69's were concerned with night driving and how this can be improved. The 70 and older drivers did not mention night driving with nearly the same passion. This could perhaps imply that many 65 to 69 year-olds are still driving at night, while the 70 year-olds may have already self restricted this aspect of their mobility. A second difference that may also reflect declining functioning is that the oldest drivers were more passionate about representational signs. Representational signs they felt would be self explanatory and not require reading. This preference may suggest further decline in reaction times and overall driving ability. The 65 to 69 year-old drivers preferred color and shape to indicate messages as opposed to representational figures.

Several suggestions for object markers were concluded. The type mentioned most frequently was small, subtle reflectors placed directly on the hazardous objects. The drivers felt that this simple modification would best alert attention without increasing workload. This sample of the driving public was sensitive to the issue of "too many signs" and relished the idea of simplifying and standardizing roadways as well as object markers. Representational signs were popular in the participant drawings; however, as one astute participant mentioned these pictures may confuse drivers by adding to the overpopulation of signs and leave them wondering 'what about the curb/tree/bridge.' As found in earlier studies, arrows were again extremely reliable in portraying directional information to drivers. Another symbol well known is the popular "do not" circle with a slash through it. This easily comprehensible design may also be utilized when providing drivers with informational messages about hazardous objects. The color that was most effective indicating a sense of warning was yellow. Red came in a distant second and, as was expected, usually indicated stop or extreme danger, with the exception of reflectors where red was simply attention getting. The third most popular color mentioned was white, stressing that it must be of a reflective material.

Novel ideas that emerged include more clearly marking lanes to keep drivers in their intended paths. Drivers also felt that additional illumination of particularly dangerous roadway sections would be helpful and suggested using solar batteries for power in remote areas. Of particular interest was the statement by many drivers that they ignore rectangular signs most of the time. This could be similar to the anecdotal results of previous studies which indicated that many drivers do not pay attention to particular hazards while driving either. This led to the suggestion by several drivers to indicate messages directly on the pavement, for example the word 'SCHOOL' painted in school zones. Drivers felt that they were most often looking at the pavement and lane markers while driving.

CHAPTER 7. RATIONALE FOR SELECTION OF ALTERNATIVE MARKERS FOR LABORATORY STUDIES

The results of the problem identification studies established that the present object markers are not well comprehended and conspicuous, but were unclear as to the solution. The conspicuity study showed that markers only improved a driver's ability to identify a hazardous roadside object when the object was already quite visible. There seemed to be no transfer of marker-to-object association to less visible hazardous objects. Markers only had an effect when the object was large and easily visible, such as a bridge pier, or a large, solitary tree. The comprehension experiment showed that drivers did not understand the markers, especially when compared to other signs. Although the comprehension of the Type 3 (OM-3) object marker averaged higher than that of the Type 1 (OM-1) or Type 2 (OM-2), this may be explained by the size and visibility of the objects in the scene with the OM-3. The same experiment showed that the drivers considered the markers very unfamiliar, despite their widespread use.

The third study, designed to find population stereotypes in the design of an alternate marker, found none. The groups, in every age range, generated a wide range of new markers, including: 1) representational symbols, such as a tree symbol to mark a tree, 2) directional symbols, such as arrows, and 3) generic symbols, such as a diamond, or an eye (for 'watch out'). Although the differences were not statistically significant, the oldest group tended to choose the first type, the 65 to 69 year-olds tended toward the second, and the 20 to 40 year-olds tended toward the third type. In the focus-group discussion that followed the sign production, the two older groups argued forcefully against signs and argued for better road marking. They felt the signs were belaboring the obvious (you should not have to tell a driver not to run into a tree), and added to the plethora of signs that were already hard to comprehend. They felt more good would be done by raising the visibility of the lane lines, showing drivers where they <u>should</u> go rather than where they should <u>not</u> go.

A series of three laboratory experiments was conducted to evaluate new alternative markers on comprehension, recognizability, and conspicuity; screen out any that did not perform satisfactorily; and select the most promising to carry forward for field verification. These markers were compared to the current Type 1, 2, and 3 object markers. The alternative object markers included (1) two types of pavement treatments: hash marks and a double edge line, the additional line to be put down on the outside of the existing edge line; (2) two post-mounted designs: two sets of directional arrows derived from a French gore marker (two isosceles triangles back to back) and a chevron alignment sign; and a representational symbol (a traffic cone).

There are five possible advantages of pavement markings:

1. Older drivers may be more likely to notice a pavement marking than an object marker on a post or painted on the object based on the focus group results (***hereafter in this document, 'post-mounted' will refer to both possibilities***).

2. The hash marks, the double edge lines, and the RPM fit into the general FHWA philosophy of 'positive guidance.' The driver's path is more clearly defined, rather than drawing attention to an object that should not be hit.

3. They are more central to the driver's field of view.

4. Based on the focus group results cited earlier, current post-mounted markers are not noticed well, if at all.

5. They would be more visible in heavy fog conditions.

Despite potential benefits, there are possible problems with pavement markings that may limit their applicability to all situations, or that may suggest they be used in conjunction with post-mounted markers. There are four possible disadvantages of pavement markings:

1. Aside from the RPM, the markings would be less visible during rain. All three would be totally obscured during a heavy snowfall. An object marker on a post would be visible in all but the most extreme weather conditions.

2. Since any markings inside the travel lane would influence the driver to go out of that lane, the hash marks would require a shoulder of approximately 1 m (3 ft). Even a double line would require almost 30 cm (1 ft) to the right of the existing lane line. This means only RPM could be used on rural roads where there was no shoulder.

3. Installation and maintenance costs would be higher for pavement markings than for a post-mounted sign. The double line would be the simplest to apply, since most paint trucks are already equipped with double spray heads. The hash marks would require hand operations plus careful engineering of the spacing, especially for sites at crests of hills, so the lines did not blend into one mass of paint. The RPM layout would likewise require more engineering and installation time. Finally, the life of the markings would be much shorter than that of a post-mounted sign.

4. The pavement markings would warn the drivers there was something unusual at that point and direct them to stay in their lane, but would not tell them how far they could go off the road if they were in a controlled emergency situation (moving out of the way of emergency vehicles). The post-mounted object marker, placed on the near edge of the hazard, would tell them exactly how much lateral leeway was there.

The four types of pavement treatments suggested for use in the laboratory experiments were: 1) hash marks; 2) sinusoidal lane lines; 3) concentrated raised pavement markers (RPM), and 4) a double edge line, the additional line to be put down on the outside of the existing edge line. Pavement marking 1 and 4 are illustrated in the rough sketch in figure 15 on the following page. The sinusoidal line 2) was discarded as being the most unwieldy to put down, least likely to be understood by the driving public, and least likely to be accepted by AASHTO officials and highway workers. Additionally, the concentrated raised pavement markers (RPM) were discarded due to cost of installation and maintenance.

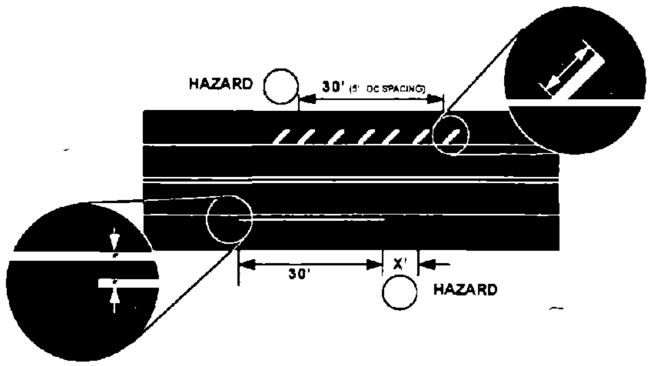


Figure 15. Rough sketch of the pavement markings:
Hash marks and double line.

In addition to the pavement markings, two post-mounted designs were developed. The first was a set of two types of object markers with directional information (figures 16 and 17). The second marking set was a representational symbol (figure 18). The arrow markers in figure 16 stem from the French gore marker which is two isosceles triangles back to back. The figure 17 variation indents the back of the triangle, forming a second arrow, similar to the chevron alignment sign, but different enough in shape that it should not be interpreted as a change in alignment. Together, the markers in figure 16 or 17 could replace all types of the current object markers. Various color combinations were considered, including black on yellow, white on yellow, and green on yellow. White on yellow was discarded because of low contrast. Combinations including the unassigned FHWA colors were considered, including strong yellow-green which is likely to be assigned as the background for non-motorized crosswalk signs (i.e., pedestrian, school, and bicycle crossings), coral (no sheeting available), and purple or light blue (both deemed unsuitable by all members of the expert discussion group). The colors chosen for the arrows were black on yellow.

Figure 18 shows the representational symbol shape, that of a cone. It was chosen by the expert discussion group as the best symbol to represent the need to avoid a hazard, even though no research subject conceived of it in the marker production study during the problem identification studies. Colors chosen for the cone were black on yellow and black on strong yellow-green were selected for inclusion in the laboratory studies. Additionally a third color combination, black on a coral-like background was investigated informally (i.e., not submitted to statistical analysis) as no sheeting was currently available.

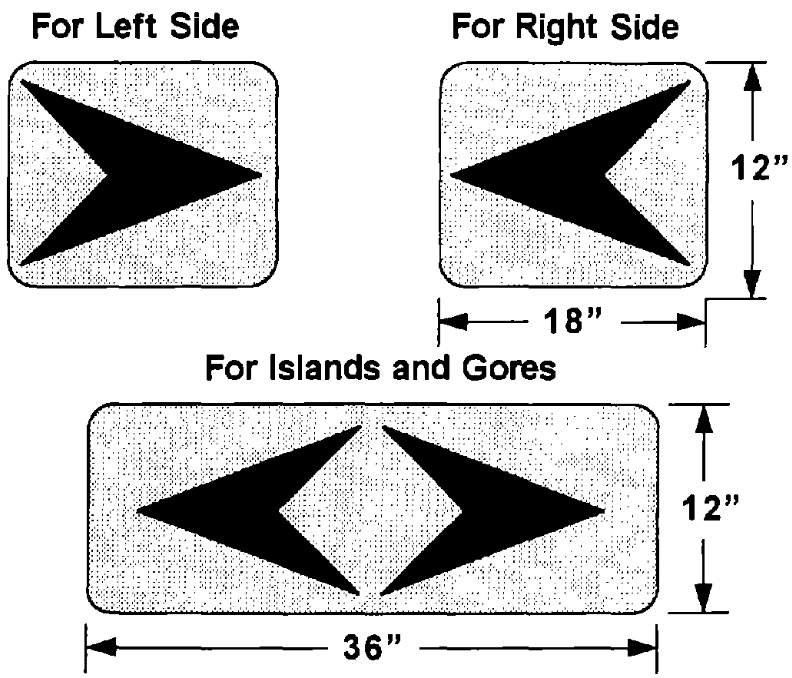


Figure 16. Directional arrows derived from French gore marker.

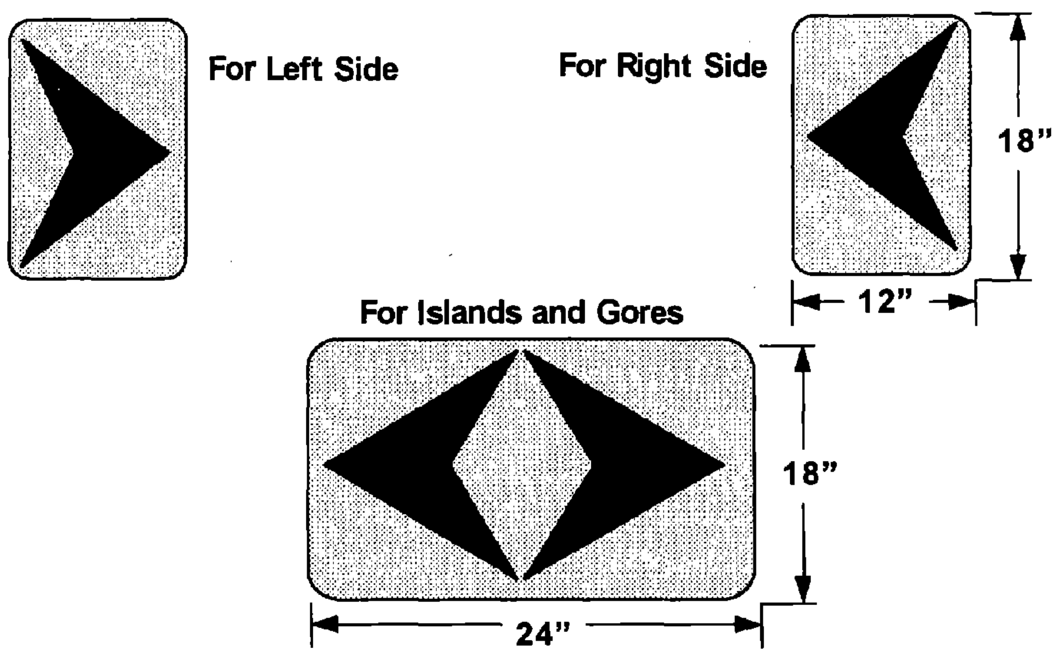


Figure 17. Directional arrows derived from chevron alignment sign.

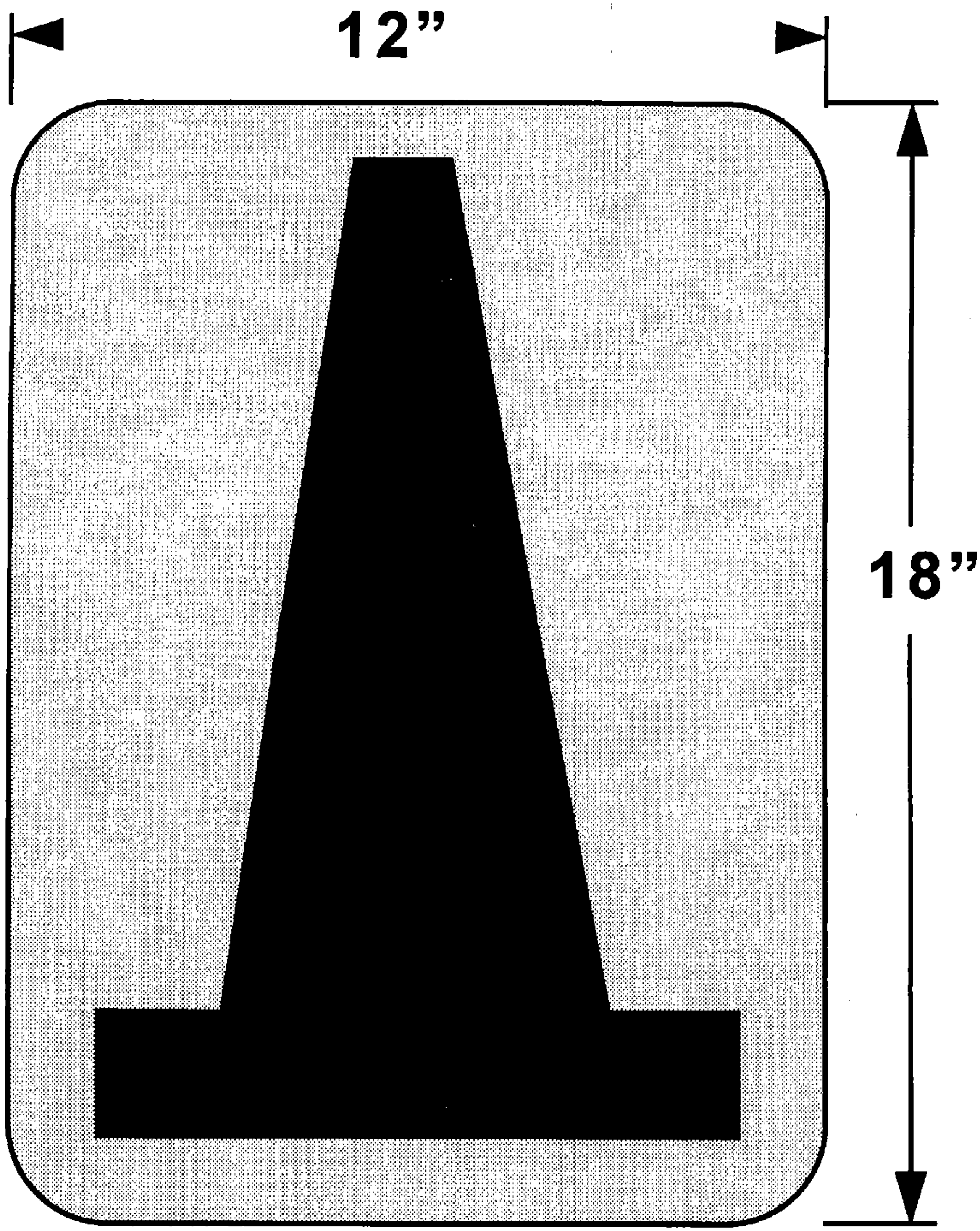


Figure 18. Representational symbol (cone) for an alternate object marker.

CHAPTER 8. OVERVIEW OF LABORATORY INVESTIGATIONS FOR STATIC MARKERS

A series of three laboratory experiments was conducted, addressing the issues of marker comprehension, recognizability, and conspicuity. The purpose of the laboratory investigations was to evaluate new alternatives on all of these important criteria, screen out any that did not perform satisfactorily, and select the most promising to carry forward for field verification. The current object markers were included in all three experiments for comparison. All subjects in the laboratory studies did not participate in problem identification studies, and as in those studies, a subject could participate in only one of the three experiments.

Experiment 1 of the laboratory studies was a comprehension experiment. It was similar to the comprehension experiment in the problem identification studies, except that the familiarization and danger scales were not administered. Since there was no difference in the earlier comprehension experiment between button copy and sheeting, only sheeting was used for the current OM-1 and OM-2 markers in the experiment.

Experiment 2 was a feature recognizability experiment conducted by the subcontractor. The data for this experiment was collected on the test track facility at the Pennsylvania Transportation Institute. Full-scale stimuli were used in the study. Sessions were conducted under both daytime and nighttime conditions. The experimenter drove along the test track, with the subject sitting in the passenger seat. Whenever the subject was just able to discriminate some feature of the marking (color, shape, pattern, etc.), the experimenter was told to stop. The feature was recorded, along with the distance from the stimulus. The trial continued until all relevant features had been identified.

Experiment 3 was a conspicuity experiment, using a verbal report technique developed and validated by researchers at the Australian Road Research Board.[21] Each subject viewed an edited videotape containing many short scenes of local roads, most of which included a hazardous object. As in the conspicuity experiment in the problem identification studies which used briefly projected slides, each scene was viewed with the current markers, and with the alternate markers or pavement markings. As before, no subject saw the same scene twice in order to reduce order effects. This way it could be deduced if the proposed treatments increased the probability of an object or its marker being seen.

CHAPTER 9. LABORATORY EXPERIMENT 1: COMPREHENSION OF PROPOSED DESIGNS

Rationale. As discussed in the literature survey, object markers may be useful to drivers even though the drivers cannot identify specifically what the purposes of the object markers are. Even though confusions among current object markers and other current warning signs or post-mounted delineators were identified in the problem identification experiments, this laboratory study did not continue that examination. The focus of this study was to investigate whether the proposed markings were better understood than current markings in communicating hazards. The problem identification studies indicated that current markings are not well understood and the results from the population stereotype study indicated that there is no universally understood symbol for a hazardous object.

Because in the problem identification experiments there were no differences found between button copy and sheeting, only the sheeting version was used in the comprehension experiment . 3M Diamond Grade sheeting was used for all treatments. It provides added retroreflectivity over 3M High Intensity Grade sheeting. It provided the desired color combinations for all laboratory studies. As coral sheeting was not available, a cone sign with a coral background was constructed using coral paint. Data from the coral sign was analyzed informally and post-hoc.

Objectives. The specific objectives for laboratory experiment 1 were:

1. To identify what the proposed markers mean to drivers.

2. To investigate if the proposed markers are more understandable than the current markers.

3. To investigate if pavement markings alert older drivers to hazardous objects better than post-mounted markers.

4. To investigate if any color combination tells the driver stay away from this hazardous object.

Methodology. As in the problem identification studies, the subjects saw re-useable stimulus booklets, with the subjects recording their answers on separate sheets. They completed open-ended questions on meaning/action for a set of traffic control devices (TCD), presented in a booklet. Each TCD was shown in context, using many of the same photos from the problem identification studies. The answers were then coded 5, 'correct'; 4, 'partially correct'; 3, 'incorrect, but not dangerous'; 2, 'confusion, possible danger'; 1, 'dangerously wrong, dangerous confusion'; or 0, 'no answer.' Three researchers coded the answer booklets after formal training. The 20 'confusion and additional stimuli' were also coded for meaning and action. The confusion signs and markers are those that are sometimes used instead of, or confused with, object markers. Fourteen additional signs were included to distract the subjects from the real intent of the study.

Each group met at a site mutually convenient to its members. Meeting places, aside from various conference rooms, included church/synagogue meeting rooms, or rooms at community centers, libraries, and recreation centers.

Given that the proposed treatments were all novel, patterns of familiarity were not collected in this task. Additionally, danger ratings investigated in the problem identification studies, were not investigated again in this experiment.

Variables.

1. Independent. Age-group, hazardous object treatment type, and situation.

2. Dependent. Correctness of answers.

Stimulus materials. Subjects saw 40 color scenes, each with a TCD, confusion or additional stimuli, randomized to blend any order effects. The scenes were color photographs of prototype or confusion signs temporarily placed in a situation where they would normally appear. Thus, the stimuli were an actual driver's eye view showing true scene color and shadows. Color swatches were provided to the photograph developer in order to provide the correct sign color when printing photos. As coral sheeting was not available, a cone sign with a coral background was constructed using coral paint.

The following treatments were used in independent groups:

1. Current practice (OM-1, OM-2, and OM-3).
2. The representational symbol sign.
3. The directional symbol sign.
4. The pavement treatments.

The laboratory studies used only a subset of the foils used in the studies due to site-use restrictions required by Maryland DOT. Many freeway and urban situations were considered unsafe for project personnel to photograph hazard markings, and presented a safety hazard for motorists as well. Additionally, several situations listed in the workplan for this experiment could not be identified in geographic areas specified for use by Maryland DOT (e.g., no hazardous cargo, etc.). These situations were replaced by other foils. The confusions and additional foils used are listed in table 36.

Table 37 presents the 19 hazard situations and the set of markers used for each situation. The four columns on the right correspond to the independent groups. 'Cone' refers to the representational marker alternatives; 'Hash' to hash marks; and 'Dble' to double edge lines. Selection of current OM types per hazard was based on their use in the problem identification studies. Both color combinations of the 'cone' were used at all sites as well as both shape variations of the arrow (vertical and horizontal). Selection of the arrow symbol was based on the side of the road in which the hazard was located.

Table 36. Confusion and additional foil stimuli used in the comprehension experiment. (Codes in parentheses are sign number or pages from the MUTCD).[1]

Confusion and Additional Stimuli	
Confusions	
Keep Right (R4-7)	Chevron Alignment (W1-8)
Large Arrow (W1-6)	Divided Highway (W6-1)
Large Arrow (W1-7)	Double Arrow (W12-1)
Additional Stimuli	
No Right Turn (R3-1)	Restricted Lane Ahead (R3-13)
No Left Turn (R3-2)	Playground (W15-1)
No U-Turn (R3-4)	Camping (D9-3)
Two-Way Traffic (W6-3)	Horse Crossing (W11-7)
Pedestrian Crossing (S2-1)	Deer Crossing (W11-3)
No Parking (R8-3a)	Truck Crossing (W8-6)
Tractor Crossing (W11-5)	Fire Truck Crossing (W11-8)

Recruitment procedures for test subjects. Subjects in this experiment were recruited from the contractor's present subject pool. Additional subjects were recruited using area churches, community and recreation centers.

Number and age grouping of subjects. There were 64 subjects in all, 16 in the 20 to 40 year-old group, 24 in the 65 to 69 year-old group, and 24 in the 70 and older group. This concentrated resources in the age ranges of greatest interest. The booklet format allowed experimenters to vary group size and to intermix age groups since each subject worked independently.

Experimental protocol. Once the subject group had gathered and introductions had been made, the experimenter explained that they were studying, on behalf of FHWA, how well drivers understand traffic signs and situations. They then handed out the booklets which included an informed consent sheet. Subjects read the consent form and signed it. The experimenter then read the detailed instructions presented in appendix C.

Subjects were given as much time as they needed to complete their booklet. When they had completed all scenes in their booklet, the experimenter checked the answer sheets to insure each question had been answered and that the subject number was on each answer sheet.

Table 37. Hazardous situations used in Experiment 1.

Hazard Situation	Grp 1 Current OM Type	Grp 2 Cone Type	Grp 3 Arrow symbol	Grp 4 Pavement marker
Gore, Urban	1 & 3	Cones1 and 2	< >	n/a
Gore, Urban	1 & 3	Cones1 and 2	< >	n/a
Island, Rural	1 & 3	Cones1 and 2	>	n/a
Island, Urban	1 & 3	Cones1 and 2	>	n/a
Island, Urban	1 & 3	Cones1 and 2	>	n/a
Inlet, Rural	2 & 3	Cones1 and 2	<	n/a
Culvert, Rural	2 & 3	Cones1 and 2	<	Hash & Dble
Street Light Pole, Urban	2 & 3	Cones1 and 2	<	n/a
Utility Pole, Rural	2 & 3	Cones1 and 2	<	Hash & Dble
Utility Pole, Urban	2 & 3	Cones1 and 2	<	n/a
Tree, Rural	2 & 3	Cones1 and 2	<	Hash & Dble
Tree, Urban	2 & 3	Cones1 and 2	<	n/a
Bridge-Rail End, Rural	2 & 3	Cones1 and 2	<	Hash & Dble
Bridge-Rail End, Urban	2 & 3	Cones1 and 2	<	n/a
Guard-Rail End, Rural	1 & 3	Cones1 and 2	<	n/a
Guard-Rail End, Urban	1 & 3	Cones1 and 2	<	n/a
Bridge Pier, Urban	1 & 3	Cones1 and 2	<	Hash & Dble
Bridge Abutment, Rural	1 & 3	Cones1 and 2	<	n/a
Bridge Abutment, Urban	1 & 3	Cones1 and 2	<	n/a

Scoring. The open ended responses were then scored according to the following protocols:

To be 'correct' (5) for an object marker, a response had to state clear recognition of the particular hazard. The 'correct' action was to drive to the proper side of, and avoid the hazard.

To be 'partially correct' (4), any answer involving caution, general warning or general hazard was accepted. The 'partially correct' action was to be cautious, or generally avoid the hazard.

An 'incorrect but not dangerous' (3) answer was any reference to the situation that did not involve the hazard or an aspect of caution.

Answers scored as 'confusion, possible danger' (2) were any that could possibly put the driver in a dangerous situation.

Likewise, answers scored as 'dangerously wrong, dangerous confusion' (1) were any that would most likely put the driver in a dangerous situation. An example would be interpreting the markers as "Do Not Enter" at the mouth of an underpass.

Blank answers were coded 'no answer' and scored (0). This included answers such as "I have no idea, I can't even guess."

LABORATORY EXPERIMENT 1 RESULTS: COMPREHENSION OF PROPOSED DESIGNS

Analyses. To assess the degree to which proposed hazardous object markers are understood when compared to current markers and other warning signs, 64 subjects viewed 40 color photographic illustrations of an object marker situated within a roadway context scene. These 40 illustrations were presented in a counterbalanced order among the subjects to minimize any potential response bias. For each roadway scene viewed, subjects gave open-ended written responses to the following two experimental questions: (1) Exactly what do you think this [marker] means? and (2) What action would you take as a driver if you saw this [marker]?

Subjects' responses for the above two experimental questions, Meaning and Action, were rated on a 5-point scale. This scale is denoted in table 38. The rated scores of all responses to the Meaning and Action questions for current and proposed object markers correlated around .70 ($p < .01$). Often, an action was embedded in the meaning responses. For example, subjects would report the meaning of the marker and include the action they would take if they encountered this marker. Because Meaning and Action scores were significantly correlated (which was also found in the problem identification studies), it was decided to take the higher rating of either the Meaning or Action question as the dependent variable for this experiment; all reported results and statistical analyses are based on this higher score of either the Meaning or Action variable. The frequency distribution of responses falling in the five rating categories is also shown in table 38. This distribution (as well as all reported results from hereon) is based on responses to a subset of current and proposed markers only. The definition of the subset and rationale used to exclude certain markers from the final analyses is described in the following section.

Table 38. Score and frequency of highest rated response for either meaning or action for all subjects.

Numeric Score	Rating	Frequency of Responses
5	Correct	177
4	Partially Correct	501
3	Incorrect, but not dangerous	279
2	Confusion, possible danger	6
1	Dangerously wrong, dangerous confusion	2

Ratings for each higher scored response per marker/situation combination were divided into two categories for purposes of descriptive statistics and statistical analyses. A correct response was defined as a response that was awarded a 4 or a 5 rating. An incorrect response was defined as a response that was given a 1, 2, or 3 rating. As shown in table 38, most of the incorrect responses were considered incorrect but not dangerous (n=279). Thus, although there may appear to be a sizable number of incorrect responses, the majority would not necessarily result in a dangerous driving maneuver, but rather only a possible misinterpretation of the object marker by the driver.

The responses for the confusion and foil markers were excluded from the final data analysis of this study. Only the current (OM-1, OM-2 and OM-3), the proposed pavement, and the post-mounted markers were used to address comprehension issues of the revised object marker designs. The foils and confusion markers were included in this study simply to mask the purpose of the experiment to the subjects. Subjects were told that this was a study to "determine how well drivers understand traffic signs and situations." Thus, many types of traffic signs were viewed, but only a subset of these signs were pertinent to answer the study hypotheses.

Results. Thirteen object markers and 11 hazardous situations were used to address the research questions of interest for this experiment. The marker and situation combinations used in this experiment are shown in table 39. The percent of correct responses for all markers in all situations was 70.3 percent. That is, out of 965 responses, (27 of which were missing), 70.3 percent were rated as correct (4 or 5) on either the meaning or action score for all object marker and situation combinations. However, this observed percent correct may be confounded with marker type, since all markers did not occur in all situations.

The 64 subjects were grouped into 3 age categories: 20 to 40 years old (n=16), 65 to 69 years old (n=24), and 70 years and older (n=24). Younger subjects had a higher number of percent correct responses than older subjects: 82.7 percent for the 20 to 40 year olds, 68.3 percent for the 65 to 69 year-olds, and 63.7 percent for the 70 and older group ($p < .01$). Pairwise post-hoc comparisons showed differences between the younger subjects when compared to the two older subject groups. The percentage of correct responses for each object marker in all hazardous situations is shown in table 40.

The second row of table 39, labelled "All Markers," reports the percent of responses rated as correct for all object markers placed at each situation type, e.g., all object markers which occurred at a median island, all object markers at a gore, etc. To test for differences between the number of correct and incorrect answers for the various markers at each situation, frequency counts of correct (numeric rating of 4 or 5) and incorrect (numeric rating of 1, 2, or 3) scores for the marker/situation combinations were analyzed using chi-square analyses. For 6 of the 11 situations, i.e., median island, utility pole, culvert, inlet, bridge abutment, and street light, the type of object marker used at each location had a significant influence on subjects' responses, or how drivers interpreted the meaning of the object markers for that hazardous situation. For half of these six situations (median island, inlet, and bridge abutment), current object markers were most often interpreted correctly. At a culvert, both OM-3 and hash marks were always understood. At the utility pole and the street light, the proposed post-mounted markers of green cones were best understood. It should be noted however that for the street light situation, current markers were not included.

The second column of table 39, labelled "All Situations," reports the percent of responses rated as correct for all situations in which each object marker was placed, e.g., all situations where an OM-1 occurred, all situations where an OM-2 occurred, etc. Only differences for the OM-3 and the double edge lines reached statistical significance. Therefore, in this experiment, multiple situations (or context) do not seem to have much of an effect on the meaning that drivers assign to an object marker. The individual cells of table 39 report the percent of responses rated as correct for any particular marker and situation combination.

Object markers were also grouped according to experimental types as denoted in table 41. Average percent correct scores for each marker type category collapsed over all situations is reported in this table. Analysis of markers by these categories yielded a statistically significant difference overall ($p < .01$). Post-hoc analyses revealed two specific pair-wise differences: (a) between the current markers and the proposed pavement delineations ($p < .01$), and (b) between the current markers and the proposed post-mounted directional symbols ($p < .01$). Current markers had higher scores than all the proposed markers collapsed together: 80.1 percent correct versus 65.8 percent correct respectively, although not significant.

Table 39. Highest rating for object marker meaning or action response.
(The numbers listed in this table are percent correct by situation.)

	All Situations [2]	Median Island [1]	Gore	Bridge Pier	Bridge Rail	Utility Pole[1]	Tree	Culvert[2]	Inlet[1]	Bridge Abutment[1]	Street Light[2]	Guard Rail
All Markers[2]	***70.3***	***79.9***	***69.9***	***60.9***	***79.8***	***62.4***	***64.2***	***69.4***	***63.0***	***73.6***	***59.4***	***73.7***
OM-1	***82.3***	87.5	80.0	75.0						93.8		68.8
OM-2	***72.9***				80.0	73.9	62.5	62.5	87.5			
OM-3[2]	***82.2***	100.0	75.0	50.0	100.0	66.7	62.5	100.0	87.5	93.8		81.3
Double Edge Lines[1]	***48.7***			50.0	100.0	25.0	50.0	25.0				
Hash Marks	***72.5***			62.5	75.0	62.5	62.5	100.0				
Yellow Cones	***74.0***	82.6	46.7	62.5	87.5	60.0	75.0	85.7	75.0	64.3	87.5	87.5
Green Cones	***78.5***	72.7	73.3	100.0	75.0	93.3	93.3	87.5	66.7	68.8	87.5	60.0
Left French Gore	***52.3***			25.0	75.0	56.3	46.7	28.6	37.5	46.7	37.5	75.0
Right French Gore	***78.3***	78.3										
2 French Gore	***56.3***		56.3									
Left Modified Chevron	***52.8***			62.5	53.3	37.5	53.3	62.5	25.0	71.4	25.0	68.8
Right Modified Chevron	***56.5***	56.5										
Double Modified Chevron	***87.5***		87.5									

[1] $p < .05$
[2] $p < .01$

Table 40. Percent correct by age group per object marker in all hazardous situations.

Object Marker	# obs	Age Group 20 - 40	65 - 69	over 70
OM-1	79	80.0	82.8	83.3
OM-2	70	94.4	68.0	63.0
OM-3	152	94.7	79.3	76.8
Double Edge Lines	39	50.0	50.0	46.7
Hash Marks	40	90.0	66.7	66.7
Yellow Cones[1]	146	89.7	65.4	70.9
Green Cones[1]	144	94.6	75.0	70.9
Left French Gore	109	67.9	52.5	41.5
Right French Gore	23	83.3	88.9	62.5
2 French Gore	16	50.0	66.7	50.0
Left Modified Chevron	108	67.9	56.4	39.0
Right Modified Chevron	23	66.7	50.0	55.6
Double Modified Chevron	16	75.0	83.3	100.0
Overall Percent	70.3	82.7	68.3	63.7
Total Observations	965	248	353	364

[1] $p < .01$

Table 41. Markers grouped according to experimental type categories.

Marker Category	Markers Included	Average Percent Correct
Current Markers	OM-1, OM-2, OM-3	80.1
Proposed Post - Cones	Yellow Cones, Green Cones	76.2
Proposed Pavement	Double Edge Lines, Hash Marks	60.8
Proposed Post	Left French Gore, Right French Gore, 2 French Gore, Left Modified Chevron, Right Modified Chevron, Double Modified Chevron	57.0

Of the proposed markers, the percent correct did not differ between the pavement and all proposed post-mounted markers: 60.8 percent versus 66.5 percent correct respectively. For the proposed post-mounted cone markers, there was no difference between yellow and green backgrounds: 74.0 percent correct versus 78.5 percent correct respectively.

The results from Laboratory Experiment 1 showed that the context or hazardous situation in which each marker occurred did not have a pronounced effect on the interpretation of the meaning or action conveyed by that object marker (see table 39). Subjects usually understood an object marker at about an equal level regardless of the hazardous situation in which that marker was placed. If an object marker was not well understood in general, then the object marker was not understood regardless of the hazardous situation. Current OM type markers were fairly well understood. For the proposed markers, the cone symbol and the hash mark delineations were comprehended at a level similar to current OM markers, (72 to 82 percent) even though cones and hash marks were unfamiliar to subjects. The French gore, modified chevron, and double edge lines all showed lower comprehension rates.

On the other hand, looking down table 39 by columns, it can be seen that in over half of all hazardous situations (6 out of 11), the situation did have an effect on the understanding and comprehension of the different object markers used for that situation. For some situations, subjects showed a high level of understanding for the currently used markers (OM-1, OM-2, and OM-3). This may be due to the fact that these markers are presently used to designate hazardous situations and drivers are very familiar with their occurrence and meaning. For other hazardous situations such as a tree and a utility pole, the proposed post-mounted cone markers were better understood than current markers. Perhaps a novelty effect for these proposed markers may explain the higher comprehension than that of current markers. Alternatively, drivers may not consider a utility pole or a tree as a hazardous situation, since these common objects occur frequently along the roadway. Furthermore, these objects are usually far enough away from the roadway (although this was not necessarily the case in the present experiment). Currently, object markers are not often placed on trees and utility poles, which may account for the lower comprehension of the current object markers on these two hazards.

Finally, it should be noted that the high levels of comprehension for all object markers should not be interpreted literally since the results may be explained in part by the experimental design of the study. Subjects were required to provide their interpretation of an object marker which was clearly identified in each roadway scene by the researchers. For each scene viewed, subjects were provided with a line drawing of the marker on their answer sheet in order to help them locate the marker in the photographic illustration. By explicitly drawing their attention to the marker of interest, subjects may have been able to more easily infer or guess what the newly proposed object markers meant even though these markers have not been seen before. Whether or not these markers would be interpreted as well had they not been pointed out for the subjects cannot be determined from this study. Furthermore, scoring criteria were lenient: a response to a marker was treated as "correct," for purposes of analyses, if it was coded as either fully or partially correct, for either the meaning or action components of the answer. Thus the reported levels of correctness deal with a communication of the general hazard message, but not necessarily more specific message components. In addition, whether drivers can recognize hazardous situations and the object markers denoting these hazardous situations while actually driving cannot be determined from this study either.

CHAPTER 10. LABORATORY EXPERIMENT 2: RECOGNIZABILITY OF PROPOSED DESIGNS

Rationale. In developing TCD, comprehension alone does not constitute good design. Sign and roadway markings must have both cognitive and perceptual integrity. Previous tasks have determined the ease with which observers are able to understand the meaning of the proposed designs of object hazard markers. TCD must, however, be visible and recognizable in sufficient detail at some minimum distance to elicit the desired driver response. Laboratory experiment 2 was designed to assess the recognition distance of the new designs and compare the visual performance of these new designs with those currently in use. The results of this study were intended to aid in the stimuli selection for the full-scale dynamic field testing portion of the research effort.

Objective. The specific objective for Experiment 2 was to assess the recognition distance of features of object markers, including current and proposed designs, under daytime and nighttime driving conditions.

Methodology. The data for this experiment were collected on the test track facility at the Pennsylvania Transportation Institute. Full-scale stimuli were used in the study. Sessions were conducted under both daytime and nighttime conditions. The experimenter drove along the test track (5-10 mph), with the subject sitting in the passenger seat. Whenever the subject was just able to discriminate some feature of the marking (color, shape, pattern, etc.), the experimenter was told to stop. The feature was recorded, along with the distance from the stimulus. The trial continued until all relevant features had been identified.

Variables.

1. Independent. Age group, lighting condition, and hazardous object treatment type.

2. Dependent. Recognition distance of identifying features (color, shape, pattern, graphic elements, array characteristics). For post-mounted markers, the identifying features were: post-mounted marker detection, color, panel shape, and symbol shape. For pavement markings, they were: detection, color, and symbol shape (marking pattern). The operational definition of threshold was the greater of two consecutive distances at which the subject was able to correctly identify a particular feature. For markers 3, 6, 7, 8, and 9, the symbol shape dependent variable was the threshold distance at which the shape of the symbol on these post-mounted markers was identified. For markers 1 and 2, it was the distance at which the subjects could tell that there was no symbol, and for markers 4 and 5 it was identifying the base of the cones. For marker 10 it was determining that the second edge marking was parallel to the first and for marker 11 it was when the hash marks were seen as oblique to the edge line.

Stimulus materials. The stimulus set included both current and proposed object marker designs. The procedure used full-scale model versions of the hazard markers made from actual sheeting materials and pavement marking materials. The retroreflective material used on the signs was 3M diamond grade yellow sheeting with the exception of number four which used 3M diamond grade fluorescent yellow sheeting (strong yellow-green). The white lane-marking materials were 3M detour grade. The experimental vehicle was a 1991 Chevrolet Cavalier sedan. The following object markers were used:

1. OM-1
2. OM-2
3. OM-3 left version
4. Cone post-mounted marker, black on yellow-green
5. Cone post-mounted marker, black on yellow
6. French Gore post-mounted marker, left arrow
7. French Gore post-mounted marker, combined left and right arrow
8. Modified Chevron post-mounted marker, left arrow
9. Modified Chevron post-mounted marker, combined left and right arrow
10. Double edge line pavement marking
11. Diagonal hash mark pavement marking

Recruitment procedures for test subjects. Subjects were recruited through local church and civic organizations and the Pennsylvania State University. Each session lasted approximately 1 h.

Number and age grouping of subjects. Fifty subjects were recruited for participation in this study. The subjects were selected on the basis of age and divided into three groups. Group 1 consisted of 12 daytime and 11 nighttime subjects from 17 to 40 years of age; that is, 10 subjects ran both day and night, 2 ran only in the day, and 1 ran only at night. Group 2 had 18 daytime and nighttime subjects from 65 to 69 years; that is all subjects were tested under daytime and nighttime conditions. Group 3 had 20 daytime and 17 nighttime subjects 70 years of age and older; that is all subjects were tested at night, and 17 of these participants were also tested in daytime. A total of 96 sessions were run, 50 daytime and 46 nighttime. All participants were required to have a current automobile driver's license.

Experimental protocol. After introductions, the experimenter explained that the research was to determine, on behalf of FHWA, how people see and recognize roadway signs and markers. Subjects read and signed the informed consent sheet (see appendix A) and were taken to the test track. The equipment was checked and the subject seated in the passenger seat of the vehicle. During the subject instructions, stress was placed on identifying particular features, as opposed to waiting until the overall stimulus was recognized. Answers based on stimulus meaning and driver action were discouraged in favor of answers dealing with particular details including colors of figure and background, and shape.

Eleven trials were conducted for each lighting condition. Each subject was tested under daytime and nighttime conditions except for normal attrition. The procedure was the same for daytime and nighttime sessions. Each subject saw all stimuli, and only one subject ran at a time. The first trial for a particular design or pavement marking and the first trial of a particular color combination were counterbalanced.

All post-mounted hazard marker heights and lateral offsets were consistent from sign to sign and conformed to MUTCD standards. The signs were mounted at 1.8 m (6 ft) lateral offset from the right edge line at a mounting height of 1.2 m (4 ft) from the road surface to the sign's bottom. The procedure was consistent with recent studies conducted at the PTI test track. The second edge line was 9 m (30 ft) in length, placed parallel to and 15 cm (6 in) from the existing edge line. The six hash marks were 0.9 m (3 ft) in length, 20 cm (8 in) wide, and were placed at 1.8 m (6 ft) intervals at a 45 degree angle to the edge line and aimed downstream.

Each trial began at 305 m (1,000 ft). The experimenter drove along the test track toward the object marker with the subject seated in the passenger seat. When the subject was just able to discriminate some feature of the marking, he or she told the experimenter to stop. Detection distance and feature recognition distance were recorded. At this point the experimenter approached the stimulus in discrete steps of 15 m (50 ft). At each step the experimenter asked the subject to identify the salient features of the stimulus. The subject reported the stimulus appearance either orally, or pictorially by means of an erasable drawing board. As the subject correctly identified each feature, the experimenter recorded the distance on a laptop computer. Each trial continued until either all relevant features had been identified for that stimulus or the distance between the vehicle and the stimulus was 15 m (50 ft). The experimenter then turned the vehicle around and again assumed the position at 305 m (1,000 ft), while a second experimenter set up the next stimulus. After completing this procedure for the 11th stimulus, the subject was paid, thanked, and escorted to his or her car.

LABORATORY EXPERIMENT 2 RESULTS: RECOGNIZABILITY OF PROPOSED DESIGNS

<u>Analyses</u>. Formal statistical analyses were conducted separately for the daytime and nighttime conditions. Multivariate Analysis of Variance (MANOVA) statistical techniques were used to examine the relation between age group and object marker type. Separate MANOVA were run for marker detection, color recognition, panel shape recognition and symbol shape recognition. All significant interactions between age group and marker type were further probed with single factor ANOVA. Because of the large number of levels in the object marker type variable, the conservative Tukey HSD post-hoc test was used to differentiate between the means. For marker detection, color recognition and panel shape recognition, MANOVA were run on the post-mounted markers only as it was clear without statistical analysis that threshold distances on these dependant variables were significantly greater for the post-mounted marker types than pavement marking types.

Nighttime Results.

Post-mounted Marker Detection Distance. All of the subjects detected all of the markers at 305 m (1,000 ft). As there was no variance in any of the variables, there was no age group effect or interaction between age group and marker type.

Pavement Marking Detection Distance. No main effects of age group or marker type, and no interaction between these variables ($F=2.81$, $p=.072$; $F=.2$, $p=.658$; $F=1.51$, $p=.232$) was found. Mean nighttime detection distance for the hash marks was 68 m (224 ft) and for the double edge line 69 m (226 ft).

Post-mounted Marker Color Recognition Distance. As 41 of the 46 (89%) subjects never saw the yellow-green cone post-mounted marker (marker 4) as green but yellow, the color recognition data were analyzed without this marker. Excluding the green cone resulted in no significant differences between the color recognition distances ($F=1.95$, $p=.062$). No age group effect ($F=.82$, $p=.448$), nor any age group by marker type interaction ($F=1.31$, $p=.2$) was found. With the exception of the green cone post-mounted marker, the range of distances for nighttime color recognition was from 284 to 303 m (932 to 993 ft).

Pavement Marking Color Recognition Distance. There was a borderline significant main effect of age group in this analysis ($F=3.26$, $p=.048$). The mean color recognition distances for the 3 age groups were 71, 65, and 57 m (234, 214, 187 ft) for the 20 to 40 years, 65 to 69 years and 70 and older groups respectively. No main effect of marker type ($F=.06$, $p=.813$) or interaction between marker type and age group ($F=1.02$, $p=.369$) was found. The mean color recognition distances were 63.7 and 64.3 m (209 and 211 ft) for the double edge line and hash marks, respectively.

Post-mounted Marker Panel Shape Recognition Distance. There was no age group main effect ($F=.94$, $p=.4$) or interaction between age group and marker type ($F=.77$, $p=.723$) on the panel shape recognition dependant variable. There was, however, a significant main effect of marker type ($F=9.66$, $p<.001$), as shown in figure 19. This effect was probed with a Tukey HSD post-hoc test, the results of which are detailed in table 42.

Pavement Marking and Post-mounted Marker Symbol Shape Recognition Distance. This analysis included pavement markings as well as post-mounted markers. The symbol shape analysis was conducted with the pavement markings because there was not such a clear demarcation between the post-mounted markers and pavement markings as there was with the other dependant variables. Significant main effects of age group ($F=4.01$, $p=.026$) and marker type ($F=163.93$, $p<.001$) were found, (see figure 20), but no interaction was found between the two ($F=1.21$, $p=.244$). Marker data were collapsed and a single factor ANOVA was conducted on the three age groups followed by post-hoc Tukey-HSD. The post-hoc analyses showed the significant age group main effect was the result of significantly different mean thresholds for the 20 to 40 year olds at 159 m (522 ft) vs. the 70 and older group at 134 m (440 ft). Results of the marker type post-hoc analysis are depicted in table 43.

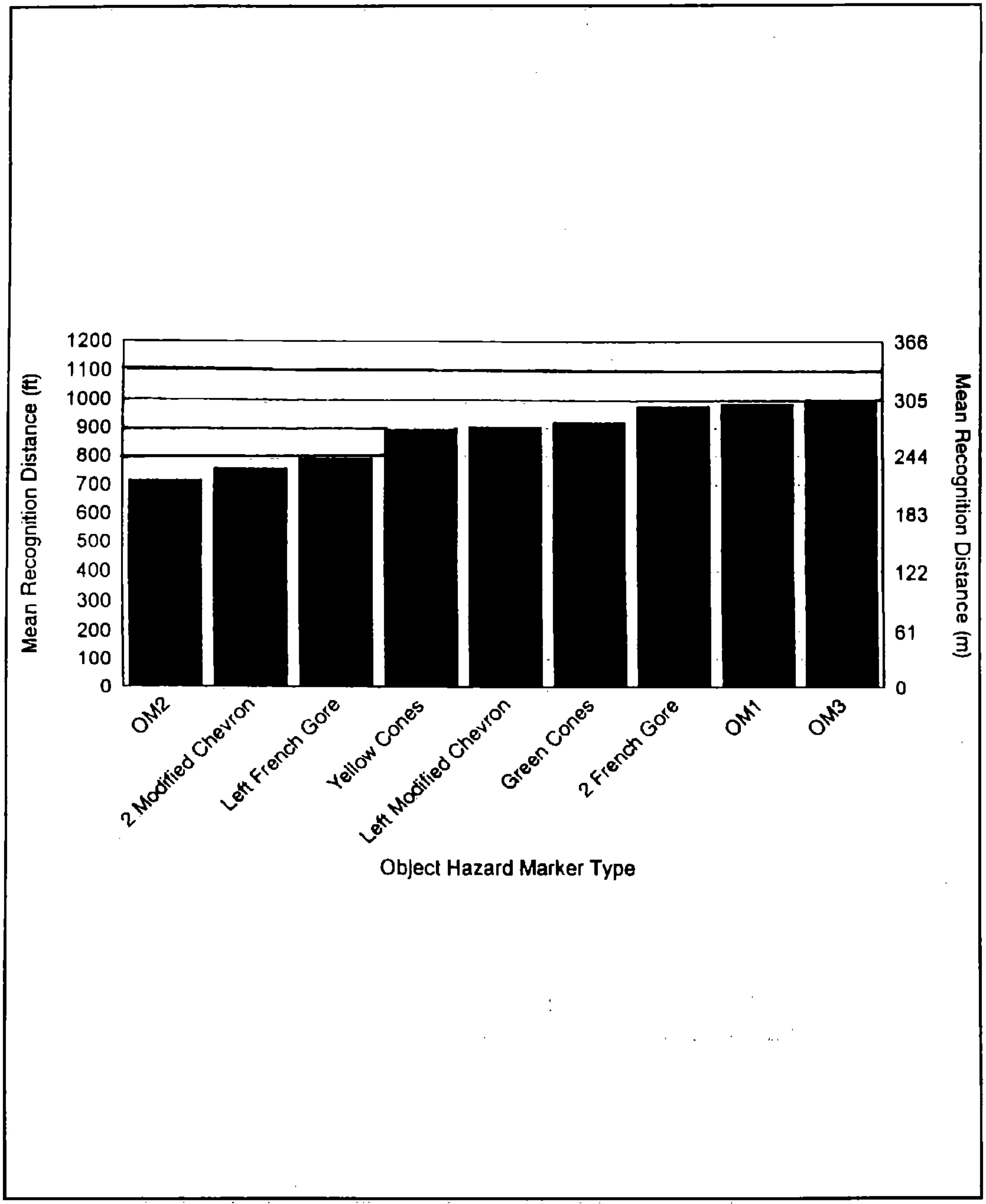


Figure 19. Nighttime main effect of post-mounted marker type on panel shape recognition distance.

Table 42. Nighttime main effect of post-mounted marker type on panel shape recognition distance.

	OM-2	2 Mod. Chev.	Left French Gore	Yellow Cone	Left Mod. Chev.	Green Cone	2 French Gore	OM-1	OM-3
OM-2									
2 Mod. Chev.									
Left									
Yellow	*								
Left Mod.	*	*							
Green	*	*							
2 French Gore	*	*	*						
OM-1	*	*	*						
OM-3	*	*	*						

* significant differences between means

Table 43. Nighttime main effect of marker type on symbol shape recognition distance.

	Hash marks	Green Cone	Yellow Cone	Double Edge	Left French Gore	Left Mod. Chev.	2 Fr. Gore	2 Mod. Chev.	OM-2	OM-1
Hash marks										
Green Cone										
Yellow Cone	*									
Double Edge	*									
Left French Gore	*	*	*	*						
Left Mod. Chev.	*	*	*	*						
2 French Gore	*	*	*	*	*					
2 Mod. Chev.	*	*	*	*	*					
OM-2	*	*	*	*	*	*				
OM-1	*	*	*	*	*	*	*	*	*	
OM-3	*	*	*	*	*	*	*	*	*	*

* significant differences between means

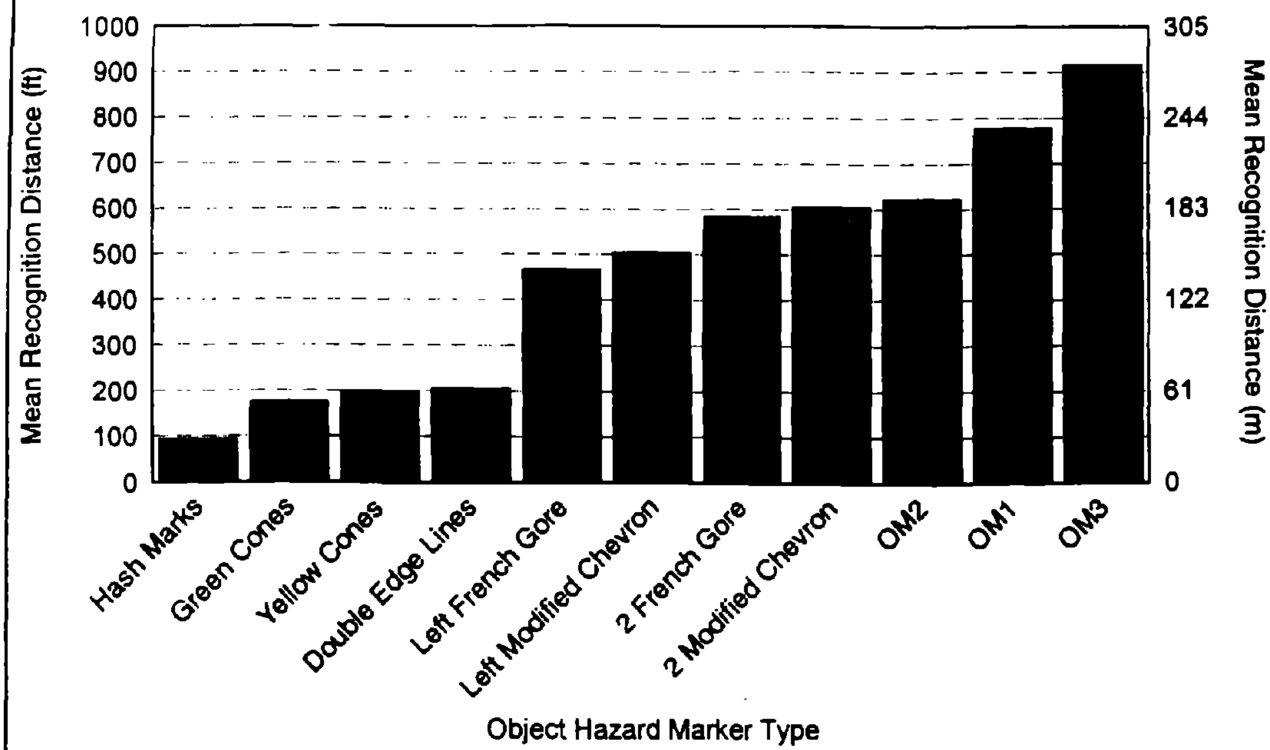


Figure 20. Nighttime main effect of marker type on symbol recognition distance.

Daytime Results.

Post-mounted Marker Detection Distance. There was a significant main effect of age group (F=3.91, p=.027), marker type (F=13.03, p<.001) and a significant interaction between the two variables (F=3.29, p<.001). A closer look at the data revealed 11 of the 12 subjects in the 20 to 40 year old group detected all markers at 305 m (1000 ft). The 12th subject saw all but the OM-2 type marker at 305 m. In the 65 to 69 year group all of the 18 subjects detected all but the OM-2 marker at 305 m. This age group had a mean detection of the OM-2 at 280 m (919 ft). The data for the 70 and older age group was similar to that of the 65 to 69 year-olds with mean detection for the OM-2 post-mounted marker at 245 m (803 ft) while the range in distance for the other eight markers was from 297 to 305 m (973 to 1000 ft). In summary, the only marker that resulted in a significant change in detection distance was the very small OM-2 marker (as shown in figure 21), the detection of which was significantly different between the 20 to 40 and 70 and older age groups.

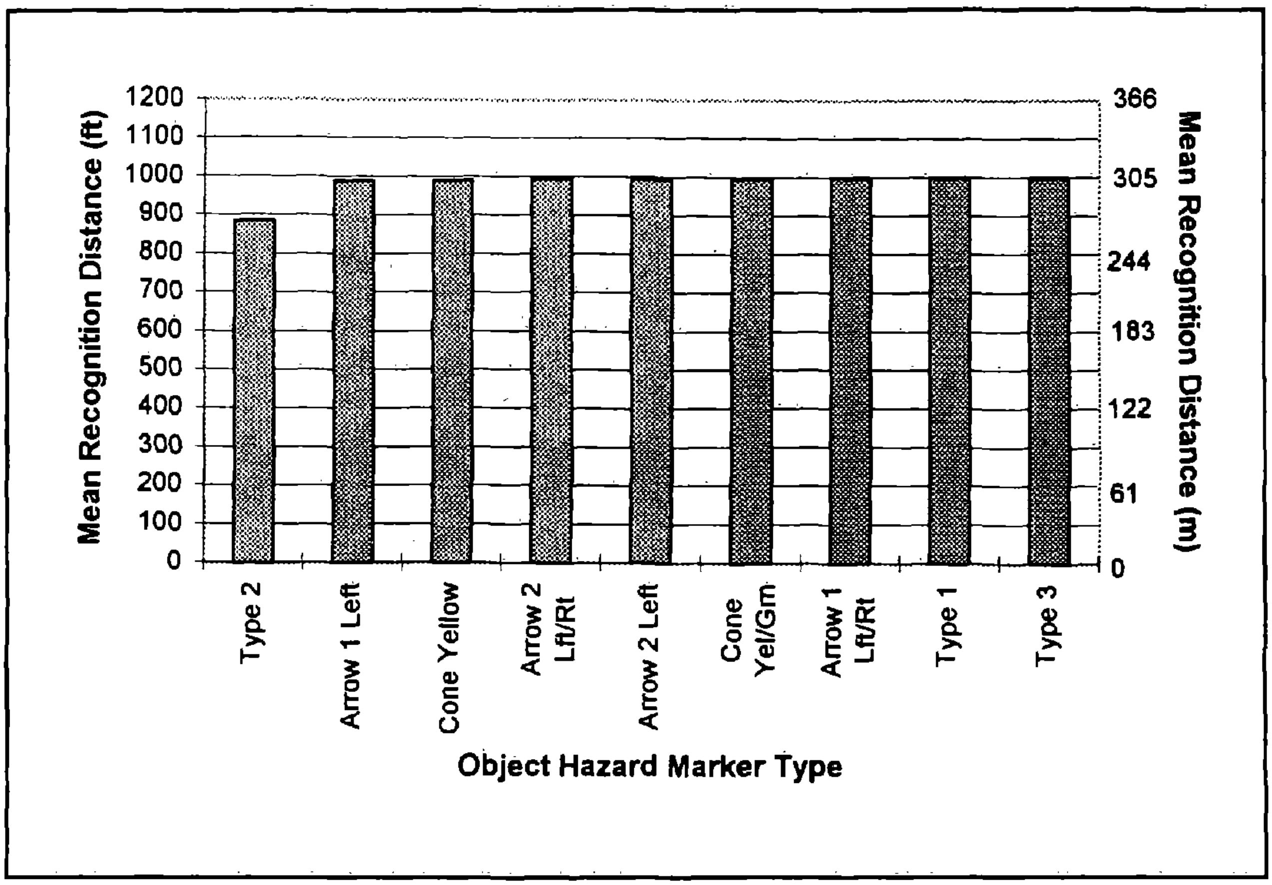


Figure 21. Daytime main effect of post-mounted marker type on symbol recognition distance.

Pavement Marking Detection Distance. There was a significant main effect of marker type ($F=60.16$, $p<.001$), but no main effect of age group or interaction between the two variables ($F=2.65$, $p=.082$; $F=.79$, $p=.46$). The hash marks were detected at a mean distance of 62 m (204 ft) and the double edge line was detected at a mean distance of 104 m (341 ft).

Post-mounted Marker Color Recognition Distance. There was no age group main effect ($F=1.94$, $p=.155$) and no age group by marker type interaction ($F=1.24$, $p=.232$). There was, however, a significant main effect of marker type on color recognition distance. Figure 22 shows the mean color recognition distance for daytime viewing conditions. A post-hoc test revealed that (with the exception of the two cone markers) the OM-2 marker resulted in significantly shorter mean color recognition distance than any other marker.

Pavement Marking Color Recognition Distance. There was a significant main effect of age group ($F=3.89$, $p=.028$). The 20 to 40 year old subjects recognized the pavement marking colors at a significantly greater distance than the 70 and older group with respective distances of 97 and 75 m (319 and 245 ft). Marker type was also significant ($F=65.69$, $p<.001$) with the hash mark color recognizable at a mean distance of 59 m (194 ft) and the double edge lines at 104 m (341 ft). There was no interaction between the two variables ($F=.55$, $p=.58$).

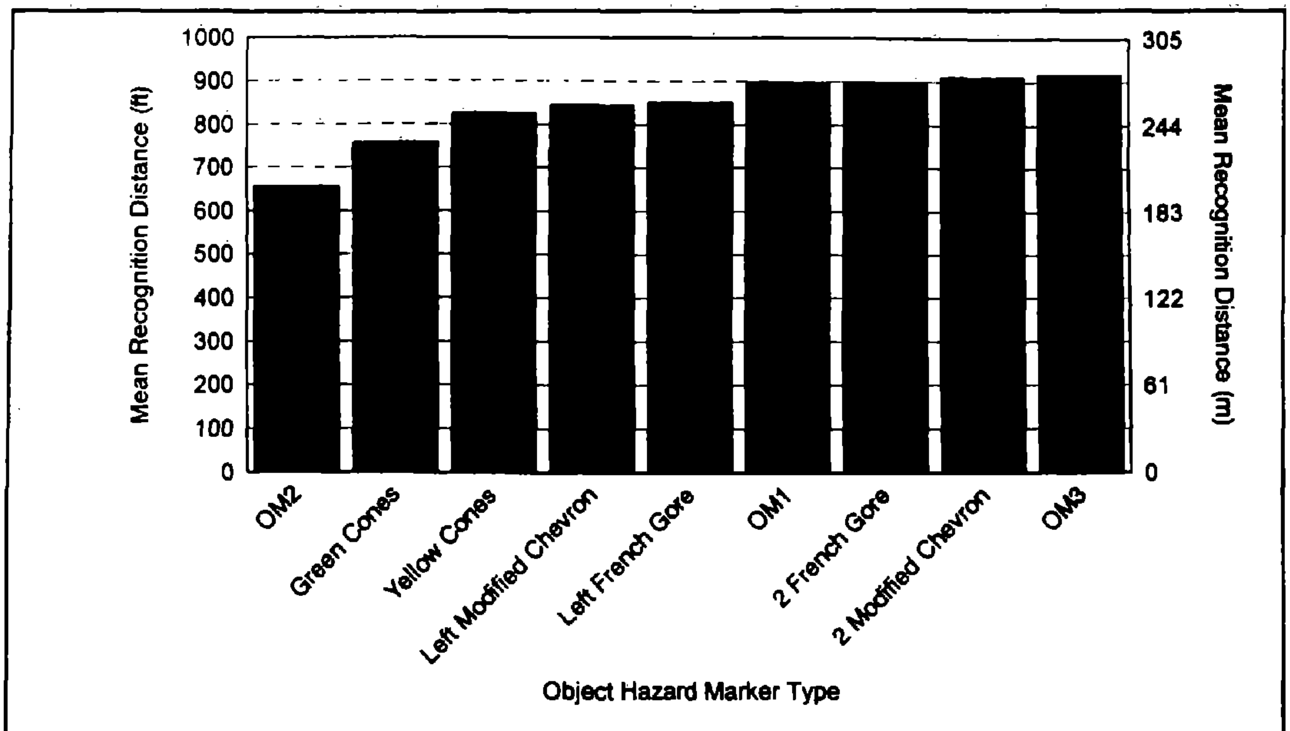


Figure 22. Daytime main effect of post-mounted marker type on color recognition distance.

Post-mounted Marker Panel Shape Recognition Distance. There were significant age group and marker type main effects ($F=7.92$, $p<.001$, and $F=13.70$, $p<.001$), but no significant interaction between the two variables ($F=1.66$, $p=.051$). Figure 23 shows the mean panel shape recognition distance for daytime conditions. Table 44 shows the marker types that had significantly different shape recognition distance means as determined by a post-hoc Tukey-HSD.

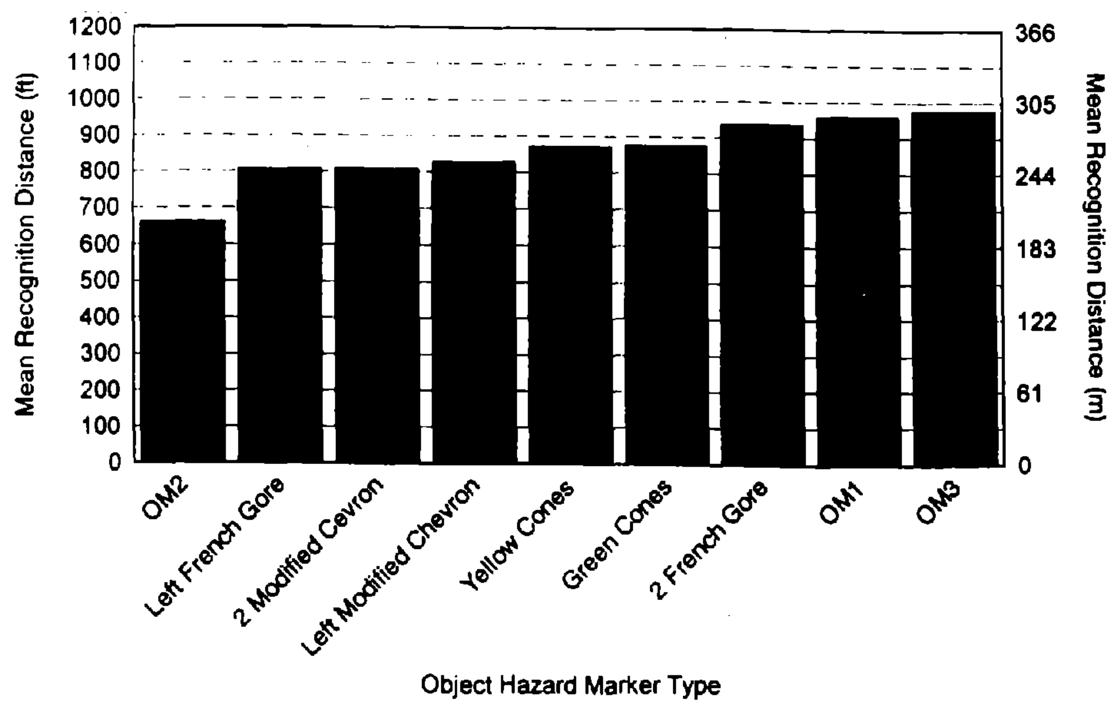


Figure 23. Daytime main effect of post-mounted marker type on panel shape recognition distance.

Table 44. Daytime main effect of post-mounted marker type on panel shape recognition distance.

	OM-2	Left French Gore	2 Mod. Chev.	Left Mod. Chev.	Yellow Cone	Green Cone	2 French Gore	OM-1	OM-3
OM-2									
Left French Gore	*								
2 Mod. Chev.	*								
Left Mod. Chev.	*								
Yellow Cone	*								
Green Cone	*								
2 French Gore	*								
OM-1	*	*	*						
OM-3	*	*	*	*					

* significant differences between means

Pavement Marking and Post-mounted Marker Symbol Shape Recognition Distance. Again, and for the same reason stated above, this analysis included pavement markings as well as post-mounted markers. There were significant main effects of age group ($F=4.76$, $p=.013$) and marker type ($F=152.32$, $p<.001$) but no interaction between the two ($F=1.31$, $p=.167$). The marker data were collapsed and a single factor ANOVA was conducted on the three age groups followed up by a post-hoc Tukey-HSD. The post-hoc analyses showed that the significant age group main effect was the result of significantly different mean thresholds for the 20 to 40 year old subjects at 202 m (664 ft) vs. the 70 and older subjects at 157 m (514 ft). The results of the marker type main effect is pictured in figure 24 and the significant differences are shown in table 45.

Detection. All post-mounted object markers evaluated were of sufficient luminance and size to be detected at the furthest distance tested by all subjects at night under low beam headlights. This finding was replicated in daylight with the exception of the OM-2 marker. Even this very small marker was detected at a mean distance of 245 m (803 ft) by the 70 and older group of subjects tested. Detection of the pavement markers was poor by comparison resulting in mean threshold distances ranging from 61 to 107 m (200 to 350 ft). Marker color (yellow vs. yellow-green) had no effect on detection distance in either daytime or nighttime testing.

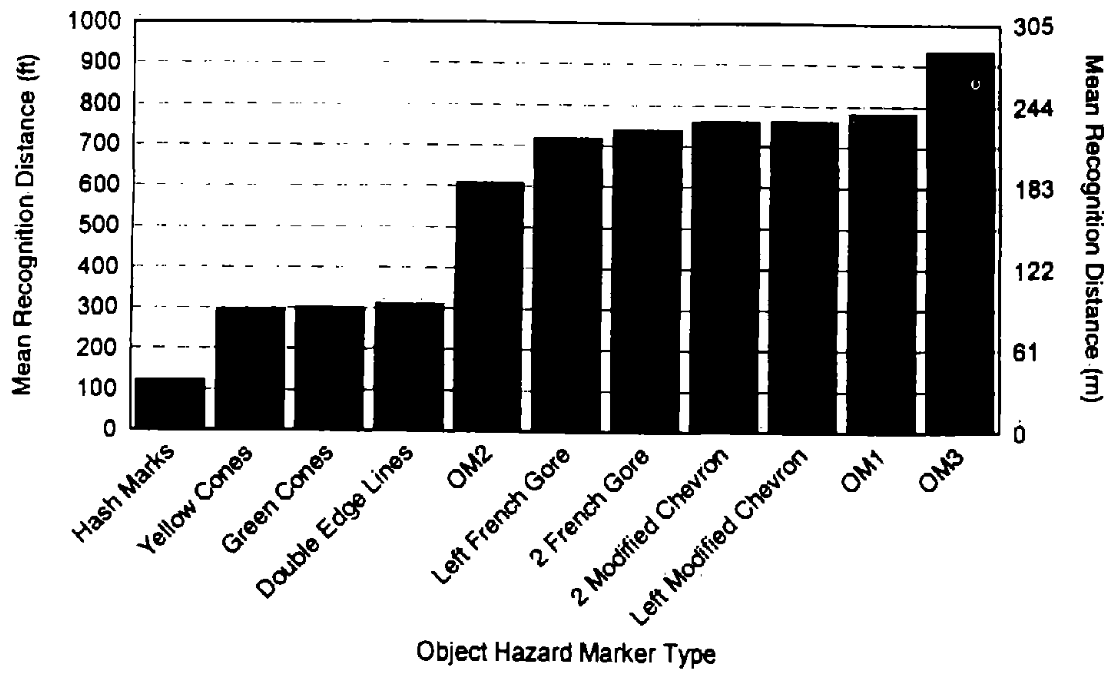


Figure 24. Daytime main effect of marker type on symbol recognition distance.

Color Recognition. At night, the yellow-green marker was seen as yellow (correct response was green or yellow-green) by 89 percent of the subjects tested. Panel size and shape had no effect on the nighttime recognition of color. In the daytime, the yellow-green marker was seen as green by most of the subjects and at a distance comparable to the other signs. Panel size did have an effect on color recognition, with the color of the OM-2 sign being determined at a much closer distance than the others.

Panel Shape Recognition. In both daytime and nighttime conditions the panels that were both larger and more exaggerated in shape resulted in the furthest panel shape recognition distances. The panel that performed best both day and night was the large rectangular OM-3 marker and the worst performer was the small rectangular OM-2 marker.

Symbol Shape Recognition. The pavement markers and cone post-mounted markers resulted in the shortest symbol recognition distances under both daytime and nighttime conditions with mean nighttime thresholds less than 61 m (200 ft) and daytime less than 91 m (300 ft). The remainder of the revised designs did not perform as well at night as the existing OM-3 and OM-1 markers, or the OM-3 marker in daylight. At distances ranging from 145 to 183 m (475 to 600 ft) at night, and 213 to 229 m (700 to 750 ft) in daytime, however the symbol recognition distances for the revised markers is sufficient for permanent hazardous object markers.

Table 45. Daytime main effect of marker type on symbol shape recognition distance.

	Hash marks	Yel. Cone	Gr. Cone	Dble Edge	OM-2	Left Fr. Gore	2 Fr.Gore	2 Mod. Chev.	Left Mod. Chev.	OM-1
Hashmarks										
Yel. Cone	*									
Gr. Cone	*									
Dble Edge	*									
OM-2	*	*	*	*						
Left Fr. Gore	*	*	*	*						
2 Fr. Gore	*	*	*	*						
2 Mod. Chev.	*	*	*	*	*					
Left Mod. Chev.	*	*	*	*	*					
OM-1	*	*	*	*	*					
OM-3	*	*	*	*	*	*	*	*	*	*

* significant differences between means

CHAPTER 11. LABORATORY EXPERIMENT 3: CONSPICUITY OF PROPOSED DESIGNS

Rationale In real-world settings, there are no instructions given to the driver to pay attention to the meaning, colors or shapes of object markers. Since these are the smallest highway signs in the MUTCD, except for the post-mounted delineators, the question of whether the driver notices them at all is very important.[1] In fact, the question of whether the driver notices even standard-sized signs has been long debated in the literature.[28]

Even the conspicuity experiment in the problem identification studies had a specific question which directed the attention of the subjects to hazardous objects, although the question was next to lowest in priority. This experiment was even more subtle because there was no reference to signs or objects in the instructions to the subjects. They were told only, "Tell me all things or objects that attract your attention as you watch the videotape." A success was defined as correct identification of either the marker or the object. In this way, sign, pavement marking, or color combination could be identified which were most likely to be helpful.

A useful lesson learned from the conspicuity experiment in the problem identification studies is that although individual scenes are perceived differently, the statistical analysis using categorical data and repeated measures quickly becomes unwieldy if not impossible. Therefore, rather than use simple counts of 'noticed' and 'not noticed' from each scene, averages for 10 different conditions were computed, collapsing across scene, although many different scenes were shown to increase the applicability of the results. The 10 conditions are listed below. No less than five scenes went into the average for each condition, with the exception of conditions 8 and 10. This double arrow configuration was only appropriate at gores and consequently did not yield five scenes each.

1. OM-3.
2. OM-1 or OM-2.
3. Double edge lines near a hazardous object with at least a narrow shoulder.
4. Diagonal 'hash' marks near a hazardous object with a wide shoulder.
5. The 'Cone' post-mounted marker in black on yellow.
6. The 'Cone' post-mounted marker in black on yellow-green.
7. The 'French Gore arrow' (single right or left arrow) post-mounted marker in black on yellow.
8. The 'French Gore arrow' (gore, both right and left arrows) post-mounted marker in black on yellow.
9. The 'Modified Chevron arrow' (single right or left arrow) post-mounted marker in black on yellow.
10. The 'Double Modified Chevron arrow' (gore, both right and left arrows) post-mounted marker in black on yellow.

Objectives The specific objectives for Experiment 3 were:

1. To covertly assess the attention conspicuity of both the current and proposed object marker designs.

2. To assess whether pavement markings were more conspicuous than post-mounted signs.

3. To assess whether one color combination on a post-mounted marker was more conspicuous than another.

Methodology. Videotaped drives of actual highway scenes were used to compare the conspicuity of current and proposed marker treatments. This technique was adapted from a method developed and validated by researchers at the Australian Road Research Board (ARRB). ARRB researchers conducted various successful on-the-road studies of the conspicuity of TCD using a technique whereby drivers verbally reported those features that attracted their attention.[21]

Sites, with hazardous objects, were selected from the Washington, DC area, including Howard, Frederick, and Calvert Counties. As footage of these sites was filmed, the vehicle traveled at 80 percent of the posted speed to increase the time that signs and markers were visible, since the best videotape visibility was still worse than the visibility of on-the-road driving. Each video segment was 30 to 90 s long and the position of the hazardous object relative to the start of the segment was randomly varied among sites. Each type of site was videotaped with all possible markers and color/material combinations that were appropriate (for example, sites with no shoulder were not able to have the two pavement treatments, and sites at a gore or other choice point did not use OM-2 or single arrow markers). This was done by temporarily installing the treatment for the length of time it took to videotape the segment. Existing markers were covered by a camouflage material that blended into the background. Current markers were represented by new markers, even if they were the same as the marker at the site, this ensured that the sheeting material was new and bright for all conditions. Thus, the new proposed markers were not compared to weathered current markers. Each video segment began with a 'fade from black' and ended with a 'fade to black' to make the transition from one scene to the next more comfortable for the subject.

These segments were then edited and spliced together into eight different viewing tapes. Each edited tape lasted approximately 30 min. Each subject saw two edited tapes which allowed a break from concentrating on the monitor. The particular two tapes the subject saw were randomly chosen, with the proviso that the same tape could not be seen both times. The subject was instructed to view the tape and report verbally "all objects or things that attracted your attention." The subject was told the purpose of the experiment was to see how different road types and traffic conditions affect driver attention.

Each videotape was coded to record when the marker came into site for each scene.

Computerized data collection software ran simultaneously with the videotaped sessions. The experimenter had two buttons for use during the session. The 'object' button was pressed *if* the subject correctly identified the hazardous object and the 'marker' button was pressed *if* the subject correctly identified the marker. These responses were mutually exclusive. Although this methodology lacked the efficiency of group data collection, it compensated for it by doing away with hand scoring and data entry because the computer gathered and recorded the responses immediately.

Variables.

1. Independent. Age-group, type of marker treatment, and sign background color (e.g., yellow versus strong green-yellow background).

2. Dependent. Whether or not the subject noted the roadside hazard or its delineation.

Stimulus materials. The stimulus set included 58 scenes with both current and all applicable proposed object marker designs as well as confusion signs. Videotaped drives of actual highway scenes were utilized to investigate the conspicuity of alternative design and implementation strategies. Each scene was videotaped with all appropriate treatments. Each videotaped drive, when edited, took approximately 30 min.

All materials and markers were new. Sheeting came from 3M research labs and signs were assembled in the Maryland State Highway sign shop in Hanover, MD. Post-mounted markers were mounted on a moveable base or existing supports. Pavement markings were temporarily laid down and taken up after videotaping.

Recruitment procedures for test subjects. Subjects were recruited from the subject pool and from area adult community and recreation centers.

Number and age grouping of subjects. There were 80 subjects in all, 16 in the 20 to 40 year-old group, 32 in the 65 to 69 year-old group, and 32 in the 70 and older group. This concentrated resources in the age ranges of greatest interest.

Experimental protocol. After introductions, the experimenter explained that they were studying, on behalf of FHWA, how the attention level of drivers is affected by different roadway and traffic conditions. The subject read and signed the informed consent sheet, was seated in front of the monitor and read the instructions (see appendix C).

At the end of the second tape the subject was paid, thanked, and escorted to the waiting room.

LABORATORY EXPERIMENT 3 RESULTS: CONSPICUITY OF PROPOSED DESIGNS

Analyses. To assess the attention conspicuity of the current and revised object marker designs, 80 subjects (who were not a part of the sample for Experiments E or 2) verbally reported all object markers or hazardous situations that attracted their attention while viewing two 30-min videotaped drives of numerous actual highway scenes. These videotapes were taken from the driver's point of view, and subjects were told to "report anything [objects or things] which attracts your attention, no matter how inconsequential it may seem."

Data collection during the study session was computer automated for the researcher; while each subject viewed the videotape, the researcher could press one of two buttons to record whenever the subject correctly identified the object marker or hazardous situation for each roadway scene. A correct identification was scored as a "hit" or success; a non-identification was scored as a "miss." The design of the study did not allow us to determine whether the subject truly did not see either the marker or object, or if they saw it but felt it was not important enough to report. Although the subject was explicitly instructed to report anything that attracted their attention, including both the object marker and the hazardous situation, the structure of the computer program only allowed for the recording of the first thing the subject identified (either object marker or the hazardous situation, but not both). Object markers and hazardous situations were coded separately however, and both were used for the analysis of the results. The same object markers in similar hazardous situations were used for this experiment as in Experiment 1.

Results. The same 13 object markers and a similar set of 11 hazardous situations were used in this experiment as in Experiment 1. The marker and situation combinations used are shown in table 46. As in Experiment 1, not all object markers were tested at all hazardous situations, since the placement of some markers will never or rarely occur in certain situations. Confusion markers were included in the stimulus set, but not analyzed. The cells of table 46 report two numbers, the first being the percent of subjects who reported the object marker first, the second being the percent of subjects reporting either the object marker or the hazardous situation first.

There were a total of 2,468 trials over all subjects. For all object markers and hazardous situations, subjects reported the marker 15.0 percent of the time, and the hazardous situation 10.7 percent of the time for a total of 25.7 percent "hits" of either marker or hazardous situation. The remaining 74.4 percent of the time, subjects either missed or failed to report both the marker and the hazardous situation. Although the hit rate may seem somewhat low, this is probably a procedural artifact. The Australian Road Research Board has developed and employed this methodology in a number of research studies, and has found comparably low verbal report rates for signs and markers.[21,29] Despite this, the method yields meaningful, field-validated results for comparing alternatives to one another. Thus, the reporting rates gathered during the present study should be compared to one another on a relative basis, but not taken as literal absolute numbers.

Table 46. Percent of subjects reporting object markers by hazardous situation.

	All Situations[2]	Median Island[1]	Gore	Bridge Pier	Bridge Rail[2]	Utility Pole[2]	Tree[2]	Culvert	Inlet	Bridge Abutment	Street Light	Guard Rail[2]
All Markers[2]	***15.0*/25.7****	***18.5/37.3***	***11.8/12.2***	***3.1/5.0***	***8.6 / 43.9***	***22.3/24.8***	***15.2/23.1***	***9.4/9.4***	***36.1/36.1***	***22.0/28.0***	***7.5/7.5***	***9.6/30.0***
OM-1[2]	***17.2/24.2***	30.7/45.2	11.1/11.1	5.0/5.0						15.0/27.5		10.0/10.0
OM-2[2]	***5.7/20.3***				14.6/63.4	2.6/10.3	0.0/7.9	0.0/0.0	16.7/16.7		0.0/0.0	
OM-3[2]	***13.1/24.0***	15.0/25.0	7.1/7.1	5.6/11.1	12.5/75.0	19.5/19.5	7.7/18.0	0.0/0.0	52.4/52.4	8.3/22.2	0.0/0.0	15.0/15.0
Double Edge Lines[2]	***0.0/19.19***			0.0/4.8	0.0/88.9	0.0/0.0	0.0/10.0	0.0/0.0				
Hash Marks[2]	***6.1/21.2***			5.0/10.0	14.3/76.2	0.0/5.6	0.0/0.0	10.0/10.0				
Yellow Cones[2]	***13.4/23.2***	20.6/44.4	5.3/5.3	5.0/5.0	7.3/17.1	15.4/17.9	7.7/15.4	15.0/15.0	31.6/31.6	24.4/29.3	10.0/10.0	5.0/35.0
Green Cones[2]	***16.8/23.7***	20.0/33.3	11.9/11.9	0.0/0.0	7.5/17.5	32.5/32.5	22.5/32.5	10.5/10.5	28.6/28.6	25.8/28.2	5.0/5.0	7.5/30.0
Left French Gore[2]	***24.9/33.1***			4.8/4.8	10.3/25.6	34.2/34.2	39.0/43.9	23.8/23.8	50.0/50.0	29.3/29.3	21.1/21.1	10.5/50.0
Right French Gore	***8.3/33.3***	8.3/33.3										
2 French Gore	***20.0/22.5***		20.0/22.5									
Left Modified Chevron[2]	***20.6/31.6***			0.0/0.0	0.0/27.5	50.0/55.0	27.5/37.5	15.0/15.0	35.0/35.0	28.2/30.8	9.5/9.5	9.5/40.5
Right Modified Chev.	***15.8/42.1***	15.8/42.1										
Double Modified Chevron	***15.0/15.0***		15.0/15.0									

[1] $p < .05$
[2] $p < .01$

*The first number is the percent of subjects reporting the object marker first.
**The second number is the percent of subjects reporting either the object marker or the hazardous situation first.

The cells in the second row of table 46, labelled All Markers, report the percent of markers followed by the percent of markers or hazardous situations reported for any particular situation type, such as all markers out of all markers or hazardous situations which were detected at a median island, at a gore, etc. For hazardous situations that may be hidden such as culverts or inlets, subjects reported the markers only but not the hazardous situation itself; for example, markers were reported 9.4 percent and 36.1 percent of the time for culverts and inlets respectively but no one mentioned the hazardous situation itself first. On the other hand, some hazards which are large and conspicuous may more easily be recognized as a hazard, such as a median island, bridge rail, or guard rail. In these instances, subjects reported the situation first more than the marker. Still other objects or situations, subjects may not consider as hazardous, such as street lights, utility poles, or gores. In these cases the majority of the time subjects reported the markers but not the situation itself.

The second column of table 46, labelled "All Situations," reports the percent of markers and markers plus the situation reported at all situations in which a specific type of marker was placed, e.g., all situations where an OM-1 type marker was placed, OM-2, OM-3, etc. As seen from table 46, the results of Experiment 3 show that for those current and proposed object markers placed at multiple hazardous situations, the situation type did have a statistically significant effect on the likelihood of reporting either the marker or the situation ($p < .01$) when analyzed with chi-square analysis. Therefore, when drivers are not prompted to pay attention to any particular marker or hazardous situation, the situation (or context) in which the event occurs does play a significant role in the likelihood of recognizing the event as a potential hazard.

The 80 subjects were grouped into the same 3 age categories: 20 to 40 years old ($n=16$), 65 to 69 years old ($n=32$), and 70 years and older ($n=32$). The percentage of hits per age group for object markers only, hazardous situation only, and marker or situation are reported in table 47. These data were analyzed by chi-square analysis and the results were statistically significant for age ($p < .01$), with the younger group reporting markers and situations a greater percentage of the time than the older subjects. However, because the number of observations for any one particular object marker was small, all post-hoc pairwise comparisons for the age groups per object marker failed to reach significance (the one exception being that for the strong yellow-green cones ($p < .01$); therefore the scores of all age groups for each object marker were pooled and analyzed as a whole.

Table 48 displays the percentage of subjects by each age group who reported the object marker first, followed by the percentage who reported either the object marker or hazardous situation for each object marker type. Although the majority of differences between age groups were not statistically significant, some interesting trends did appear. For example, the percentage of subjects reporting either the object marker or hazardous situation for the current markers (OM-1, OM-2, and OM-3), the pavement delineations (double edge lines and hash marks) and the proposed representational symbols (yellow cones and strong yellow-green cones), was very consistent for the 65 to 69 year olds and the over 70 group, ranging from 20.0 to 25.8 percent and 15.9 to 22.7 percent respectively. The comparable reporting rate of the younger subjects for the same markers was more variable, with a range of 20.0 to 39.5 percent. For all subjects, the hit rates tended to be higher for the directional markers (French gores and modified chevrons) and more variable both between and within age groups. These results may in part be due to the larger physical size of the markers themselves, which would make them more conspicuous and therefore lead to higher conspicuity and reporting rates. In addition, some of these directional markers were only tested at one hazardous situation type; with fewer sites being tested, one would expect more variability in the resulting data. Table 49 displays the same reporting percentages for each hazardous situation. The only post-hoc pairwise comparisons for the hazardous situations to reach statistical significance were the median island and the bridge abutment.

Table 47. Percent of hits per age group for all subjects.

Age Group	% Reporting Marker	% Reporting Situation	% Reporting Marker or Situation
20 - 40	21.8	10.3	32.1
65 - 69	15.3	11.4	26.7
70 and older	11.7	10.2	21.9

Object markers were also grouped according to experimental treatment types as denoted in table 50. The average percent of reported markers only, hazardous situations only, and markers plus situations for each treatment type for all situation types collapsed together is displayed. Analysis of these marker categories by a chi-square analysis yielded a statistically significant difference between categories ($p < .01$). Post-hoc analyses revealed that these differences are specifically between the current markers and the proposed pavement delineations ($p < .01$) and the current markers and the proposed post-mounted directional symbols ($p < .01$). For the proposed post-mounted cone markers, there was no difference between the yellow and green backgrounds: 23.2 percent versus. 23.7 percent markers and situations reported for each background color respectively. Of the proposed pavement delineations, subjects never reported the double edge lines (0 percent out of 19.2 percent for markers or situations). Hash marks fared only a little better, with subjects reporting the marker 6.1 percent out of 21.2 percent for either the marker or situation. However, the only hazardous situation in which hash marks were reported was at bridge piers and bridge rails.

Table 48. Percent of subjects reporting object markers by age group.

Object Marker	# Site Types	Age Group		
		20 - 40	65 - 69	over 70
OM-1	5	25.0* / 32.5**	14.3 / 21.4	15.9 / 22.7
OM-2	6	8.3 / 22.2	6.4 / 20.6	3.9 / 19.2
OM-3	11	19.7 / 26.3	12.0 / 24.8	10.8 / 22.3
Double Edge Lines	5	0.0 / 20.0	0.0 / 22.9	0.0 / 15.9
Hash Marks	5	10.0 / 25.0	5.7 / 20.0	4.6 / 20.5
Yellow Cones	11	19.7 / 29.0	13.6 / 25.8	10.5 / 18.6
Green Cones[2]	11	30.3 / 39.5	15.7 / 20.9	11.8 / 18.8
Left French Gore	9	35.7 / 42.9	26.0 / 34.0	19.2 / 28.0
Right French Gore	1	16.7 / 41.7	11.1 / 33.3	3.3 / 30.0
2 French Gore	1	25.0 / 22.2	25.0 / 55.6	12.5 / 22.2
Left Modified Chevron	9	19.6 / 33.9	24.5 / 35.3	17.7 / 27.4
Right Modified Chevron	1	25.0 / 41.7	11.1 / 55.6	14.8 / 33.3
Double Modified Chevron	1	25.0 / 25.0	25.0 / 25.0	5.0 / 5.0

[1] $p < .05$
[2] $p < .01$

*The first number is the percent of subjects reporting the object marker first.
**The second number is the percent of subjects reporting either the object marker or the hazardous situation first.

Table 49. Percent of subjects reporting object markers or hazardous situations for each hazardous situation by age group.

Hazardous Situation	Age Group		
	20 - 40	65 - 69	over 70
Median Island[1]	27.8* / 48.6**	18.3 / 39.7	14.6 / 30.5
Gore	16.7 / 16.7	13.1 / 14.3	8.5 / 8.5
Bridge Pier	6.3 / 9.4	1.8 / 1.8	2.8 / 5.6
Bridge Rail	10.7 / 42.9	8.2 / 45.9	7.9 / 42.9
Utility Pole	30.4 / 30.4	21.4 / 26.5	19.4 / 21.0
Tree	23.2 / 28.6	18.4 / 26.5	8.9 / 17.9
Culvert	12.5 / 12.5	10.7 / 10.7	7.0 / 7.0
Inlet	45.8 / 45.8	40.5 / 40.5	28.3 / 28.3
Bridge Abutment[2]	35.4 / 41.7	22.6 / 26.2	15.4 / 23.1
Street Light	16.7 / 16.7	7.1 / 7.1	3.7 / 3.7
Guard Rail	12.5 / 35.4	7.1 / 28.6	10.2 / 28.7

[1] $p < .05$
[2] $p < .01$

*The first number is the percent of subjects reporting the object marker first.
**The second number is the percent of subjects reporting either the object marker or the hazardous situation first.

Table 50. Percent of subjects reporting marker, situation, and marker or situation for all hazardous situations.

Marker Category	**% Reporting Marker**	**% Reporting Situation**	**% Reporting Marker or Situation**
Current Markers	12.4	10.8	23.2
Proposed Post - Cones	15.1	8.3	23.4
Proposed Pavement	3.0	17.2	20.2
Proposed Post	20.5	11.2	31.7

CONCLUSIONS

Based on the findings of the laboratory experiments, the following recommendations were made for the field evaluations:

1. Proposed markers with poor comprehensibility should be dropped from further consideration; these include French gore and double edge lines.

2. Because the hash mark pavement marking has relatively poor legibility distance and conspicuity, it should not be used in isolation. Subsequent research should evaluate it as a supplement to object markers for problem situations.

3. Since no advantage was found to the use of a novel (strong yellow-green) color for the cone maker, and since that color is being considered for a reserved application, only the black on yellow version should be subsequently evaluated for the representational symbol design.

CHAPTER 12. FIELD VERIFICATION STUDY 1: COMPREHENSION AND CONSPICUITY OF STATIC MARKERS

Rationale. In order to verify findings from the laboratory studies field studies were conducted to collect realistic, on-the-road data from subject drivers, using tasks that parallelled the laboratory investigations for the sign characteristics of comprehension and conspicuity.

To that end two field studies were conducted. The first field study investigated the comprehension and conspicuity of the static signs recommended from earlier tasks. The second field study investigated the use of active or dynamic hazard markers (e.g., flashing beacons) at the same sites and compared measures of conspicuity and comprehension to those of static object markers.

Objective. To confirm and refine the recommendations made in the laboratory studies.

Methodology. A route was structured in Calvert County, MD, working with the cooperation of the State of Maryland and Calvert County Departments of Transportation. All sites and delineations were reviewed with the appropriate officials before installation. Selected treatments were installed at appropriate sites, with the route requiring approximately 25 to 30 min to navigate at posted speeds, not including extra stops associated with the second run. The subject's speed was monitored staying within 8 km/h (5 mi/h) of the posted speed limit. Since the subjects were asked to drive the route twice, the overall participation time was approximately 2 h. Data was collected only during non-rush hours.

The subject first drove the route in the conspicuity procedure, using a verbal report technique that was approximately identical to that employed in laboratory Experiment 3. The subject verbally reported all objects that attracted attention during the drive. This technique has been used successfully by ARRB researchers in other studies of TCD conspicuity. As a precaution, instructions were structured and procedures piloted to ensure that subjects experienced minimal adverse effects during the drive as a result of distraction or confusion caused by the experiment.

Following this, the subject repeated driving the route, this time implementing the comprehension procedure where the experimenter pointed out the marker on approach. After the object/marker was passed, a convenient and safe pullover was used to administer comprehension questions. The subject answered two questions, What do you think this marker means? and What action, if any, should you as a driver take in response to it? For both drives, an in-vehicle microphone was used to record the driver's verbal responses. Recognition distances were not collected as they were investigated during Experiment 2.

Variables.

1. Independent. Age-group, object marker (current versus proposed), lighting (night versus day).

2. Dependent. a) Percentage of markers/objects noticed, and b) Percentage of correct answers. Percentages will be based on number of current markers seen and number of proposed treatments seen.

Stimulus materials. The stimulus set was established after analyzing the results of the experiments in the laboratory studies. The set included a subset of the stimuli used in Experiment 1 (see table 3). The stimuli included in the field studies were those novel markers that fared the best in the comparisons of the laboratory studies, along with a sample of the most appropriate current object marker treatments. Table 51 describes the stimuli used during the experiment.

During the first half of the field test (i.e., 18 subjects), the configuration was outlined under treatment route 1 while the second half utilized treatment route 2. This was essentially a swapping of candidate and conventional treatments between similar site types, as shown in table 51.

Recruitment procedures for test subjects. Subjects were recruited from organizations involved with older adults and through bulletins at meeting places of older adults in the northern Calvert County, MD area. All subjects were required to be willing to drive during night or day although they actually drove in only one of the two conditions. This recruitment condition was maintained to ensure that the daytime drivers were not substantially different from those willing to drive at night. Subjects were randomly assigned to lighting conditions.

Number and age grouping of subjects. There were 36 subjects in all, 12 in the 20 to 40 year-old group, 12 in the 65 to 69 year-old group, and 12 in the 70-and-older group. Twelve of the subjects drove at night and 24 drove during the day. Within each cell of 6 subjects, half were female and half were male.

Experimental protocol. The experimenter and each subject met at a public location. After introductions, the experimenter explained that the study was being conducted on behalf of a Federal Agency to investigate what kinds of things capture drivers' attention. Subjects read and signed an informed consent form while the experimenter installed the recording equipment and then read the instructions to the subject (see appendix C).

After the first 3.2 km (2 mi) of the route, the experimenter had the subject stop in an appropriate location. At this time, the experimenter provided the subject with feedback or clarification of the intended procedure and answered any questions. This period was used as practice for the procedure to ensure that the subject had an understanding about the type and quantity of information expected during the drive. To focus the drivers' feedback somewhat, indications of signs or road markings were reinforced by the experimenter as needed and extraneous information regarding activity or objects not related to the driving exercise was discouraged. The purpose of this feedback was to keep the subject focused without biasing them toward simply looking for signs or roadway markings. This stopping point also provided the experimenter with the opportunity to terminate the experiment, if the subject exhibited unsafe driving tendencies or was unable to comprehend the requirements of the experimental procedure. If all aspects of the practice run were acceptable, the run then continued, uninterrupted until they returned to the starting location.

Table 51. Treatment conditions used in field verification study 1.

		# of Site	Treatment Route	
			1	2
Site Types	U-Poles	6	Cone	OM-2
		10	OM-2	Cone
	Culverts	5	OM-2 & Hash Marks	OM-2
		7	OM-2	OM-2 & Hash Marks
	Ditches	8	Cone Array (<4)	OM-2 Array (<4)
		9	OM-2 Array (<4)	Cone Array (<4)
	Bridge Columns	2	Cone	OM-3
		3	OM-3	Cone
	Gores	1	Double Modified Chevrons	OM-1
		4	OM-1	Double Modified Chevrons

Before beginning the second navigation of the route, the experimenter read instructions defining the reason for this portion of the study and the subject's responsibilities for the second drive around the route. During this drive, subjects were cued to the novel and conventional treatments as the subject approached them. After passing each treatment, the subject was directed to pull off the road into a safe parking area to allow two standard questions to be administered about each site. First, they were asked "*Exactly what do you think this sign/marking means?*" and then "*What action, if any, should you as a driver take in response to it?*" This procedure was repeated until all the sites had been completed.

At the completion of both drives, the subject was paid and thanked for participating.

FIELD EXPERIMENT 1 RESULTS: COMPREHENSION AND CONSPICUITY OF STATIC SIGNS

Comprehension Results. The rated scores of all responses to the Meaning and Action questions for current and proposed object markers correlated around .68 ($p < .01$). Often, an Action was embedded in the Meaning responses. For example, subjects would report the meaning of the marker and include the action they would take if they encountered this marker. Because Meaning and Action scores were significantly correlated as in the problem identification studies and the laboratory studies, it was decided to take the higher rating of either the Meaning or Action question as the dependent variable for this experiment; all reported results and statistical analyses are based on this higher score (see Chapter 9 for more details).

The frequency distribution of responses falling in the five rating categories is shown in table 52. Ratings for each higher scored response per marker/situation combination were divided into two categories for purposes of descriptive statistics and statistical analyses. A correct response was defined as a response that was awarded a four or a five rating. An incorrect response was defined as a response that was given a one, two, or three rating. Thus, although there may appear to be a sizable number of incorrect responses (n=86) as shown in table 52, the majority would not necessarily result in a dangerous driving maneuver, but rather only a possible misinterpretation of the object marker by the driver.

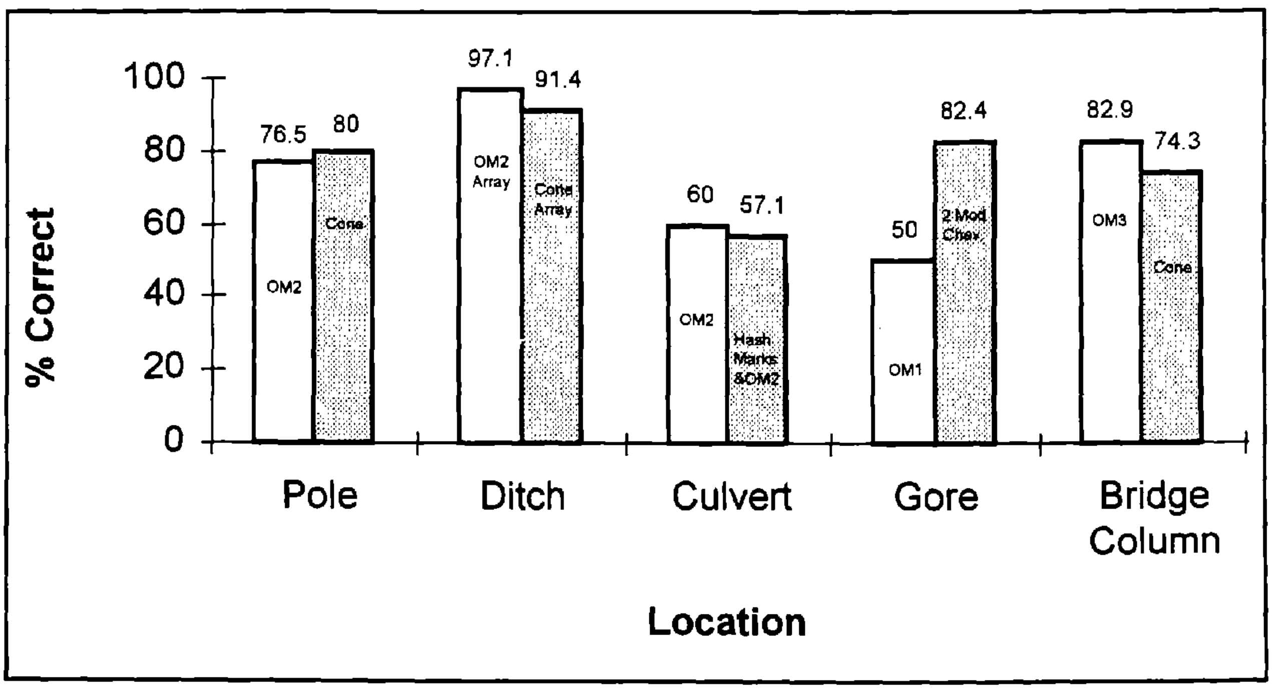


Figure 25. Highest score at each location.

Table 52. Score and frequency of highest rated response for either meaning or action for all subjects.

Numeric Score	Rating	Frequency of Responses
5	Correct	177
4	Partially Correct	84
3	Incorrect, but not dangerous	63
2	Confusion, possible danger	23
1	Dangerously wrong, dangerous confusion	0

Eight object marker types and ten hazardous situations (2 each of 5 types) were used to address the research questions of interest for this experiment. Overall results are depicted in figure 25. The marker and situation combinations used in this experiment are shown in table 53. The percent of correct responses for all markers in all situations was 75.2 percent. That is, 75.2 percent were rated as correct (4 or 5) on either the meaning or action score for all object marker and situation combinations.

The second row of table 53, labelled "All Markers," reports the percent of responses rated as correct for all object markers placed at each situation type (e.g., all object markers which occurred at a pole, all object markers at a gore, etc.). To test for differences between the number of correct and incorrect answers for the various markers at each situation, frequency counts of correct scores for the marker/situation combinations were analyzed using chi-square analyses. The individual cells of table 53 report the percent of responses rated as correct for any particular marker and situation combination. The second column of table 53, labelled "All Situations," reports the percent of responses rated as correct for all situations in which each object marker was placed, e.g., all situations where an OM-1 occurred, all situations where an OM-2 occurred, etc.

Markers at Each Location. The Double Modified Chevron marker used at gores was the only marker that showed a significantly better level of understanding than its counterpart conventional marker (OM-1). Of the respondents, 84.2 percent correctly reported its meaning, while only 50 percent understood the conventional marker ($p<.01$). Thus, there is no apparent net gain in comprehension for novel versus conventional markers except in the case of gores, where replacement of the existing markers may improve understanding for the overall driving population.

Day vs. Night by Marker. There were some unusual results between day and night for the understandability of individual markers. Specifically, OM-2 markers were better understood at night (84.6 percent) than day (45.5 percent) at culverts ($p<.05$) and similarly at poles (100 percent vs. 61.9 percent respectively, $p<.01$), while Double Modified Chevron markers were better understood during the day than at night (95.2 percent vs. 61.5 percent respectively, $p < .01$). The Double Modified Chevron marker was understood better ($p < .01$) than the OM-1 at the gore during daytime conditions. These findings, in combination with general trends of the data, suggests that perhaps something about the design of the Double Modified Chevron (e.g., polarity of black and yellow elements) may affect its comprehension negatively at night.

Table 53. Highest rating for object marker meaning or action response. (The numbers listed in this table are percent correct by situation.)

	All Situations[1]	Pole	Ditch	Culvert	Gore[1]	Bridge Column
All Markers[1]	***75.2***	***78.3***	***94.3***	***58.6***	***66.2***	***78.6***
OM-1	***50.0***				50.0	
OM-2	***68.1***	76.5		60.0		
OM-3	***82.9***					82.9
Yellow Cones	***77.1***	80.0				74.3
Double Modified Chevron	***82.4***				82.4	
OM-2 Array	***97.1***		97.1			
Yellow Cone Array	***91.4***		91.4			
Hash Marks & OM-2	***57.1***			57.1		

[1] $p < .01$

Age. No statistically significant differences attributable to age were found with the exception of OM-2 markers, which were understood significantly better ($p < .05$) by the 20 to 40 year-old age group than the 65 to 69 year-old age group. The percentage of correct responses for each object marker by age group is shown in table 54. No other comparisons were statistically significant.

Conspicuity Results. The same 8 object markers and a similar set of 10 hazardous situations were used in the conspicuity portion of this experiment. Figure 26 shows the conspicuity results for each of three successful reporting categories. The cells of table 55 report three numbers that correspond to the size of each component of the stacked bars in figure 26, the first being the percent of subjects who reported the object marker only, the second being the percent of subjects who reported the hazardous situation only, and the third being the percent of subjects who reported both. Thus, the sum of the three numbers is the overall reporting rate for that situation and the difference between 100 and that sum equals the percentage of times that the situation was not reported at all.

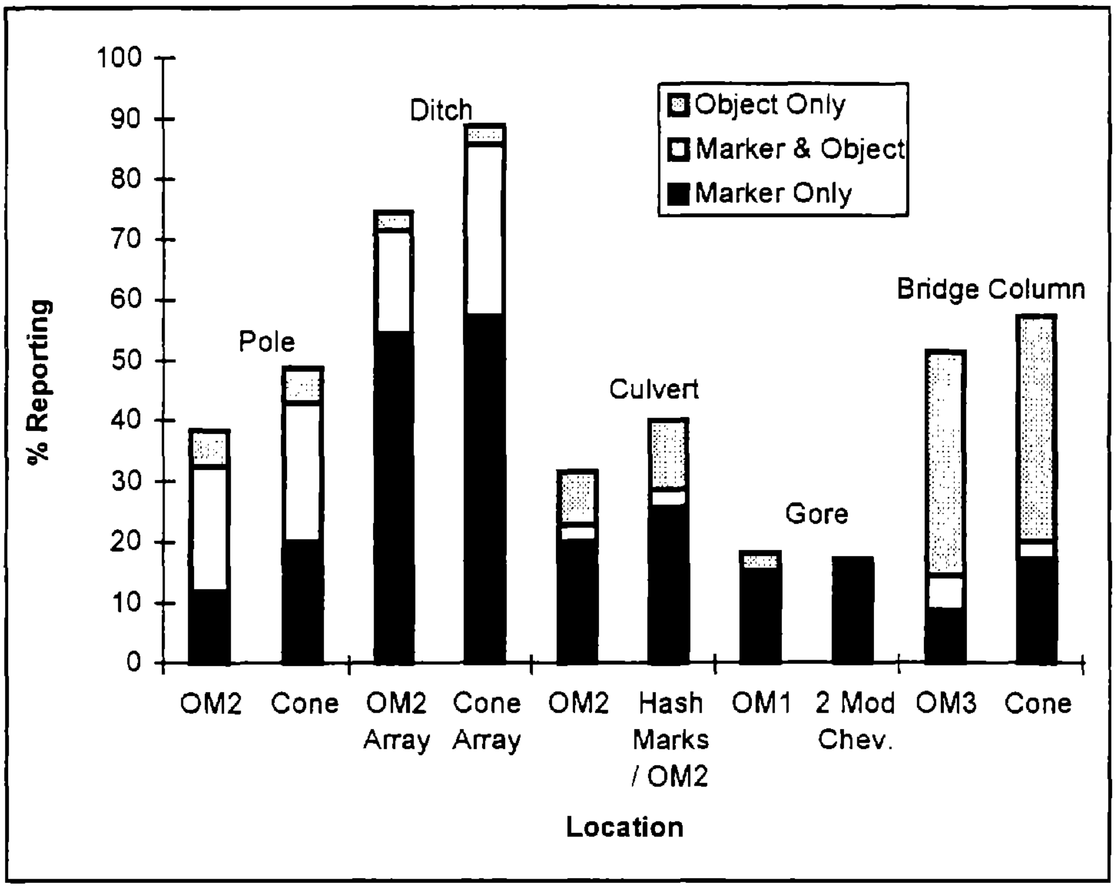


Figure 26. Percent reporting at each location.

There were a total of 346 trials over all subjects. For all object markers and hazardous situations, subjects reported the marker alone 24.9 percent of the time, and the hazardous situation alone 11.6 percent of the time, and both the situation and the marker 10.4 percent of the time for a total of 46.0 percent "hits" of either marker, hazardous situation, or both. This hit rate was relatively high (i.e., nearly double) compared to the hit rate measured in Experiment 3 in which video drives were used in lieu of real drives. The remaining 54.0 percent of the time, subjects either missed or failed to report both the marker and the hazardous situation. Misses were coded when extenuating circumstances prevented the subject from performing the reporting task (e.g., interfering traffic, missing or covered sign, etc.). These occurrences constituted a fairly low percentage of the overall opportunities (1 percent). The second column of table 55, labelled "All Situations," reports the percent of markers only, objects only, and both reported at all situations in which a specific type of marker was placed, e.g., all situations where an OM-1 type marker was placed, OM-2, OM-3, etc.

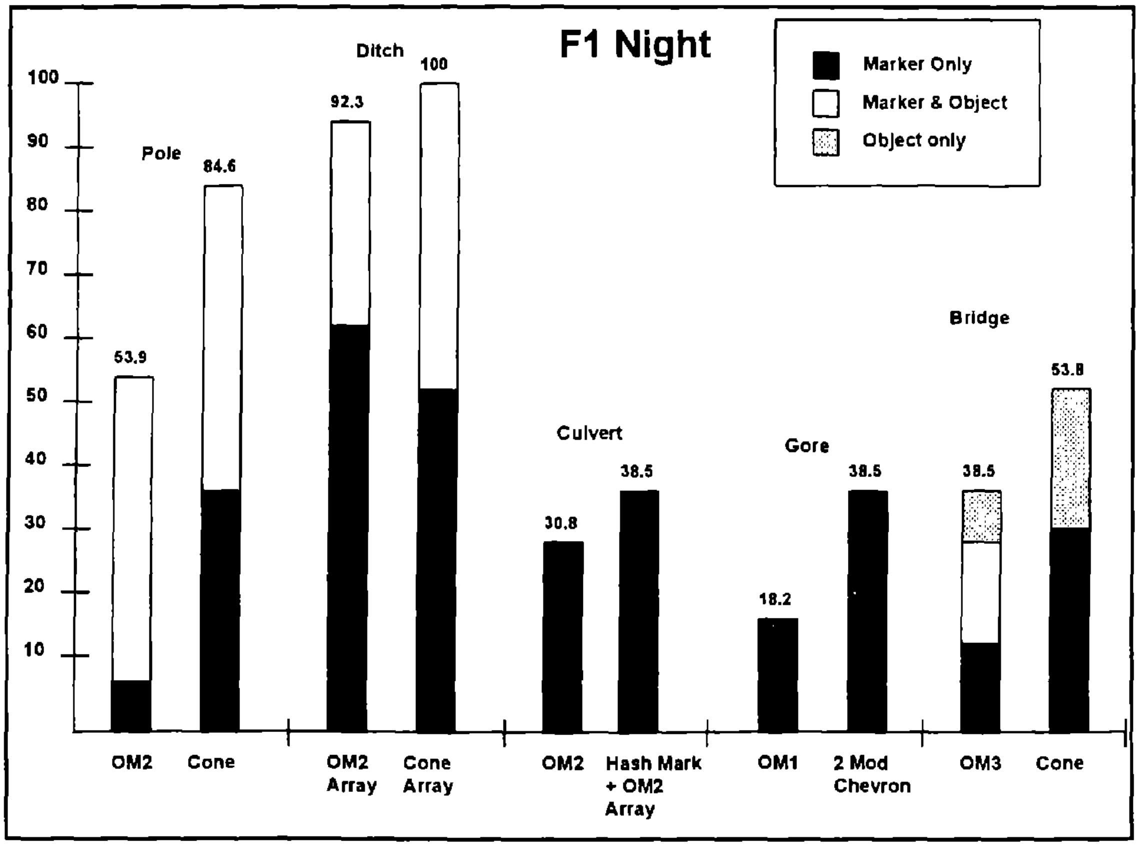


Figure 27. Percent reporting at each location (night condition).

Table 54. Percent correct by age group per object marker in all hazardous situations.

Object Marker	# obs	Age Group		
		20 - 40	*65 - 69*	*over 70*
OM 1	34	66.7	50.0	30.0
OM 2[1]	69	83.3	47.8	72.7
OM 3	35	75.0	83.3	90.9
Yellow Cones	70	79.2	75.0	77.3
Double Modified Chevron	34	81.8	75.0	90.9
OM 2 Array	35	100.0	91.7	100.0
Yellow Cone Array	35	91.7	91.7	90.9
Hash Marks/OM 2	35	66.7	58.3	45.5
Overall Percent		80.7	69.8	75.2
Total Observations	347	119	119	109

[1] $p < .05$

Reporting of the marker or object was higher for the novel treatment for five of the six location types, and this difference appears attributable to higher reporting of the marker. Reporting rates for the hazard itself were nearly identical. Although higher reporting rates on the order of 5 to 15 percent were observed for the novel treatments at four types of sites, chi square tests for individual sites were unable to confirm the statistical reliability of the finding. Thus, it is not clear whether the differences are due to chance or the relatively low power of the chi square test with this limited number of observations.

Table 55. Percent of subjects reporting object markers by hazardous situation.

	All Situations[2]	Pole	Ditch	Culvert	Gore	Bridge Column
All Markers[2]	*24.9* / 11.6** / 10.4 ****	*15.9 / 5.8 / 21.7*	*55.7 / 2.9 / 22.9*	*22.9 / 10.0 / 2.9*	*16.4 / 1.5 / 0.0*	*12.9 / 37.1 / 4.3*
OM 1	*15.2 / 3.0 / 0.0*				15.2 / 3.0 / 0.0	
OM 2	*15.9 / 7.3 / 11.6*	11.8 / 5.9 / 20.6		20.0 / 8.6 / 2.9		
OM 3	*8.6 / 37.1 / 5.7*					8.6 / 37.1 / 5.7
Yellow Cones	*18.6 / 21.4 / 12.9*	20.0 / 5.7 / 22.9				17.1 / 37.1 / 2.9
Double Modified Chevron	*17.0 / 0.0 / 0.0*				17.7 / 0.0 / 0.0	
OM 2 Array	*54.3 / 2.9 / 17.1*		54.3 / 2.9 / 17.1			
Yellow Cone Array	*57.1 / 2.9 / 28.6*		57.1 / 2.9 / 28.6			
Hash Marks /OM 2	*25.7 / 11.4 / 2.9*			25.7 / 11.4 / 2.9		

[1] $p < .05$
[2] $p < .01$

*The first number is the percent of subjects reporting the object marker only.
**The second number is the percent of subjects reporting the hazardous situation only.
***The third number is the percent of subjects reporting both the object marker and the hazardous situation.

Age. No statistically significant differences attributable to age were found.

Markers at Each Location. Though the general trend in the overall data showed slight improvements in conspicuity for the novel over the conventional treatments, no statistically significant differences attributable to marker type at each location were found. That is, the type of marker was not a significant indicator of whether a particular hazard would be noticed. Chi square analyses were preformed to look at the performance enhancement provided by adding the markers to a given situation.

Day vs. night. Marker recognition was a prerequisite for all object reporting at night, except for the bridge column. That is, no gores, poles, ditches or culverts were reported at night without also detecting the object marker. At the poles, even though the poles by themselves were never noticed at night, subjects reported more overall detections (markers alone and objects with markers) at night than during the day. The poles and their associated markers were reported significantly more at night than during the day. Thus, it appears that markers do play an important role in making these hazards more noticeable at night. Daytime impact of the markers is minimal in comparison.

Day vs. night by marker. Cones at the poles and Double Modified Chevrons at gores were reported significantly ($p < .01$ for both) more at night than during the day, as shown in figure 26. This is most likely a function of contrast and scene complexity.

Conclusions. From the results of the first field study using static markers, it appears that the Double Modified Chevron at gores is the only novel treatment that shows promise over conventional treatments. It too had problems as it was reported at a slightly lower rate than its counterpart OM-1 during daytime conditions. However, its comprehension was significantly higher than its conventional counterpart. Aside from this, no meaningful results were found to support the conversion from conventional to novel treatments. Neither detection or comprehension were greatly or consistently improved by substituting the novel for the conventional treatments.

1. In actual roadway context, no benefits to meaning were seen, except for Double Modified Chevron vs. OM-1 at gores.

2. For conspicuity, novel treatments were not statistically significant for any given site.

3. The rate of reporting of hazards and/or markers varied considerably for applications. Ditches, culverts and gores seldom had the hazard reported, suggesting the importance of markers for these situations; however, while marking treatments yielded high rates of reporting for the ditches, they were only moderate for the culverts and low for the gores. This may suggest that arrays are more effective for attracting attention at hazardous situations.

4. At night, the number of people reporting the bridge column was only about half the number as during the day. Object markers appear important for improving driver attention at night for this more visible hazard, as well as for those less apparent hazards (e.g., culverts).

CHAPTER 13. FIELD EXPERIMENT 2: COMPREHENSION AND CONSPICUITY OF ACTIVE MARKERS

Objective. To investigate in a field setting active devices that may be implementable as object markers.

Methodology. The methodology for this study paralleled that used in the previous field study investigating current and alternative markings. However, only the "worst case" conspicuity scenario (daytime conditions) was used. Data was collected only during non-rush hours.

Variables.

1. Independent. Age-group, proposed active device marker.

2. Dependent. a) Percentage of markers/objects noticed, and b) Percentage of correct answers. Percentages were based on number of current markers seen and number of proposed treatments seen.

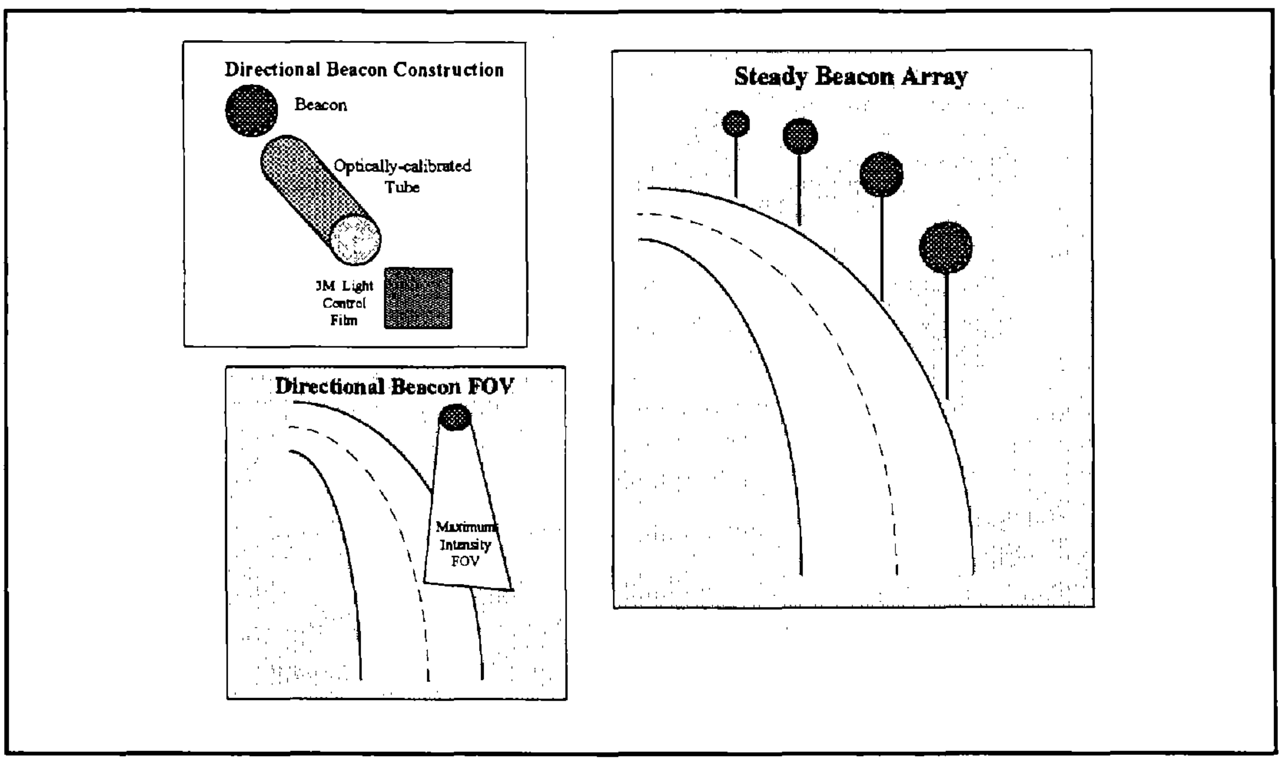


Figure 28. Beacon descriptions.

Stimulus materials. The stimulus set was composed of the following active devices (see also figure 28):

1. Steady Beacons (array and single). These amber lights were similar to those used on construction site protective barrels. They were powered by a 12-volt DC battery and were designed for daytime visibility at up to 305 m (1,000 ft) (high intensity). Essentially, this beacon was a 152.4-mm (6-in) diameter flashing beacon having continuous day and night visibility (36 candelas) with the flashing mechanism disabled. These beacons are referred to as Federal Spec "B" beacons.

2. Flashing Beacon (single). These amber lights were similar to the steady beacons described above except for the integral flashing capacity. The flash rate for these beacons was approximately 60 flashes per minute in accordance with Part VI of the MUTCD and ITE Standard ST017.

3. Directional Beacon (single). This beacon was specially fabricated to allow precise aiming (i.e., programming) of the unit's directionality. It consisted of an amber beacon, similar the steady beacon described above, mounted on an optically tuned tube with a sheet of 3M light control film at the near end (see figure 29). Essentially, the system worked like a programmable signal head, not unlike those sold by 3M which allows the signal to be tightly controlled in terms of its range of visibility. Specifically, this unit was fabricated from one of the beacons described above, again having a disabled flashing mechanism. The beacon was fitted to the far end of a 152.4-mm (6-in) inside diameter tube

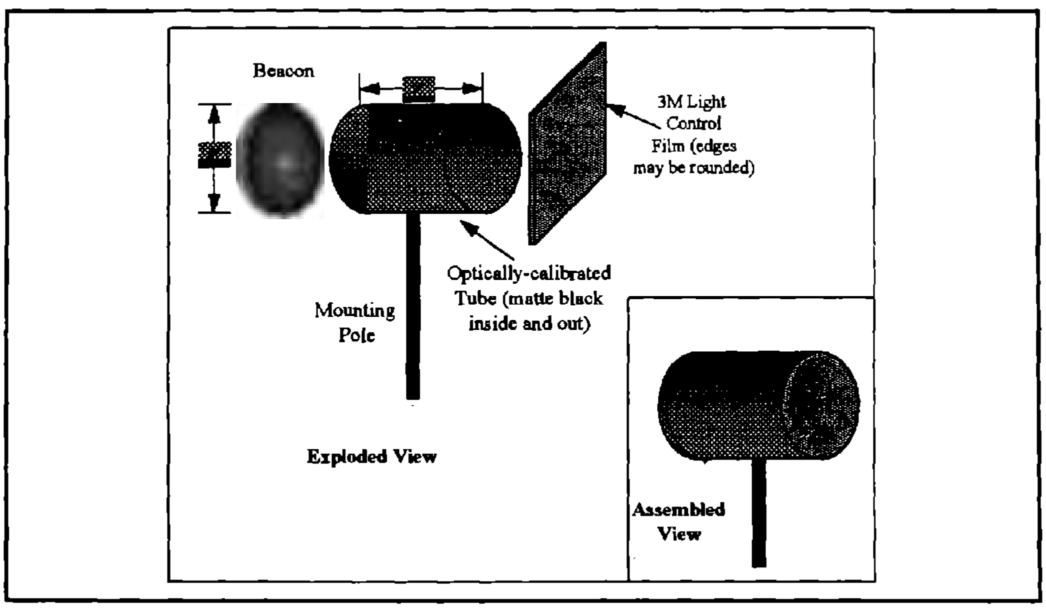
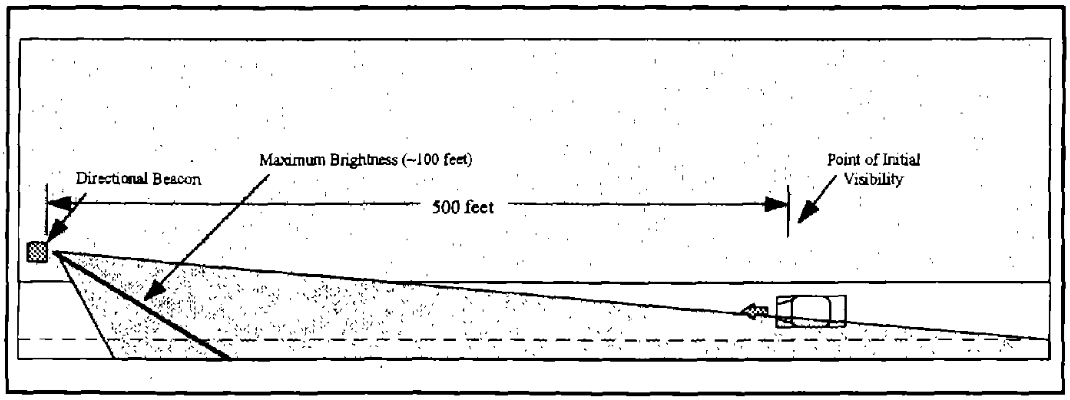


Figure 29. Detailed views of directional beacon.

228.6 mm (9 in) long. The normal beacon lamp was replaced with a GE high beam round headlight (model 4001) to provide the correct brightness. At the near end of the tube, a sheet of 3M light control film (30 degree offset) cut to fit inside the tube and covered with a protective sheet of 3.2 mm (1/8 in) polycarbonate was mounted. Power, mounting height, and mounting means were similar to that used for the other beacons, though aiming was carefully controlled according to the scheme in figure 30.



1 ft = 0.305 m

Figure 30. Directional beacon aiming.

All beacons were controlled by radio frequency switches allowing selective activation only when subjects participating in this study passed the instrumented sites. The experimenter triggered the activation switch inconspicuously before sites were visible to the driver. All flashing and steady beacons as defined above were mounted at 1.22 m (4 ft) above the ground, similar to counterpart passive markers. These beacons were mounted using a custom mounting bracket on a green steel pole, similar to those used for mounting other marker treatments. Batteries for these implementations were placed on the ground behind the poles with battery boxes camouflaged to the degree possible. For the bridge column conditions, the flashing beacon was mounted concentrically on the OM-3 with the center of the OM-3 mounted at 1.22 m (4 ft) above the ground.

During the first half of the field test (i.e., 18 subjects), the configuration outlined under treatment route 1 was used, while the second half utilized treatment route 2. Essentially, this approach consisted of a swapping of candidate and conventional treatments between similar site types, as shown in table 56.

Recruitment procedures for test subjects. Older participants were recruited from organizations involved with older adults and through bulletins at meeting places of older adults in the northern Calvert County, MD area. Younger participants were recruited from the local community college and through classified newspaper advertisements. These subjects have not participated in this research project in earlier lab and field studies.

Table 56. Treatment conditions used in field verification study 2.

		# of Site	Treatment Route 1	Treatment Route 2
Site Types	Utility Poles	6	Flashing Beacon	OM-2
		10	OM-2	Flashing Beacon
	Culverts	5	Directional Beacon	OM-2
		7	OM-2	Directional Beacon
	Ditches	8	Steady Beacon Array (4)[1]	OM-2 Array (4)
		9	OM-2 Array (4)	Steady Beacon Array (4)
	Bridge Columns	2	OM-3 & Flashing Beacon	OM-3
		3	OM-3	OM-3 & Flashing Beacon

[1] Note that all ditch treatments include four markers.

Number and age grouping of subjects. There were 36 subjects in all, 12 in the 20 to 40 year old group, 12 in the 65 to 69 year old group, and 12 in the 70-and-older group. Males and females were represented equally in the sample and within each age group.

Experimental protocol. The experimenter and each subject met at a public location. After introductions, the experimenter explained that the study was being conducted on behalf of a Federal Agency to investigate what kinds of things capture drivers' attention. Subjects read and signed an informed consent form while the experimenter installed the recording equipment and then read the instructions to the subject (see appendix C).

After the first 3.2 km (2 mi) of the route, the experimenter had the subject stop in an appropriate location. At this time, the experimenter provided the subject with feedback or clarification of the intended procedure and answered any questions. This period was used as practice for the procedure to ensure that the subject had an understanding about the type and quantity of information expected during the drive. To focus the drivers' feedback somewhat, indications of signs or road markings were reinforced by the experimenter as needed and extraneous information regarding activity or objects not related to the driving exercise were discouraged. For example, some subjects may point out type of foliage in yards, lawn furniture, or cars parked in adjacent driveways. Though these may have been interesting or eye-catching to the subjects, they do not represent things that the driver typically pays attention to as they drive, and were therefore not of interest. Feedback in situations like this included reinforcement of good verbal flow, but a request to "limit your focus to things that are closer to the road and that might affect the way you drive." Based on past experience, we felt that this was effective for narrowing the responses without leading the subjects into only pointing out signs, markings, hazards or roadway features. The purpose of this feedback was to keep the subject focused without biasing them toward simply looking for signs or roadway markings. This stopping point also provided the experimenter with the opportunity to terminate the experiment, if the subject exhibited unsafe driving tendencies or was unable to comprehend the requirements of the experimental procedure. If all aspects of the practice run were acceptable, the run then continued, uninterrupted until they returned to the starting location.

Before beginning the second navigation of the route, the experimenter read aloud the instructions defining the reason for this portion of the study and the subject's responsibilities for the second drive around the route. During this drive, subjects were cued to the active and conventional treatments as the subject approached them. After passing each treatment, the subject was directed to pull off the road into a safe parking area to allow two standard questions to be administered about each site. First, they were asked "*Exactly what do you think this sign/marking means?*" and then "*What action, if any, should you as a driver take in response to it?*" This procedure was repeated until all the sites had been completed. At the completion of both drives, the subject was paid and thanked for participating.

FIELD EXPERIMENT 2 RESULTS: COMPREHENSION AND CONSPICUITY OF ACTIVE DEVICES

Comprehension Results. The rated scores of all responses to the Meaning and Action questions for current and proposed object markers correlated around 0.50 ($p < .01$). Often an Action was embedded in the Meaning responses. For example, subjects would report the meaning of the marker and include the action they would take if they encountered this marker. Because Meaning and Action scores were significantly correlated, it was decided to take the higher rating of either the Meaning or Action question as the dependent variable. The same procedure was used in the analysis of the field study of the static object markers (see chapter 12 for additional details).

Frequency of responses (higher of Meaning and Action) for all subjects and tasks were tabulated. Ratings for each higher scored response per marker/situation combination were divided into two categories for purposes of descriptive statistics and statistical analyses. A correct response was defined as a response that was awarded a 4 or a 5 rating. An incorrect response was defined as a response that was given a 1, 2, or 3 rating. Of the responses 81.1 percent were scored as correct (a 4 or 5 response) and 18.8 percent were scored as incorrect. The results are shown in table 57. These results compare with a rate of 75.2 percent correct in the static marker experiment.

Table 57. Frequency breakdown of the responses.

Numeric Score	Rating	Frequency of Responses	Percent
5	Correct	168	58.5%
4	Partially correct	65	22.6%
3	Incorrect, but not dangerous	53	18.5%
2	Confusion, possible danger	1	0.3%
1	Dangerously wrong, dangerous confusion	0	0.0%

Seven object marker types and eight hazardous situations (two each of four types) were used to study the research questions of interest. The percentage of correct responses broken down by object marker and hazardous condition is shown in figure 31. This figure can be compared to figure 25 for the experiment using the static signs. The results indicate that the dynamic object markers do not provide any greater comprehension. In fact for the culvert, the directional beacon performed significantly worse that the OM-2 marker ($p < 0.05$). The only marker that was used in two locations was the OM-2 marker, and the location did not have a significant effect on performance. Table 58 shows the comprehension scores among the age groups. Interestingly the 65 to 69 age group had significantly lower comprehension scores then the other two age groups.

Table 58. Percent correct by age.

Object Marker	#	20-40	65-69[1]	over 70
OM-2	72	79.2	70.8	79.2
OM-3	36	91.7	91.7	100
OM-2 array	36	100	83.3	100
OM-3 flashing	36	91.7	83.3	100
Steady Beacon Array	36	100	91.7	91.7
Directional Beacon	36	50	16.7	58.3
Flashing Beacon	36	91.7	58.3	83.3
# observations	288	96	96	96
% Correct		85.4	70.8	86.5

1 $p < .01$

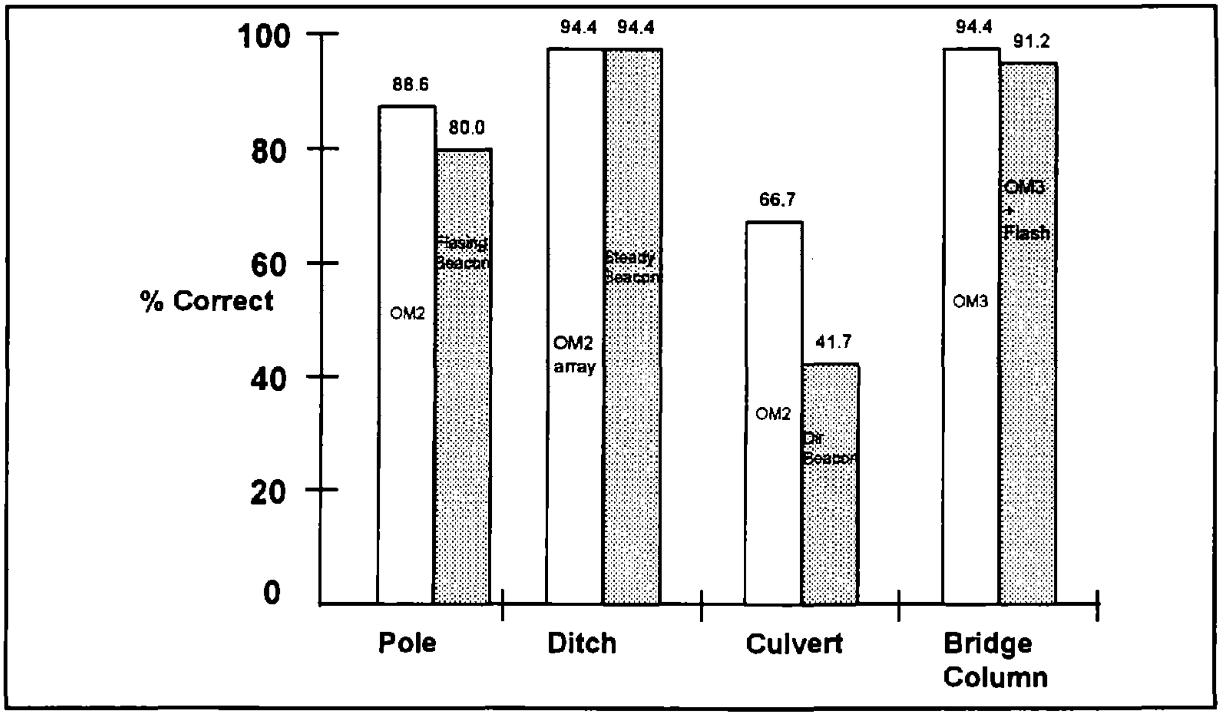


Figure 31. Percent correct by location for dynamic and static signs. (The only significant difference was the directional beacon was significantly worse than the OM-2.)

__Conspicuity Results.__ The subjects' verbal reports were coded to determine the conspicuity of the hazards and the hazard markers. Overall there were 288 data points collected (8 sites and 36 subjects). The conspicuity results were coded as marker only, object only, marker and object or neither. Table 59 shows that 64.6 percent of the time neither the object (hazard) nor the marker were reported. The following table (59) shows the breakdown of the responses.

Table 59. Summary of conspicuity responses.

	Count	Percentage
Both	29	10.1
Marker Only	34	11.8
Object Only	39	13.5
Neither	186	64.6
Total	288	100%

The breakdown of conspicuity of responses by object marker type and hazardous situation is shown in figure 32. The only dynamic marker that improved performance was the flashing beacon on the pole. This marker was reported significantly more often than OM-2 ($p < .01$) located in the same position.

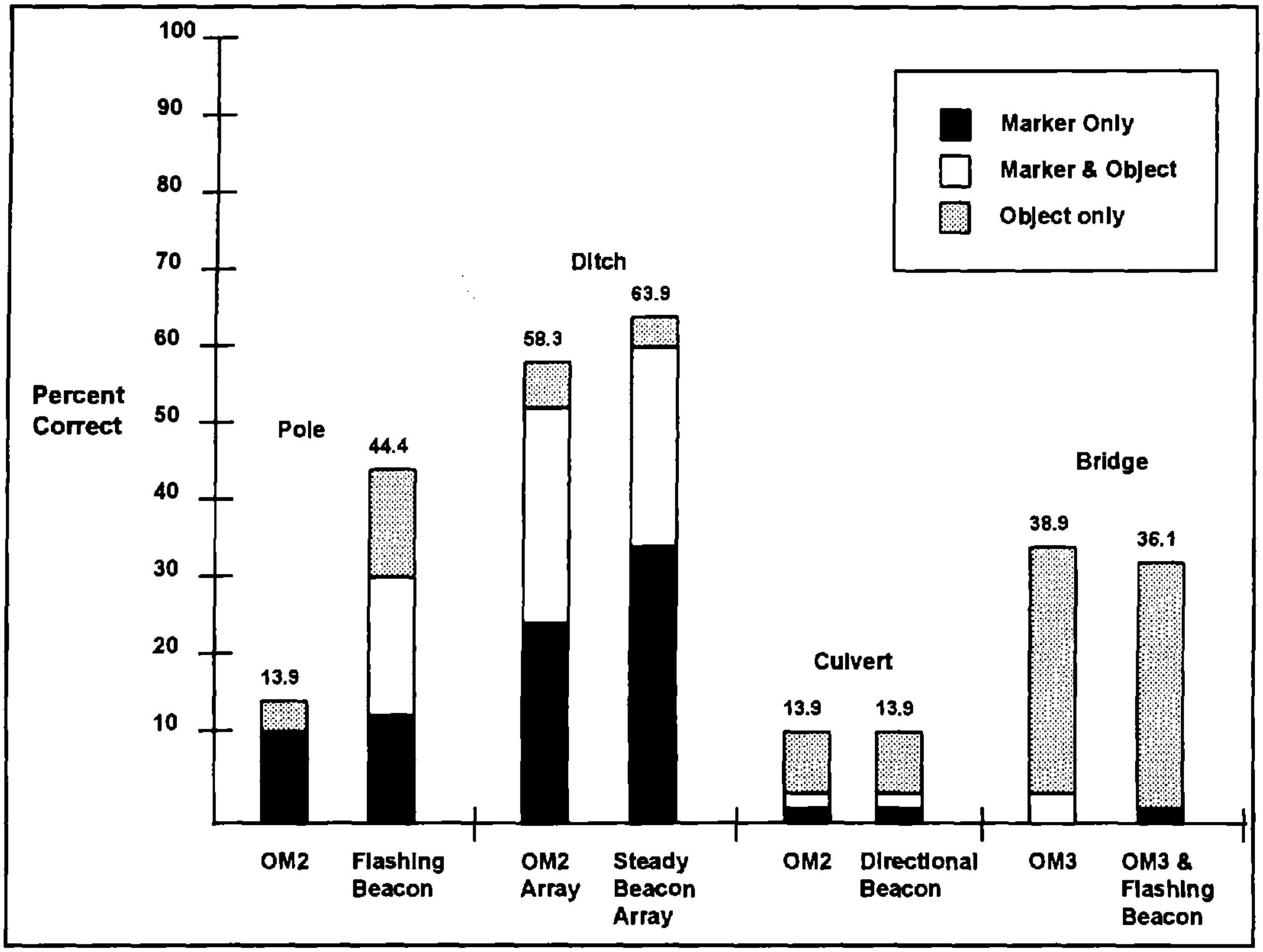


Figure 32. Conspicuity results for each sign type at each location.

<u>Conspicuity and age.</u> Table 60 shows the breakdown of conspicuity results by age group. There are no significant difference in overall conspicuity for the different age groups.

Conclusions. Directly comparing the findings of the active marker field study with the static marker study is difficult. By using the same sites and the same control markers (OM-2 and OM-3) in the two experiments it was hoped that direct comparisons of all the treatments at a site would be possible. However, comparing the performance for the OM-2 and OM-3 control conditions in the two experiments, it is apparent that the percentage of subject reporting the marker on hazard was substantially higher in the first experiment. This is true when only the daytime data from the first experiment is considered. Because of this difference, it is only meaningful to compare the performance of the markers within an experiment, not between them. There are many possible causes of the difference including a different time of year and a different experimenter. However, one result is clear, as expected, a flashing beacon is more conspicuous than a OM-2 marker. No age effects for conspicuity were found.

Table 60. Conspicuity responses by age group for all markers.

Saw/Age Group	20-40	65-69	over 70
Both	10.4 %	8.3 %	11.5 %
Marker Only	14.6 %	8.3 %	12.5 %
Object Only	15.6 %	14.6 %	10.4 %
Neither	59.4 %	68.8 %	65.5 %

CHAPTER 14. COST-BENEFIT ANALYSIS

BACKGROUND

Highway agencies are continually faced with safety-related decisions in today's environment of increasing demand on decreasing resources. It is therefore crucial that these decisions accommodate making the best use of the limited available funds. Cost-effectiveness analysis provides a systematic approach to these decisions via the comparison of benefit-cost computations between alternatives.

Benefit-cost methods of analysis usually entail application of a benefit-cost ratio, which is the ratio of the present worth of benefits (stated in terms or dollars) taken over the life of a project, to the present worth of initial capital costs and future costs less the present worth of salvage value.[30] The procedure generally involves the comparison of a number of alternatives, the intent of which is to determine the best alternative by virtue of the largest benefit-cost ratio.

The implementation of highway safety improvements usually considers benefits such as estimated accident reductions and resulting monetary savings associated with lives saved and injuries avoided. Non-safety benefits typically include travel time savings, operating cost reductions, and reduced maintenance/repair costs.

A comprehensive study of highway-safety project cost-analysis methods analyzed specific data elements which are typically applied in benefit-cost studies.[31] The objective of this study was to determine both the feasibility and soundness of applied benefit-cost techniques based on applied data. Among the significant conclusions was that limited availability of reliable input data meant that benefit-cost study results should be used with caution. The reliability of specific input data elements was weighted on a scale of 10 to 90 percent. The lowest rankings were associated with no or limited data: the highest ranking were associated with controlled studies. Engineering judgement was assigned a weight of 50 percent. This critique emphasized the applicability of specific input data, i.e., reductions in accidents injuries, fatalities and travel time, and operating, repair, and maintenance cost savings.

Cost-effectiveness studies are also documented for instances in which non-monetary measures are applied to assess associated benefits of various engineering alternatives. Most documented studies of this type have utilized weighting techniques, e.g., systematically assigning values to attributes that are measures of effectiveness. One example applied in NCHRP Report 162 was to apply an index of assigned weights as follows: fatal accident = 20, injury accident = 9, and property-damage-only accident = 1. Utilizing the Solomon data-reliability criteria noted above[31], it follows that the assigning of subjective judgement in not considered to be a sound cost-effectiveness analytical approach.

Highway safety improvements using traffic control techniques are well documented as having the highest overall benefit/cost ratio of any highway safety improvement due their relatively low cost by comparison with other appurtenances.[32] However, a limited studies have been documented which apply benefit-cost analyses to traffic control devices. One such study applied safety indices based on estimated accident reductions.[33] That study evaluated object markers, referred to as "reflectorized guide markers." Results indicated that object markers placed on bridge abutments produced a 40-percent reduction in accidents, while those placed at horizontal curve locations produced a 30-percent reduction.

Only one cost-effectiveness study of delineation treatments could be cited in the literature.[34] Under this research study, the effect of various delineation treatments on accident rates was assessed by analyzing accident data from more than 500 roadway sites in 10 States for various curve sections on two-lane rural highways. Cost-benefit and cost models for evaluating specific delineation treatments were developed and guidelines were formulated by executing the cost-benefit models for selected delineation treatments.

While the above cited cost-effectiveness studies utilized accident cost savings to quantify benefit, one documented traffic control device benefit-cost analysis was based on operational measures.[35] That study, reported in *NCHRP Report 337*, evaluated the effects of warning lights on moving highway maintenance vehicles. The measured benefit of tested lighting systems was increased lane-change time as motorists approached the work zone. An applied benefit-cost study entailed the determination of unit-costs for the operational benefit, i.e., seconds motorists' advance lane-change preparation time. This operational benefit was directly applied to various lighting systems to derive a benefit-cost ratio for each tested device. The applied analytic technique was quite effective in discriminating between high-cost and efficient traffic control applications.

A similar approach is applied in the current study. That is, operational measures are considered to be safety surrogates. In the present study, device effectiveness is measured in terms of driver-reported interpretation, i.e., observation and comprehension. These values are quantified in terms of response percentages and numerically applied in benefit-cost calculations.

COST-EFFECTIVENESS ANALYSIS

The literature has noted the validity of benefit-cost input data based on well-controlled study. The present study evaluated a set of innovative object marker treatments and applied driver-perceived measures of conspicuity and comprehension. Experimental control in this field study was achieved by the comparison of results obtained with the innovative devices with those obtained for baseline standard devices. Therefore, benefit-cost analysis criteria are validly applicable in accordance with cited Solomon study findings noted above.

Device Costs. Cost analyses consider initial installation, (i.e., materials and manpower), subsequent maintenance requirements, and overall service life. A relative cost-effectiveness computation is then based on the annualized present worth of each alternative.

In the present study, initial materials costs were obtained from various suppliers. Annual operation and maintenance costs were then derived from the literature.[36,37]

Derived cost estimates for the tested devices are as listed in table 61. Installation costs consider materials and labor. Operation costs result from power requirements for the beacon devices. Maintenance requirements consider estimations from the literature that 10 to 50 percent of object marker devices will have to be placed over their lifetime. Moreover, cleaning of reflective devices is occasionally required. The total cost shown is the annualized cost, assuming a 5-percent interest rate for a 10-year service life.

Table 61. Derived cost estimates for tested devices.

Device	**Installation**	**Annual Operation**	**Annual Maintenance**	**Annualized Total**
OM-1	65.16	0	5	15.6
OM-2	38.1	0	5	11.21
OM-3	87.08	0	5	19.18
Hash Marks	190	0	165	169.07
Double Modified Chevron	82.9	0	5	18.5
Cone Symbol	55.85	0	5	14.1
Fl. Beacon	900	100	65	311.6
Dir. Beacon	1000	100	65	327.89
Beacon Array	1100	100	65	344.18

Device Benefits. The derived effects from each of the tested innovative devices consisted of driver-reported measures, considered to be safety surrogates, under specific study conditions. Benefits were assessed in terms of observed response differences elicited by the each innovative device by comparison with a corresponding baseline device in its controlled study context.

Referring back to figure 25, calculated percentage differences for comprehension effects for each tested innovative passive device are as follows (see table 62). For example, in the case of the cone symbol application at the bridge, the observed comprehension (80 percent) represented a + 4.6 percent increase by comparison with the baseline comprehension (76.5 percent) associated with the OM-2. Similar observed differences for passive devices are shown in tables 62 through 64.

Table 62. Percentage differences for comprehension effects of passive devices.

Device	Comprehension
Cone symbol (Pole Application)	+ 4.6
Cone Symbol (Bridge Application)	- 10.4
Cone Array	- 5.9
Hash Marks	- 4.8
Double Modified Chevrons	+ 64.8

Referring back to figures 26 and 27, calculated percentage differences for day and night conspicuity effects for each tested passive innovative object marker are as follows (see table 63).

Table 63. Percentage differences for day and night conspicuity effects of passive devices.

Device	Day Conspicuity	Night Conspicuity
Cone Symbol (On Pole)	+ 26.9	+ 57.0
Cone Symbol (On Bridge)	+ 11.1	+ 39.7
Cone Array	+ 19.2	+ 8.3
Hash Marks	+ 27.0	+ 25.0
Double Modified Chevrons	- 6.7	+ 111.5

Observed effects for active devices (in terms of response percentages) calculated from data presented in figure 32 were as follows (see table 64).

Table 64. Percentage differences for conspicuity effects of active devices.

Device	Conspicuity
Flashing Beacon	+ 219.4
Steady Beacon Array	+ 9.6
Directional Beacon	0.0
Flashing Beacon	- 7.2

Benefit-cost Ratio Computations. Benefit-cost (B/C) ratios directly compute a measure of benefit (e.g., operational performance associated with studied object marker treatments in the present analysis) with the associated cost (e.g., annualized dollar costs of the tested object marker treatments). The achieved cost-utility effect (e.g., benefit or liability) is calculated by comparing B/C ratios between baseline and treatment conditions. Computation of the achieved B/C difference involves subtracting B/C ratios for baseline conditions from those observed for corresponding treatment conditions. The applied computations parallel the illustrated driver-measure analyses contained in the previous report section.

Figure 25 addressed comprehension effects of tested passive object marker treatment conditions. Associated costs (taken from table 61) and benefits, i.e., observed percentage correct responses observed in the field studies, for baseline and treatment conditions were applied in B/C computations. B/C ratio differences shown below are simply the calculated benefit divided by the cost. B/C ratio differences with a plus sign indicate a positive benefit (corrected for cost), and those with a negative sign indicate a calculated cost-liability. The table below (65) indicates that positive driver interpretation effects were found to be associated with the Double Modified Chevron placed at the gore area and the Cone Symbol placed at the bridge column.

Table 65. Object marker overall comprehension effects.

Treatment Alternative	Baseline Cost ($)	Baseline Benefit (%)	Treatment Cost ($)	Treatment Benefit (%)	B/C Difference
Cone v. OM-2	11.21	76.5	14.10	80	-1.2
Cone Array v. OM-2 Array	44.84	97.1	56.40	91.4	-0.5
Hash Marks addition	44.84	60	213.91	57.1	-1.1
Double Modified Chevron v. OM-1	15.60	50	18.50	82.4	1.2
Cone v. OM-3	19.18	82.9	14.10	74.3	0.9

Figure 26 addressed overall (day and night) conspicuity effects of tested passive object marker treatment conditions. Similar calculations to those shown above indicated no difference for the single cone symbol placed on the utility pole and a positive benefit-cost ratio for the Cone Symbol placed on the bridge column. Results are shown in table 66.

Nighttime conspicuity benefit-cost ratio comparisons (see table 67) indicated benefits of the Cone Symbol placed on both the utility pole and bridge column and the Double Modified Chevron placed at the gore area. It is interesting to note that hashmark application produced the same B/C ratio (-0.5) under both conspicuity conditions. Thus the data strongly attest to the lack of any justification for the relatively costly hashmarks.

Table 66. Object marker overall conspicuity effects.

Treatment Alternative	Baseline Cost ($)	Baseline Benefit (%)	Treatment Cost ($)	Treatment Benefit (%)	B/C Difference
Cone v. OM-2	11.21	38.3	14.10	48.6	0.0
Cone Array v. OM-2 Array	44.84	74.3	56.40	88.6	-0.1
Hash Marks addition	44.84	31.5	213.91	40	-0.5
Double Modified Chevron v. OM-1	15.60	18.2	18.50	17	-0.2
Cone v. OM-3	19.18	51.4	14.10	57.1	1.4

Table 67. Object marker nighttime conspicuity effects.

Treatment Alternative	Baseline Cost ($)	Baseline Benefit (%)	Treatment Cost ($)	Treatment Benefit (%)	B/C Difference
Cone v. OM-2	11.21	53.9	14.10	84.6	1.2
Cone Array v. OM-2 Array	44.84	92.3	56.40	100	-0.3
Hash Marks addition	44.84	30.8	213.91	38.5	-0.5
2 Mod Chev v. OM-1	15.60	18.2	18.50	38.5	0.9
Cone v. OM-3	19.18	38.5	14.10	53.8	1.8
No hashmark effect at night					

Computed B/C ratios associated with active device application are shown below. Negative B/C comprehension and conspicuity values were shown for all tested devices (see tables 68 and 69).

Table 68. Active device comprehension effects.

Treatment Alternative	Baseline Cost ($)	Baseline Benefit (%)	Treatment Cost ($)	Treatment Benefit (%)	B/C Difference
Flashing Beacon v. OM-2	11.21	88.6	300.39	80	-7.6
Beacon Array v. OM-2 Array	44.84	94.4	299.34	94.4	-1.8
Directional Beacon v. OM-2	11.21	66.7	316.68	41.7	-5.8
Flashing Beacon addition	19.18	94.4	330.78	91.2	-4.6

Table 69. Active device conspicuity effects.

Treatment Alternative	Baseline Cost ($)	Baseline Benefit (%)	Treatment Cost ($)	Treatment Benefit (%)	B/C Difference
Flashing Beacon v. OM-2	11.21	13.9	300.39	44.4	-1.1
Beacon Array v. OM-2 Array	44.84	58.3	299.34	63.9	-1.1
Directional Beacon v. OM-2	11.21	13.9	316.68	13.9	-1.2
Flashing Beacon addition	19.18	38.9	330.78	36.1	-1.9

SUMMARY AND INTERPRETATION

Traditional benefit-cost studies compare various safety alternatives on the basis of accident-cost effects. However, operational measures of effectiveness are applicable for benefit-cost analyses when the study is properly controlled. The present study applied driver response measures (i.e., comprehension, conspicuity) in a controlled application of baseline and innovative object markers. These measures were quantified by subject response percentages for each device and applied as device benefits in this benefit-cost study.

While the purpose of object markers according to the *MUTCD* is to "mark obstructions within or adjacent to the roadway," the devices do not necessarily convey any specific message to drivers.[1] In an emergency situation, the mere presence of a brightly-colored reflectorized device implies avoidance. Therefore, interpretation of the benefit-cost analysis can logically place a high weight on conspicuity results. Thus, the primary issue posed in this analysis was whether the additional cost of certain obtrusive object markers was justified.

With regard to the passive object markers, the Double Modified Chevron and the single Cone Symbol demonstrated good results. Both devices showed positive B/C ratios in the comprehension studies. Both of these devices produced the highest B/C ratios in the both overall and nighttime conspicuity tests. Nighttime conspicuity test results demonstrated positive B/C ratios for both the Double Modified Chevron and the single Cone Symbol.

The device with the lowest benefit-cost payoff was the painted pavement hash marks. The analyses consistently demonstrated that costs associated with hash mark application in the context of this study were not justified. With regard to active device applications, none of the additional costs was justified on the basis of a benefit-cost analysis based on the applied driver response measures. However, in view of the high conspicuity demonstrated by the single flashing beacon and its general acceptance when deployed as a hazard warning beacon, it may very well serve to alert motorists to hazards. Therefore, this device is recommended for further consideration via application of a traditional accident-based benefit-cost study.

CHAPTER 15. DISCUSSION AND RECOMMENDATIONS

The sequence of three laboratory experiments served to define a set of candidate delineation treatments to carry forward for field evaluation. Experiment 1 screened out markings that were not adequately comprehended by viewers. Experiment 2 determined whether the legibility distance for various marker treatments was adequate. Experiment 3 compared alternative markers in terms of conspicuity. The major findings of all experiments suggest that there is an opportunity for improved hazard marking which may promote motorist comprehension and hazard awareness.

The results of Experiment 1 (comprehension) suggested a fairly good understanding of the general message conveyed by current OM markers in context. The percentage of subjects who correctly interpreted the meaning of OM markers ranged from 72 to 82 percent. However, the large majority of "correct" responses fell in the partially correct category; subjects understood the general cautionary message but did not necessarily understand the specific hazard. Further, the experimental procedure emphasized the context of the warning, which may have inflated the likelihood of a correct response. There is still room for improvement in terms of driver comprehension of meaning for current hazardous object markers and awareness of the actual hazard.

The results of Experiment 2 (recognition) indicated that in both day and nighttime viewing conditions, current object markers, particularly the OM-3, were the most visible of the markers tested. This may be partially due to familiarity with the marker; drivers encounter this marker frequently and might recognize it at a greater distance than unfamiliar markers. Of the proposed markers, the post-mounted directional markers fared best, which may in part be due to their larger physical size compared to the other proposed markers. The double edge pavement marking and the cone representational symbols were equally visible in day and night conditions, and all three were more visible than the hash mark pavement delineation. Results from Experiment 3 (conspicuity) suggested that the hash mark pavement delineations are rarely reported; however, double edge pavement markings were not reported at all.

Although the hash mark delineations were not reported as often as the post-mounted cone symbols or the OM markers in Experiment 3, the combination of the hazardous situation and the object marker was noticed about as often with the hash marks as with the cones or OM. Thus, while the experimental procedure of Experiment 3 leads to low reporting of road markings per se, the markers do appear to positively influence hazard detection. When an OM marker can be placed on a raised object such as a tree or utility pole, the OM may be more effective than the hash marks. But where a hazardous object is low to the ground, such as a culvert, the hash marks result in the hazard being as conspicuous, or even more so than the current OM markers.

The proposed post-mounted representational symbols (yellow and green cones) and the hash mark pavement delineations were about as well understood as current OM markers. Several of the proposed markers (e.g., French gore) most often reported in Experiment 3 (conspicuity) had sizably lower comprehension scores than the existing OM markers. Novelty effects for the proposed markers may somewhat explain their higher success in Experiment 3. Subjects may have reported proposed markers more often since these markers are novel, while the subjective importance of current markers may not have been as high, especially in a laboratory experimental setting.

Results from Experiments 1, 2, and 3 showed no differences in overall performance between the strong yellow-green and yellow cone markers. Since it is likely that the strong yellow-green color may be used in the future for non-motorized cross-walk signs such as pedestrian crosswalks or bicycle paths, the green background was dropped from further consideration and the yellow background for roadway object markers was carried forward to the field study.

The results of the on-road study with static markers were fairly consistent with Experiments 1 through 3. The percent of correct responses for all markers in all situations was 75.2 percent, nearly the same level as that in the earlier experiments. The only novel treatment that stood out as significantly better in terms of comprehension at a particular site type was the Double Modified Chevron at gores. Of the respondents, 84.2 percent correctly reported its meaning, while only 50 percent understood the conventional marker. Some differences in comprehension were also noted between day and night for the various markers tested. Generally, higher rates were noted at night for the more abstract conventional OM's, while the directional signs (Double Modified Chevron) was understood better during the day. Cones did not show the same trend. The results of the active marker field study indicate that the dynamic object markers do not provide any greater comprehension. In fact for the culvert, the directional beacon performed significantly worse that the OM-2 marker ($p < 0.05$). The only marker that was used in two locations was the OM-2 marker, and the location did not have a significant effect on performance.

The conspicuity portion of the static marker field study showed better reporting rates than those described for Experiment 3. In fact, the overall reporting rate was nearly double that associated with the video "drives" carried out under that earlier experiment. Specifically, for all object markers and hazardous situations, subjects reported the marker alone 24.9 percent of the time, the hazardous situation alone 11.6 percent of the time, and both the situation and the marker 10.4 percent of the time for a total of 46.9 percent "hits" of either marker, hazardous situation, or both. Trends in the data suggest higher reporting rates for the novel treatment at five of the six location types seemingly attributable to the marker. However, statistical analyses were not significant. Additional observations may improve the significance level. The overall data suggest that markers do play an important role in making hazards more noticeable at night. Hash marks were ineffective at providing any significant impact on reporting rate over OM-2's alone.

Directly comparing the findings of the active marker field study with the static marker study is difficult. By using the same sites and the same control markers (OM-2 and OM-3) in the two experiments it was hoped that direct comparisons of all the treatments at a site would be possible. However, comparing the performance for the OM-2 and OM-3 control conditions in the two experiments, it is apparent that the percentage of subject reporting the marker on hazard was substantially higher in the first experiment. This is true when only the daytime data from the first experiment is considered. Because of this difference, it is only meaningful to compare the performance of the markers within an experiment, not between them. There are many possible causes of the difference including a different time of year and a different experimenter. However, one result is clear, as expected, a flashing beacon is more conspicuous than a OM-2 marker. No age effects for conspicuity were found.

Conclusions that can be drawn from this set of studies can be outlined as follows:

- In actual roadway context, no benefits to meaning were seen for the novel markings compared to current markings, except for Double Modified Chevron vs. OM-1 at gores. Here it appears that the novel sign is more meaningful and could potentially provide a benefit to the hazardous situation.

- The rate of reporting of hazards and/or markers varied considerably for applications. Ditches, culverts and gores seldom had the hazard reported, suggesting the importance of markers for these situations. However, while marking treatments yielded high rates of reporting for the ditches, they were only moderate for the culverts and low for the gores. This may suggest that arrays are more effective for attracting attention at hazardous situations.

- For conspicuity, novel treatments generally were reported slightly more often, but this was not statistically significant for any given site.

- At night, the number of people reporting the bridge column was only about half the number as during the day. Object markers appear important for improving driver attention at night for this more visible hazard, as well as for those less apparent hazards (e.g., culverts).

- Sizable and statistically significant benefits of novel roadway markings as a means to mark hazardous objects were not demonstrated, either alone or in combination with other markers. There was a non-significant 5 to 15 percent improvement, generally. It may warrant follow-on with larger samples to see if this effect is reliable <u>if</u> this size benefit would be cost effective.

Using the findings from the lab and field studies, the cost-benefit analysis found that for the passive markers, the Double Modified Chevron and the single cone symbol demonstrated good results when a high weight was placed on conspicuity. The device with the lowest benefit-cost payoff was the painted pavement hash markers. None of the additional costs of the active device applications were justified on the basis of the cost-benefit analysis.

As a result of the findings of this project the following recommendations should be considered:

- Replacement of OM-1 markers at gore areas with Double Modified Chevrons should be considered. Comprehension appears better, though the lower rates evident in nighttime situations should be investigated.

- Maintain the OM-2 and OM-3 signs as simple means of drawing attention to hazardous situations. As abstract as they may be, they serve a purpose of heightening awareness of the situations they mark, allowing drivers to then assess and react appropriately to the hazards.

- Arrays of OM's should be considered where conspicuity of the hazardous situation is lacking, or when the hazard is spatially extended, or severity of the hazard warrants a more conspicuous marking.

- With regard to active device applications, none of the additional costs was justified on the basis of the cost-benefit analysis based on the applied driver response measures. However, in view of the high conspicuity demonstrated by the single flashing beacon and its general acceptance when deployed as a hazard warning beacon, it may very well serve to alert motorists to hazards. Therefore, this device is recommended for further consideration via application of a traditional accident-based cost-benefit study.

- Based on the problem identification studies which found that drivers did not understand the meaning of the directional slanted lines of OM-3 markers, modify the MUTCD to eliminate distinction between right and left OM-3 markers.

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