AN INTEGRATED SYSTEM FOR VEHICLE LIGHTING AND SIGNALLING

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SUMMARY

The information needed by the vehicle driver in his driving task are conveyed partly by objects that are placed intentionally and that convey a coded message (signals) and partly by environmental cues that are "just there". Markers (markings) may be considered as an in-between form. At night, lighting is needed to make these objects visible. Signals and some markers are constructed as lighting equipment ("signalling"). The visibility of environmental cues usually is realised by directing light onto them ("illumination"). These considerations are the basis for a proposal for an integrated vehicle lighting system, that includes both signalling and lighting, and is effective under different ambient situations.

1. VISUAL INFORMATION

The modern society calls for a large amount of transportation of persons, goods and information. Transportation of persons and goods is performed by air, ship, rail and road. When one considers road transportation more in detail, it is clear that - at least at the moment and in de near future - road transportation is performed primarily by means of motor vehicles, which in their turn can be described as follows: they carry their own source of energy, they are conducted by a driver aboard, a driver who within the limits given him by the vehicle, the other traffic and the environment, may choose his own position, his own course and his own speed. This choice is made on the basis of the information the driver may collect - at that particular time and place; there is very little central "traffic control" of the type that is customary in air transportation. A certain but small amount of this information is required from the instruments within the vehicle, some by other means like noise and vibration, but far out the greatest portion of the information is derived from the visual inspection of the environment.

The type, the quality and the quantity of the visual information which is needed depends, obviously, directly on the things the driver wants to do on the basis of this information. Thus, the driving task has a central position in the considerations regarding the visual information. Now, the driving task is rather complex, and some simplification has been acquired by splitting it up in a number of levels of decision making. One of these levels is the level of performing the appropriate manoeuvres needed in order to complete the journey. These manoeuvres are related to the perception and maintenance of position, course and speed relative to the road lay-out and relative to other road users and obstacles within the driving field.

In all cases, there are certain objects in play, from which information of some kind is needed. This information may be of one out

of two kinds and will include either signals or cues according to the following description.

The object itself or some characteristics of it (in this case described as "signals") is set up on purpose in order to convey a message of a kind to the observer. The message usually is directly connected with the driving task and particularly with some kind of required response, such as: "stop", or "keep right". This message is conveyed to the observer in a coded fashion (such as a red, circular light, or a white arrow on a blue background). The message is made explicite, and the coding is conventional. The message is coded in the object and decoded by the observer; thus, the observer must know the coding-key. Further, the coded message may suffer from disturbance (or "noice"). It should be realised that according this description "road signs" should be classified as "signals".

Another type of information is conveyed by objects within the field of view that are self-explanatory. Mostly they are not placed on purpose, and are often "just there". Usually, such objects are called "cues". The information they convey is implicite and non-conventional, and they relate to the stimulus aspects rather than to the response.
As an example, the curvature and lay-out of a bend will indicate to the (experienced) driver which will most likely be the appropriate speed to round that bend. However, contrary to the case of signals the speed itself is not indicated; it is left to the driver to decide upon this. As the objects are self-explanatory, there is no coding. The information can therefore be used by all (experienced) drivers. On the other hand the information is implicite and because the objects often just "are there", specifications of the objects cannot be set up.

The distinction between signals and cues is not an absolute one. In some cases it turns out to be useful to define an intermediate form. These may be indicated as "markings". Markings may be considered as signals with a very simple message (such as "presence"

and nothing more) or as cues (cue-objects) that are placed on purpose without, however, the explicite purpose of conveying a coded message.
Thus a row of dots or cats-eyes on the road may have no particular legal meaning, but it marks clearly the centre of the carriageway. On the other hand, when a continuous line is present at the middle of the road, this line may not be crossed.

At day under normal conditions, the cue-objects, being mostly self-eplanatory, offer little problems as regards their visibility, as long as they are properly placed, large enough, and show a distinct contrast (both as regards colour and luminance) with their direct background. Signals that convey coded information need often a special treatment. In most cases these objects are in fact (signalling) lights and the message is coded by means of colour, size, shape, configuration, intensity and flashing frequency of these lights.

At night, or under situations of reduced visibility (fog, snow, heavy rain) most non-luminous objects are not visible any more. Special measures are needed in order to maintain the information transport. At night this is generally realised by shining light directly to these objects, trusting that they still will be self-explanatory. This will be described as "illumination". Also the signals, the signal lights, need to be adapted to nighttime situations of reduced visibility. This will be indicated as "signalling".

2. VEHICLE LIGHTING (ILLUMINATION)

In nearly all traffic situations it is enough to illuminate "objects" that are nearly straight ahead of the vehicle. As indicated, illumination is needed primarily for the self-explanatory objects that convey structured or unstructured information. As regards vehicular road traffic at night under normal weather conditions, the illumination can be realised adequately in two distinct ways: fixed (overhead, public) street lighting, and lighting by means of vehicle headlamps. Under optimal conditions, the visibility can be similar with these two systems. Both, however, have severe draw-backs. Public lighting is expensive and is therefore often considered as not justified economically for rural roads with little traffic. Vehicle lighting causes severe glare for opposing traffic (both vehicles and pedestrians). The glare can be reduced by the adoption of low beam (passing beam) headlights, which, however, can be used safely only for low speeds, and which suffer from dirt, water and misaim. The glare can be avoided by the application of polarised headlights, by one-way roads, or by dual-carriageway roads with very wide central reserves - all three expensive.

For adequate visibility, the luminance in the field of view - or at least in the important parts of it, such as the road surface ahead, and the objects on or near it, should be in the order of 1 cd/m^2. For public lighting this falls well within the region of what is technically speaking easy to make, but as indicated the costs are high. This level can be realised with high-power high beam vehicle lights of some 10^5 to 10^6 cd. With low beam this luminance level can only be realised at a short distance in front of the car.

There should be mentioned, however, another factor. With overhead lighting, most objects stand out as a dark silhouette against a relatively light background. With vehicle lights, the reverse is true. Thus, the combination is often less favourable, because the two may counteract. Research and practical experience did show that when as a result of overhead lighting the luminance (e.g. the

road surface luminance) is over some 0.2 cd/m^2, the visibility of objects is not improved when low beam headlights are switched on, even although at 0.2 cd/m^2 the visibility as such generally is definitely inadequate. The obvious exceptions are: reflectorised materials, and objects at very short distances.

3. SIGNALLING (SIGNAL LIGHTING)

As has been indicated earlier, signalling is usually realised by means of lights, particularly at night.

The object of signal lighting is twofold. Firstly, the presence of the relevant object has to be signalled. This sets some requirements as regards the light intensity and position of the "marker" lights, but sets none as regards colour, configuration, etc. Secondly, several characteristic aspects of the relevant object have to be signalled. Which aspects are most important depends amongst others on the traffic situation. Some lights serve a double purpose, i.e. marking and signalling. It should be kept in mind that if a high intensity is selected for the marking function, the signalling function may suffer from this.

By "signalling" we will understand: putting across a coded message by means of a light signal. The possibility of decoding must be considered as part of the signalling system. As said above, "marking" may be considered as a special case of "signalling" (i.e. signalling the presence, and nothing more).
Signalling, taking in this sense, is a more complex problem than illuminating for the following reasons.

1. A number of variables may have to be signalled simultaneously to others.
2. It is not always clear for whom the signals are meant: for which category of road users and for which traffic situation. The only certainty is that they are <u>not</u> meant for the driver of the vehicle to which the signals are attached.
3. In the case of signalling all directions must be considered, and not only the front of the vehicle.
4. Particularly in respect of signalling towards the front of the vehicle, matters may be considerably complicated by the presence of (glaring) headlamps.
5. Most signals are not continuously in operation.

Not only the position of all relevant objects (i.e. vehicles) at a certain time is important, but it is also extremely important that some sort of prediction may be made about the future position and changes therein.
Furthermore, particularly in order to judge these future positions more or less accurately, it is important to know broadly speaking the type of vehicle that is to be encountered. Therefore, the main characteristics that vehicles should signal to the drivers of other vehicles are:

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

In the day-time some of these characteristics are quite clear to other drivers. Nevertheless a number of them are obviously not perceptible, particularly planned changes in speed and direction that have not yet been effectuated. For this sort of information, some means of signalling is needed even in the day-time.

As regards the possibilities of coding a message, the literature leads to the following conclusions:

1. Colour is not suitable as a primary coding dimension.
2. Because red is nearly exclusively restricted to the rear of vehicles, only yellow and white are left for the vehicle front lighting.
3. The dimensions are not critical for the signalling function. This leaves ample for the design of the signalling lights.
4. The luminous intensity should be adjusted to the environmental conditions. The following values can serve as a first approximation:

- night, clear atmosphere	20 - 1000 cd
- night, fog - day, clear atmosphere	200 - 2000 cd
- day, fog	over 5000 cd

5. The configuration of the lights on the vehicle offers possibilities for indication of the class to which the vehicle belongs.

6. A standard position makes the estimation of distance and speed (differences) more accurate. Furthermore, the position on the vehicle may influence the visibility.

4. AN INTEGRATED SYSTEM

Based on the considerations given above a system of vehicle lighting and signalling can be designed. An example of such a design will be given here. In this example, there is quite much in common with to-day's practice, but there are also important differences. Introduction of a system like this will cost money, and therefore should be considered very carefully. The benefits cannot be quantified in detail at the moment. However, it is likely that such a system will improve road safety and driving comfort in a degree which can be indicated qualitatively.

The design that will be given here (as an example) is based on the following considerations:

A. Signalling lights for position, speed, and their change and future changes, are indispensable.

B. Such signalling lights must operate at day and at night, and in different condition of visibility.

C. It is required that several classes of vehicles can be distinguished like bicycles, cars, long or very wide trucks, slow-moving vehicles.

D. The signalling is needed for all directions.

E. At night without public lighting (or with lighting of poor quality) vehicles need lights to illuminate the road.

F. The driving task should be kept as simple as possible.

It should be pointed out that the operation of the system is not considered here in detail. This is a separate subject. Some additional remarks will be made regarding these points.

Ad. A.

It is assumed that it is sufficient to signal to other road users:

- presence - position - speed (by means of marker lights);
- changes in direction (direction indicators);
- braking (brake lights).

These could be completed by signals for coasting, for emergency braking, and others; the need is not very clear.

Ad. B.

The example specified for a car, includes a number of lamps for different directions, most of them can function at different intensities. It is assumed that three levels will be sufficient for nearly all cases:

- high for day, reduced visibility;
- medium for day, clear atmosphere and night, reduced visibility;
- low for night, clear atmosphere.

Further, it is assumed that for direction indicators and brake lights, two levels will be sufficient: no separate low level seems necessary because the risk of glare is not great for lights which are not constantly in operation. Thus, only medium and high are necessary.

Next, it is assumed that the high level front marker lights can be used as well to illuminate the road when no adequate road lighting is present.

Ad. C.

For classification purposes, usually the configuration of the light is applied. Several proposals do exist, but they are not yet generally accepted.

Ad. D.

Finally, it is usually considered possible to have lower intensities at the rear and the side of vehicles than at the front. This assumption looks sensible with regards the difference in relative speed.

These considerations are included in the example given in Table 1.

5. CONCLUDING REMARKS

The system described here may be considered as the logical outcome of trying to combine the well-known, thorough, but mutually insulated research efforts which have been concentrated either on the front lighting or on the rear lighting of vehicles.

At present, the system is only a concept. The cost, however, will presumable be not high, and the benefits might prove to be considerable because the advantages of both improved front lighting and improved rear lighting are combined. Thus, further serious consideration of such a system can be recommended.

The literature is not referred to explicitely because most material for this paper stems from unpublished reports. Some further information, and particularly further references to literature may be founded in the studies of Mortimer (1,2), Roszbach (3,4), Rumar (5,6), Schreuder (7,8) and OECD (9).

	Day, fog	Day, clear Night, fog	Night, clear
Front markers	high beam	low beam	improved side lights*
Direction indicators (both front and rear)	high	medium	medium
Rear lights	high**	medium	low
Stop lights	high	medium	medium

The actual values should be specified in further details

* sometimes indicated as city beam, dim-dip headlamps etc.

** similar to the present fog rear lamps

Table 1.

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