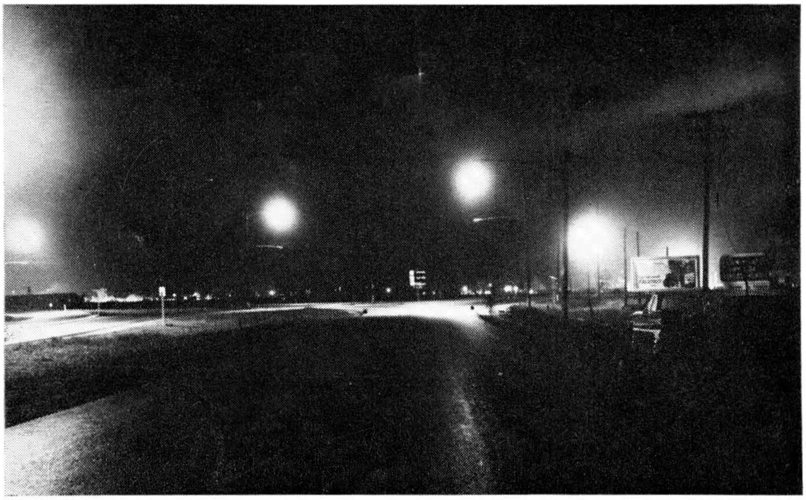
SUMMARY REPORT 5-9(S)

INTERSECTION AND SIGN ILLUMINATION FOR HIGHWAY SAFETY AND EFFICIENCY

SUMMARY REPORT
of
Research Report Number 5-9
Project 2-8-57-5



Cooperative Research Program of the
Texas Transportation Institute and the Texas Highway Department
In Cooperation with the
U. S. Department of Commerce, Bureau of Public Roads

August, 1966

TEXAS TRANSPORTATION INSTITUTE

Texas A&M University
College Station, Texas

Intersection and Sign Illumination For Highway Safety and Efficiency

by

Charles J. Keese and Donald E. Cleveland
(Prepared by Neilon J. Rowan)

In 1957, the Texas Transportation Institute initiated a research project which dealt with the effect of highway safety illumination on traffic operations at typical intersections and the effect of illumination on signs. The project was originally sponsored by the Texas Highway Department as RP-11. It was continued during 1958-59 as a part of HPS-1(18), and in 1959-60 as a part of HPS-1(21)A under joint sponsorship by the Texas Highway Department and the Bureau of Public Roads. From 1960 to 1964 when the project terminated, it was designated as Research Project 2-8-57-5, "Intersection Illumination."

The various phases of this research are covered in detail in seven interim reports and an unpublished paper. They are listed as follows:

Research Report 5-1, "Roadside Sign Legibility and Roadway Illumination."

Research Report 5-2, "Lighting Studies of the Texas City Wye."

Research Report 5-3, "Rural Intersection Illumination and Driver Tension Response."

Research Report 5-4, "Overhead Signing and Traffic Operations."

Research Report 5-5, "Unpublished paper—Roadside Sign Studies—II."

Research Report 5-6, "Driver Tension Responses and Intersection Illumination."

Research Report 5-7, "Traffic Operations—Illumination Studies."

Research Report 5-8, "Overhead Sign—Illumination Relationships."

In the comprehensive investigation of intersection illumination, a typical rural Y-type highway intersection, the Texas City Wye, was selected for extensive study. Four (4) different illumination systems were designed for the intersection to facilitate a relative comparison on the basis of lighting characteristics and their effects on traffic operations. These four systems are referred to as "continuous," "intermediate," "minimum," and "point," listed by brief descriptive titles in the reverse order of the relative amount of light output. The continuous, intermediate, and minimum systems were intended to accomplish a common objective, that is, to illuminate the entire intersection area. Luminaires comprising these systems were installed at 30- and 45-foot mounting heights. Different longitudinal spacing between lighting units produced different illumination patterns and differences in total illumination on the roadway, thus constituting the continuous, intermediate, and minimum systems. The point illumination system was based on the concept that only the conflict points or points requiring a decision should be illuminated.

A fifth illumination system was subsequently installed at the Texas City Wye. This installation was based on the recommendations of D. M. Finch who had made studies of the other systems at the test site. Principally, the system recommended by Finch was a continuous system with transitional lighting.

In a comparative study of the various illumination systems, extensive photometric data were obtained including horizontal and vertical illumination, brightness, visibility, and glare. The photometric data were analyzed and used in conjunction with a subjective evaluation of the various systems to demonstrate a number of significant lighting design features. These design features are as follows:

1. The complete brightness pattern of the roadway and adjacent area is the all-inclusive concept to keep in mind for design purposes.

2. The brightness pattern must include elements for orientation and guidance as well as provide the necessary contrast for form perception and detail visibility.

3. For a distance of 400 to 500 feet ahead, the complete roadway scene should be tied together visually by a meaningful array of continuous lines, areas, and shapes, all with adequate contrast well above threshold levels.

4. In the area between the entrance and exit regions of the intersection, objects on or above the roadway should be visible.

5. Extraneous brightnesses in the field of view, such as the overhead lights should be reduced as much as possible to provide relief from discomfort glare.

6. The brightest area in the field of view should be along the line of sight at the roadway level. All entrance and exit directions to the intersection should decrease in brightness away from the central area.

7. The brightness levels within and on the approaches to the intersection should be adjusted in accordance with the driver's adaptation level determined by the roadway brightness and should be two to three times the brightness of the adjacent areas.

Each of the lighting systems were examined and compared on the basis of the above generalized statements. Finch concluded that the 30-foot continuous system was generally superior to others except that it presented the most severe condition of glare. The 45-foot intermediate system was better than the 30-foot continuous system insofar as glare was concerned. It also had more uniform pavement brightness distribution and better brightness transitions, but the brightness pattern did not extend far enough ahead of the intersection. The other systems were generally inadequate.

On the basis of these studies, Finch recommended the addition of transitional zone lighting of lower intensity in conjunction with the continuous lighting system. Also, some of the units were to be increased to 45-foot mounting heights to improve uniformity of brightness. It was further recommended that all luminaires be shielded to cut off the main beam at approximately 3.5 times the mounting height along the roadway. In addition to the changes in the lighting system, it was further recommended that reflex reflector roadway delineators be installed on the center lines and that delineators be installed on the curbs around the divider islands.

Traffic Operations at the Texas City Wye

In 1960 and 1961 and again in 1963, studies were conducted at the Texas City Wye to investigate the effects of various conditions of illumination on the characteristics of traffic operation. Methods employed in these studies included motion picture techniques developed in a pilot study at a similar intersection in Austin, Texas. In addition, a method of determining vehicle speeds in several sections on each approach to the intersection was developed and used. This method consisted of roadtubes and pneumatic switches placed at strategic points on the approaches, and interconnecting them with an event recorder. Travel times were measured and speeds were computed for each vehicle.

Although a considerable amount of data was obtained using both study techniques it was later found that much of the data was not sufficiently accurate or particularly applicable to a comparison of the various conditions of illumination. The speed data were judged to be of greatest reliability and therefore constituted the main basis for comparison.

Principally, these studies were designed to investigate the effects of the different illumination conditions on driver performance. It was assumed that driver performance would be reflected by changes in the speed of the vehicle, and the variability of speed in individual vehicles within the traffic stream. To facilitate this comparison, it was considered necessary to vary certain characteristics of the intersection which are dependent upon illumination for driver guidance. Since signing is the basic means of directing, directional signing at the intersection was selected as the variable. Three different types of signs, with variations in letter size and letter type were used in this comparison. The results of these studies showed that there was no practical or statistically significant difference in observed speeds regardless of the type of sign used. Differences in average speeds for all the data were no more than 5 miles per hour. Daytime studies for all of the signs showed a variation in average speed of less than 2 mph.

When the transitional illumination system recommended by Finch was compared to the 30-foot continuous and the minimum lighting systems, there was some indication that smoother operation was observed for the continuous and the transitional lighting systems. Although the difference was small, these two systems did show some improvement over the minimum system.

Even with an elaborate measuring system it was not possible in this research to detect significant reactions of drivers on the highway to a wide range of illumination conditions. In other words, the benefits of illumination are not necessarily reflected in the characteristics of traffic operation.

It is believed that any new research on the problem of night visibility reaction should employ devices which deal directly with the driver such as the acceleration noise meter and the galvanic skin response. Use of such equipment appears to offer the only analytical hope at the present time of evaluating illumination by means of driver reaction.

Human Response to Lighting Conditions

Using the galvanic skin response (GSR) technique of psychologists, experiments were conducted to determine the extent of driver tension on the approaches to the Texas City Wye intersection at night under lighted and unlighted conditions. The general purpose of this work was to further explore and evaluate the possibility of using the GSR to measure the effect of illumination on driver comfort. The experimentation was designed primarily to facilitate a comparison of driver tension responses as related to conditions of continuous illumination, point illumination, and no illumination.

The GSR instrument, which measures the galvanic skin response in units of the logarithm of conductance (the reciprocal of resistance), was used to measure tension responses of ten male driver subjects as they drove a vehicle through the test intersection under the various conditions of illumination.

The results of this study indicated that the GSR can be used by trained engineering personnel with selected driver subjects to produce consistent results. The GSR revealed differences between the conditions of illumination, producing only 80% as many tension responses under illuminated conditions as when a test intersection was not lighted. Both the number of responses and the total magnitude of responses as measuring variables for each test showed progressive reduction when darkness was changed to point illumination and then to continuous illumination at the intersection. This effect was similar for the different drivers tested.

The roadway geometry seemed to have some effect on tension responses. Greater tension responses were observed on the more difficult and complex paths through the intersection. Shorter turning radii caused greater response than smooth flowing turns. Also, it is believed that passing under the individual luminaires produced a response due to the repeated trips through the intersection while it was illuminated. However, the drivers returned to their original tenseness when illumination was eliminated.

Appraisal of the findings indicates that the GSR can be used to obtain a quantitative measure of driver comfort at intersections at night, and warrants further study.

Scale Model Studies of Illumination

A scale model (1" = 5 feet) of the Texas City Wye intersection was constructed to provide a means of studying illumination of intersections in the laboratory. The model for this research was approximately 8 feet square and was constructed using selected materials to simulate the brightness and contrast characteristics of the intersection area in complete detail. Lighting units, modeled after conventional roadway luminaires, were designed and constructed to provide model lighting systems. A miniaturized light meter was developed to measure the intensities provided by the model lighting system. The lighting units could be mounted at 30- or 45-foot mounting heights (to scale), and could be moved about on the model highway intersection. Also, an experimental tower 70 feet high (to scale) was constructed to investigate the characteristics of a single, high, large light source as opposed to numerous low mounted conventional units as a potential for intersection lighting.

Methods were devised in order that observers could view the "highway" through the windshield of a model automobile as the automobile was pushed along the roadway.

A number of studies relative to sign placement with the respect to light sources, variations of light sources, and relationships between luminaire placement and sign placement were made on the model intersection. Also, observers were called in at different times and asked to place the model luminaires at those locations and in those positions which they felt would effect significant illumination variations. In fact, several of the lighting systems used in studies at the actual intersection were developed or evaluated using the model.

The model intersection proved itself as a study tool in comparison of data of a full-scale experimental system of lighting constructed at the site of the Texas City Wye intersection. Researchers felt that with practice models could be economically built for intersections studies.

SIGN LEGIBILITY AND ILLUMINATION

Sun Shadow Effects on Signs

The shadows of overhanging projections reduce the legibility of highway signs on sunny days, and thus, frequently cause indecision and misinterpretation with operators of vehicles under the stress of speed and traffic. Since there are certain daily and seasonal regularities in the sun's movement across the sky for a given locality, shadows from a projection can readily be predicted. The factors of latitude, time, and sun's directional transit and angular position with the earth can be correlated to make this possible. It stands to reason, therefore, that a procedure for calculating shadow patterns to be encountered for a projection from a sign could be established and would serve to aid designers of signing for highways.

Because the usual projection over a highway sign is the illumination system, research to simplify prediction of shadow patterns has dealt with it. The work centered on determining the limiting conditions for minimization of sun shadows. Results of the experimentation are two-fold: first, an analytical expression was developed which defines the pattern produced by an overhanging illumination system; and second, this analytical expression has been programmed for processing by a digital computer.

The analytical procedure used in this research furnished specific information concerning sun shadows on signs. With this basic information the opportunities for designing sign illuminating systems so as to minimize sun shadow interferences were limited only by the required illumination intensity (size of unit), structural requirements, economic feasibility, and the design engineer's ingenuity.

In summary, well-known, predictable, and widely used sun-time relations have been adopted to develop a computer program which will produce values which make extremely simple calculations for sun shadow patterns possible. The computer program will furnish precise data for any latitude and any sign surface orientation. The results of this study are general but may be easily extended to embrace various design parameters. In addition, statistical data concerning cloud cover and other climatological data may be readily incorporated into the input data program. It is apparent that sun shadows on highway signs cannot be entirely eliminated. It is possible, however, to minimize the effect of these shadows or to put the shadows to use.

Overhead Sign-Illumination Relationships

A comprehensive controlled study was conducted to determine legibility distances of overhead signs under various conditions of illumination. Overhead signs with several types of commonly used background materials were used in combination with several types of reflectorized letters for this study. Also, an internally illuminated overhead sign was included to facilitate a direct comparison with externally illuminated and reflectorized signs.

The purpose of this investigation was to examine the relationships between the legibility of overhead signs and the brightness configurations which can result when various vehicle, sign, and roadway lighting conditions exist for a number of commonly used high-type sign materials. The specific variables in lighting included: (1) the longitudinal positioning of one and two luminaires with respect to the sign, (2) two different types of fixtures for external sign illumination and one condition of internal illumination, (3) the two-headlamp and four-headlamp automobile lighting system, and (4) high-beam and low-beam operation.

Six different signs were used in these studies, each having different combinations of background materials and letter materials. The combinations were as follows:

1. Reflex reflector letters on porcelain enamel background.

2. Reflex reflector letters on exposed lens reflective background.

3. "Signal" letters on reflective sheeting background.

4. Cut-out reflective sheeting letters on reflective sheeting background.

5. "Signal" letters on exposed lens reflective background.

6. Internally illuminated sign.

The signs were evaluated by observers riding in slow moving vehicles. The test record was the distance at which the legend on the sign could be read, a measure of "pure legibility." The study was conducted with the test vehicle moving at a speed of approximately 15 mph.

In a generalized summary of the average legibility distances for each of the sign configurations, it was found that average legibility distances varied from 983 feet to 651 feet. The sign composed of reflex reflector letters on a porcelain enamel background was at the top of this range while the internally illuminated sign was at the bottom of the range.

The results of this research indicate that, under rural conditions it is possible to use several methods of improving the legibility of overhead signs that are not internally illuminated. It was found that the legibility distance of various high-type signing materials under generally dark surrounding conditions varied as much as 20 percent as the external illumination of the sign was varied. Sign fixtures, high-beam operation and roadway luminaires in front of the sign will each make a contribution. The effects are not additive and the use of any one of the above makes the need for the other two less apparent. Also, it is apparent that differences in illumination result in meaningful differences in legibility and that this should be taken into account in design. This is an individual problem and very difficult to standardize. From a legibility point of view it is concluded that satisfactory legibility can be achieved under many conditions without the use of overhead sign lighting fixtures.

Legibility of Roadside Signs

Studies were conducted to determine the effect on nighttime sign visibility of the placement of roadside signs in relation to luminaires. Two types of signs were mounted at various locations in relation to one 400-watt mercury vapor luminaire mounted 30 feet above the pavement edge. In the first phase of this research, a Texas Highway Department Standard destination sign with 7-inch black letters on a 1' x 7' white reflectorized background was used. In these tests, ten observer subjects were used to determine recognition and legibility distances for the sign located in various longitudinal positions of 2-, 14-, and 26-foot distances from the edge of the pavement over which the luminaire was installed. Tests were conducted with the test vehicle displaying both low- and high-beam headlamps and with and without an opposing vehicle located 300 feet behind the sign and in the adjacent opposite lane.

From these tests it was concluded that real and substantial improvements in night sign legibility will result when roadside sign location and luminaire location are coordinated at the design stage. Signs should be placed from 25 to 75 feet beyond the luminaire for maximum legibility. The lateral location of signs is not as critical as the longitudinal positions, but the optimum placement is approximately 10 feet to the right of the luminaire.

The second phase of the research was conducted to compare the above results with a sign composed of 8-inch reflex reflector letters on a black background. Because the effect of opposing headlights was negligible in the first phase, this variable was not included in this study. All other conditions of the tests were the same in both studies.

Analysis of the data showed that the longitudinal effect, which was so apparent in the previous study, was quite irregular and of no significance in this study. Bright headlights gave no better results than did low-beams. The lateral positioning effect, although not significant showed the same pattern as found in the first phase.

The results of this study and the previous study indicate that the effect of roadway illumination on roadside sign position varies with the type of reflective materials used in sign construction. The reflex reflector letters on a black background were just as easily read with low-beam headlights as they were with bright headlights, and the sign location was not important, while the standard material was sensitive to both of these characteristics.