SUGGESTIONS FOR IMPROVING VEHICLE FRONT LIGHTING

R-76-44

D.A. Schreuder

Voorburg, 1976

Institute for Road Safety Research SWOV, The Netherlands

FOREWORD

This report is presented to the Steering Committee of the OECD. In the final version, the remarks and suggestions made by members of the Steering Committee at the meetings in Madrid, October 1974, and Paris, May 1975, have been taken into account. The report has been accepted by the OECD initiated Group on Lighting, Visibility and Accidents at its meeting in London, September 1975.

This report is based to a large extent on the report "Vehicle front lighting within built-up areas", prepared by D.A. Schreuder. This report can be made available by the Institute for Road Safety Research SWOV, P.O. Box 71, 2270 AB Voorburg, The Netherlands.

1. INTRODUCTION

Today's road traffic requires that the drivers can command a large amount of visual information regarding their direct environment. This visual information, and some other information added to it, permits the driver to perform his driving task. At day, at least when the atmosphere is clear, most of the required information can be acquired sufficiently accurate as a result of the fact that the environment is illuminated by the natural daylight - some obvious exceptions being traffic and vehicle signalling lamps. At night, however, in all cases some artificial light is needed in order to acquire the required visual information. Some of the lighting devices are stationary, and some are attached to the vehicles. This report is restricted to vehicle lighting, and more in particular to vehicle front lights to be used in built-up areas, which, as is generally understood, have practically always some sort of stationary lighting as well. This report will be concentrated on questions related to the optimisation of such vehicle front lighting.

A still more general approach to the optimisation of traffic could be conceived, which includes that two further questions have to be answered before the lighting of vehicles are discussed. These two questions are: firstly in how far have drivers to rely on visual information, and what is this information more in particular, and secondly, what are the most adequate ways to acquire this information - adequate means here with the highest pay-off in terms of cost-benefit. It has been felt that these questions can be left unanswered in this particular report, because it is quite natural to expect that vehicle lighting and signalling will at any rate be and stay an important factor in road transport.

In the early years the lights on cars were not regulated by law. With the increase in traffic density, glare caused by oncoming traffic became, however, a major problem. The solution was found in two directions: on the one hand the road lighting, which

already existed for purposes of public safety, was adjusted to meet the requirements of motorised traffic, and on the other hand a lighting system was fitted to cars which struck a compromise between illuminating a lot and dazzling little: a double lighting system consisting of a high beam and a low beam.
However, the constantly increasing travel resulted in the fact that road users must to an increasing extent use their own lights. In recent times it became ever more clear that the lighting was not adequate, and that improvements should be made.
Before the optimum lighting system for vehicle will be discussed, it is necessary to analyse first the function that "traffic facilities" have for road users: "to offer road-users the possibility of reaching the final destination of their journey safely, quickly and comfortably, and at minimum cost".
Of these three, safety can be regarded as a necessary, though not a sufficient, precondition for a "good" traffic flow. Speed and comfort are conditions that the road-user usually considers very important. They form an important basis in the design and construction of many other traffic facilities.

In the following the emphasis will be on the safety aspect.

2. THE FUNCTION OF LIGHTING

Drivers need a great deal of visual information about their surroundings (the road, the areas alongside the road, obstacles, other vehicles, pedestrians, etc.).
In the dark, artificial lighting is needed to enable the driver to obtain visual information. This artificial lighting has two distinct aspects: the signalling of objects and their characteristics and illuminating the objects themselves. The word "object" is used here in a wide sense and covers stones, but also road markings and road signs. However, in most cases "object" will mean either "pedestrian" or "car".

The purpose of signalling is twofold. Firstly, the presence of the object has to be marked. This sets some requirements as regards the luminous intensity and position of the lights, but sets none as regards colour, configuration, etc. Secondly, several other aspects of the object may have to be signalled. Which aspects are more important depend on such things as the traffic situation. To signal these aspects, a clear and unmistakable coding system is required. It is important to note that lights with a high luminous intensity may reduce the signalling function because of the glare and irradiation they cause.

For the illumination of objects two systems are suitable: fixed road lighting and lighting by means of headlights.
In the case of road lighting, where the illuminance on vertical surfaces is usually not very strong, almost all objects stand out as dark silhouettes against a relatively light background. Conversely, car lighting makes many objects - especially light ones - show up light against a dark background, for in this case the illuminance is strong on vertical surfaces facing the light source - and thus the observer. Therefore, the luminance is high even when there is a low reflection, whereas that part of the road surface situated further away and forming the background is hardly illuminated at all.

3. THE SPECIFICATION OF VEHICLE FRONT LIGHTING

On unlit roads the nighttime visibility of the road itself and of objects on it, must be guaranteed by the vehicle headlamps. When no other traffic is present, this is possible by the high beams of the order of 100 000 cd or more in total. When other traffic is present, the glare of high beams is severe. Today's practice is to use the low-beam headlights. These are characterised by a stringent reduction of light above the "cut-off", to some 400 cd to 2000 cd (two lamps) and by some 2000 cd to well over 20 000 cd (two lamps) below the horizon. In streets with a low standard of (overhead) lighting, that is streets where the average road surface luminance is below some 0.1 cd/m^2 to 0.2 cd/m^2, the situation is similar to unlighted roads. This means that high beams or at least low beams are indispensable to arrive at least a mediocre standard of visibility. The glare, however, is nearly as disturbing as on unlit roads.

There is ample proof that visibility in roads where the street-lighting results in an average road surface of between 0.2 and 0.7 cd/m^2 the visibility is insufficient for safe and fast traffic, particularly on roads with mixed traffic. Driving comfort is low as well under these conditions. However, it is definitely wrong to believe that the situation will improve when vehicles use their low beams on this type of road.
First, the standard of visibility and driving comfort is still lowered by glare from oncoming vehicles. Second, without opposing traffic the visibility of objects will change very little by switching on low-beam headlamps (in stead of side-lights alone). This does not hold for retroflectors; furthermore, the type of beam distribution is of influence.

Thus, vehicle front lighting (high beams and low beams) have, apart from their signalling function, an "illumination" function only on unlit and very poorly lit roads. On all other roads - both of mediocre and good standards of public lighting, and at day - vehicle front lights have only a function as "signalling" lights.

The specification for adequate illumination are: a peak intensity of about 100 000 cd (two lamps) and a beam width of several degrees. When low or median speed is considered, the peak intensity may be lower, and the beam is prefered to be wider. (Note: 100 000 cd results in 10 lux at 100 m). These requirements are easily met by high-beam headlamps and are approached by well-designed low beams. For obvious reasons, at day and in good quality road lighting, illumination by means of vehicle headlamps is not needed.

The specification for adequate signalling are more complicated. Primarily, they depend on the ambient lighting. The specifications will be expressed in terms of the peak intensity of the lights. This gives fairly adequate information. Requirements regarding other aspects are given a.o. by the ECE.

When only the presence of the vehicle should be indicated, no specifications for the maximum intensity can be given: the more the light the better. Here, however, often the mistake is made that it is enough to mark the presence alone. A careful consideration of the road situation will show, that presence is only one, and generally often only a subordinate characteristic of the vehicle. Position, class of object, distance, movement, and changes and future changes in position and movement have to be signalled. In this respect, too much light - causing glare and irradiation - may hamper the proper signalling function.

As a first approximation, the following values are generally accepted for adequate signalling capacity for vehicle lighting:
(each lamp separately)
a. night, clear atmosphere: about 50 cd (between 20 and about 100)
b. night/fog; and day/clear atmosphere: about 500 cd (between about 200 and about 2000)
c. day/fog: 5000 cd or more.

The specifications for illuminating and signalling are clearly conflicting: the minimum peak intensity for adequate illumination

is well above the night-time maximum for adequate signalisation. The conflict does arise only in those situations when vehicle lamps for illumination are needed: for other situations it is enough to provide vehicles with adequate signalling lamps. It should be pointed out here, that most vehicle signalling lamps are below the intensity standards indicated above. A clear improvement, however, may be noted in modern vehicles.

The essential problem in the present situation is that within built-up areas a large portion of road is equipped with road lighting below the "mediocre" and another large portion above the "mediocre". This means that in many roads the visibility will prove by using low-beam headlamps, and in many roads not. Glare, however, will always increase. A further complication, particularly for international harmonisation is that fact that the overall quality of road lighting, and the overall traffic situation and composition may differ largely from one country to another. A densely populated, highly industrialised country like The Netherlands, for example, has a short, well lit urban road network and dense, very inhomogeneous traffic.

Everywhere, however, there are many roads below the mark and many roads (mainly important traffic routes) above the mark. The obligatory and general use of low beams, essential in poorly lit roads, offer important disadvantages in well-lit roads. It should be pointed out that primarily the "weaker" road users like cyclists and pedestrians suffer most from glare.

Universal use of side lights offers not a good situation either - apart from the fact that most side lights are too weak.

It is therefore clear that an improvement of the situation cannot be found by looking at vehicle lighting isolated, but that the fixed road lighting must be taken into account.

4. CONSIDERATION FOR THE IMPROVEMENT OF VEHICLE FRONT LIGHTS

It has been indicated earlier that present low-beam headlamps are reasonally adequate for illumination purposes at least for low speed traffic. Further improvements, however, are possible and desirable. It may be noted that other international bodies (ECE, CIE) occupy themselves with them. Therefore, this matter will not be dealt with in this report.

The way to promote improvements in the vehicle front lighting system can probably best be explained by considering first the present situation, when vehicles have either present low beams (of some 1000 cd each - including misaim, etc.) or present side lights (of some 1 to 10 cd - including soiling, voltage drops etc.).

The matter is often reduced to the question of whether it is better for road safety that cars use side lights or low-beam headlights on lighted roads. This, however, cannot be answered on the basis of accident statistics. A number of investigations has shown that the accident pattern is hardly influenced, if at all, by the type of vehicle lighting.* Furthermore, if the choice is left to the driver himself, the outcome mostly is the combined use of side lights and low-beam headlights.

One may try to approach the problem in a different way: "What is the optimum lighting to be carried on the front of vehicles on lighted roads?" In answering this question one might start with the following two points:

1. The contribution of present-type low-beam headlights to visibility is negligible.
2. Present low-beam headlights are brighter than is needed in order to function optimally as signalling lights.

---

* See full report Appendix A1.

It follows therefore that considering an optimum lighting, one has to assume that it functions solely as a signal lighting, and that the "illumination" (visibility of objects) is provided by overhead road lighting.

The main characteristics that vehicles should signal to the drivers of other vehicles are:

a. presence
b. position
c. type of vehicle (as regards size, category, and more in particular, modes of movement that can be expected from the vehicle, e.g. turning circle, top speed)
d. speed, direction
e. changes in speed and direction
f. future (planned) changes in speed and direction.

It is not necessary to install a separate signalling light for each of the characteristics mentioned above. Marker lights transmit more information than presence alone. The position, but also speed and direction, can be assessed according the way the marker lights are observed. Thus marker lights are of major importance.

The luminous intensity of vehicle front marker lights - which serve as indicated above, more purposes than marking alone - should as indicated preferably be not lower than about 20 cd, and not higher than about 100 cd. The values quoted above relate to the direction straight ahead. Further investigations may be required in order to assess the optimal spatial light distribution, notably regarding the peripheral vision of pedestrians and drivers (horizontal spread) and the reflection in wet road surfaces and reflectorised road markings (vertical spread). This, and the following section, is primarily focussed on marker lights because there lies the main problem. Present day marker lights (side lights) are not adequate, and neither are low beams. Most other signalling lamps, however, like direction indicators etc. are reasonably well fitted for their task.

5. CONSEQUENCES OF THE IMPROVEMENT OF VEHICLE FRONT MARKER LIGHTS

5.1. The vehicle

Two distinct ways of reaching the desired range of 20 to 100 cd for the vehicle front marker lights can be indicated.
The first is to reinforce the present side light (e.g. by inserting another bulb). As nearly all other vehicle signalling lights are within this intensity range (brake lights, direction indicators etc.) it will be clear that virtually no consequences will present themselves like extra costs etc. - both for new and for old vehicles.
The second way is to "dim" the present low beam e.g. by inserting a resistor in the circuit. Again here the consequences in costs and otherwise are small. The "dimmed" low beam concept has some advantages as the dimension and the position on the vehicle are well standardised, and that the dimming can be automated rather easily. Finally, a "dimmed" low beam is compatible with other suggested improvements in vehicle lighting.
Three more remarks should be made. In some cases the present side light is used also as a parking light. The need for this kind of combined use should be reconsidered. Further, road-side control of luminous intensity is still desirable; measuring equipment adapted for the improved vehicle front lights is being developed. And finally, although small, the cost factor need to considered in further detail notably in connection with the required cost/benefit assessment.

5.2. The road and road-users

The most important consequence of the introduction of the suggested improvements to vehicle lights is that the quality of road lighting for a number of roads will have to be improved. Only when there is very little road lighting, the present low-beam headlights provide an improvement in the visibility of objects compared to the present side light. This does not mean, though, that all road lighting above this level is automatically good; we merely observed that the

situation is not improved by switching on low beams. This criterion (no improvement when low-beam headlights are switched on) is reached at about 0.2 cd/m^2. This level, however, is not yet reached on all roads that have an important traffic function. This is, obviously, only a simplification. Other quality criteria of road lighting have to be taken into account, such as the glare and the non-uniformity, particularly during rain.

As regards the visibility of reflectorised materials, there is no great difference between present low-beam headlights and the suggested improved marker lights. For the same material the difference in visibility is about 50%. This follows from the fact that the visibility distance is dependent upon the fourth-power root of the intensity.

When comparing "E"-type low beams in directions above the horizon with improved vehicle lighting they differ about a factor 5, and $\sqrt[4]{5} \approx 1{,}5$. Further raising the reflectivity of the materials by a factor 5 will keep the situation unchanged; in view of the more recent developments in techniques used for manufacturing reflectorised materials, this would seem to be one of the possibilities for traffic signs and road signs. For road markings the situation is less favourable because there are fewer possibilities for improvements to road marking materials.

It should be noted that according to the ideas given in this report, there is in no way an "extra light". The task of the driver will either be identical or simpler than to-day, depending upon the system that will be adopted.

5.3. Other road-users and other conditions

For obvious reasons the benefits (e.g. in accident reduction) of a new system cannot assessed directly. When considering the improvement on vehicle front marker lights one may expect a reduction in accidents notably in those including pedestrians. Further research

is needed, however, to quantify this reduction. In several countries (a.o. The Netherlands) such research is under way or planned. It should be pointed out, that as a result of the expected low costs, also the benefits need only be small in order to arrive a "net profit". Some points made here will be specified further.

Both pedestrians and drivers equally prefer the "city lights" over low-beam headlamps. Another aspect involves the visibility of pedestrians, especially shortly before or during crossing. Crossing can often give rise to conflict situations or accidents. Two cases can be differentiated: firstly, crossing takes place on a "zebra" (that is a pedestrian crossing where the pedestrian has priority) or, secondly, on some other section of the road. In the first case the (road) lighting at or near the zebra proves important, the main factors being the signalling of the zebra, the marking of the zebra and the possibilities of that the pedestrian on or near the zebra will be detected by the approaching driver. The type of lights the cars are carrying is mainly of importance for the pedestrian's decision whether to cross or not. The need for improving the present vehicle front lights is, therefore, especially felt in this situation.
In places where there are no "zebras", the detection of pedestrians will depend primarily on the luminance contrast between them and their immediate background. In this respect, there is little difference between pedestrians and other objects as regards their detectability.

As regards cyclists, as a rule they are moving in the same direction as car drivers and on the same side of the road. This means that usually only the rear of the cycle is visible. If the recommendations are adopted for the rear lighting of bicycles that were drawn up for country roads where low-beam headlights are used, adequate visibility will be ensured when lights with lower intensity are used on roads within built-up areas - i.e. with low speeds.

6. CONCLUSIONS

- In lit streets, low-beam headlights contribute little to the visibility of objects, cause glare and can obscure direction indicators. Side lights are too weak to provide any effective illumination and are often relatively inconspicuous. It is proposed to consider a number improvements in vehicle signalling lights, particularly in front marker lights.
- Presently, it is feasible to adapt the existing vehicle lighting such that it will be characterised by a minimum value of the luminous intensity of about 20 cd and a maximum of about 100 cd in a direction straight ahead. The spatial light distribution required further consideration.
- Such adaptation can be realised by an alteration of the side light or of the low beam. The latter seems to be the most promising.
- Such improvements of present vehicle lights is expected to lead to an improvement of night time travel in general, and to road safety more in particular.
- Inherent in the introduction of the improvements is an improvement in road lighting for very poorly lit roads with have an important function for the road traffic.
- Further information is needed regarding to the quantified values of costs and benefits.

7. RECOMMENDATIONS

Based on these conclusions, the following recommendations can be given:

Recommendation 1: It is recommended to encourage further research regarding the beam distribution and the luminous intensities in different directions of the "dimmed" low-beam headlamps.

Recommendation 2: It is recommended to envourage further research concerning the possibilities for a reduction in intensity (e.g. by an adjustable reduction of the luminous flux of the lamps) of the (adapted) low-beam headlamps. Thus a more effective signalling for vehicle front lighting on lighted streets may be arrived at.

Recommendation 3: It is recommended to promote research which will present a more precise assessment of the cost/benefit ratio of improvements in vehicle front lighting. The research might focus on the following items:

- collection of detailed accident data involving pedestrians (and cyclists) and vehicles with different types of front light
- design of prototypes for different constructions, in order to test the technical feasibility and the costs
- study of the administrative and legal aspects of improvements in vehicle lighting.

Note: Several international bodies (CIE, ECE, ISO, CEMT) presently occupy themselves with some of the problems and recommendations given above. The continuation of the exchange of ideas and data might prove to be useful.