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DESIGN OF SIGN LETTER SIZES

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SYNOPSIS

There has been a growing interest and attention among traffic engineers, and others, in improving the design of highway warning and destination signs. The effectiveness and usefulness of the highway are increased by proper signs just as the proper use of a mechanical article of merchandise is insured by clear and adequate instructions on the box.

There are two characteristics of properly designed highway signs: (1) They must be readable and they must give the motorist sufficient warning to permit making the maneuver comfortably; and (2) they must be designed so as to gain the motorist's attention. To gain attention (characteristic (2)) is a complex problem which deserves separate treatment and is beyond the scope of this paper. Since certain standard color combinations are now agreed upon by state and national highway agencies, these standard color combinations will be assumed in the paper.

FUNDAMENTAL FACTORS IN LETTER SIZE

On the basis of measurements that have been made of the various factors resulting in the readability, or legibility, of a sign, it is possible to derive methods and formulas for practical determination of the minimum letter size necessary to make them effective under given traffic conditions on the highway.

It is obvious that the size of the letters must depend not only on traffic characteristics (since drivers need more warning at high speeds), but also upon vision because the effectiveness of sign copy depends upon what the driver can see. Knowledge is now available from studies of these various factors to set up a method of the size of letters on highway signs. To compute the size of a letter for a highway sign it is necessary to consider design speed, the location of the sign, warning time, type of letter (letter proportion), and legibility distance.

NOTE.—Written comments are invited for immediate publication; to insure publication the last discussion should be submitted by May, 1942.

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The following sub-factors influence the determination of warning time: Time for the minimum glance, safety factor in case the sign is not seen at the first possible moment, perception-reaction time, and stopping or deceleration time as necessitated by circumstances.

Design Speed.—Design speed may be defined as that speed at, or below which, a certain proportion of the vehicles operate at the location in question. The proportion (or percentile speed) used by different engineers has ranged from 80% to 90%,³ and D. W. Loutzenheiser, Jun. Am. Soc. C. E., in 1940, reported⁴ an analysis of speed data in an attempt to derive a similar definition for the design application. This report indicates that at least a 90 percentile speed is desirable. Since the higher percentile value results in a higher speed and a longer warning distance, it represents the conservative choice; and the 90 percentile speed of vehicles operating on the highway at the point to be signed is to be recommended for the design of sign-letter size.

Obviously, it is not practicable to make a "spot speed study" at all points along the highway, and since most highways in open country show similar speed characteristics throughout certain sections, it is sufficient to use one speed determination for such sections and another for special conditions, such as suburban and congested urban conditions. At special locations, such as curves, the techniques now in use for speed zoning would be continued. Thus the spot speed check might be replaced by the use of a speed determination from the ball bank indicator, calibrated for such special application.

Sign Location.—The position of the sign on the highway will influence the necessary letter size longitudinally and laterally. In the first place, the sign placed ahead of the hazard will allow the use of a smaller letter size, whereas one at or behind the hazard will require a larger letter size if the driver is to see it at a given distance or warning time away. In the second place, the lateral placement of the sign will influence the point at which the driver's gaze must leave the sign and return to the road. Longitudinal placement is illustrated diagrammatically in Fig. 1. If the driver of vehicle 1 is to read the sign at the

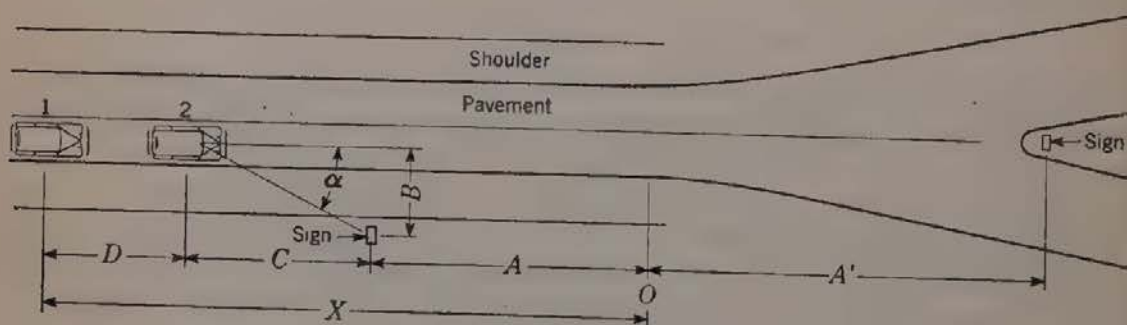


FIG. 1

position indicated, and if O represents the point of hazard or the point at which the maneuver must begin, a sign placed at a distance A ahead of this point will require a smaller letter size than a sign placed at a position A' behind this point.

³ "Report of Committee on Safe Approach Speeds," by H. H. Hammond, *Proceedings, Highway Research Bd.*, 1940, Vol. 20, p. 653.

⁴ "Percentile Speeds on Existing Highways," by D. W. Loutzenheiser, *ibid.*, 1940.

Therefore the distance A may be subtracted or the distance A' added to the necessary warning distance in deriving the necessary legibility distance.

Whether the signs should be placed at position A' or at position A involves the question of attention values, which is beyond the scope of this paper. The lateral position of the sign affects the "cutoff" point of the driver's vision as illustrated in Fig. 1 by the position of vehicle 2. At this point, the line of sight, as the driver is looking at the sign, will form angle α with the center line of the lane of travel as shown. If the maximum allowable angle α is known, the position of vehicle 2 beyond which the driver's line of sight must leave the sign and return to the road can be determined; thus:

$$C = B \cot \alpha \dots \dots \dots (1)$$

in which B is the distance in feet from the sign to the center line of the traveled lane. The clearest seeing occurs⁵ in a small zone in the center of the visual field which is delimited by an optical angle of about 5° . In the area just outside of this 5° , the degree of clear vision reduces rapidly until at about 10° (5° to either side of the line of sight) there is a sharp break in the acuity curve indicating that in a position more lateral than this, the vision experienced in the periphery of the eye is of the fuzzier type. The driver ordinarily glances about the landscape with short quick eye movements, resembling flashes of a highly focused spot light or search light.⁶ A practical value for the angle α may be obtained on the basis of allowing two minimum 5° eye movements to the side of the center line of the traveled lane. This will allow some part of the traveled lane to remain in the 10° cone of fairly clear vision up to about 50 ft ahead of the car.

Then, assuming $\alpha = 10^\circ$, Eq. 1 becomes

$$C = B \cot 10^\circ = 5.7 B \dots \dots \dots (2)$$

From this relationship, if B is 17.5 ft (one half of the 10-ft lane plus a 10-ft shoulder, plus 2.5 ft from the shoulder to the center of the sign) the distance C will be approximately 100 ft. This gives a rule-of-thumb idea of the magnitudes involved. The hypothetical position of vehicle 2 should be in the lane most unfavorable for vision of the sign in the location in question.

Warning Time.—The importance of thinking in terms of time in order to allow the driver sufficient warning has already been mentioned. Since the process of reading, as well as the perception and reaction of the driver, may be assigned fairly definite time values, and since the use of time values automatically corrects for the greater distance at higher speeds, they are fundamental. If sufficient warning time is given the driver and if he is duly impressed with the nature of the hazard to which he is coming, he will be able to operate comfortably and without any surprise element. To be adequate, warning time must allow for: (1) Minimum time for reading, (2) a safety factor in case the sign is not seen at the first possible instant, (3) perception-reaction time, and (4) stopping or deceleration time necessary for the maneuver involved. Ordinarily, the first three of these time values (those in connection with reading and perception reaction) will pass before any slowing occurs. Therefore, they may

⁵ "Textbook of Physiology," by W. H. Howell, W. B. Saunders Co., Philadelphia, Pa., 1940.

⁶ *Transactions, Am. Soc. C. E.*, Vol. 106 (1940), p. 456.

be treated as pure time values and converted into distance values by multiplying by the design speed.

Minimum Reading Time and Safety Factor.—The shortest possible glance from the road to read the sign and back to the road consumes from 0.6 to 1.0 sec. During this glance the maximum amount of copy which can be read by the ordinary person is from three to four familiar words.⁷ This time value results from the fact that it takes approximately 0.2 sec for the eye to stop, focus and read, and another 0.2 sec for the eye to start and move through one of the 5° or 10° jumps. To be conservative, therefore, 1.0 sec is adopted as the time necessary for a single minimum glance from road to sign and back to the road, allowing the shortest possible glance at both the road and the sign.

If more than three familiar words are included in the copy, it has been shown that the time for reading the sign may be increased to as much as from 3 to 11 sec,⁸ and such signs, therefore, are impracticable on high-speed highways. Where they are unavoidable the reading time should be increased by one second for each additional three or four familiar words, thus making allowance for the driver to glance back to the road between glances at the sign.

It is still necessary to add a time interval as a safety factor in case the sign is not seen at once. The smallest possible safety factor is one 1-sec glance; that is, the minimum reading time is $2 t_g$, in which t_g is the time required for a single glance or 1.0 sec and when signs contain the minimum number of words. When the sign contains more than three words:

$$t_g = \frac{N}{3} + 1.0 \dots \dots \dots (3)$$

in which N equals the number of familiar words on the sign. If the attention or target value has been properly designed into the sign, the motorist will have seen it before he is able to read it, and Eq. 3, with 2 sec as an absolute minimum, will guarantee him time to read the sign twice unless something distracts him or obstructs his vision.

Perception-Reaction Time.—It takes time for the human nervous and muscular system to react, just as it takes time to complete a call through the telephone exchange. This time value increases as the complexity of the process increases, so that there is a range of time values that may be classified under three headings in order of magnitude—that is, simple brake-reaction time such as that in an emergency situation (from 0.5 to 0.7 sec),⁹ perception-reaction time in ordinary traffic situations of medium complexity, and finally, judgment perception-reaction time (2.8 to 3.5 sec).¹⁰

The perception-reaction time needed to observe signs is intermediate between the simple reaction time and the complex skilled judgment that involves the longest time interval. Interpolated between the values of these two, it

⁷ "A Method for Analysis of the Effectiveness of Highway Signs," by T. W. Forbes, *Journal of Applied Psychology*, Vol. 23, 1939, p. 669.

⁸ "Improvement in Highway Safety," by A. R. Lauer, *Proceedings, Highway Research Bd.*, Vol. 12, 1932, p. 389.

⁹ "Driver Test Results," by H. R. DeSilva and T. W. Forbes, Harvard Traffic Bureau and WPA of Massachusetts, Boston, 1937.

¹⁰ "Methods of Measuring Judgment and Perception Time in Passing on the Highway," by T. W. Forbes, *Proceedings, Highway Research Bd.*, Vol. 19, 1939, p. 218.

will not be far in error to assume a perception-reaction time of 1.5 sec for sign design.

Deceleration Time.—Consider a point at which some vehicles are decelerating (case 1) while others are continuing with practically no change of speed. This case is best illustrated at grade-separated intersections where some drivers are decelerating and turning off while others are going on through the intersection. Obviously, those drivers who wish to turn off must have the time and distance to decelerate comfortably; and at the same time those who proceed at initial velocity must have sufficient warning to choose the correct lane and to avoid incoming and outgoing vehicles. Somewhat similar conditions hold for intersections at grade on low-volume high-speed highways.

A report by John Beakey,¹¹ in which the speed checks were made on vehicles approaching a stop sign at a rural intersection, indicates that the general driving public utilized approximately 10 sec on the average for decelerating from 55 miles to 20 miles per hr. If the deceleration times for lower initial speeds as reported in this study are examined, it will be found that deceleration to 20 miles per hr in each case approximated 8 sec. These measurements would seem to justify the use of a value of 8 to 10 sec for comfortable deceleration time on most highways. Since this paper is dealing with the minimum values for necessary warnings, the lower value of 8 sec will be adopted. Deceleration to 20 miles per hr was chosen as being applicable in the majority of highway intersection applications. Time values for higher final speeds are given elsewhere.¹¹

Regardless of the speed at which they are operating or the point at which they begin their deceleration, various motorists whose vehicles were checked give themselves about the same time to decelerate. The motorists traveling at 30 miles per hr or less could have decelerated in a shorter time if they had desired. It may be assumed, therefore, that 8 sec represents a comfortable time to the motorist and that where a vehicle is proceeding straight through at ordinary speed, a similar time interval should be allowed for weaving and dodging incoming or outgoing cars. Since the through speed will be V_i (which is assumed as 55 miles per hr), it will always be a higher velocity than the average velocity $\frac{V_i + V_f}{2}$. Therefore, $t = 8$ sec and V_i for determining warning distances will allow sufficient time and distance for both the high speed and the decelerating vehicles.

When all cars must come to a stop (case 2), the stopping distance is the controlling factor, but it must be borne in mind that the value of deceleration used must be such as to allow the motorist 8 sec or more in order to satisfy the time requirement for comfortable operation as derived for the case of simple deceleration without stopping. Transforming Eq. 3,

$$t = \frac{1.47 (V_i - V_f)}{a} = 8 \text{ sec.} \dots \dots \dots (4)$$

in which V_i is in miles per hour, V_f equals zero, and a is deceleration in feet per second per second.

¹¹ "Acceleration and Deceleration Characteristics of Private Passenger Vehicles," by John Beakey, *Proceedings, Highway Research Bd.*, Vol. 18, 1938, Fig. 9, p. 81.

MANEUVERING OR DECELERATION DISTANCE

Case 1.—For this case, utilizing the foregoing values for simple deceleration time, the maneuvering distance D is as follows:

$$D = 1.47 V_i t = 8 \times 1.47 V_i \dots \dots \dots (5)$$

in which V_i is the design speed (90 percentile speed of approach and of through vehicles) in miles per hour.

Case 2.—If the distance necessary to stop comfortably results in a corresponding stopping time greater than that shown (case 2), the stopping distance may be used for computing the total warning distance. Deceleration and stopping distance is given by the following familiar formula:¹²

$$s = \frac{(1.47)^2 (V_i^2 - V_f^2)}{2a} \dots \dots \dots (6)$$

in which V_i is initial velocity in miles per hour, V_f is the final velocity at deceleration (which becomes zero for a stopping distance), and a is the deceleration in feet per second per second. The stopping distance thus becomes:

$$s = \frac{1.08 V_i^2}{a} \dots \dots \dots (7)$$

To determine comfortable stopping distances for sign-design purposes, it is necessary to choose a value of deceleration a that will fulfil several conditions. It must result in comfortable stopping, must allow the motorist sufficient warning time, and must fulfil the requirements of safe stopping under adverse surface conditions, such as ice, snow, and wet pavements. In other words, the distance allowed the motorist should be adequate under all conditions. Mr. Beakey's study shows a time of 12 sec for a stop from 55 miles per hr, which corresponds to an average deceleration value a of 6.8 ft per sec². However, the actual instantaneous deceleration from which this average value was computed ran as high as approximately 12 ft per sec² as the vehicle approached the actual stopping point. A report by E. E. Wilson¹³ in 1940 indicates 8.6 ft per sec² to represent a comfortable (average) deceleration as reported by drivers and passengers in stops from 50, 60, and 70 miles per hr. Thus, from 6 to 8 ft per sec² as an average deceleration apparently represents the comfortable deceleration range chosen by motorists. Maximum instantaneous values will be much higher, of course, but this does not concern the present application.

It is recommended that an average deceleration value of 4 ft per sec² be used for designing sign letters. This will maintain the maneuvering time in the 8-sec range indicated by Mr. Beakey's study for the lower speeds. For instance, in computing stopping distance from 30 miles per hr, 8 ft per sec² gives $t = \frac{1.47 \times 30}{8} = 5.5$ sec, which is an inadequate time value. The deceleration of 4 ft per sec² raises this value to 11 sec, which is adequate. Furthermore,

¹² "Skidding Characteristics of Automobile Tires," by R. A. Moyer, *Bulletin No. 120*, Iowa Eng. Experiment Station, 1934.

¹³ "Deceleration Distances for High Speed Vehicles," by E. E. Wilson, *Proceedings, Highway Research Bd.*, Vol. 20, 1940, p. 393.

allow at least minimum reading time (see Eq. 3). Therefore, from Fig. 2,

$$D = X - A - C = X - A - \cotan 10^\circ \dots \dots \dots (14)$$

For a sign with three words or less, $D \cong 1.47 V_i \times 2 t_g$.

Case 1.—When some cars proceed, some decelerate, but none must stop, the design speed is determined first by computing X from Eq. 9, or reading it from Table 1. If the sign is to be 400 ft ahead of the hazard ($A = 400$) the necessary legibility distance $L = X - 400$ ft. Next obtain the legibility per inch of letter height (l) from the text (see heading "Choice of Letter Size").¹⁵

The letter height $H = \frac{L}{l} = \frac{X - 400}{l}$. To check for sufficient reading time, obtain C by Eq. 2. Then the following condition must hold (see Eq. 13): $D = L - C \cong 1.47 V_i \times 2 t_g$.

For 3-word or 4-word signs this becomes $1.47 V_i \times 2$. For more words, t_g should be increased as shown in Eq. 3.

Case 2.—Where all vehicles must stop, the design speed is determined as before; the total warning distance X is computed from Eq. 11 or Table 1; and A or A' is subtracted or added, respectively. Again suppose it is desired to place the sign 400 ft ahead of the hazard; then $L = X - 400$ and the letter height $H = \frac{X - 400}{l}$, in which l is legibility distance of the letters to be used.¹⁵

Finally, the designer should check for sufficient reading time as in case 1. In both cases, if the reading time is too short, determine A , or the sign location, by reversing the last few steps. Obtain D from Eq. 14, C from Eq. 2, and $A = X - (C + D)$. The sign must be mounted at the position indicated. Finally, compute L and H for the new sign position by the appropriate method for either case 1 or case 2.

PRACTICAL CONSIDERATIONS

Obviously certain practical decisions as to where the sign is to be placed, whether both pre-warning and a sign at the hazard or intersection are necessary, and similar questions must be answered before the necessary letter height can be determined. Furthermore, in choosing which of the standard alphabet series to use for the sign copy the designer must take into consideration such factors as the length of place names involved and the general shape and limiting dimensions allowable for his sign. In certain cases where practical requirements make it necessary to include more than three words in a given sign, it has been found desirable to use two different letter sizes in the copy. A larger size has been used for certain important words intended to be read at the greatest distance and a smaller size for the less important legend intended to be read at a closer position and with a second glance of the driver's eye.¹⁶

SUMMARY

A method has been described for determining the necessary letter size for effective highway sign design in terms of warning time, warning distance, and a

¹⁵ Sign Specifications of the Pennsylvania Turnpike Commission, Missouri State Highway Dept., and others.

¹⁶ For case 1 or case 2. PRACTICAL CONSIDERATIONS Obviously certain practical decisions as to where the sign is to be placed, whether both pre-warning and a sign at the hazard or intersection are necessary, and similar questions must be answered before the necessary letter height can be determined. Furthermore, in choosing which of the standard alphabet series to use for the sign copy the designer must take into consideration such factors as the length of place names involved and the general shape and limiting dimensions allowable for his sign. In certain cases where practical requirements make it necessary to include more than three words in a given sign, it has been found desirable to use two different letter sizes in the copy. A larger size has been used for certain important words intended to be read at the greatest distance and a smaller size for the less important legend intended to be read at a closer position and with a second glance of the driver's eye.¹⁶

90 percentile design speed. The increased warning distance necessary at higher speeds has been provided through the use of driver warning time as the basic consideration. Appropriate braking distances have been introduced where necessary.

Table 1 (or Eqs. 9 and 11) furnishes values for convenient computation of the letter height needed, and a simplified outline of procedure is given in the paper.

By use of such a method, it is possible to fit the sign to the highway and the driver and to obtain consistently effective signs for widely varying conditions of velocity and sign location with respect to the hazard or the maneuver point.