LIGHT SIGNALS FOR ROAD TRAFFIC CONTROL

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SUMMARY

Signals for road traffic control are a major constituent of the modern traffic scene, particularly in built-up areas. A vast amount of research has been executed in the last two decennia, resulting in a fairly generally accepted view what are the requirements for effective traffic lights.
They can be summarised as follows:
- The colour should be limited so that in particular drivers with defective colour vision have as much information as possible. This leads to an orange-like red, a pure yellow, and a blue-ish green.
- At day, the luminous intensity in the beam centre should be not less than 200 cd maintained value. The maximum value should be not so large as to cause glare. At night, glare is avoided and visibility is ensured if the intensity is between 50 and 100 cd. Values under 25 cd and over 200 cd should be avoided at night.
- For normal urban conditions, where on complicated intersections usually more than one light faces the traffic at the same time, the beam width usually is adequate if the luminous intensity is over 100 cd for angles smaller than 11^{o} laterally and 8^{o} downwards from the beam axis.
- Directional arrows and symbols on traffic lights should be light emitting on a dark background.
- Visibility of the signals is increased, and the possible confusion with other non operational lights is decreased when the sun phantom is reduced as far as possible.
- The use of background shields around the signals is recommended, particularly if the signals are seen against the direction of the sun, or against the clear sky.

1. INTRODUCTION

Light signals for road traffic control are used in an increasing number of cases in order to assist the flow of traffic at highly-trafficked intersections. Although individual waiting times may increase, it is generally accepted that the capacity of intersections is increased by applying traffic signals. As their function is essentially to regulate the entry of the various traffic streams - only one stream is admitted at a time - one should expect also that the road safety would benefit from signalisation, since the number of potential conflicts is reduced. This assumption, however, is not clearly supported by research results at present, mainly because the statistical data of road accidents are inadequate to indicate such effects with sufficient accuracy. As a consequence these data are even more inadequate to assess the accident reduction potential of specific types of road traffic control signals. On the other hand, international harmonisation of industry and traffic requires a certain standardisation; in the absence of more formal justification, these standards usually are based on the plausible assumption that, in order to improve road safety, road traffic control signals must be "clearly visible" for all road users. "Clearly visible" cannot be defined precisely, but it is usually understood as: well above the threshold of visibility as being found in a laboratory set-up.

In recent years, a number of countries have set up national recommendations, regulations or standards. Although they show a certain similarity, important discrepancies do exist, which are undesirable to trade and to transportation. The Commission Internationale de l'Eclairage took the initiative for further international harmonisation. For this, a Sub-Committee on Signals was created under the auspices of the Technical Committee TC-1.6 (Visual Signalling). The Sub-Committee prepared a Technical Report, which has just been published (CIE, 1981).

2. PRINCIPLES

The Technical Report is not a set of recommendations. The aim of the report is to bring together present-day knowledge and experience, and give suggestions on which future recommendations may be based. The scope of the report is restricted to those aspects of road traffic control signals that are directly seen by the users, and which are directly related to the signalling function. The scope is restricted to road traffic, emphasis being placed on motor traffic on the normal public highway, and on pedestrian traffic. It does not cover other important matters concerning traffic signals: traffic engineering, which includes the location of signal lights and the coupling of them within and between road intersections; the regulatory status, which includes the number and sequence of colours in the system, and the legal obligations of local authorities and the road user; and electrical and mechanical engineering, which includes standardisation and interchangeability.

The visibility of light signals depends on many factors, the most important of which for this report are the colour, the luminous intensity and the luminous intensity distribution of the lights. Since the correct recognition of a traffic signal light may be seriously affected by sun phantom, this problem is discussed also. Nowadays recognition of "cut-out" figures, or symbols, used with lights has become important, so the report examines some details of their shape and size. Some of the design considerations for traffic engineering are also included. And finally, on very practical grounds, only lanterns of 20-cm and 30-cm diameter are considered.

3. COLOURS

In all countries, standard road traffic control signal lights consist of three separate units, emitting red, yellow (or amber) and green light. They are either circular (roundel) or are meant for restricted groups. The latter carry symbols; their colours, however, are the same as those of the general lights. For some specific applications, white as a colour has been included.

The colours given in the Technical Report are in agreement with the CIE recommendation (CIE, 1975). In road traffic, colour-defective people can take part as pedestrians and drivers. Therefore, even the "restricted" green was considered too wide, and further restrictions are suggested. In the colours, the additional burden of colour-defective persons has been considered as being more important than the easiest recognition by colour-normal persons (Table I). The result is a rather blue-ish green, an amber yellow, and a light (nearly orange) red. See Verriest (1980).

Colour of signal	Boundary	Equations
Red	Purple+	$y = 0.990 - x$
	Yellow+	$y = 0.320$
	Red+	$y = 0.290$
Yellow	Red	$y = 0.382$
	White	$y = 0.790 - 0.667x$
	Green	$y = x - 0.120$
Green	Yellow+	$y = 0.726 - 0.726x$
	White	$x = 0.650y$
	Blue	$y = 0.390 - 0.171x$
White	Yellow+	$x = 0.440$
	Purple	$y = 0.047 + 0.762x$
	Blue	$x = 0.285$
	Green	$y = 0.150 + 0.640x$

+ Denotes as restricted boundary

Table I. Recommended colour boundaries for light signals for road traffic control

4. PEAK INTENSITY AND LIGHT DISTRIBUTION

It has been indicated that the effectiveness of road traffic control signals can be described in terms of supra-threshold visibility. This assumption is related directly to the practical experience that problems in perception of signals usually present themselves around the first moment when the signal should be recognised. In other words, signals should be such that they can be perceived clearly and unambiguously from a considerable distance. This observation leads to a number of important considerations.

Firstly, it is important to know what is the critical distance from which the signal should be "clearly visible". (It has been pointed out that at this moment "clearly visible" cannot be defined more precisely). This distance follows from considerations of traffic engineering. Although at present this cannot be worked out in enough detail in quantitative terms, the considerations are included in the Technical Report. For practical purposes, for normal roads and for built-up areas, the rule-of-thumb value of 100 m has been adopted.

Secondly, when perceived from 100 m, lenses of 30-cm and of 20-cm diameter have discernible dimensions. However, experiments did show that for viewing conditions as pertain to practical conditions of road traffic - notably taking into account the peripheral vision - the "power" of the beam can be described adequately in terms of the luminous intensity alone - thus regarding the signal as a point source. Considerable research has indicated that under full daylight conditions a peak value (maintained value) of 200 cd ensures adequate visibility. See e.g. Adrian (1963); Cole & Brown (1968); Jainski & Schmidt-Clausen (1967); Fisher (1971). For lower values of ambient illumination lower values of the intensity should be provided. It is shown in practice, however, that two levels are sufficient to cover all practical values of ambient illumination. It is desirable that at night the peak intensity should be between 50 and 100 cd. It is suggested that intensities of less than 25 cd or more than 200 cd should be avoided. A further consequence is

that it does not seem to be useful to suggest different values for 20-cm and 30-cm lenses.

And finally, it follows that the most critical area of observation corresponds with a rather narrow angle. Thus, the beam distribution may be rather narrow. It has been suggested that at least 100 cd should be provided in directions making an angle of $\pm$ 11° lateraly or 8° down with the beam axis. Further research is required to find out whether a more detailed description of the beam and of the light distribution is necessary. By relating the intensity distribution to the beam axis, it is assumed that the aiming of the lantern is done on the road, according to the requirements of the specific road layout and traffic situation.

It should be pointed out that the combined requirements of colour, intensity and beam spread have important consequences on the optical design and lamp type to be applied. The requirements can be met by applying high-voltage or low-voltage lamps, using a paraboloid reflector and a specially-designed lens as the image-forming optical system. With such systems, however, it is often very difficult to restrict the sun phantom sufficiently. We will come back to this later.

5. SHAPE OF SYMBOLS

According to the Vienna Convention, signals and signs for road traffic should exhibit as far as possible non-verbal symbols, and should avoid words. In road traffic control signal lights the following aspects are important:
- indication of specific manoeuvres, notably direction: for this, arrows are used;
- indications for specific groups of road users: unrestricted (roundel) signal lights relate to all traffic; special signal lights can be required for bicycles or pedestrians;
- indication for lane-usage: for this, usually green arrows for allowed usage and red crosses for prohibited usage are installed; however, these signals are not universally in use.

In all cases, it is recommended to have the signal as a light-emitting cut-out figure on a dark (black) background, rather than a dark symbol on a bright background. The latter suffers from irradiation, so that the signal with symbol can be easily confused with the roundel signal without symbol. Suggestions are given as regards dimensions and shapes for the different symbols. It is important to ensure that the luminance of the symbol is reasonably uniform. Some suggestions are given as well in this matter.

Two distinct optical systems are used. Most common is the usual lamp/reflector/lens design, provided with a mask that leaves the symbol open. The other applies "fiber optics". The Technical Report does not indicate preference for one or the other, provided the (suggested) requirements are met.

6. PHANTOM EFFECT

When light enters from the outside into the lantern, it may - after reflection and refraction - be emitted in a way similar to the way light is emitted from a signal in operation. These effects are called "phantom effects", or, more specific, "sun phantom"; they can be disturbing or even dangerous. Their adverse effects can be reduced in a number of ways:

a. reduction of the light falling into the lens (e.g. by means of hoods, louvres, etc.);

b. reduction of the light emitted after refraction (e.g. by special optical construction of the lens, or the mirror; by special lamps; by additional - internal - shields, etc.);

c. by ensuring that signals in operation are always considerably "brighter" than the sun phantom (e.g. the minimum value of 200 cd);

d. limiting the confusion by means of additional signals, locating them in less "vulnerable" positions in the intersection.

The second solution is the most generally valid. At present, however, it is not possible to give very specific recommendations which are directly applicable, because the required values and the measuring set-up differ from one country to the other. Further research in this matter is desirable, particularly as it is not completely clear at this moment at what level the phantom effect begins to be really disturbing.

7. ADDITIONAL EQUIPMENT AND LOCATION

The most important piece of additional equipment is the background screen. This helps to identify and to localise the signal in the road, and - by reducing the glare from the sky - may reduce the requirement for the peak intensity. Background screens are considered as an essential part of all road traffic control signal installations. The Technical Report gives suggestions for shape, dimension, colour and location. In some countries similar recommendations are given, sometimes in conjunction with recommendations regarding the design of masts, etc.

The location of the signals at the intersection is also important. However, because intersections may vary considerably in size, shape, layout, etc. general rules hardly can be given. Furthermore, there still exist legal differences as regards traffic regulations, etc. from one country to the other.

8. CONCLUSIONS

The Technical Report is the first attempt for international harmonisation and standardisation for road traffic control signal lights. The obvious next step is to prepare official CIE Recommendations. As the results of the first tentative steps of international co-operation already indicate, such recommendations can be of considerable benefit for road traffic.

9. REFERENCES

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