VISIBILITY ASPECTS OF ROAD LIGHTING

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VISIBILITY ASPECTS OF ROAD LIGHTING (ABSTRACT)

Road traffic requires that the user participates by means of his own actions and decisions made on line and based on visual information collected in situ. At night artificial lighting is essential in order to acquire the required visual information. The function of the lighting is to enable the traffic to function "more or less" as during the day.

The effectiveness of road lighting is expressed in the reduction of the night-time accidents. For important urban roads the installation of "good" road lighting will result in a reduction of some 30% of the night-time injury accidents when compared with no or very poor lighting.
The efficiency of road lighting is expressed in terms of supply-and-demand. Both the supply and the demand can be expressed in conspicuity. It is possible to measure the supplied conspicuity of a lighting installation, and the conspicuity required by road users.

In this way it is not possible to find a go-no-go limit for road lighting quality. Taking part in traffic, more in particular as a driver of a car, involves much more than visual activities alone. Driving is not primarily a visual task: in the first instance it is a decision-making task.
Reaching the destination is the first aspect of the (driving) task.
Avoiding accidents represents the second aspect on the task.
In task I route selection and control, speed and position selection and controle are relevant. In many cases disturbances represent conflicts or dangers; some conflicts or dangers might develop into accidents (collisions) if no avoiding manoeuvres are executed. (Task II) In all cases the disturbances are sudden, unpredicted and unwanted and they involve situations where the information is inadequate.
Collision-avoiding manoeuvres are:
- coming to a stop
- avoiding by leaving the traffic lane
- avoiding by swerving around within the traffic lane
- adjusting (reducing) speed
- just going on.

The required preview time for coming to a stop is the greatest, for just going on the smallest.

It is required to know the specific (or critical) visual object. It is not necessary to stop for a stone of 20x20 cm^2, but it is necessary to stop for a stationary truck on a two-lane, two-way road when opposing traffic is present. And it is necessary to swerve around the stone but not around a newspaper or a matchbox. It is difficult to set up an inventory of the critical objects. However, the 20x20 cm^2 obstacles are not frequent. It seems that in the first place the curves in roads and other traffic participants are imported. This is in line with the restricted information that can be deduced from accident data.

All this relates to the "demand"-side; the picture can be completed only when we know more about the different specific or critical visual objects.
As regards the "supply"-side, the picture is nearer to completion. The system built by Blackwell and accepted by CIE provides the possibilities to asses the relation between the photometric and geometric aspects of lighting installations and the degree in which specific objects may be seen.

VISIBILITY ASPECTS OF ROAD LIGHTING

1. At present, the road traffic participants (the car drivers as well as all other classes of road users) are required to participate in transport by means of their own actions, which have to be performed on the basis of their own decisions which have to be made on line, based primarily on visual information collected in situ. Thus, the visual information is crucial in the road-transport system. That system is usually designed in such a way that at day under normal conditions the acquisition of the visual information can take place without further special means or commodities. At night, however, artificial lighting is essential in order to acquire the required visual information. The function of this lighting is therefore to enable the traffic participants to function in traffic "more or less" as during the day. (We will come back on this "more or less"). It is customary to regard the number and severity of road accidents as a criterion for the degree in which the traffic functions appropriately.

2. The effectiveness of lighting as a traffic measure (more precisely as a road-safety measure) can be expressed in the number of accidents it prevents: its efficiency by the comparison of the "costs" of the measure and the "benefits" as regards accident reduction. In order to be able to regard the effectiveness as sufficient, the lighting should supply at least as much as is required (in visibility): this is the supply-and--demand approach. In order to be efficient, the benefits must exceed the costs. It should be noted here that a purely monetary approach is not sufficient to cover all the relevant cost, neither all the relevant benefits! In the following we will concentrate on the effectiveness, applying the supply-and-demand approach.

3. The effectiveness of road lighting can be assessed by looking at the reduction of the night-time accidents. A large number of studies has been made, usually of the before-and-after type. A road - or a part of a road network - was compared as regards the accidents before and after the installation (or the upgrading) of the lighting installation. In spite of the fact that nearly all of the individual studies show important flaws as regards the set-up or the methodology, one can conclude that for important urban roads the installation of "good" road lighting will result

in a reduction of some 30% of the night-time injury accidents when compared with no or very poor lighting. For rural roads similar data are found, be it with a somewhat larger spread due to the smaller sample (CIE, 1983; OECD, 1980; Schreuder, 1983).

4. Now, which lighting may be considered as "good"? It might seem possible to find out the answer in the same way by making accident studies (of the before-and-after type, or other). The major studies along these lines are those of Janoff et al. (1977) and of Hargroves & Scott (1979). In both cases it was clearly shown that the relative night-time danger is reduced when the lighting is improved. It was not possible, however, to deduce a lower limit for the lighting quality, a go - no go limit. And that is of course the thing required by the policy makers.

5. A theoretical approach is to subdivide the supply-and-demand, the basic consideration being that in essence the supply and the demand can be expressed in conspicuity. Schreuder (1977) did propose a chain (rather, two chains) that link the supply and demand in terms of conspicuity with the effectiveness of road lighting.

6. In principle it is possible to measure directly the supplied conspicuity of a lighting installation, and the conspicuity required by road users. In fact, precisely this was done by Economopoulos (1977) and Gallagher & Meguire (1975) respectively. Economopoulos measured what objects could still be seen by a driver in different lighting installations. It was no surprise that he found the "visibility" continues to increase by increasing lighting quantity (luminance level). Gallagher on the other hand measured the reactions of naive drivers in normal traffic, but under different lighting conditions, when confronted with an (not quite realistic) obstacle. Here it was found that an increase in lighting (luminance) did increase the "visibility" (here expressed in required time-to-target!) only up to a certain value. It may be argued that precisely at that lighting value the supply begins to exceed the demand!

7. One might suppose that in this way the go - no go limit could be found. A number of reasons, however, make this step impossible. The major ground is that taking part in traffic, more in particular as a driver of

a car, involves much more than visual activities alone. Driving is not primarily a visual task: in the first instance it is a decision-making task. Furthermore it is not completely clear at the moment in which way the visual aspects of any task (including the tasks of traffic participation) can be described numerically - a matter necessary for a quantitative analysis. The metrics of Visibility Index, Visibility Potential etc., have their merits, but they have only limited applicability. This lack of quantification shows itself in the poor way the different numericals can be converted from the one in the other: when dealing with truly quantified concepts, this never is a problem! All these restrictions are quite obvious if one recalls that both Economopoulos and Gallagher required special objects to be placed intentionally in the road; objects that normally are not present - obviously these objects do not represent the normal traffic (driving) task. Taking into account these restrictions, one should not be surprised that the very clever and well-executed experiments of Economopoulos and Gallagher did not provide the crucial answers, and neither did the brilliant analysis of the situation given by Blackwell & Blackwell (1977). Another approach is clearly required.

8. The other approach is to start with the traffic task: the task in traffic of the traffic participant. For short we will speak of the driving task. The driving task is derived from the function of the transport system: allowing the participants to reach the destination of the trip. The need to reach the destination, the need to make the trip, is of a higher level, and will not be discussed here. (Furtheron we will clarify what we mean by "higher"). Reaching the destination of the trip therefore is the primary aspect of the (driving) task. However, the destination must be reached without accidents; avoiding accidents represents a second aspect of the task. Obviously there is quite some overlap between these two aspects; further study indicated, however, that a quite workable model can be set up by stating that the two aspects can be separated completely: reaching the destination and avoiding collisions (rather than accidents). We will call these two aspects task I and task II respectively.

9. Task I may be regarded primarily as a decision-making task. Decisions are made by the traffic participant (the operator) in order to reach a

goal. A "goal" immediately suggests a "road" as well, a road along which the goal may be reached. Following the road is an activity in its own right, requiring its own (type of) decisions. In this way, there emerges a hierarchical structure: a goal at a certain level presupposes a road and the road is a "goal" on a lower level. Similarly, a goal on a certain level may be regarded as a "road" on a higher level. In this way the socio-economic considerations at the basis of the need to make a trip can be regarded as still "higher". The actual driving, however, takes place on lower levels: the selection of the route and the selection (and performance) of manoeuvres. It turns out to be more clear to divide the level of manoeuvres in three sub-levels: the levels of compound manoeuvres, of elementary manoeuvres and of manoeuvre-parts. Still "lower" levels concerning the actual maintaining of the vehicle (the operation of the controls like accelerator or steering wheel) are of major interest for the study of vehicle cybernetics, but they need not to be considered here.

10. Decision making presupposes the availability of information. When discussing decisions in traffic, three sources of information may be discerned: the internal information taken from memory, experience etc.; the external visual and the external non-visual information. Here, we will deal exclusively with the external visual information. In all cases, the information is needed to perform a certain action (just doing nothing included!) after the decision leading towards it. As the actions and the decisions are grouped in different hierarchical levels, also the visual information must be grouped in these levels. In principle it is possible, within each level, to indicate for each manoeuvre (for each decision that is) the required type of visual information. And it is postulated (be it on sound ground!) that the required type of visual information can be described for each manoeuvre in terms of a specific visual object in combination with the time at which that object must be seen (the preview time). For the lowest level the inventory of specific visual objects can easily be made; for the higher levels further study is still required. A number of interesting studies, mainly of a "pilot"-character, have been made by Walraven (1980), Padmos (1984) and Riemersma (1979). Provisionary results suggest primarily that the road markings are essential, and secondly that a preview time of some 3 s seems to be adequate. For other modes of transport other results have to be expected.

11. For the higher levels only little data are available. It is quite clear that the simple "visibility" hardly is relevant; from practical experience regarding the positioning of traffic signs it follows that many hundreds of meters or even several kilometers are required, corresponding with preview times up to several minutes. However, these data relate to coded information, and it should not be taken for granted that similar distances or times are required for uncoded (structured or unstructured) information.

12. Task I is related to reaching the destination: matters of route selection and control, of speed and positon selection and control are relevant. If nothing happens, all this is sufficient (by definition!) to reach the destination. Now, in real life quite often something <u>does</u> happen to disturb this ideal situation. In many cases these disturbances represent conflicts or dangers; and again in many cases these conflicts or dangers might develop into accidents (collisions) if no avoiding manoeuvres are executed. In all cases the disturbances are sudden, unpredicted and unwanted: if they were otherwise, they would have been incorporated in the plans that are the basis of Task I. Therefore, whatever happens that requires a manoeuvre of that type that is designated as Task II represent always an emergency (in fact, this is just a matter of convention: we have made the distinction just this way!). Another way of expressing this is to state that Task II always involves situations where the (quality or quantity of) information is inadequate - thus designating the cases where the information is adequate as Task I. In this way the difficulties that follow from the overlap between Task I and II may be avoided.

13. The possibilities for avoiding collisions are restricted. The "coping behaviour" is restricted to the lowest level, the level of manoeuvre-parts, just because it deals with coping with emergencies. The activities are purely reactive: advance planning for unexpected emergencies is fundamentally impossible. This of course does not mean one may not be prepared: training, experience and education are very powerful means to improve road safety. According to our model, however, these aspects come under the "internal" information, because at the moment of the emergency they are not provided by the environment.

14. The manoeuvre-parts that come under consideration are: (in the order of decreasing magnitude in which they influence what happens on the basis of Task I):

- coming to a stop
- avoiding by leaving the traffic lane
- avoiding by swerving around within the traffic lane
- adjusting (reducing) speed
- just going on

It should be noted that "just going on" is included because it often is the outcome of a decision-making process (in fact, both regarding Task I as well as Task II!). The preview time for coming to a stop is the greatest, for "just going on" the smallest of the list (it is <u>not</u> zero as a decision-making process is involved!). The other manoeuvre-parts require a preview time in between these extremes.

15. Just as when dealing with Task I also here the manoeuvre that is required follows from the information from the environment - from the specific (or critical) visual object. It is not necessary to come to a stop for a stone of 20x20 cm^2, but it is necessary to stop for a stationary truck on a two-lane, two-way road when opposing traffic is present. And it is necessary to swerve around the stone - particularly when riding a motor or a pedal bicycle! - but not around a newspaper or a matchbox. It is difficult to set up an inventory of the critical objects. However, the 20x20 cm^2 obstacles are not frequent. The pilot studies of Walraven (1980) and Padmos (1984) suggest in the first place the curves in roads and other traffic participants. This is in line with the restricted information that can be deduced from accident data and from near accidents (Padmos, 1984).

16. All this relates to the "demand"-side; the picture can be completed only when we know more about the different specific or critical visual objects - different for the different task aspects (Task I and II) and for the different levels of decision making. Future study should therefore focus on these aspects.
As regards the "supply"-side, the picture is nearer to completion. The system built by Blackwell and accepted by CIE (1981) provides the possibilities to asses the relation between the photometric and geometric

aspects of lighting installations and the degree in which specific objects may be seen. As we have indicated above, the restrictions of the Blackwell-system rest on the description and assessment of the visual aspects of the driving task - an assessment for which we propose the application of the "Analysis of the driving task" (Schreuder, 1983).

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