

THE USE OF YELLOW LONGITUDINAL MARKINGS ON ROADS WITH
TWO-DIRECTIONAL TRAFFIC

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Safety at Night

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1. Road networks usually consist of roads of many different types and characteristics, carrying different types and volume of traffic and subject to different legal rules. For short, this all will be indicated by categories.

2. In those cases where the category of the road makes a certain type of behaviour obligatory or preferable, it is necessary or at least to be preferred that the road user will be able to discern these roads from roads of other categories where other behaviour is obliged or preferred (e.g. motorways versus double-carriageways with mixed traffic, speed limits of different kinds). In other cases, the category of the road, perhaps of administrative importance may be of no concern for the road user, so that it is to be preferred not to confuse the road user even more by indicating that category (e.g. distinction between state and provincial roads). Apart from the general characteristics often other characteristics of local or temporal nature are signalled to the road user, such as discontinuities, cross-roads, road repair, fog, congestions etc. These will not be considered here.

3. The decision whether the two categories "one way" and "two way" traffic ought to be coded for the use of the road user, should be based on the differences in expected behaviour and more in particular on the consequences of any errors in this respect. Errors of two types might be made

3.1. unjustly not overtaking. This can happen on one-way roads (the half of a motorway or normal one-directional roads). The result is nothing more than a slight decrease in road capacity and travel speed.

3.2. unjustly overtaking on two lane roads. This might result in extremely dangerous situations like head-on collisions.

Here, however, a further distinction must be made. An error of the kind as discussed here may take place when the opposing traffic was visible and was perceived, but when the overtaking driver believed that the opposing vehicle was on another carriageway. Another similar error may be made when the opposing traffic was

not visible but close by on another carriageway close to a merging point. See point 16.1.b.

When opposing vehicles were not visible or not perceived on through-going segments of two lane roads, the error must be classified as a "normal" faulty overtaking.

4. The two kinds of error can happen only (by definition as indicated in 3) if information on the category of road is not effective, more in particular:

4.1. some long rural routes consist of different segments both with single or dual carriageways, so that the driver may have to adapt his behaviour many times to the one or the other type of road.

4.2. many modern two-way two-lane rural highways are based on design criteria similar to those of motorways, so that the roads might look very much alike (e.g. regarding on- and off ramps, curvatures, superelevation, pavement etc.) More particular, this will be the case when the two-lane two-way road is part (e.g. one carriageway) of a future motorway.

4.3. late at night when the traffic density on all roads drops to very low values.

Particularly in these cases an explicit coding of the traffic direction might be considered.

5. It is not possible to give once and for all a conclusive answer to the question whether or not to use a coding system in order to distinguish between one-way and two-way roads. In order to do this, one must have answers to the following questions:

5.1. How often the system under consideration is not effective.

5.2. What are the negative consequences when the system is not effective and how often.

5.3. What are the positive consequences when the system is effective (as compared with no coding system) and how often.

So long as these questions cannot be answered in a quantitative way, an answer cannot be given. It is obvious, however, that the answer not only depends upon the distinction to be effectuated,

but also upon the coding or signalling system the application of which is considered. All this will involve a fair amount of research work.

6. It does not follow automatically, however, from the fact that in some or maybe even many cases a certain confusion might arise, that the situation as regards road safety will improve when a coding system is applied. This will be explained, taking the coding of the traffic direction as an example.

6.1. When it is certain that the signals are visible and will be seen (that is, when the coding is effective), an improvement can be expected. The road user will be certain of the category of the road, and will or at least can adapt his driving behaviour accordingly. It is likely that this results in less errors and less variation in behaviour, and therefore in more predictable behaviour.

6.2. When the signals are not effective under many different conditions in a way that is not completely predictable for the road user, much of the confusion will stay. The road user presumably will not trust the coding system, and will rely for his behaviour in other cues. This implies, of course, that the coding is not efficient.

6.3. When the signals are highly effective in the great majority of cases, but when the system breaks down in particular, unpredictable and rare occasions, a dangerous situation might arise, more in particular if the road user, while driving on a two-way road, not only believes, but even trusts he is on a road with one way traffic only. Here, this error may have very severe consequences.

7. In this connection, a completely different aspect must be mentioned. It is clear, even from a casual inspection, that a great number of categories of roads could be discerned; it is equally clear (a.o. from information theory and from ergonomic research) that only a fairly small number of dimensions are available in order to code these different categories of road. Furthermore, when no direct side-by-side comparisons can be made

the number of available levels within every single dimension is limited as well.

Therefore, the total number of categories that may be coded in sufficiently different ways, is very restricted. Before any decision is made to use one of these available coding entities and allot it to a certain category of road, one must be able to have good judgements on the relative priorities of the different categorial differences. One must at least be able to adjust them in an ordinal scale. As regards the question under consideration here, such a priority is not generally known. Here again, an answer can be found only after a considerable amount of (scientific) research.

8. When road markings are applied for coding purposes, several dimension can be discerned, each of which may be scaled in a number of levels, e.g.:

8.1. colour;

8.2. intensity(brightness);

8.3. shape, size;

8.4. position, orientation and number;

8.5. intermittency (e.g. continuous, or discrete etc. but also position along the road for stationary signs and moving observers).

In this respect normal interrupted center-lines e.g. 3-9 m, are considered as continuous.

It may be derived from practical experience e.g. in applied ergonomics that best results are achieved when a certain redundancy is built in the system, e.g. by using several dimensions at the same time. Variations in the level of one dimension only generally yields unsatisfactory results, more in particular of the one used is colour. Practical experience, backed by scientific investigations yields also that in a coding system where colour is used as one of the dimensions, yellow and white should not be used within one and the same coding system (ref. 1).

It is, however, found that colour can be very effective in road traffic systems as means of transmitting extra information towards

the observer. This will be indicated as intentional redundancy (also in those cases where the function of the colour in the system has been assessed afterwards).

The literature on this subject is rather extensive. See e.g. ref. 2, 3, 4 and 5.

9. When considering a full system of coding and signalling of categories of road, the following subdivision of visual signs and markings might be applied.

9.1. in time: continuous - repeated - single;

9.2. in position: horizontal - vertical;

9.3. in place: on the road - at or near the kerb - in the verge.

10. The preceeding arguments yield to the tentative conclusion that it is preferable to be very careful in adopting a certain coding system in order to discriminate between the following categories of road: one-directional roads and two-directional roads, more in particular if such a decision would be made without further (scientific) research.

Regarding this research, it may be concluded also from the foregoing, that it should not be related exclusively to some small fragment of the problem. Ideally, the required research should entail the following steps:

a. formulation of a complete statement of the problem;

b. formulation of the requirements based upon the function of the (part of the) road under consideration;

c. derivation of generally applicable rules, and, in order to arrive at a desirable degree of uniformity and compatibility within the system, presumably designing of a compromise;

d. from these, setting up standards and rules for the particular problems under consideration.

11. Other considerations than quoted in the earlier sections might prove strong enough to make the adoption of a coding system for one- or two-way roads desirable, before the systems analysis and the

systematic investigation of the more general aspects of road marking and signalling are completed. One has to consider under these circumstances what possibilities are available, and which solution seems to be the optimal solution. Even in this restricted scope, close attention should and could be paid to the following points:

- 11.1. the system to be adopted should be effective under as many adverse conditions as possible;
- 11.2. the system should be compatible with other accepted and applied systems of road markings;
- 11.3. the system should involve a minimum of alterations to the markings of existing roads as these generally involve high costs, traffic obstructions and extra hazards.

More in particular, the question is raised whether the application of a colour difference for the central line on the road is the best solution available for the coding of the categories of road under consideration. It has been proposed to apply yellow centerlines on roads with two-way traffic and white centerlines on roads with one-way traffic. Such a proposal raises a number of comments and objections that will be discussed in the next sections, keeping in mind the possibilities of proposals for alternative systems.

12. The function of road markings (i.e. the horizontal marker lines on the surface itself) is primarily to guide the vehicle along the road, more in particular regarding the course, the lateral position and the speed. It is difficult to conceive other means, especially regarding the lateral position (and, therefore, of dividing the pavement into lanes) that come close to the effectiveness of horizontal road markings. It must be made perfectly clear, therefore, that all other coding propositions for which the markings should be used, must not interfere with the primary function, more particularly because keeping the correct lateral position is considered as one of the most important aspects of the driving task of the road user (See ref. 6)

Other purposes of applying road markings and other marking devices as e.g. studs, delineators, signs and even of other facilities as

e.g. road lighting may be:

- 12.1. to indicate the category of the road;
- 12.2. to indicate the presence and any further characteristics of place or time-related variations in road features;
- 12.3. to indicate the lateral position of other vehicles;
- 12.4. to give information about routes (See ref. 6).

13. Regarding the mechanical and constructional properties of road marking materials the following remarks can be made:

13.1. conventional horizontal road markings (paint, thermoplastics, plastic sheets, both reflectorized or not) are invisible or nearly invisible under a number of common but adverse circumstances like snow, heavy rain, wet road surface, low sun, fog, heavy traffic.

It must be remarked that the markings are particularly needed under these circumstances because generally the driving situation is deteriorated in other respects as well.

13.2. the difference in colour between yellow and white horizontal markings is invisible or nearly invisible (apart of course from the circumstances quoted in 13.1.) in a number of other common situations. These include:

- a. all distances over some 20 to 30 m, and this under nearly all conditions both at day and at night (It should be stressed here, however, that this remark is based on qualitative observations only and not on experimental research findings.);
 - b. under most light sources for public lighting. This is completely the case for the (monochromatic yellow) low pressure sodium lamps and to a large degree also for the high pressure mercury lamps that give a band spectrum. No data are available for high pressure sodium lamps and fluorescent tubes.
 - c. it is to be expected that the difference will hardly or not at all visible where yellow headlamps are used. No research results are available, but this is concluded from the fact that even with white headlamps the difference is small, and from direct observations.
- 13.3. the colour difference proves to be adequately visible under most conditions at a very short distance before the vehicle (order of 10 m). The use is limited, because this short distance leaves little time for any reaction of the driver;

13.4. In general, it turns out that - at least as regards the normal road markings materials - the white materials are superior in comparison to the yellow materials (See ref. 7, 8)

- a. most yellow materials are 15-30% more expensive than the corresponding white materials (7);
- b. there are reasons to believe that in general yellow markings have a shorter life than the corresponding white markings;
- c. because the yellow colour is arrived at by the selective absorption of the blue light, by consequence yellow markings have lower reflection than the corresponding white markings. For new materials the average values of a number of samples of the luminance factor as measured with the $45^{\circ}-0^{\circ}$ method is 0,37 for yellow and 0,80 for white (7). This measuring set-up is considered as being relevant for day-time visibility. As regards the retroreflection of new beaded samples is found to be 180% for white and 110% for yellow when measured in the appropriate standard way (7). This standard way (angle of incidence - $3,5^{\circ}$, angle of observation 5°) corresponds with a distance from driver to sample of some 15 m;
- d. at this moment materials are available that in new condition fall as regards the colour within the recommended region (7, 1). However, no products are available that stay in this region; as a result of a.o. ultraviolet radiation, all yellow materials tend to become grey (7);
- e. the light reflection of other colours is too low to consider them seriously for road surface markings.

14. The application of road marking is dealt with in detail elsewhere (7,8,9). Regarding the colour two more remarks may be made.

14.1. In several countries, yellow markings are applied for temporal markings e.g. at construction sites, and white for "normal" use. This is in accordance with the Draft European Road Marking System of March 31; 1971 where it is explicitly stated that "temporary road markings shall be of a colour other than that normally used for directing traffic or for prohibiting standing or parking" (as quoted in ref. 7).

In practice, the difference between temporary yellow and permanent white markings includes more than the colour only. In accordance with the principles of coding as outlined in point 13, the shape, dimensions, position and intensity is different, and acoustic effects are added, because the temporary markings are mainly executed with close-spaced reflectorized studs. In this connection, the colour is only one of the five differences between the two categories. Under these circumstances, it is even questionable whether the colour plays an important rôle after all. It might be recommendable to reconsider this point again when a more general revision of road marking systems is taken into consideration.

14.2. On roads where "tidal flow" traffic regulations (reversible lanes) are applied, all road markings are white. Here, however, the tidal flow system, and more in particular which lanes have to be used for one or the other direction of traffic is indicated by the installation and operation of lane indicating traffic lights, showing a green arrow when the lane over which it is placed can be used in the direction indicated. A red cross is shown in the opposite condition. Here the markings are not much more than an additional sign. More important, this system is not compatible with the use of yellow for two-way roads.

15. One may conclude from the above that a continuous coding or signalling of the categories of two-way or one-way roads by applying exclusively the colour difference between yellow and white center-lines respectively:

- a. is little efficient because the colour difference, poorly visible under the best conditions, is invisible under many unfavourable conditions. The worse so because particularly under those unfavourable conditions the gathering of information is hampered to a great extent;
- b. is little efficient while only one dimension of coding has been used;
- c. cannot be applied when the colour difference has been used already to code or signal other categories of road or other road or traffic situations.

16. It is, however, an open question whether the coding of one or two-way roads ought to be continuous. Part of the answer may be derived from the following considerations.

16.1. It follows from practical experience that one single isolated sign at the beginning of a one-way stretch is not enough to give the road user enough information. (Also here, however, objective research data like e.g. accident statistics are not available.)

This is more pressing for three different reasons:

a. the signalisation of the beginning of a one-way stretch (e.g. the beginning of a dual carriageway segment of the route) is not universally adopted and is executed, when applied, in most countries like advisory signs.

b. the signalisation is placed on or near the beginning of the one-way stretch. This can lead in certain geometric design systems to the situation that drivers, when seeing no oncoming traffic on the two-way stretch directly ahead, may begin a passing and overtaking manoeuvre, when in fact opposing traffic may be dangerously near on the still invisible other carriageway of the one-way stretch. Examples of this type of geometry can be found in at grade crossings of the type called "Staphorster" in the Netherlands. The remedy of course is a pre-warning sign at a great distance which may have to be several hundreds of meters. Incidentally, the continuous system using the colour difference exclusively as a coding dimension breaks down as well under these conditions, because the colour of the center line is absolutely invisible at such a distance.

c. the end of a one-way (e.g. dual carriageways) stretch of road is indicated even less frequent than the beginning, although one might expect that it offers an even more dangerous situation. And where a signalisation is present, mostly it is not unambiguous. So it is customary to have at the end of the "staphorsters" mentioned before, a prohibition of overtaking, and an extra striped area is installed. Prohibition of overtaking and striped areas, however, may be installed for a great number of other reasons as well.

16.2. Nearly all motorways, which are by definition dual carriageway facilities, have signs at all entrance ramps indicating this particular category. It is often argued that this single sign is

not enough; in fact, it is partly in order to avoid faulty driving behaviour on this type of road that the two-colour system is proposed. 16.3. Experience in other fields of road signalisation supports that an intermittent system of indicating the category of road could be sufficiently effective. Priority roads and prohibition of overtaking generally is indicated by signs at regular and fairly large spacings. Although one must be careful in drawing general conclusions from practical experience, it may be expected that for the question under consideration here, an intermittent signalling system could be effective.

17. These considerations leave many ways open for alternative signalisation and coding systems. The design of an alternative system that keeps the advantages of the proposed system but avoids its draw-backs, must be a matter of very careful consideration, more in particular in view of the fact that the investigations should include the whole signalling and marking system and the relative priorities of categories of road to be signalled.

As indicated already before, this area deserves an extensive experimental approach. In order to indicate that the ways open for alternative systems really do exist, that is, that alternative systems really are possible, a number of considerations will be given which might suggest such alternatives. It should be stressed, however, that these examples should not be considered as fully worked-out proposals for signalling systems.

17.1. A continuous system is worked out in ref. 6. Essentially, that system consists of the application of one center-line for one-way roads, and two center-lines close together for two-way roads. When overtaking is permitted, all these lines are interrupted, while they are full-drawn when no overtaking is permitted. The primary distinction for coding of the two different categories is the shape and the position of the marking. Colour could be added as a further means of distinction, but now as an intentional redundancy. Whether this is possible depends upon other factors as well, several of whom will be discussed afterwards. The advantages of such a system are, (apart of the improved visibility):

- a. it is compatible with most existing road marking systems. More particularly, it is compatible with the presently widely accepted system of having two center-lines, one full-drawn line and one adjoining interrupted line for those conditions where overtaking is permitted for one direction of traffic only (e.g. in curves);
- b. when colour is not used as an intentionally redundant signal, it is compatible with the present system of using yellow for temporary and white for permanent markings;
- c. the system can be applied also when "reversible lanes" are used.
- d. the visibility is better when white is used;
- e. the difference between the two states (one or two lines) of the system can be seen at a greater distance as compared with the white/yellow system;
- f. on basis of its compatibility with the current two-line system for directional overtaking (point a) the system is not particularly suited for signalling other categorical differences, so that the adoption for the signalisation of one-way or two-way traffic does not interfere strongly with the wish to keep open coding facilities for future purposes.

Such a system can have several disadvantages as well:

- a. compared with a single centerline system it could be more expensive because more marking material is needed. On the other hand, when no colour coding is used, some gain is to be found in the fact that only one colour has to be used;
 - b. in all cases where more lines are used, one has to reckon with an increase in slipperiness as long as, like to-day, the road marking materials as a whole have a lower skid resistance than normal road surfaces;
 - c. a more general drawback similar to all horizontal road markings is the fact that the whole system becomes useless under those conditions when the horizontal road markings are invisible.
- As indicated before, this may happen fairly often, it even can be considered the main challenge for research in the field of road markings to design and develop markings that stay visible during rain, in wet road surfaces and snow, and when the sun is low.

17.2. the last paragraph indicated conditions where horizontal road markings could break down. Apart from new developments (e.g. raised markers that are inexpressive, stay clean, can withstand snow-plows etc.) one possibility is to add to the continuous system a non-continuous, repeated system.

Of course, one could also look into the possibilities of having such a repeated system alone.

A possibility for this are the delineators that are installed along most mainroads anyway.

In this respect, one could imagine a system where small arrows are fastened at the delineators, at two sides of the road, each pointing towards the road axis, in combination with a colour coding like e.g. white left and red right on two way roads, and both red on one way roads (more or less analogous to the colour of vehicle lamps to be seen on those roads). Such a system, especially when combined with the system in order to acquire the necessary degree of redundancy might seem promising enough to warrant further research. Here again, however, it should be stressed that the research meant here must cover the whole system of road marking and signalling.

18. CONCLUSIONS

18.1. At this moment, there is no proof that a decision at short notice has to be made as whether yellow or white ought to be used for road markings, provided of course this decision has not to be made for other reasons. If so, it might be recommended to reconsider these reasons.

18.2. At this moment, no results of systematic investigations are available that give indications that the question whether the distinction between one-way and two-way roads deserves such a high priority as to use one of the few coding possibilities for it. For this, of course, the same proviso must be made that neither the distinction has been coded already nor the coding possibility has been used for other purposes. If so, it might be recommended again to reconsider those earlier decisions.

18.3. When it is considered necessary to have a coding system by means of horizontal road markings in order to indicate the difference

between these two categories of road, the exclusive use of a colour difference for this coding should not be recommended because the difference will not be prominent under favourable conditions and hardly visible or not visible under unfavourable conditions.

Of course, the applicability of both road markings and colour coding in general is a matter of further consideration.

18.4. When it is considered necessary to have a coding system in order to indicate the difference between these two categories of road, a number of alternative and more promising systems could be conceived, several of which are already worked out in some degree.

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