PRACTICAL ASPECTS OF CONSPICUITY PRINCIPLES

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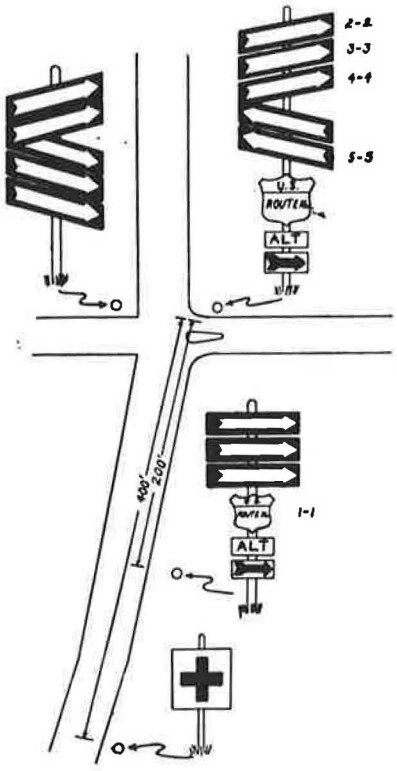
My assignment is to furnish a brief general background for other more technical papers on the program. First, though, a bit of history and some definitions. When some of us were beginning to study visibility on the highway in the early 1930's, the highway and driving conditions were very much different from those of today. Speeds were lower, the requirements for highway and equipment visibility was less and sign visibility and legibility were much poorer. It was common to find a large number of place names, each on a separate wood board mounted one above the other on "totem poles" at road intersections. Figure 1 gives the layout of a typical crossroad installation from an early research report (3). Figure 2 illustrates an early expressway sign, a reduced "totem pole."

As compared to these early highway conditions, present highway signing and traffic conditions are much improved. Speeds are higher on both types of roads, however, and conspicuity and legibility can still be improved. Figure 3 shows an overhead mounted sign on a freeway. This example illustrates not only improved legibility and conspicuity, but also an off-ramp to the left.

As noted in a recent report, conspicuity is more necessary where alignment is contrary to the usual right hand off-ramp which most drivers expect. This expectancy factor is of considerable importance as pointed out by these authors.

FIGURE 1: "Totem pole" sign layout at an intersection studied in early research (3).



Needs for Definitions

Before discussing the various interrelated factors and needs for conspicuity on the highway, definitions of conspicuity and related terms will be considered to avoid possible confusion as to meaning of terms.

Definition of Conspicuity

According to Webster, the term "conspicuity" comes from the Latin meaning "get sight of" and thus means (1) obvious to the eye or mind, and also (2) attracting attention. The latter meaning has also been applied in some uses to auditory and other methods of obtaining attention.

Related Terminology

The following related terms are defined thus--the first three from Webster:

1. Visibility--The distance objects can be identified visually with the naked eye. For certain purposes, this distance is often used as a measure of visibility.

2. Detectability--Characteristics such that the fact of presence or existence can be determined, i.e., this is the minimum even before the object can be identified.

3. Recognizability--Characteristics of the thing such that it will be perceived as something previously known. Thus visibility involves both detectability and recognizability according to these definitions.

4. Attention Value--Having characteristics which attract attention.

5. Target Value--Visual characteristics of signs, usually luminance and contrast, giving visibility and attention value, i.e., conspicuity of one type.

FIGURE 2: Modified "totem pole" sign on expressway in 1941.

FIGURE 3: Modern sign on a freeway.

FIGURE 4: View of an intersection illustrating highway elements requiring conspicuity.

This last term was originally used by the late Guy Kelcey referring to attention-getting effects of high luminance of sign legends using retroreflective buttons. It was adopted in connection with some of the earliest studies of highway sign legibility and visibility (3). It, therefore, refers to conspicuity of one type.

Need for Recognizability in Addition to Conspicuity

Conspicuity on the highway may be obtained without recognizability, and recognizability is highly important. For example, a flashing light on the highway ahead will definitely provide conspicuity. But if the driver is to make the required judgments and responses correctly, he must know whether he is seeing a railroad crossing warning, a railroad engine headlight, an emergency vehicle flasher or a police car flasher, or an advertising sign.

Again, a vehicle ahead on a two-lane road may be of sufficient size and color to be conspicuous, but a driver must recognize: 1) whether it is a car, truck, bus (or school bus); 2) whether it is going in the same or opposite direction; 3) and, in overtaking situations, whether it is coming towards him in the wrong lane. He must be able to recognize the proper alternative in order to stop, continue and pass or quickly pull off the road.

What Has to Be Made Conspicuous?

After this preliminary introduction, we will now look at some of the wide range of highway elements, vehicles, people and animals which have to be made conspicuous in the interest of safe and good driving. For completeness, Table 1 lists first highway elements, then vehicles and then animals. It will not be necessary to discuss these in detail since they are rather self-evident, but they will illustrate the range of items to be considered.

Who Needs Conspicuity?

To increase safety and to reduce the probability of accidents, everyone on the highway whether operating a vehicle, motorcycle or bicycle, carrying on various kinds of maintenance tasks, or when crossing or walking along as pedestrians, has a vital need for conspicuity. All of these people can be classified under 1) vehicle operators and regular road users, 2) pedestrians of various types and 3) others on the highway. Table 2 lists these.

Again, it is not necessary to go over these item by item. It is clear that car drivers, motorcycle, moped and bicycle riders all need to be seen by other operators and in turn they need to see vehicles, people, signs, signals and where the road goes. Similarly, maintenance workers, enforcement personnel and others such as railroad crews and drivers at crossings must have conspicuity in order to operate safely. Pedestrians have a vital need for conspicuity in order to be seen and avoided by drivers. Heavy vehicle operators, because of the longer time to stop or avoid hazards, have an especially great need for conspicuity of other vehicles, highway features and other users of the road.

When Is Conspicuity Needed?

All would agree, I think, that conspicuity is needed at all times when driving, walking or just being on the highway or its shoulder. This includes, of course, ordinary daylight but also shadow and partly dark conditions in tunnels. (See Table 3).

Lighting and reflectorization factors are especially important at night, or course. Such factors as even lighting distribution vs. "visual noise" from spotty lighting are highly important as are effects of glare on visibility and conspicuity. Also lighting alone does not necessarily provide conspicuity since sometimes lighting produces shadows which actually hide certain objects.

Practical Methods of Obtaining Conspicuity

Certain basic factors shown in Table 4 are both important and well-known. Many of these factors such as color contrast, brightness contrast, placement and relative size will be discussed in more technical detail later. A few examples follow which illustrate well-known practical applications of such factors.

TABLE 1. WHAT HAS TO BE MADE CONSPICUOUS?

1. HIGHWAY ELEMENTS
   - A. Signs
   - B. Signals
   - C. Pavement markings
   - D. Changes in horizontal alignment
   - E. Dips or bumps
   - F. Pavement vs. shoulder
   - G. Obstructions and barricades
   - H. Construction areas
   - I. Roadside hazards
   - J. Bridge approaches

2. VEHICLES
   - A. Cars
   - B. Trucks and trailers
   - C. Busses
   - D. Bicycles and mopeds
   - E. Motorcycles
   - F. Recreational vehicles
   - G. House trailers
   - H. Other vehicles being towed
   - I. Farm vehicles and equipment
   - J. Construction vehicles and equipment
   - K. Railroad trains and engines

3. ANIMALS
   - A. Seeing-eye dog
   - B. Pets
   - C. Farm animals
   - D. Harness animals
   - E. Riding animals
   - F. Deer and other wild animals

TABLE 2. WHO NEEDS CONSPICUITY?

1. VEHICLE OPERATORS AND REGULAR ROAD USERS
   - A. Car and truck drivers, motorcycle, moped, and bicycle riders*
   - B. Traffic engineering crews for safety
   - C. Maintenance workers and flagmen
   - D. Enforcement personnel and vehicles
   - E. Emergency personnel and vehicles
   - F. Railroad crews and drivers at crossings
   - G. Others on special roadways e.g., airport roadway and taxiways
   - H. Maritime pilots at highway bridges

2. PEDESTRIANS
   - A. General public
     1. Adults
     2. Children
   - B. Joggers
   - C. Crossing guards
   - D. Fire fighters
   - E. Police
   - F. Construction, maintenance and utility crews
   - G. Motorists or repairmen adjacent to vehicles

3. OTHERS ON ROADWAY
   - A. Bicyclists
   - B. Mopedists
   - C. Motorcyclists
   - D. Equestrians
   - E. People on roller skates or skateboards

*To see: Signs and signals, both urban and rural. Where the road goes, especially rural. Each other; urban, rural, and roadside.

TABLE 3. WHEN IS CONSPICUITY NEEDED?

1. AT ALL TIMES WHEN DRIVING OR WALKING IN:
   - A. Ordinary daylight, shadow or tunnel conditions
   - B. In dusk, darkness, and dawn
   - C. In poor weather conditions - snow, fog, rain and other

2. LIGHTING AND REFLECTORIZATION AS FACTORS AS NIGHT
   - A. Even lighting distribution vs. "visual noise"
   - B. Lighting alone does not necessarily provide conspicuity
   - C. Glare, visibility, and conspicuity

TABLE 4. PRACTICAL METHODS OF OBTAINING CONSPICUITY

1. BASIC FACTORS
   - A. Color contrast
   - B. Brightness contrast
   - C. Intermittent stimulation
   - D. Relative size
   - E. Placement (re: driver's line of sight and to avoid competing objects

2. EXAMPLES OF PRACTICAL METHODS
   - A. Reflectorized signs and high luminance signals
   - B. Oversized stop signs and symbol signs
   - C. Lane width flashing arrows protecting approach to road work
   - D. Fluorescent orange flagman's vest
   - E. Flashing lights on police vehicles
   - F. Flashing lights on emergency vehicles
   - G. Addition of sirens and auditory warnings
   - H. Bi-modal stimulation (e.g., rumble strips)

3. INCONSPICUITY - EXAMPLES
   - A. Car hits freight train across road
   - B. Driver misses one-way arrow, goes wrong way
   - C. Road turns, driver continues straight (off road)
   - D. Laying recording tapes on highway
   - E. Pedestrian on road side
   - F. Rear-end stopped vehicle in the rain or without lights

Examples of Practical Methods

Flashing lights as attention getters are well known. Reflectorized and oversized stop signs have been used widely, and there have been studies to determine the best method of using them. Road work approach warnings consisting of flashing arrows and fluorescent orange vests for flagmen are widely used.

Addition of signs and auditory warnings or rumble strips have been found helpful for hazardous locations, toll booths and other special facilities such as bridges.

Examples of Inconspicuity

Of equal importance are examples of lack of conspicuity. Late night accidents where a car hits a freight train across the road happen all too often. A driver who goes the wrong way on a divided highway having missed a one-way sign illustrates a very hazardous effect of lack of conspicuity.

Figure 4 is a daylight scene where a road turns, but the driver at night may easily continue straight ahead. Pedestrian accidents and rear-end collisions with a stopped vehicle are all too common.

Maintenance people, I am sure, will recognize the need for conspicuity to allow road work with reasonable safety. It is very significant that the Institute of Transportation Engineers, in cooperation with various other highway organizations, has developed a special training course on flagging in a training program for construction and maintenance personnel. All of the features in the course are basically concerned with improving conspicuity and safety (1).

Research on Conspicuity Requirements

A great number of researches have been done all over the United States, Europe and Japan, but only a few examples will be mentioned to illustrate research in three areas. These are (1) visibility of pedestrians, (2) visibility of vehicles, and (3) visibility of highway signs. A fourth area is research on visual sensitivity of people which, of course, is basic for visibility of any kind.

Conspicuity of Pedestrians

Visibility of pedestrians depends, of course, on both lighting of the pedestrian and reflectivity of his body and clothing. Many of the same factors apply to visibility of bicyclists and motorcyclists.

Richards (13, p. 8) reviewed his own and other previous studies. In one study, pedestrians dressed in dark brown and a reflective factor of 30 percent. Under headlights on a city street this gave a luminance 50 percent greater than the road at 25 feet but at 100 feet was only half as bright. Therefore, seeing the pedestrian changed from direct to silhouette seeing at about 50 feet. Distances, of course will be different with modern headlights and with different reflectivity of pedestrian clothing and road materials.

Allen (2, pp. 150-153) reports that although 11.8 percent of drivers claim they did not see a pedestrian in daylight, at night 23.4 percent claim they did not see them before the impact. In his studies, pedestrian clothing reflectances ranged from 9 percent for black to 16 percent for gray and 75 percent for white. Dummy pedestrians represented the range of clothing reflectances to be expected on the highway. Critical visibility distances (stopping distances) were checked against visibility distances for the pedestrians. For the darker clothing, safe visibility distance was obtained only to 30 mph, whereas white "pedestrian" clothing increased conspicuity to a 50 mph stopping distance (185 feet). Reflectorized tape increased the visibility distance even farther.

Richards (12) reported an extensive series of tests carried out in Massachusetts by several cooperating organizations to determine the safest color for clothing to be worn by hunters. Attention was given both to normal and to color impaired observers. Lighter colors were the more visible under low lighting conditions such as twilight, but yellow might be confused with white at such times. Fluorescent colors, especially blaze orange, were seen best especially at dusk. Red, on the other hand, tended to disappear at dusk and might be confused with other colors.

Fluorescent orange has been adopted not only for hunters' clothing but also for vests to be worn by flagmen and other personnel who must be on the highway for maintenance or for other purposes at all times of day.

Sleight (15) in his chapter on the pedestrian, summarized research on the pedestrian and quoted the determination of critical visibility distance by Hazlett and Allen (9). He noted the pedestrian accident rate is much higher in darkness than in daylight.

Daytime accidents involving pedestrians also may involve conspicuity. Factors of vehicle design for visibility may affect conspicuity as discussed in detail by several authors (Merrill Allen (2) and Mortimer (1), among others).

Conspicuity of Vehicles

Informal experiments on improving the conspicuity of vehicles have been carried on by bus companies. They have reported that the use of headlights by their busses during daylight as well as at night has reduced accidents. Hard data on this are scarce, but it would be expected that headlights would help with conspicuity by showing which way a bus is going especially on two-lane highways.

Vehicle color and luminance may affect conspicuity of passengers, cars and larger vehicles including recreational vehicles. Allen (2) gives a plot of color against relative visibility through a filter and shows that shades from white to cream have much greater visibility than the darker colors. He claims that 10 times as many accidents happen to black cars as to white ones (2, pp. 138-139).

Contrast with the background against which the vehicle is seen may be as important as the color. Automobiles are often seen against a dark highway or other background which might explain poorer conspicuity and safety for darker colored cars as reported by Allen. However, in northern areas where cars may be seen against a white snow bank, darker colors may have greater conspicuity. Therefore, a combination of dark and light colors may be advantageous for vehicle safety. In daylight and shadow the findings of the Massachusetts hunter study would suggest use of fluorescent colors. At railroad highway crossings, low illumination and shadow conditions are often found. Therefore, markings on the side of railroad cars and on engines might be most conspicuous if light colors and even fluorescent colors are used.

Headlights and Rear Lights

Improving rear signal visibility on automobiles by higher placement of rear signals and use of colors specific to the meaning of the indication are suggested by Allen (2 pp. 130-137). Mortimer (11, pp. 200-212) discusses interference with the view of the driver from the design of the vehicle and methods of avoiding this. He also points out the need for rear visibility requirements and discusses different possible types of vehicle marking and signalling. Problems with certain types of suggested rear light signals are pointed out by Mortimer.

Other studies on improving conspicuity of highway vehicles and railroad cars have been done in past years (e.g., those by A. R. Lauer) but these examples will suffice for the present purpose.

Conspicuity of Highway Signs

A number of investigators have carried on research on visibility as well as legibility of highway signs. As a specific example, as series of 13 studies on visibility and attention value of highway signs was reported by Forbes, Pain, Fry and Joyce (5-7). A very brief review of methods and results follows.

The first part of the study was carried out in the laboratory where simulated highway signs and backgrounds were projected onto a moving picture screen. To make the slides, miniature test signs were made and photographed against pictures of backgrounds obtained at actual highway locations. Groups of about 25 subjects viewed a given set of conditions. Each subject, acting as an observer, indicated which of four signs was "seen first and best."

As an auxiliary "loading task, " the subject was required to relight small red lights in a matrix when certain of the lights were extinguished on a random basis by automatically controlled equipment. At certain times in this sequence, the blank background scene (i.e., without test signs) was suddenly replaced by the same scene with test signs in the picture. By pressing one of four buttons, the subject indicated which of the four test signs he judged to be seen "first and best." The small matrix of red signal lights served as a visual focal point and maintained dark adaptation.

The results were analyzed for each combination of signs. A large number of combinations of different parameters gave results for color, brightness, symbol and sign size, contrast of legend to sign background and contrast of sign background to surround.

The details of the results are given in the three publications listed in the references. Briefly it was found that mounting location over the highway gave better relative visibility than sign mounting beside the highway. Therefore, the remaining presentations and observations were made with mounting over the highway. One of these mountings with test signs as seen by the subject is shown in Figure 5.

Relative size also proved to be a factor, and this was held constant for other analyses. Color and brightness of the sign background and brightness of the white legends or symbols affected visibility.

Contrast with background gave a higher percent seen first. When measured luminance of the colors was plotted against percent seen "first and best" on an average basis for three different luminance backgrounds, the percent increased for the lighter colors (higher luminance). However, contrast proved to be important when percent seen first was plotted separately for each of the three backgrounds (See Figure 6). Here the lighter colors were seen best against the darker background, but against a lighter background, the darker colors gave better visibility.

Figure 7 shows results of actual outdoor observation distances for signs on the highway compared with expected calculated visibility distances. A mathematical model derived from laboratory relationships and based on luminance contrast of legend, sign background and surround background modified by relative size was used for calculated distances.

Applying this result to vehicles would explain why light colored cars would be more visible and may have an advantage for safety when reports from all backgrounds are averaged, but against snow backgrounds a darker car would be expected to have an advantage. Therefore, the combination of a bright and dark color on the same vehicle is suggested.

Another study by Forbes (4) showed that against a relatively even luminous background green and blue were seen better at low levels, while white, yellow and orange required a larger ratio of color luminance for color recognization as the ambient background luminance level increased from .127 to 15.25 cd/m2. In other words, color recognition was affected markedly by the luminance of the surrounding background.

The relationships are complex and will be found in the paper. It is clear from both studies, however, that contrast with surround and background is a very important feature both for conspicuity and for color recognition.

Visual Sensitivity of People

The various characteristics of human visual sensitivity obviously will affect the conspicuity of objects, people, vehicles and other features of a scene. Among the characteristics of most importance are visual acuity, color sensitivity and low contrast sensitivity under night vision conditions.

The first two factors are discussed at length and their optometric characteristics given in detail by Richards (13) and by Allen (2) and cannot be included here. Psychological factors of visual perception are discussed in the next paper.

Low contrast sensitivity under night vision conditions also may be of great importance for conspicuity. A study by Forbes and Vanosdall (8) of 371 subjects of ages 16 to over 60 showed that some individuals have much poorer low contrast sensitivity under night vision conditions than others. Such reduced sensitivity had been thought to be more characteristic of older subjects, but this study indicated that there was also a significant proportion in the younger groups showing this difficulty. It was recommended that all age groups should be educated concerning night vision deficiencies.

It is true, of course, that under night conditions higher luminance usually gives greater contrast of the illuminated object with background. But silhouette seeing of pedestrians with an illuminated roadway behind them may be very important. Thus for conspicuity, luminance contrast is of importance as well as color and luminance alone.

FIGURE 5: Subject observing simulated signs against a bright sky and snow background (5).

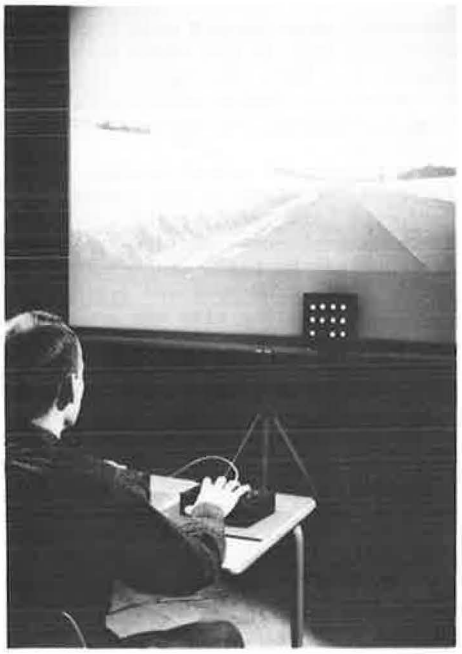


FIGURE 6: Effect of contrast with three backgrounds - green signs of four luminance levels (7).

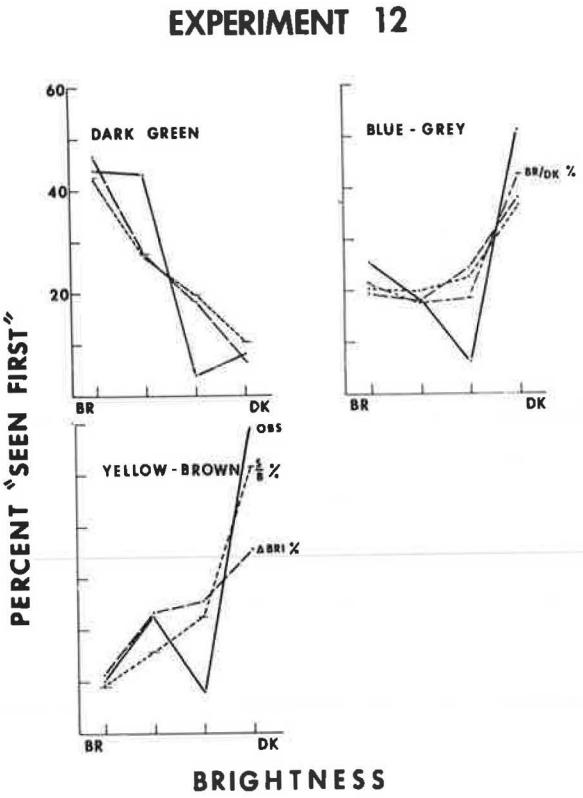
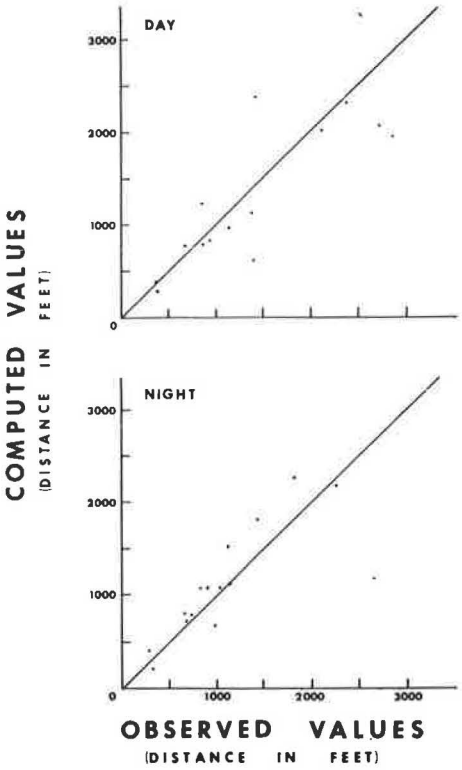


FIGURE 7: Outdoor Observations - Calculated and Observed Distances (7).



Summary

1. A brief overview has been presented of the wide variety of highway characteristics, vehicles, people and other objects that must be made conspicuous. It is clear that conspicuity is important for safety and for smooth traffic operation.

2. The complexity of requirements for conspicuity has been indicated. Other speakers deal with certain of these complex factors in more detail.

3. Color and luminance contrast, relative luminance, relative contrast and relative size have been shown to be very important factors for conspicuity and recognition. A few examples have indicated some of the research which has been carried out in related areas. Other examples have been given to show practical application of these factors for safety and smooth operation of traffic.

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