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FROM HEADLAMP ILLUMINATION TO HEADLAMP PERFORMANCE: A CRITICAL REVIEW OF ISSUES RELEVANT TO THE FORD MOTOR COMPANY "DETECT" MODEL

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16. Abstract

This report reviews a range of issues relevant to evaluating visibility provided by automobile headlamps, with emphasis on the driver visibility model DETECT (developed by the Ford Motor Company). The first section of the report discusses general issues concerning evaluation of headlamp performance. The main sections of the report review the major features of DETECT, its limitations, and suggested improvements. Finally, it is argued that further progress in the development of headlighting models and their increased acceptability is contingent on reaching a consensus regarding what good headlighting should be able to do. Consequently, a worldwide survey of experts in industry, academia, and government on desirable aspects of headlamp performance is advocated.

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CONTENTS

INTRODUCTION

Headlights are indispensable components of automobiles: They provide illumination for nighttime driving. This man-made illumination is needed (1) to guide the driver (by illuminating road delineation), (2) to make the driver aware of potential obstacles on or near the roadway (such as potholes, pedestrians, or animals), and (3) to enable the driver to detect, read, and interpret non-illuminated traffic signs.

The basic headlighting issues concern how much of the light should be delivered to various locations. The lateral demands on the light output stem from horizontal-curvature characteristics of the roadway, and obstacles and traffic signs that can appear left or right of the roadway. Vertical demands on the light output are influenced by the traveling speed (in an inversely proportional manner), vertical curvature of the roadway, and placement of non-illuminated overhead traffic signs.

On the other hand, the issue of "how much light" is guided primarily by considerations regarding the oncoming traffic: Oncoming drivers are visually impaired and discomforted by the light from the headlamps impinging on their eyes (disability and discomfort glare).

The preceding makes it clear that the demands on the headlamps are multifaceted and often contradictory. The multifaceted visibility demands led to establishment of numerous spatial test points below horizontal that have to satisfy minimum light requirements. On the other hand, the contradictory visibility vs. glare considerations resulted in additional test points above horizontal that have to satisfy maximum light requirements. The locations of the test points and the corresponding minima/maxima, however, differ substantially in the U.S. from those in Europe. Whether this difference reflects differential environmental demands or particular local bias remains a source of argument.

Much of the recent headlighting research attempted to address the issue of "how much light and where." Most recently, Olson and Sivak (1983) performed a range of field and laboratory studies that evaluated visibility distances, disability glare, and discomfort glare as functions of various headlighting systems. As a result of this extensive research, modifications were recommended for an improved low-beam headlighting system.

Headlighting specifications in terms of a range of photometric test points attempt to provide a balance between visibility and glare throughout the relevant parts of the driver's visual field. A completely different approach to guaranteeing quality headlamps would involve setting up performance specifications. Theoretically it is possible that instead of using a photometer to evaluate the light output (as is the case now), the lamps would be subjected to performance evaluation. Such evaluation could consist of tests designed to assure compliance with a range of visibility tests (for evaluating direct visibility and indirect visibility [of the oncoming driver who might be affected by the disability glare]), and discomfort-glare tests.

There are, however, obvious problems with such an approach. The principal problems are as follows:

(1) **What targets should be used for the visibility tests?** There is no consensus among researchers and lighting engineers as to the design target(s). Past research has utilized a plethora of different targets, including actual pedestrians (Olson and Sivak, 1983), flat targets that approximate the outline of pedestrians (Bhise et al., 1976), 1-ft square targets (Bhise et al., 1976), small T-shaped targets (Mortimer and Olson, 1973), various road-side debris (Halstead-Nussloch et al., 1979), road delineators (Bhise et

al., 1976), parked vehicles (Halstead-Nussloch et al., 1979), etc. In addition to the size and shape, the targets in the various headlighting studies differed considerably in terms of reflectivity.

(2) **Where should the targets be located?** Again, little consensus exists on this issue. The locations used in previous studies included various positions on the roadway (e.g., Mortimer and Olson, 1973; Bhise et al., 1976) or off the roadway (Halstead-Nussloch et al., 1979; Olson and Sivak, 1983).

(3) **How should discomfort glare be evaluated?** There is some agreement that the most appropriate rating scale is the one developed by de Boer (1973). However, there are major difficulties even with this scale. First, it is not a *priori* clear what point on the scale (out of nine points) should be used as the maximum allowable discomfort. (The most frequently suggested cut-offs correspond to the scale values of 4 or 5.) Second, the de Boer scale is a subjective scale, and is therefore prone to the so-called range effect: Subjective evaluations of a given stimulus are affected by the range of other stimuli presented during the experimental session (e.g., Lulla and Bennett, 1981). In the headlighting context, Olson and Sivak (1984) have shown that as the upper range of the stimuli is increased (to include higher glare levels), a given stimulus is judged as being less discomforting.

(4) **How should the visibility tests be scored?** There are two obvious alternatives. The first one involves using a two-point scale, such as pass/fail. The other option consists of using a finer gradation. For example, such a scale could have 101 points, from 0 to 100.

(5) **How should the discomfort glare be scored?** Again, the two options for scoring visibility are applicable here as well.

(6) **How should the visibility and discomfort-glare scores be combined (weighted)?** If pass/fail scoring is selected for all tests, should there be a requirement that an overall "pass" rating is awarded only if there are no "fail" scores on the individual tests? If a finer scoring is selected for all tests, should the total score be the sum of the individual scores, or should certain tests be weighted more than others?

Even if agreement were to be reached on all the above considerations, a problem about the mechanism of the actual evaluation would remain. Would we have to convene a group of standard subjects (or at least a design driver) to evaluate the lamp according to the agreed-upon protocol?

The impracticality of this approach was the primary motivation for the development of computer models for evaluating headlamp performance. Recent advances in high-speed computers made possible the development of models that perform repetitive calculations needed for multifaceted evaluations of certain products. In the field of headlighting, examples of such models include the model developed at The University of Michigan Transportation Research Institute (Mortimer and Becker, 1973; Becker and Mortimer, 1974), and the Ford Motor Company CHESS model (Bhise et al., 1977). The next section of this report will briefly introduce CHESS and its core model DETECT.

WHAT IS CHESS AND DETECT

CHESS (Comprehensive Headlamp Environment Systems Simulation) is the most comprehensive, realistic, and up-to-date headlighting model in existence. It simulates thousands of nighttime encounters, and computes a Figure of Merit (FOM) as an index of the headlamp performance. The FOM corresponds to the percent of the simulated driving distance in which the following three conditions are simultaneously met:

(1) The seeing distance to a pedestrian target is equal or greater than an appropriate critical distance.

(2) The seeing distance to a delineator target is equal or greater than an appropriate critical distance.

(3) Discomfort glare experienced by the opposing driver is less than a selected critical value.

CHESS was developed by simulating a core model called DETECT under a wide variety of encounters involving pedestrian and delineation targets with opposing vehicles on a three-dimensional roadway topography. The DETECT model (Matle and Bhise, 1984) sets up given encounters and predicts seeing distances and glare effects experienced by both the observer and oncoming drivers.

DETECT is based on contrast-threshold data of Blackwell (1952).[1] These data were obtained in a laboratory setting, using highly practiced and alerted subjects. As the first step in the development of DETECT, a mathematical model was fitted to the Blackwell data. DETECT incorporates this mathematical model of the Blackwell data. The predictions in DETECT are based on target size, and brightness values of

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[1] Both Bhise et al. (1976) and Bhise et al. (1977) reference incorrectly Blackwell (1954) as the source of these data.

the target, background, and veiling glare. Furthermore, DETECT uses contrast multipliers to account for (1) effects of target complexity and transient adaptation, (2) age-related degradation in visual performance, (3) degree of driver alertness, and (4) lower threshold for road-delineation targets. These multipliers were developed on the basis of field studies that evaluated seeing distances to various targets for twelve alerted subjects. The output of DETECT--seeing distance--"is determined by computing actual and threshold contrast by converging on a distance and using an iterative procedure until the threshold is reached" (Bhise et al., 1976, p. 2).

The major contribution of DETECT lies in simultaneously considering pedestrian visibility, road-delineator visibility, and discomfort glare. Consequently, it provides a more comprehensive evaluation than models dealing with only one (or two) of these three aspects of headlamp performance. Furthermore, DETECT uses the following independent variables:

Road topography
Road reflectance
Ambient brightness
Highway type
Target characteristics
Weather
Driver age (via visual performance)

The selection of the actual values of these variables is based either on surveys conducted by the Ford Motor Co., or on the (then) best available data. Each CHESS model run is based on several thousand nighttime encounters in DETECT. Consequently, DETECT provides the capability to comprehensively evaluate headlamp performance not only across three different criteria, but also across an extensive range of nighttime situations. (Additional details on DETECT are outlined in Bhise et al., 1976.)

LIMITATIONS OF DETECT

In the spirit of constructive criticism, this section will concentrate on potential limitations of DETECT and how DETECT is utilized by CHESS. These limitations will be presented in three groups: possible problem areas, general concerns, and considerations that should be included in DETECT.

Possible Problem Areas

(1) **Targets seen in negative contrast.** The model appears to have problems with negative contrast. For example, the field validation of the visibility distances for 1-ft square targets found that in situations where a target had reached (according to the model) a suprathreshold level of negative contrast, subjects tended not to see the targets. Furthermore, they indicated detection of the targets only when (at significantly shorter distances) positive contrast had reached a suprathreshold level. "For example, the 6.6 percent reflectance target under the high beam was found [by the model] to be visible between 0 and 68 m (0 and 225 ft) when it appeared brighter than the background and between 91 and 236 m (300 to 775 ft) when it appeared darker than the background. The field data, however, show that most detections occurred when the target was brighter than the background" (Bhise et al., 1976, p. 7). However, it is unclear whether this reflects problems with all negative-contrast targets, or only with the particular situations tested (where the targets achieved first negative and then positive contrast).

(2) **Glare car between car and target.** The model appears to have difficulties in predicting visibility distances for situations where a glare car is between the target and the subject's car, since no predictions were made for these situations (Bhise et al., 1976, Figures 15 and 16). Bhise et al. (1976) felt that in such situations "the subjects either did not or could not begin to search for the

target before passing of the glare vehicle" (p. 9). However, as Hemion has pointed out in the discussion appended to the Bhise et al. (1976) paper, the data presented in Figure 15 of Bhise et al. (1976) do not support this argument. This figure shows that the mean detection distance in several conditions was greater than the separation of the target and the glare car. This appears to be an important limitation of DETECT, since in actual driving situations "a glare vehicle" is frequently between the target and the driver.

According to Bhise (personal communication), a likely explanation for this problem is that drivers involuntarily fixate the glare source when the glare car is between the observer's car and the target. This is a plausible hypothesis that could be evaluated by monitoring driver eye fixations. If proven correct, this hypothesis would argue for inclusion of behavioral variables in addition to purely photometric considerations in headlighting models such as DETECT/CHESS.

General Concerns

(1) **How the results from DETECT are utilized by CHESS.** The several thousand DETECT encounters were selected to represent "traffic and travel characteristics, pedestrian exposure, weather exposure, road illumination and the relative involvement of pedestrian and run-off-the-road accidents" (Bhise et al., 1977). However, the resulting selection of weights (Bhise et al., 1977, Table 5-1) determine, in part, the absolute evaluation of a given headlamp, as well as the relative ranking of any two headlamps. The data that led to the development of the various weights were based on estimates from the early 1970's. Consequently, the utilized weights should be examined in light of current data. Especially critical appears to be a re-assessment of the relative importance of pedestrian vs. delineation visibility: Based on the data from the early 1970's, Bhise et al. (1977) estimated that a

failure in pedestrian detection is 30 times more serious than a failure in delineation detection.

(2) **Target size as a factor in DETECT.** The data that form the basis for the DETECT model were obtained for relatively small targets (between 1' and 64'). The mathematical model that was fitted to these data features target size as a parameter. However, it is well known that while target size is important in detection of relatively small targets, it is irrelevant for detection of relatively large targets. For small targets (less than 10'), the threshold luminance is inversely related to the size of the target, a relation known as Ricco's law (Luminance x Area = Constant [Bartlett, 1965]). In the transition zone (for targets between 10' and 1°), the relation between threshold luminance and size is according to Piper's law (Luminance x Area$^{-(1/2)}$ = Constant [Bartlett, 1965]). For even larger targets, the threshold luminance is independent of the target size (Bartlett, 1965). (There is no general agreement as to the values of the transition angles. They depend on various factors, including retinal location, duration, and dominant wavelength [Baumgardt, 1972]. Therefore, the above-indicated transition angles [10' and 1°] are provided only for general guidance.)

These considerations suggest that target size should not be a factor in calculations where the expected visibility distance produces target size of 1° or greater.[2] For example, the height of a pedestrian target (1.82 m tall) at 100 m subtends a visual angle of approximately 1°. However, the detection distance to pedestrian targets under glare proved to be less than 100 m when using a low beam (Bhise et al., 1976, Figure 15).

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[2] Since the Blackwell data are for targets no greater than about 1° (the largest target was 64'), it appears that extrapolation (and not interpolation) had to be used in the development of DETECT for targets larger than about 1°.

(3) **Goodness of fit provided by the model.** The predictive equations for pedestrians were found not to apply to road-delineators. Consequently, a new contrast multiplier was empirically developed to fit the data for the delineators. However, even with the separate contrast multiplier for the delineator targets, the overall congruence between the predicted and field-validation data proved to be only fair (Bhise et al., 1976 [Figures 12 through 16]). (A similar point was made by Mortimer in the discussion appended to the Bhise et al. [1976] paper.) However, this is a subjective call, and Bhise et al. (1976) in their closure to the discussion point out that DETECT provides similar or better fits to experimental data than do other models.

(4) **Adequacy of field validation studies.** The field validations (Bhise et al., 1976) used only a relatively small number of subjects (twelve), and all were relatively young (25 to 48 years of age).

(5) **Choice of the Blackwell data as basis for DETECT.** It is not *a priori* clear that the Blackwell data are the best data to use as the basis of a headlighting model. The major unsettled issues affecting the selection of the basic experimental data involve the following: (a) laboratory vs. field data, (b) threshold vs. suprathreshold data, (c) contrast sensitivity vs. spatial-frequency sensitivity (if threshold data are being utilized; see (9) below), (d) how to assess conspicuity (if suprathreshold data are being utilized; see (10) below), and (e) alerted vs. unalerted subjects.

(6) **Choice of mathematical model to fit the Blackwell data.** The mathematical model fitted to the Blackwell (1952) log contrast-sensitivity data is a quadratic function of log background (adaptation) brightness. However, there is no general agreement about the best-fitting function to account for the available contrast-sensitivity data. For example,

Blackwell (1972) discusses five different theories concerning the shape of the contrast-sensitivity function:

> Log contrast sensitivity is related to log background brightness in terms of a specific negative exponential function (Hecht, 1935).
>
> The inverse of contrast sensitivity is a declining normal probability integral as a function of log background brightness (Crozier, 1940).
>
> Contrast sensitivity is related to the background brightness by a linear function with a slope of -1/2 (de Vries, 1943).
>
> Log contrast sensitivity is a continuous function of log background brightness, passing through zones with slopes of -1, -1/2, and 0 as the background brightness is increased (Bouman et al., 1963).
>
> Log contrast sensitivity is related to log background brightness by a continuous function passing smoothly between the limiting slopes of -1 and 0 as the background brightness is increased (Blackwell, 1963).

However, as Blackwell (1972) has pointed out, "of these five theories, only the original de Vries theory can be rejected on the basis of currently-existing experimental data" (p. 80). The relevance of the preceding to headlighting models is that the selected function introduces bias for and against certain sets of conditions. This is a consequence of the fact that a given function will overshoot the true means in some regions of the data, and undershoot the true means in other regions. Importantly, these biases in the fit are likely to be different from one function to another.

(7) **Representative set of encounters vs. critical encounters.** The several thousand DETECT encounters were selected to produce an index of the average performance. A frequently raised objection to this type of approach argues that of more importance is the headlamp performance in a few

critical situations. An example of such a situation involves an older, fatigued, alcohol-impaired driver, driving a car with dirty and misaimed headlamps, confronting during a rain a pedestrian near the left road edge on a left curve.

(8) **Criteria for sufficient pedestrian and delineation visibility.** For DETECT, CHESS defines sufficient pedestrian visibility distance as the distance equalling or exceeding the stopping distance from the given speed. The calculations of the stopping distance are dependent on the assumed brake reaction time and average deceleration rate following the brake application. The model currently uses a mean reaction time of 1.42 sec, with a standard deviation of 0.45 sec. The best current data are probably those of Olson et al. (1984), since they are based on unexpected encounters by ordinary drivers. Olson et al. (1984) suggest that their data be corrected for such factors as alcohol, fatigue, and inattention. The net effect of such a correction would be to increase upper percentile values by about 50%. If this is done, the median reaction time is about 1.4 sec, and the standard deviation is about 0.4 sec. Clearly, the values used in the model for driver reaction time appear quite reasonable.

The model uses a deceleration level of 0.5 g on dry roads. No particular justification is offered for this value, except that it is well within the capabilities of most cars. Wet-road stopping distance is a more complex issue. Stopping distance is a function of such variables as pavement friction (which depends on texture and water depth), tread depth, and the ability of driver to take advantage of the deceleration capabilities of the vehicle. Data on this subject are reported by Olson et al. (1984) for both passenger cars and trucks. A comparison of stopping distances in their Figure 6 (which assumes about a 15th percentile road) with stopping distances calculated using 10th percentile skid numbers given in Bhise et al. (1977)

shows the results to be quite close, when a controlled stop for passenger cars is assumed. However, Olson et al. (1984) estimated stopping distances of large trucks to be 39 to 75% greater than those of passenger cars (the increment being dependent on the assumed speed).

For delineation visibility the model uses a 2-sec cutoff as the criterion. However, there is recent experimental evidence suggesting that the desired (and thus desirable) preview time is speed-dependent. For example, Godthelp et al. (1984) have shown that the Time-to-Line-Crossing (time necessary for the vehicle to reach either edge of the lane, assuming fixed steering strategy) is related to the lengths of time subjects are willing to drive without visual input. However, and most importantly, both the Time-to-Line-Crossing and the tolerated occlusion time were related to the speed: For example, the mean occlusion time dropped from about 5.5 sec for a speed of 20 km/h to about 2.5 sec for 120 km/h. These findings suggest that preview time for delineation visibility should be conceptualized as speed dependent.

(9) **Spatial-frequency considerations.** DETECT does not consider the spatial-frequency distribution of the relevant nighttime targets, although the human visual system is selectively sensitive to targets of different spatial frequencies. The peak sensitivity (i.e., the lowest threshold contrast) is for targets in the neighborhood of 4 cycles per degree (Finlay and Wilkinson, 1984; Ginsburg and Evans, 1984). (The location of the peak depends, among other factors, on the level of illumination [Westheimer, 1982].) Recent studies have shown that spatial-frequency sensitivity is a better predictor than visual acuity of pilots' detection performance in aircraft simulators (Ginsburg et al., 1982) and observers' discrimination of traffic signs (Evans and Ginsburg, 1985). Furthermore, evidence suggests that the human visual system might be

decomposing complex stimuli into their frequency components via a process called Fourier analysis (Kaufman, 1979). Consequently, spatial-frequency sensitivity *may* prove to be relevant not only to perception of periodic stimuli (such as gratings), but also to perception of stimuli in general.[3]

(10) **Threshold contrast vs. target conspicuity.** As indicated above, DETECT is based on contrast at detection threshold. However, many accidents (daytime or nighttime) are not the result of insufficient contrast but of insufficient conspicuity: The target (e.g., pedestrian) might be above the contrast threshold, but it is not responded to. This is especially applicable to situations where other visual inputs "compete" for the driver's attention. In such situations, because of the limited processing capability, the attention is directed towards the most conspicuous target. However, Cole and Hughes (1984) have found that "conspicuity was not strongly dependent on either object reflectance [determining the contrast] or size." Consequently, while threshold detection (whether in terms of contrast or spatial frequency) might be an appropriate parameter in the (few) visually impoverished environments, conspicuity might be the critical parameter in cluttered environments.

Considerations That Should Be Included in DETECT

(1) **Observer bias.** The model does not deal with observer bias: It is well known that an experimentally

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[3] The two targets encountered in each DETECT run could be assumed to represent two different one-period square waves, with their frequencies related to the the corresponding target widths. A square-wave contains most of the Fourier-transformed energy in the sine-wave component of the same frequency (Kaufman, 1974). The potential importance of spatial-frequency sensitivity becomes apparent upon recognizing that the widths of the two relevant targets in the model differ by a factor of about four. (The delineation in the model has a width of 4"; an outline of a pedestrian can be approximated by a rectangle having a width of approximately 16".)

obtained visibility distance reflects not only the visual sensitivity of the subject but also the bias (location of the criterion) for saying "yes" (Green and Swets, 1965). For example, older persons need more definite information to commit themselves one way or the other than do younger persons (Botwinick, 1973). In the driving situation, this effect would translate into older drivers needing to come closer to indicate that they do see the target, although they may see it as soon as the younger subjects.

A different example of a shift in bias can be illustrated by the fact that drivers are more likely to expect to see children (or pedestrians in general) near schools (or in cities in general) than in the open country. Consequently, they might be more on the look-out for children in front of a school, and they might act (detect) on less information than they would in the country. (The distinction between observer's sensitivity and bias is handled in some psychophysical methods. For example, the Signal-Detection-Theory approach [Green and Swets, 1965] is able to independently evaluate observer's sensitivity [d'] and observer's bias [β].)

(2) **General behavioral considerations.** The above-discussed difficulties of DETECT with a glare car between the observer's vehicle and the target illustrate the need for behavioral considerations (such as eye movement patterns), in addition to purely photometric considerations, in any headlamp visibility model.

(3) **Delineation.** DETECT can evaluate visibility of delineation at one lateral location (right or left). However, in certain situations (e.g., in a left lane of a multiple-lane-per-direction roadway) drivers often rely on both delineations.

(4) **Following and preceding vehicles.** DETECT currently does not deal with car-following situations. In such situations light from cars behind and in front of the

driver in question contribute to the target, background, and adaptation brightness.

(5) **Highway signs.** DETECT does not deal with the legibility of traffic signs. Non-illuminated traffic signs are integral components of the current road system. These signs are constructed from retroreflective material, and therefore their legibility is dependent on illumination from the headlights. (DETECT has the capability of simulating traffic signs by modifying pedestrian targets. Furthermore, since these modified targets could be located at the usual positions for traffic signs, DETECT can evaluate detection distance of traffic signs.)

WHAT SHOULD BE DONE TO IMPROVE THE UTILITY OF DETECT

The preceding section reviewed a range of limitations of the model along with suggested improvements. The present section will briefly summarize the most critical improvements. The first two of them concern DETECT, while the second two deal with how the DETECT runs are utilized by CHESS.

(1) To assure that the model is valid, it is important to perform additional field studies that would provide a more substantial data base. These field studies should include a substantial proportion of older drivers.

(2) To assure that the model is applicable to the total highway system, it is desirable to expand the model to also consider (a) legibility of traffic signs, (b) left and right delineations simultaneously, and (c) car-following situations. If this were to be undertaken, it would have to be followed by an extensive field validation.

(3) To assure the relevance to the traffic situation of the 1980's, it is important to update and revise (if necessary) (a) the various weights used in the model to emphasize certain sets of conditions, and (b) the criteria defining sufficient visibility.

(4) To provide additional flexibility, it is desirable to develop a capability to derive two additional Figures of Merit (FOMs). The first alternative FOM would provide an index of lamp performance for a selected small set of "worst possible" scenarios. The second alternative FOM would provide an index of lamp performance only in situations where low-beam usage is appropriate.

WHERE DO WE GO FROM HERE

Improvements outlined in the preceding section will not solve all the concerns regarding DETECT and the way it is utilized in CHESS. However, these concerns are primarily a reflection of the unsettled basic issues on how to evaluate headlighting. These issues, briefly discussed in the Introduction section of this report, are as follows:

(1) What targets should be used for the visibility tests?
(2) Where should the targets be located?
(3) How should discomfort glare be evaluated?
(4) How should the visibility tests be scored?
(5) How should the discomfort glare be scored?
(6) How should the visibility and discomfort-glare scores be combined (weighted)?

The usual answer to most problems that "more research is needed" is only part of the solution to the current situation. No doubt, more research is needed if DETECT/CHESS is to be expanded to consider either new targets (e.g., traffic signs) or previously utilized targets in a different context (e.g., a car-following situation).

However, substantial progress in headlighting evaluation can be achieved only when all persons involved (from industry, academia, and government) would agree on the answers to the six issues repeated earlier in this section. Furthermore, a prerequisite for worldwide harmonization of headlighting standards is a worldwide agreement on these issues. It may prove to be the case (as is frequently argued without sufficient empirical support) that there is significant polarization of opinion on these issues between different geographic regions of the world (e.g., North America vs. Europe). If that is true, this could reflect either long-standing unsupported biases or differential needs stemming from different roadway structures, vehicle population, pedestrian/moped/car/truck mixes, and roadway environments.

What is urgently needed is a survey of worldwide experts in industry, academia, and government to establish the desirable performance aspects of automobile headlighting for the 1980's and 1990's. Consequently, we propose that such a worldwide survey be conducted. While the stress in past has been on the developed countries, important (and potentially interesting) patterns of responses are likely to come from developing countries as well. Thus, it is proposed that each single United Nations country be contacted to solicit opinions from as wide a constituency as possible. To provide the depth and expertise, various standing committees dealing with lighting/vision/ transportation (such as SAE, TRB, GTB, CIE) would be surveyed as well.

In summary, the proposed survey is needed to establish the ground rules for development of generally acceptable headlighting models. Furthermore, such a survey would also provide information about possible differences in these ground rules according to geographic, economic, or political considerations.

CONCLUDING COMMENTS

Modeling headlighting performance is a complex and often frustrating affair: Whenever one develops a model that considers, say, 20 variables, there will always be people wanting to include at least 20 additional variables. That is, more or less, the situation with DETECT as well. However, DETECT and its parent model CHESS constitute without any doubt a major accomplishment in contemporary headlighting research. In the current climate of disagreement regarding what good headlighting *should* do, the development of DETECT/CHESS represents the most effective attempt to make the most of the currently available data.

DETECT is not a perfect tool, and some possible improvements to it and to the way it is utilized in CHESS were discussed in this report. However, a more universal acceptance of DETECT/CHESS and of any other headlighting model awaits emergence of an agreement (at least on a regional basis) on precisely what we want our headlights to be able to do.

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