DAYTIME RUNNING LIGHTS

Consultative document commissioned by the Road Safety Directorate

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SUMMARY

1. What do we mean by daytime running lights (DRL)? The term refers to the use of both front and rear lights on all motor vehicles during the hours of daylight. Dipped headlights could be used at the front, but special "attention lights" would be better. Their use could be achieved by making it compulsory for drivers to switch them on manually, but it would be preferable to have a device in the vehicle, e.g. linked with the ignition switch, that switches them on automatically.

2. Are daytime running lights effective? Swedish research indicates that they can have a substantial effect. It has been cautiously estimated, allowing for differences in climate, geographical location and traffic conditions, that they could produce a reduction of 5% in injury accidents in the Netherlands. This estimate is supported by the findings of studies involving fleet-owners in North America.

3. Are daytime running lights efficient? They would cost money in terms of extra fuel consumption, replacement of bulbs and enforcement. Swedish and Canadian research suggests that daytime running lights are highly efficient, and this is also likely to be the case in the Netherlands.

4. Why are daytime running lights effective? They make motor vehicles more conspicuous and complex traffic situations more recognizable. The increase in conspicuousness could be particularly useful on country roads under poor conditions of visibility (dusk, fog, rain and snow). The improvement in recognizability could be particularly valuable in built-up areas. There is no reason to assume that the benefit from daytime running lights would depend on the meteorological visibility; it is just as great in good as in poor visibility.

5. What effects would daytime running lights have on slow traffic (pedestrians and cyclists)? All road users, including slow traffic, stand to benefit from the increased conspicuousness of motor vehicles. There is a possibility, however, that pedestrians and cyclists could become less visible with vehicles using daytime running lights in the vicinity (as a result of being masked or outshone or having attention diverted from them, or a combination of these factors). Trials suggest that this does not have

a harmful effect on road safety. Lastly, it is possible that the perceived "threat" form cars using daytime running lights could affect cyclists' and pedestrians' subjective attitudes to traffic. Although this would not have a direct effect on road safety, it could have an effect on mobility; this needs to be investigated.

6. Are there other drawbacks to daytime running lights? Apart from the extra cost and the possible effect on cyclists' and pedestrians' subjective attitudes to traffic, the only disadvantage would seem to be the increase in energy consumption. In the Netherlands, on balance, the advantages are likely to outweigh the disadvantages to a considerable extent. It should be noted that the introduction of compulsory daytime running lights could give rise to legislatory and legal problems, both domestic and international.

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FOREWORD

It was partly as a result of the publication by SWOV in 1986 of a literature survey that the question of daytime running lights for motor vehicles was raised. Questions in Parliament placed pressure on the government to decide on a policy. To provide a basis for the decision SWOV was asked to look into the effects of introducing daytime running lights in the Netherlands.

In combination with the literature survey, the present consultative document provides answers to most of the questions. It concludes that daytime running lights promise to be as effective and efficient in the Netherlands as they have been elsewhere (i.e. they would improve road safety is a cost-effective manner).

Not all the conclusions are so firmly grounded as to remove all scientific doubt, and there are gaps in our knowledge; more research is needed. This could serve two additional purposes: (a) to permit better-informed choices to be made between the many alternative ways of introducing the system and equipping vehicles, and (b) to monitor the introduction of daytime running lights (to keep a finger on the pulse, as it were). Research of the latter kind could also contribute to an initial evaluation of the system.

1. INTRODUCTION

In 1985 the Dutch Association of Automobile Insurers (NVVA) asked SWOV to carry out a survey of the literature on the effectiveness of daytime running lights for motor vehicles. On the basis of the data assembled in the resulting report (Polak, 1986) it is estimated that there could be a reduction of approx. 10% in "relevant accidents" (daytime accidents involving at least one motor vehicle); this would amount to a reduction of approx. 5% in accidents overall. These estimates are taken from a separate SWOV study (Anon, 1987) and are based on a number of studies carried out in Sweden, Finland, Canada and the USA. The Swedish and Finnish studies relate to national statistics, whereas the Canadian and American data relate to fleet-owners. The findings of these studies, quoted by Polak, are shown in Table 1.

The SWOV forecast of the results of introducing daytime running lights in the Netherlands is based mainly on the Swedish experience. Sweden is the only country where DRL-use has been compulsory for many years. This applies to all motor vehicles, throughout the country and throughout the year. Also, the Swedish research is the best-documentated - albeit with considerable gaps. For a description of the Swedish system and its results see e.g. Andersson & Nilsson (1981) and Rumar (1981).

The "main conclusion from this survey of the literature is that [...] the introduction of attention lights in the Netherlands would result in a reduction in the number of road casualties which would more than make up for the cost" (Polak, 1986, p. 25). He recommends that consideration should be given to introducing the system but that the international aspects and possible drawbacks should also be looked at.

The debate on the system began immediately the report was published. The main points at issue, aside from the accuracy of the data and the resulting conclusions, were as follows:

1. How relevant are the favourable effects found in Sweden (and other countries) to the Netherlands?
2. Would vulnerable road users (cyclists and pedestrians) run a relatively higher risk of being involved in accidents as a result of a "conspicuousness race"?

3. Would compulsory daytime running lights be efficient, i.e. would the cost-benefit ratio be a good one?

To a large extent the debate took the form of a round-table meeting held on 16 November 1987 involving representatives of research organizations (TNO Institute for Perception IZF, Traffic Research Centre VSC), the government (Road Safety Directorate DVV, Department of Road Transport RDW) and pressure groups (Royal Dutch Touring Club ANWB, Dutch Cyclists' Federation EFNB and the Association for Protecting of Pedestrians VBV), as well as SWOV, the initiator of the debate. The meeting gave particular consideration to the negative effects daytime running lights might have on slow traffic. Thus to question 2 was added: Might slow traffic perceive vehicles using daytime running lights as a threat, even to the extent of restricting mobility? Daytime running lights might cause a change in car drivers' behaviour in that they might act more aggressively towards slow traffic. The report of the meeting is published separately (Anon, 1987a).

It is worthy of mention that another conference took place in September 1985 in Canada, where the introduction of daytime running lights was also under consideration, at which pressure groups were able to put forward their views on daytime running lights (Anon, 1985). In addition to the Ministry of Transport, organizations representing a wide range of interests were invited: vehicle manufacturers and importers, makers of lighting systems and accessories, representatives of consumers, cyclists, moped riders, motorcyclists, insurance companies, nursing staff etc. The representatives were unanimously in favour of daytime running lights and for their rapid introduction (which had subsequently been agreed), although there were a few reservations. Programmes were described and commented upon by Gale (1985) and Hart (1985). Public opinion was very much in favour, both car drivers (93%) and non-drivers (77%) (Nicholson, 1985). It is striking that so many non-drivers were in favour. The insurance companies also supported daytime running lights (Stein, 1985; Walter, 1985). Also in favour were consumers (McAlister, 1985) and safety organizations (Greene, 1985), nurses (Samson, 1985) and motorcyclists (MMIC, 1985) as well as most representatives of the industry (McIntyre, 1985; McKale, 1985; Thurston, 1985). McKale was the only one to express some reservations - the same, in fact, as those expressed in the Netherlands: the problems associated with the comparison with Sweden and the international aspects. It is noteworthy that in the Netherlands these reservations have been expressed not by the industry but by those representing the interests of pedestrians and cyclists. Otherwise there was broad unanimity on daytime running lights, with differences of opinion only on the photometric and geometric standards that should be applied.

The Canadian workshop showed that daytime running lights enjoy widespread support, as did the round table meeting in the Netherlands. A number of questions still remain to be answered, however.

Although the debate is not yet closed, the favourable expectations of the system expressed in the SWOV report led the Road Safety Directorate to ask SWOV to make a report on the introduction of the system by the end of 1987, giving particularly consideration to three questions posed by the Directorate:

1. What effect is the system likely to have in the Netherlands? Drawbacks for certain types of road users were to be taken into consideration.
2. Are there obstacles to the introduction of the system (i.e. is it "feasible")?
3. What would be the cost?

The resulting recommendations are contained in the present report (which takes the form of a "consultative document"). They are preceded by a discussion of a number of general points and an indication of the various alternatives available.

2. PERCEPTION

The perception of objects in traffic was previously considered purely as a question of detectability or "visibility". This was the approach employed when drawing up standards and guidelines for street lighting and vehicle lighting and signalling systems. It had long been suspected that visibility, which is defined as a 50% chance of the objects' being able to be seen under optimum observation conditions, was of secondary value in the case of road traffic - in contrast to the many applications in the maritime and military spheres.

The demands of road traffic are greater: traffic participants must be able to see the object in question under normal traffic conditions, not just under ideal conditions ("laboratory conditions"). It must be conspicuous enough to be seen amongst the distractions normally encountered in traffic. The term "conspicuousness" has been adopted to describe the relevant characteristics of the object. The introduction of this concept represented a real step forwards: now it was possible to demonstrate that, to be effective in traffic, bicycle lights and rear reflectors needed to produce much more light than was required merely to reach the threshold of visibility. (In fact conspicuousness also represents a threshold, but this time defined in terms of realistic observation conditions).

The new emphasis on conspicuousness also has its drawbacks: by increasing the conspicuousness of certain objects (certain road users) we run a - far from imaginary - risk of reducing the perception of other objects (other road users). This point was hotly debated, but no clear conclusion was reached, since perception is not shown in the national accident statistics.

It was realized, following further reflection on the traffic process, and taking account of new developments in cognitive psychology, that a particularly important factor, alongside visibility and conspicuousness, is "recognizability", by which we mean the extent to which the object is not only perceived (correctly and distinctly) in the relevant situation but also correctly classified in the category of objects to which it belongs. An essential precondition for this in that the observer is aware of the existence of the category in question. Thus there is a difference between the demands of visibility and conspicuousness, where the observer acts merely as a "physiological receptor", and those of recognition, where he acts as a decision-maker: the psychological as well as physical characteristics of the observer, his knowledge, experience, attitude, vigilance and, ultimately, his motivation, play a decisive role in recognition. This argument is outlined in greater detail in Schreuder (1985). See also Ebell et al. (1984); Hartman (1986) and IWACC (1983, 1984, 1986).

As a result of this new approach it has been realized that visual perception in traffic (especially in visually complicated situations) is not so much a matter of perceiving a number of objects but rather of becoming aware of large complexes - known as "tableaux" - and interpreting them. In fact we are concerned with not just a static tableau but a whole sequence of tableaux. The pattern of expectations is important here - the grasp of the near future and the positions and movements of the objects therein. Some visual objects are more important than others in the formation of a correct pattern of expectations; some, indeed, are indispensable, and these are often referred to as the "visually critical elements". It is essential, if a correct pattern of expectations is to be formed, that the correct objects are selected in the visual selection process (some elements are perceived "consciously" whereas others pass through the field of vision without leaving any impression) and that the correct priorities are applied to perceiving the various relevant objects.

Perception is dependent on the transmission of information concerning the presence of the object (vehicle) and its type, position and direction, and above all its future - intended - direction. Information can be transmitted in various forms, as:
- unstructured information,
- structured information, and
- encoded information.

Unstructured information in there "automatically", the message is "obvious": e.g. a row of trees that shows the direction of the road ahead, or shiny spots and shadows created by bodywork indicating the presence of a car. Structured information works on the same principle, except that the information is backed up or emphasized by special media: reflector poles alongside the road, car rear lights and sidelights. Encoded information works on a different principle: the media carry a message, as well as providing information on their own presence. The message is contained in coded form on the medium and can be read from it: to do this, however, the "recipient" must have the key to the code. Route signs contain encoded information which is of use only to those road users who at the very least know the alphabet and can read the language.

3. FUNCTION OF DAYTIME RUNNING LIGHTS

The function of daytime running lights is often described as being "to improve road safety". While this description is, of course, correct, it is not sufficiently detailed. Daytime running lights are designed - or at least supposed - to enhance motor vehicle perceptibility. There are two ways in which this could result in an improvement in road safety:
1. Vehicles using daytime running lights are more noticeable, therefore other road users are less likely to crash into them.
2. Other road users are better able to perceive, and therefore avoid, vehicles using daytime running lights.

Point 1 applies particularly to conflicts between motor vehicles, point 2 particularly to conflicts between motor vehicles and pedestrians or cyclists.

The question who benefits from daytime running lights? is thus easy to answer: all categories of road users. This does not necessarily imply that every individual road user in every category benefits in every case or that there are no drawbacks counterbalancing the benefits. The debate which ensued upon the publication of the SWOV report concentrated to a large extent on these two points, especially the question of the additional risk to cyclists and pedestrians in special cases and the likely effects on their mobility. The purpose of daytime running lights and the functional requirements they must satisfy to be effective can be determined, in principle, from what we have said in Chapter 2 about conspicuousness and recognizability.

Increasing conspicuousness can be relevant in two types of situation:
1. Where the pressure of information from the outside world is slight, increasing the conspicuousness of important (or the most important) objects can make road users more vigilant: in this case daytime running lights act as "attention lights".
2. Where the pressure of information is moderate or great, increasing the conspicuousness of a particular object can draw attention to that object, i.e. guide road users' attention.

Increasing recognizability is particularly relevant in cases where the pressure of visual information is so great as to overtax road users' abilities. The effect of the information can be enhanced by marking certain objects with encoded information. If the key is known, the interpretation of the object and the decision as to whether the object is relevant under the circumstances can be speeded up: the object is recognized for what it is. The time saved can then be used to take appropriate steps.

These considerations can be used to determine the photometric and colorimetric requirements for daytime running lights.

Another functional point is the increase in the perception of objects which are fitted with retroreflective devices - especially at twilight.

4. TYPES OF LIGHTS; WAYS OF INTRODUCING THE SYSTEM

There are various technical forms in which daytime running lights could be introduced. First, let us consider the lights themselves; here we have four alternatives:

a. regular sidelights
b. regular dipped headlights
c. dipped headlights, dimmed by means of a resistor or electronic dimmer
d. separate lights used instead of - or in addition to - sidelights.

Only type d - a separate and therefore new lighting system - affords us the opportunity to introduce a new type, which could satisfy the functional requirements better than sidelights or headlights (dimmed or otherwise). The functional requirements were investigated and standards drawn up by Rumar (1981); in a nutshell, these are that enough light must be emitted at the front and side to ensure that the vehicle is perceptible. Rumar's findings are reflected in the standard adopted in Sweden (SIS, 1978).

The beam pattern (light intensity distribution) laid down in the Swedish standard is a variation on the ECE standard for sidelights and takes the form of a relatively broad, fairly flat beam without a sharp cutoff. Adequate conspicuousness is ensured by having a minimum intensity of 300 cd at the centre of the beam; glare is avoided by setting the maximum at 800 cd; recognizability is enhanced by permitting only white or yellow light and by requiring a minimum luminous aria of 40 cm^2; lateral visibility is ensured by requiring 10% of the peak intensity to be emitted at a lateral angle of 20°. The relatively large vertical spread of the beam means that the light is not seriously affected by incorrect adjustment of changes in the vehicle's position. In all these respects the Swedish standard beam meets the functional requirements better than dipped headlights, and this is why Polak (1986, Table 6) took the Swedish standard and recommended that it be adopted in the Netherlands.

The result of the Canadian experience point in the same direction, albeit it is usually said that there is no great difference between the various alternatives. The Canadians generally recommend an intensity of approx. 1000 cd, which can be achieved with dim-dipped headlights or dimmed main beam (Attwood 1975a, 1976, 1977; see also Anon, 1984; Janoff et al., 1970; McIntyre, 1985; MMIC, 1985; King & Finch, 1969 and Samson, 1985). The photometric requirements for daytime running lights have also been investigated in the USA; the findings were similar to the Swedish ones (Kirkpatrick et al., 1984).

As regards the switching system there are two possibilities: (a) a separate switch operated manually by the driver, and (b) an automatic system, e.g. linked to the ignition and headlamp switches, which keeps the daytime running lights on all the time unless the headlamps are switched on. System a would require a separate decision and action the part of the driver; he might forget to switch the daytime running lights on, switch them on at the wrong time, or forget to switch them off, causing a flat battery. This system would only be suitable for a transitional period. System b is far and away the better of the two, since it requires no decision by the driver and the additional cost - also for conversion kits for cars without daytime running lights - would be small.

As regards ways of introducing daytime running lights, there are three options:

1. Recommend the use of daytime running lights but not make them compulsory.
2. Make the use of daytime running lights compulsory without regulating the type.
3. Make the use of daytime running lights compulsory and regulate the type.

All three have their own particular advantages and disadvantages, as regards both effects on road safety and political feasibility.

Option 1 (non-compulsory recommendation) would be easy to introduce nationally without causing legal problems domestically or internationally. It is not recommended, since the results would probably not be entirely satisfactory. Firstly, it is likely that most but not all drivers would follow the recommendation, giving rise to a situation where many but not all cars would have daytime running lights on, which would be undesirable from the road safety point of view. Those without daytime running lights (probably only a small minority) would probably run a disproportionately high risk of being involved in or causing an accident, since if almost all cars have them, road users might come to assume "no lights, no car". Secondly, it would not be possible to introduce a special type of light for the purpose; either dipped headlights or sidelights would therefore have to be used.

Option 2 suffers from the same drawbacks: it is well-known that, where personal conduct is concerned, rules are no more strictly and universally observed than recommendations. Compulsion could have significant political and social repercussions, however, even internationally. This option is also not to be recommended, since there would be political problems and social resistance to the increased cost, probably not all the benefits would materialize and there would moreover be additional risks for a minority group.

This leaves us with option 3. If, in addition to regulations on use (rules of conduct), regulations are introduced whereby all cars (e.g. starting with those registered in a particular year) must be fitted with a system which makes it impossible to drive without lights, the maximum benefit can be achieved and the risk of a small proportion of cars driving around without lights would be negligible (see also 7.1).

The Canadians compared the advantages and disadvantages of the various options in detail (see Lawson, 1986; Anon, 1985; McKale, 1985). The Americans also compared different options (see Kirkpatrick et al., 1984; Teague et al., 1980 and White, 1985). These comparisons were concerned mainly with the economic and financial aspects, however, and are not necessarily applicable to the Netherlands. A comparison of the costs of the various options related specifically to the Dutch situation is currently in preparation.

5. ANALYSIS OF THE PROBLEM

As already indicated, the Swedish data represent the experience of the only country where daytime running lights are compulsory and where there is a reasonable amount of data on the subject. It makes sense, therefore, to base our expectations as to the results of introducing daytime running lights in the Netherlands on the Swedish data.

There are some difficulties here, mostly due to the fact that the Swedish situation differs considerably in various respects from the Dutch one. The resulting specific problems will be dealt with systematically in the next chapter:

1. Sweden is situated at a higher geographical latitude than the Netherlands. Consequently the winters are longer and more severe; the daylight is often weaker in the winter; twilight lasts longer; also, the daylight can be less intense in the summer, although this is the case to only a small extent: the maximum horizontal illumination is almost the same as in the Netherlands.
2. Cyclists and pedestrians seem to account for a considerably smaller proportion of overall traffic in Sweden than in the Netherlands. However, there are no precise data on this point.
3. The Netherlands is more urbanized than Sweden: a higher percentage of the road system - in terms of road lengths - is located within built-up areas. We do not know precisely whether there is any considerable difference between the two countries in the percentage of urban traffic.
4. The Netherlands has a different priority system for slow traffic, which is required to give way to fast traffic from the left at uncontrolled intersections.
5. The cost of the various facilities is not the same as in Sweden; cost-benefit comparisons might yield different results. This is of course equally true of other countries.
6. The Netherlands is a member of the European Community; Sweden is not. This affects the introduction of regulations, in particular since, unlike the Netherlands, Sweden has an important national car industry.

Another set of difficulties in applying the Swedish findings to the Dutch situation arises from the fact that the Swedish research took the form of a statistical accident study: apart from the frequencies of accidents and the correlations with certain clear-cut factors and influences little can be said about their "causes". It is difficult to assess the contribution of individual factors to the causes of accidents, and thus the reasons why a particular system is likely to produce a good result, solely on the basis of national accident statistics. If we are dealing only with data from our own country this need not be a serious limitation to assessing the relevance of a particular piece of research, e.g. an evaluation of the effects of a particular system. If we wish to use such findings to estimate the results of the same system in different circumstances (e.g. in another country) we must ask the following questions:

- Is inconspicuousness of motor vehicles a major causal factor in daytime accidents?
- Would an increase in their conspicuousness result in improved safety?
- Would the use of daytime running lights increase the conspicuousness of motor vehicles?
- Is conspicuousness of other road users (in particular cyclists and pedestrians) a major causal factor in daytime accidents?
- Would an increase in the conspicuousness of motor vehicles during the daytime result in other road users being less perceptible?
- Would the reduction in perceptibility of the other road users due to the increase in the conspicuousness of motor vehicles result in more and/or worse daytime accidents? In particular, is it likely that drivers of motor vehicles would change their behaviour on the assumption that they are themselves more visible so as to increase the risk to other road users?
- Do we need to distinguish between different categories of motor vehicles when answering these questions? In particular, do we need to distinguish between cars and motorcycles in this context?

All the above questions are expressed in terms of conspicuousness, and although it was explained in Chapter 2 that recognizability (or lack thereof) can be a particular cause of problems in complicated situations, the conspicuousness of vehicles remains an important factor.

Before a sound policy decision can be made it is necessary to solve the problems and answer the questions outlined above. The present report represents an initial attempt to do this: all the problems and questions are discussed below. In some cases it is possible to give a definitive answer; in others it is only possible to put forward suggestions or suppositions and in some cases more research is needed. Chapter 6 discusses the differences between Sweden and the Netherlands and assesses what consequences they have; the remaining questions are dealt with in Chapter 7.

This report bases its discussion on the various problems and questions concerning daytime running lights and their possible introduction in the Netherlands on two sets of data:

- accident statistics from various countries: the Swedish experience played the decisive role since daytime running lights are compulsory there (for all motor vehicles, throughout the country and throughout the year) and the introduction of the system is well documented;
- the findings of research into perception theory (physiological and psychological).

These two sets of data reflect the different ways of assessing measures, in particular those related to technical aids designed to improve visual perception in traffic.
Firstly, we can look at the overall effect of the system, by comparing the costs and benefits involved. If it yields benefits (there is an improvement in road safety) it can be regarded as <u>effective</u>; if the costs are less than the benefits it yields a profit, i.e. it is <u>efficient</u>, or cost-effective. Of course efficiency is not enough by itself to warrant introduction of the system; other measures - and in general other interests - must also be included in the equation.
Secondly, we can look at the purpose of the system - in this case to provide visual information. This is referred to as the "supply and demand approach": we look at the amount of visual information provided by the system and the demand for visual information that ensues from the conditions required for safe (or smooth or comfortable) traffic. We can then make a straight comparison between supply and demand: the system is effective if supply exceeds demand. Thus we can assess the effectiveness of the system but not its efficiency.
The third possibility is to compare supply and demand in a causal chain: study of the separate links in the chain tells us something about the effect of the system, providing data which help us find the optimum form for it. This, however, does not enable us to form an opinion on its effectiveness or efficiency.

6. DIFFERENCES BETWEEN SWEDEN AND THE NETHERLANDS

6.1. Latitude

Sweden is situated between 55 and 69°N; the main centres of population are at about 58°N. The latitude of the Netherlands is about 52°N. As noted above, this has an effect on the light in summer and winter, and in particular on the twilight. With this in mind Finland introduced daytime running lights solely in the winter months. It might be thought from this that daytime running lights would be particularly useful in twilight conditions or at least mainly in the fairly dark northern winters found in Sweden and Finland and that they would be less effective in the Netherlands. The data available do not seem to support this supposition, however.

Firstly, we find that there was no clear correlation between the reduction in accidents and latitude when various fleet-owners introduced daytime running lights. The savings mentioned by Polak (1986) occurred in different parts of North America; there was no connection with the latitude of the area where the research was carried out (see Table 2).

Secondly, the Swedish study indicates that the reduction was observed in the summer, in particular in sunny weather (Andersson & Nilsson, 1981, pp. 26-28); see Table 3 (from op. cit, pp. 28). As far as lighting conditions are concerned we should compare the Netherlands with the Swedish summer rather than the Swedish winter. We must exercise caution with these findings, however, because (a) the reduction is not statistically significant at the 5% level, (b) during the "before" period a lot of people were already using their lights in twilight and cloudy conditions, since they often feel that this is when they are most useful, and (c) the intensity of traffic - and more importantly, any changes that may have taken place in it - was not taken into consideration. It is noteworthy that Sweden recently decided to carry out a further evaluation, which is likely to take these factors into consideration.

We may conclude that there is no reason to expect daytime running lights to be less effective in the Netherlands than in Sweden because of the difference in latitude. There is not a great deal we can say about the latitude-related difference in climate and weather conditions between the two countries, although it is likely that the net effect of making daytime running lights compulsory in the Netherlands would be small in rain, fog and twilight, since a lot of drivers are already using lights in these conditions. This has also been found to be the case in Sweden (Andersson & Nilsson, 1981), the USA (Allen et al., 1969) and Canada (Ng, 1984).

6.2. Slow traffic

It is said that there are far more cyclists and pedestrians in the Netherlands than in Sweden and that the Swedish figures cannot therefore be taken without modification as an indication of the likely effect of daytime running lights in the Netherlands. The Swedish analysis, however, indicates that the greatest "profit" was to slow traffic ("unprotected road users"); see also Table 3 (data from Andersson & Nilsson, 1981, p. 28).

6.3. Degree of urbanization

As indicated, the Netherlands has a higher proportion of urban roads than Sweden. We do not know whether this is also the case with traffic; assuming that the Netherlands also has more urban traffic, it may be questionable whether the Swedish figures are applicable to the Netherlands. The data provided by Andersson & Nilsson (1981, p. 28) indicate that in general the reductions in accidents following the introduction of daytime running lights were greater in built-up areas than in rural areas (see Table 3).

Table 3 is particularly interesting in that it shows that the greatest reductions following the introduction of daytime running lights were in accidents:

- with slow traffic
- in built-up areas
- in the summer

These are precisely the points mentioned above where differences - in some cases of a fairly substantial nature - have been noted between Sweden and the Netherlands. In all three cases the reductions were above average: of the four cases where the reduction was significant at the 5% level (of the

20 combinations) three were found in slow traffic in built-up areas. The SWOV report bases its expectations ot the results of introducing daytime running lights on the Swedish experience; since there are differences between the two countries the figures have been "rounded down" to provide an additional safety margin. It would seem, however, in view of the Swedish findings, that any differences between the two countries are likely to result in the system being more than less effective.

6.4. Priority system

The Netherlands has a priority system for cyclists which differs from that in most of its neighbours, including Sweden. There are no immediate quantitative data on the influence of this difference on the effects of introducing daytime running lights.

The study of the possible effects on road safety of a change in the statutory priority system for slow traffic showed that the perception of motorized traffic often causes problems, in the daytime as well as at night (Tenkink, 1985). These problems are likely to be increased by a change in the priority system. Also, a comparison between accidents involving cyclists failing to give way to cars in the daytime and at night shows that these are relatively common during the daytime, especially in comparison with accidents involving cars colliding with cycles. It might be hypothesized that the first kind of accident is accused to a considerable extent by cars being insufficiently conspicuous (i.e. at night). It was concluded from these data that the safety of cyclists at night would be improved by fitting cycles with side reflectors (Blokpoel et al., 1982). The same data would also seem to justify the conclusion that daytime running lights would improve the daytime safety of cyclists and, moreover, that this benefit would obtain particularly in countries where cyclists are required to give way to fast traffic coming from the left. This priority situation thus occurs twice as often as in countries where other road users are required to give way to cyclists and motor vehicles coming from the right. In other words it is likely, given the priority system in force in the Netherlands, that daytime running lights would be more rather than less effective there than in Sweden.

6.5. Costs and benefits

The economic losses due to road accidents in the Netherlands have been estimated at just under 6.000 million guilders a year (Anon, 1985a, p. 162); a figure of nearly 15.000 million guilders is also mentioned, however. The different figures primarily reflect different definitions of the "cost" of, or "loss" due to, accidents - as well as scatter due to inaccuracies in the data used (Flury, 1984).

The SWOV studies estimated the reduction in overall road accidents as a result of the introduction of daytime running lights at 5% or more (Anon, 1987); as noted above, if anything this figure is on the low side. We base the calculations below on a reduction of 10% as well as the 5% figure. This would mean a saving in money terms of 300-600 million guilders a year, assuming that all types of accident are reduced to the same extent following the introduction of daytime running lights.

The overall cost to car owners can be estimated as follows. Let us assume there are 4 million cars in the Netherlands, each covering 15.000 km a year at an average running cost per kilometre of 50 cents. The total annual running costs are then approx. 30.000 million guilders. If we require daytime running lights to be cost-effective, they must cost not more than 1-2% of the total running costs - between 0.5 and 1.0 cents per kilometre. If we take Flury's (1984) higher figures, however, the annual saving due to daytime running lights would be 750-1.500 million guilders, and the maximum cost could be between 2.5 and 5% - 1.25 to 2.5 cents per kilometre.

It is difficult to estimate the actual cost of a system of this kind, especially when there are different alternatives. Attwood (1981) compared a number of alternatives, but his findings are not applicable because they are out of date, they relate to the situation and price structure typical of North America and the alternatives offered are no longer relevant given the technological progress that has been made. The cost aspect of daytime running lights has been thoroughly investigated in Canada (Anon, 1984, 1985; Attwood, 1975, 1981; McIntyre, 1985; McAllister, 1985; Thurston, 1985). It has also been studied in the USA (Allen, 1965; Stein, 1985a). Although the quantitative data cannot be applied to the Dutch situation, the system is likely to be cost-effective here too.

A realistic approach would be to use additional lights with a power of 40 Watt (Polak, 1986, p. 21). This would probably cause an increase in fuel consumption of no more than 1%. Fuel for a car costs in the order of 20 cents per kilometre (assuming a rate of 8 km per litre and a petrol price of 1.60 guilders per litre); 1% of this would be 0.2 cents per kilometre. In relation to the figure of 0.25 to 2.5 cents per kilometre mentioned above it seems, then, that daytime running lights would be cost-effective. They would, of course, entail additional costs, on which there is as yet no detailed information. A few years ago the Government Motor Vehicle Service RAC investigated this aspect: the findings were similar to those of a recent study (unpublished) carried out by the Department of Road Transport RDW, which were summarized as follows:

"It was estimated approximately what the additional cost would be to individual motorists and to the Netherlands of using daytime running lights. If the customary strategy were to be adopted, i.e. existing cars would use dipped headlights and in the longer term all new cars would be fitted with automatic attention, the ultimate cost of the policy would be in the order of 150 million guilders a year, or about 25 guilders to each motorist; in the initial phase it would be higher, in the order of 250 million guilders a year or about 45 guilders to each motorist. It would be worthwhile to fit automatic attention lights to any existing car with an anticipated life of 5 years or more. These figures do not take into consideration the cost of police enforcement if daytime running lights were to be made compulsory."

7. PROBLEMS WITH THE INTRODUCTION OF DAYTIME RUNNING LIGHTS

7.1. International aspects

Chapter 4 sets out three options, each with its own advantages and disadvantages. The third option, which involves introducing regulations on driver conduct and vehicle equipment, could have international repercussions.

The problems are manifest: rules which make certain types of conduct compulsory cannot be laid down unless they conform to the EEC treaties, and the agreement of the ECE (United Nations, Geneva) is required in addition for binding regulations on vehicle equipment. This is a particularly serious problem for the Netherlands, which has no national car industry to speak of. Consequently the third option would take a long time to introduce. The whole problem is made even more difficult by the obligation to remove all barriers to trade within the EEC after 1992.

Despite these problems it is clear that the third option is the one that must be selected, possibly with the second option (making use of existing lights compulsory) as a transitional measure. It is noteworthy that the Canadians reached the same conclusion (Attwood, 1981). It should be noted, however, that the system will be implemented differently in Canada, where national statutes are permitted to regulate vehicle equipment but not conduct.

7.2. Conspicuousness of motor vehicles

Chapter 5 posed two questions concerning the conspicuousness of motor vehicles: (a) Is inconspicuousness a major causal factor in accidents? and (b) Is safety improved by increasing conspicuousness? In view of the interrelatedness of these questions it would seem reasonable to deal with them together.

It is not possible to give a direct answer to these questions since the national statistics do not record the perception of road users involved in accidents. We are left with three options:

1. To analyze the accident process theoretically.
2. To investigate perceptibility in situations similar to those in which the accidents took place.
3. To carry out case studies of selected accidents.

A considerable amount of research has been done into al three areas; we shall summarize the most important findings here. We shall return to this research when considering a number of the questions posed in this report.

7.2.1. Theoretical analysis

Chapter 2 discussed the various aspects of perception. In particular, al clear distinction was made between conspicuousness and recognizability: conspicuousness is linked to the object under observation, whereas in the case of recognition the observer also has an immediate and explicit role to play. We also saw that daytime running lights are a means of transmitting information.

Primarily (as "attention lights") daytime running lights are one of the ways of increasing conspicuousness and supplying structured information. This is likely to be particularly the case in relatively simple situations as regards traffic and traffic environment, e.g. in a rural area under an overcast sky. It may be concluded from the Swedish studies already cited on more than one occasion that in such circumstances daytime running lights do indeed contribute to road safety (see Table 3). The contribution they make, however, is not particularly large; we shall return to this point shortly.

If we consider situations involving heavy traffic, a complex visual environment and a complicated task for the road user, it would seem that daytime running lights are to be regarded rather as a means of increasing recognizability (helping the road user to make the correct visual selection, to select the correct priorities for observation) and that the information is encoded rather than just structured. This is likely to be the case particularly in built-up areas and in the summer, especially when different categories of road user are involved - road users who look different and have different movement characteristics. As indicated in Chapter 5, the Swedish research shows that these are precisely the circumstances where a major reduction in accidents was found following the introduction of daytime running lights; again see Table 3.

On the basis of these theoretical arguments we can try to answer the questions posed in Chapter 5. It is indeed likely that inconspicuousness is a causal factor in accidents and that safety will be improved by increasing conspicuousness. it is also likely, however, that the contribution made by daytime running lights is to be found not only - perhaps not even mainly - in increasing conspicuousness but in improving recognizability. The studies currently being carried out by the TNO Institute for Perception IZF briefly discussed below, are designed to answer this question. Accident studies can in fact often provide data on this point: inadequate perception is frequently stated as a cause (or contributory cause) of accidents. This was found in almost 50% of cases in Canada (Greene, 1985) and about 23% in Germany, although these figures should essentially be regarded as indicative, since they are based on statements made by persons involved in accidents.

A direct consequence is that any increase in conspicuousness must be moderate: it must not be achieved at the expense of a reduction in recognizability caused by glare or certain objects outshining or distracting attention from other objects - a " conspicuousness race" must be avoided. The suggestion made above that dipped headlights should not simply be adopted as daytime running lights is based partly on these arguments; it is not only for reasons of energy consumption that a less powerful light source than dipped headlights is recommended. The SWOV report includes a recommendation (Polak, 1986; Table 6). See also Chapter 4.

7.2.2. Perception studies

The effect of motor vehicle perceptibility and changes therein on accidents can be ascertained approximately from the findings of perception studies. A lot of research has been done into the perceptibility of different categories of road users; in general this research was concerned with detectability. A general survey is given in Schreuder & Lindeijer (1987); Rumar (1981, 1985) compiled and discussed a number of studies which played an important part in the Swedish decisions on daytime running lights. Similar compilations for the decision-makers in Canada were provided by Anon (1984), Attwood (1981), Lawson (1986) and White (1985).

The studies are unanimous in concluding that motor vehicle perceptibility in normal traffic situations is often poor and could easily be improved by using various aids, of which lights are the most effective.

It is evident that the conspicuousness of motor vehicles is often poor, but it must not, of course, be concluded that this is necessarily a major direct causal factor in accidents. As already noted more than once, the national accident statistics do not provide adequate data to support this conclusion.

Another important point is to what extent we take recognizability rather than conspicuousness as our criterion of perception. Rumar (1981) describes research where the "detection" of cars in real rural traffic situations was investigated in relation to various variables which it was thought might influence perceptibility, viz. colour, weather, season and light (Dahlstedt & Rumar, 1973). "Their results show that brightness contrast (colour, silhouette, flashes, headlights) is the dominating single factor (> 80%). ... When headlights (low beam) are on this was invariably the cause for detection" (Rumar, 1981, p. 3).

The time taken to detect a vehicle is often used as a criterion of perception, though it is not always possible to establish precisely whether this is a measure of recognizability or of conspicuousness. To reduce this uncertainty, among other reasons, the TNO Institute for Perception IZF carried out various studies (of which SWOV was the architect) for the Road Safety Directorate DVV (see Riemersma et al., 1988). These were simple studies, rather in the nature of a demonstration. The aims of the four studies were as follows:

1. To determine the conspicuousness of cars with different types of lights and in different types of visual environment. This study employed the "conspicuousness meter" described by Wertheim (Wertheim, 1986; Wertheim & Tenkink, 1987).
2. To determine the conspicuousness of a cyclist (without lights) in the vicinity of a car with different types of lights. This study also used the conspicuousness meter.
3. To determine the visual search pattern in different situations where a cyclist is in the vicinity of a car with different types of lights. This study was based on recordings of eye movements.

4. To determine the extent to which an observer can from an idea of an entire tableau during a brief observation, examining the observation priorities. Riemersma's "occlusion glasses" were used to limit the length of the observations (Riemersma, 1983, 1983a).

Although these studies were of an exploratory nature, the findings are extremely important to an assessment of the advantages and disadvantages of daytime running lights. They were summarized as follows.
"It can be concluded from the measurements made with the conspicuousness meter that the conspicuousness of the cyclist does not appear to deteriorate significantly when the motor vehicle has its sidelights/dipped headlights/attention lights on and the gaze is focused on the cyclist.
"Nothing was found in the recordings of eye movements to indicate that fixation on the cyclist subsequently became less frequent of briefer as a result of the car becoming more conspicuous. The selection experiment suggested rather that if the car was mentioned more frequently as a result of having its dipped headlights or attention lights on, the cyclist in its vicinity was also mentioned a little more frequently.
"To sum up, it would seem that the use of attention lights of the kind employed in this experiment (the minimum Swedish standard) increases the conspicuousness of the motor vehicle without substantially affecting the conspicuousness of slow traffic" (Riemersma et al., 1988, p. 20).
These findings, coincide with those of the summaries given previously (Hartman, 1987; Godthelp, 1987).

The above-mentioned studies thus permit us to draw a clear conclusion: the conspicuousness and recognizability of motor vehicles during the daytime can be improved simply, and to a considerable extent, by using daytime running lights. The increase in conspicuousness is likely to make a major contribution to the prevention of accidents.

7.2.3. Case studies

These are studies in which specific data on each accident are collected (insofar as they are available, of course) with the aim of reaching hypotheses on the causal relationship between the various factors. Since they cannot be carried out on a large scale because they are difficult, time-consuming and expensive, their findings cannot be regarded as generally valid: the "sample" is too small. A more serious problem of a methodological nature is that - precisely because they are "important" accidents, and the decision as to which accidents are important is not infrequently based more on political considerations than on any desire to improve road safety.

To our knowledge there are no case studies bearing directly on the subject of the present report, although there have been some on the perceptibility of vehicles. A British study (Codling, 1974; Sabey, 1973) suggested that lack of visibility is to be regarded as a major cause of accidents in many cases. It has also been found that some factors in reduced visibility, e.g. darkness or bad weather (rain and the common associated phenomenon of splash) cause an increase in risk; the increase is noticeable but not dramatic. Evidently road users are able (to a large extent at least) to adapt to the reduced visibility. Where darkness and rain occur together, however, there is a sharp increase in the accident risk; it would seem that road users are not able to compensate for two unfavourable factors at the same time (OECD, 1976).

Although these findings do not enable us directly to determine how effective daytime running lights are, they provide an indirect confirmation of the relationship found in various places between motor vehicle perceptibility (conspicuousness and/or recognizability) and accidents and thus contribute to the likelihood that daytime running lights would also be effective in the Netherlands.

7.3. Daytime visibility of motor vehicles

It was noted in the last section that inconspicuousness of motor vehicles can be regarded as a major causal factor in accidents and that an increase in conspicuousness is likely to bring about an improvement in safety. A closely related question is whether daytime running lights improve motor vehicle conspicuousness during the daytime and what photometric and colorimetric requirements they should satisfy to give the optimum improvement in conspicuousness. The latter point is particularly important; it was noted in Chapter 2 that an excessive increase in conspicuousness could have a harmful effect on the recognizability of the tableau as a whole in certain cases, and in many cases recognizability is more important than the conspicuousness of the car by itself.

The answer to the first part of the question is so self-evident as to render any further research unnecessary: obviously a vehicle is more conspicuous if it has its lights on, and if proof were needed the many studies confirm this (see e.g. Rumar, 1981). Similar studies have also given us an understanding of the requirements for the optimum type of vehicle lights for daytime use (Hörberg & Rumar, 1975; Hörberg, 1977, 1979; Rumar, 1980; Weström & Martensson, 1969; Almquist et al., 1969 and Berlin & Börklund, 1969). The colour was not important: yellow and white light perform equally well. Nor is the surface area of the light very important: the effect was the same with 70 cm^2 or 200 cm^2. The intensity in the centre of the beam should be between 50 cd and 1000 cd. Suggestions have also been made on beam width. The pattern of intensity proposed as a result of all this was adopted in the Swedish standard (SIS, 1978). See also Chapter 4. The Canadian arguments and resulting standards are similar (See Attwood, 1975a, 1976, 1977 and Kirkpatrick et al., 1984).

Lights of the type described here are not permitted in the Netherlands. If daytime running lights were to be introduced in the near future there would be no alternative to using one of the currently permissible - in fact obligatory - types: sidelights or dipped headlights. There is a certain preference for the latter, but this is not based on any research.

It has been pointed out in various quarters that the proposed requirements for daytime running lights (enacted in Sweden) are very similar to those recommended for "improved sidelights" (SWOV, 1969; Schreuder, 1976), which are compulsory in Britain. This should be remembered when considering the details of the optimum form for daytime running lights. See also Attwood (1981) and Polak (1986).
We may conclude that daytime running lights increase motor vehicle conspicuousness during the daytime, and we recommend following the Swedish standard as regards the photometric and colorimetric requirements if they are introduced.

7.4. Conspicuousness of vulnerable road users

When assessing the merits of daytime running lights, and in particular the introduction of compulsory daytime running lights in the Netherlands, we need to know what effects they have on other road users. Here we should distinguish between the "vulnerable categories" (cyclists and pedestrians) on the one hand and motorcyclists on the other. We shall return to the latter in Chapter 9.

We have already asked whether inconspicuousness of motor vehicles is a major causal factor in accidents and have decided, with certain reservations, that it is. We cannot give a direct answer because the national accident statistics do not contain the relevant data.

We now ask the same question in relation to the vulnerable categories, cyclists and pedestrians. Again, it is difficult to give a direct answer because the relevant data are not included in the national accident statistics. We are not aware of any case studies specifically concerning accidents involving cyclists and pedestrians. The theoretical arguments given in par. 7.2 apply just as much, of course, to cyclists and pedestrians as to cars. The considerably higher risk run by cyclists and pedestrians at night than by day would also seem to point in the same direction. It is likely, then, that inconspicuousness in a major causal factor of daytime accidents for cyclists and pedestrians just as much as for cars. Not all the data point in this direction, however, as shown by a British study into the relationship between the level of street lighting and the accident risk (Scott, 1980). We mention this study here on account of the natural assumption that the conspicuousness of objects is proportional to the illumination of the road surface, and it was indeed found that as this increased the relative accident risk decreased. This applied to all the accidents in the survey, including those not involving pedestrians; given the small number of cyclists in Britain, these will almost all have been accidents involving motor vehicles. The accidents in which pedestrians were involved, however, displayed a different pattern: no relationship was found between the risk and the amount of light. We must assume, then, either that there was no increase in the conspicuousness of pedestrians of that, if there was, it had little effect of the risk. The authors of the study give no explanation. It has been suggested elsewhere that accidents of this kind mainly involve pedestrians under the influence of alcohol; this cannot be proved.

In line with the findings given in para. 7.2 we would suggest that inconspicuousness of cyclists and pedestrians is a major causal factor in daytime accidents.

8. DAYTIME RUNNING LIGHTS AND ACCIDENTS INVOLVING CYCLISTS AND PEDESTRIANS

8.1. Perceptibility of cyclists and pedestrians

We noted in the last chapter that inconspicuousness of cyclists and pedestrians is also likely to be a major causal factor in daytime accidents. It is impossible to recommend, as we can in the case of cars, that cyclists and pedestrians carry lights during the daytime, since cyclists have only a small amount of electrical power at their disposal, completely inadequate for a light that would be strong enough for daytime use (Schreuder, 1985a), and pedestrians have no light at all at their disposal, unless we are to persuade them to walk around carrying flashlights during the daytime. Since even at night pedestrians do little to ensure that they are visible (Schreuder, 1985), we can hardly expect them to take much heed of a recommendation of this kind.

Given that it is impossible for cyclists and pedestrians to carry lights during the daytime, we are faced with the following problem if daytime running lights are introduced. Daytime running lights make motor vehicles more conspicuous; if motor vehicles occur in an observer's field of vision along with other road users, they could make it more difficult for these other road users to be perceived. It is not certain whether their conspicuousness is reduced, since this is determined by the contrast between the object (pedestrian or cyclist) and the background, and this does not change if cars have daytime running lights. The increased conspicuousness of certain objects could however influence the distribution of attention, or visual selection (see Chapter 2). As a result, the perceptibility of cyclists or pedestrians could be reduced by cars having daytime running lights even though there is no reduction in the perceptibility of already relatively inconspicuous road users such as cyclists and pedestrians could have a harmful effect on safety. The increased conspicuousness of cars, moreover, could result in behavioural compensations on the part of car drivers: they might take more risks (e.g. by driving faster) or pay less attention to their environment. This gives rise to four questions:

1. Would the change in perceptibility of cyclists and pedestrians that would be caused by motor vehicles using daytime running lights be important? Would it be sufficient to have a detectable effect on accidents?

2. Would the increase in relative perceptibility of cars cause a change in drivers' behaviour?
3. Could there be a transference of risk such that, even though the overall effect of daytime running lights was beneficial, there was an increased risk to certain categories (or subcategories) of road users?
4. In view of the increase in motor vehicle perceptibility, would a change in the perceptibility of cyclists and pedestrians cause an increase in the overall accident rate?

These four questions are discussed below, with a concluding discussion ot the overall effect on safety.

8.2. Effects of changing conspicuousness

In 7.2.2 the recent IZF-research was already mentioned. This research was mainly aimed at answering the question put in Chapter 5 whether the decrease of perceptibility of cyclists and pedestrians, as a consequence of daytime running lights is sufficiently important to take it into account. The results also were summarized in 7.2.2 (see Riemersma et al., 1988).

On the basis of theoretical considerations it is often stated that the decrease in perceptibility will have to be taken into account. This statement is based on two premisses:
The first premiss is that the "capacity" of the human observer has to be taken as constant, so that attention going to a certain object must be taken off the attention going to an other object. This reasoning is hardly tenable because such a constant capacity, calculated for a telephone system, is not valid for human observers and decision makers. Firstly, for decision making the "capacity" is determined primarily by the level of attention and therefore by the motivation. Secondly, there is hardly a demonstrable connection between the conspicuousness of the objects and the importance given to it by a human decision maker. Thirdly, transmission of information is not the only factor in perception and decision making on the basis of perception: subjective influences also play their part.
The second premiss is based on the idea that road users are charged to their maximum capacity when handling (visual) information in traffic.
It may incidentally be the case for some traffic participants, but simple

observation tells us that it is very exceptional, if it exists at all.
The last point indicates that attention has to be paid to this rare phenomenon, just because it is rare. The research of Michon on traffic behaviour where the "setting of a double task" is used is interesting in this respect (Michon, 1979). The fact by it self that drivers can be given a second task shows that there is no question of saturation.

So it does not appear sensible to base an argument against the use of daytime running lights on these premisses, because even for these rare instances, the absence of daytime running lights does not give the slightest guarantee that the correct decision would be taken. The possibility that daytime running lights overcharge "a channel of visual information handling" in such a way that wrong decisions are taken and accidents are caused, can be ignored.

8.3. Changes in behaviour

It is known that measures introduced to promote traffic safety often go together with changes in behaviour of road users and possibly so much so that the effect of the measure is hampered or annihilated. The changes may be the choice of a higher speed, or of smaller distances between cars, or of the acceptation of smaller gaps in the traffic flow or a reduction of the level of vigilance.

Daytime running lights make cars more conspicuous. It can be thought that drivers adapt their behaviour in such a way that the safety effect of the higher conspicuousness is hampered. To raise the speed or to decrease vigilance are among the possibilities to do so.
It is not known whether such an adaptation ever took place after the introduction of daytime running lights, whether it is to be expected in the Netherlands, or whether such an adaptation would cause more danger for cyclists and pedestrians. In the short term the phenomenon would be seen in a change in conflicts and in the long run in a change of types of accidents. The effect can be assessed by studying the conflicts and possible changes in them when daytime running lights are introduced.
If such an effect would be shown then the use of daytime running lights are might have to go together with other measures to counteract the negative effects for cyclists and pedestrians. Measures might then be taken

to reduce the driving speed or to increase the vigilance of cyclists and pedestrians in certain situations.

8.4. Shift of the accident risk

Another question in Chapter 5 was: Is there a chance that the accident risk from motorized vehicles will be shifted to the "vulnerable" road users? From Swedish results, as summarized in Chapter 4 and 6, it is clear that not only the total number of accidents has decreased with the use of daytime running lights but that the number of accidents of the cyclists and pedestrians has even decreased more (Table 3).
The question whether there are shifts within the groups of cyclists and pedestrians had not been answered. This would mean that certain groups of cyclists or pedestrians run a lower risk without than with the use of daytime running lights by cars. Only one possibility rises then: that the lights carried by the vehicles would draw the attention away from cyclists and pedestrians. The IZF-research was already referred to (7.2.2). In par. 8.1 it was shown that no great change is to be expected on theoretical grounds. This was confirmed by research (Riemersma et al., 1988).

8.5. Overall number of accident

Introduction of daytime running lights causes a higher conspicuousness of motor vehicles and may cause a change in the perceptability of cyclists and pedestrians. In view of the relationship between conspicuousness and risk a decrease is to be expected of accidents in which motorized vehicles are involved, but also a possible increase of accidents, in which bicyclists or pedestrians are involved. The experience in Sweden has proven that the total number of accidents has decreased with the use of daytime running lights by cars. In Chapter 6 it is shown that a comparable effect may be expected for the Netherlands, or even a higher decrease of the number of accidents.

The expectation is then that the increase of the conspicuousness of motorized vehicles will have a favorable effect on traffic safety greater than the possible negative effect of the change in perceptibility of bicyclists and pedestrians. No important shift is expected to take place regarding the accident risks within the groups of bicyclists and pedestrians.

9. MOTORCYCLES

Until now no distinction was made between cars and motorcycles. This chapter will deal with it.
As far as the increase in conspicuousness is concerned of the vehicle the effect is analogous for both categories, it is not identical as a result of the difference in numbers of lamps and in width (distances between the lamps).
In fact the expectation that the conspicuousness increases with the use of daytime running lights is the main reason that in most countries motorcycles switch on their lights by day. In many countries it is compulsory for motorcycles - sometimes for all motorized two-wheelers - to use daytime running lights. (If it is not compulsory by law, insurance companies mostly make it obligatory). In this respect the use of daytime running lights suits the national and international use of headlights for motorcycles.

The difference between cars and motorcycles is another matter. The most important argument for the introduction of daytime running lights on motorcycles was the fear that it might not be noticed among the cars. With using headlights by daytime the motorcycle would be more conspicuous than the car: the motorcycle placed it self in an exceptional position. Apparently the relatively low conspicuousness of motorcycles is an important cause of accidents, for almost everywhere it was found that using headlights by daytime is an effective measure for motorcycles (see Schreuder & Lindeijer, 1987). It is even expected by some that introduction of daytime running lights for all motorized vehicles will undermine the position of preference of the motorcycle. The number of accidents with motorcycles may increase this way.

A further consideration, however, shows this expectation to be unfounded. The gain in conspicuousness of motorized vehicles is the result of the increase of the contrast between the vehicle (or part of the vehicle: the headlamp) against the background (Janoff et al., 1970). This is a better explanation of the positive effect of the use of lights by daytime on the number of accidents with motorcycles than the relatively higher conspicuousness of motorcycles between cars. This contrast remains even if other vehicles use their headlamps. Only in a very dense mass of vehicles, in a traffic jam e.g., the influence of the mass of lights may overrule the contrasting effect. In that case the distances between the vehicles are very small, so that the perception is not determined by conspicuousness. Moreover the exceptional position of motorcycles will not disappear altogether because motorcycles mostly use their full headlights by daytime and for daytime running lights low-beam headlights will be used.

It seems justifiable to expect that the introduction of daytime running lights for all motorized vehicles will not cause an extra risk for motorcycle riders.
If more certainty is required the IZF-research might be extended to the conspicuousness of motorcycles close to cars with or without lights. The method of research does not have to be changed, only the number of experimental conditions increases.

10. INTRODUCING DAYTIME RUNNING LIGHTS

10.1. Use of daytime running lights

Motorized vehicles in the Netherlands often have their lights running by daytime, but no data are available. In some cases it is compulsory (dense fog; heavy rain or snow etc.); in many cases it is recommended (tunnels, special parts of roads etc.) (see Polak, 1986, pp. 12-13).
A number of observations showed that drivers on motorways easily decide to switch on their lights. Almost a 100% does so when it is raining and when the level of light is low. On roads inside built-up areas clearly less often the lights are on than on motorways. Almost all motorcycle riders always have their lights on. The great majority uses dipped headlamps; the use of the high beams, parking lights, or special lamps (fog lamps etc.) are exceptions.

No systematic measurements have been executed on the use of lights by motorized vehicles by daytime and in twilight in the Netherlands. If daytime running lights are to be introduced data are necessary for three reasons:

1. It is necessary to know how much the lights are used before the measure, to be able to estimate the effect of the measure (if most of the vehicles already have daytime running lights, the effect of legislation will not be high, even if the use of daytime running lights really is an effective measure).
2. The data are necessary to relate the number of accidents during the introduction period and after that during the period cars are being equipped with the special lamps to the numbers in these periods. This is the case if the measure is monitored by research (the "finger on the pulse research").
3. The data are needed to evaluate the effect of the measure. The evaluation may be useful for the measurement of the effectivity of political decision making, for improvement of the measure, and for the decision on the necessity for supplementary measures.

Finally it is important for scientific research. Data are needed of a period long before the introduction of the measure, which it makes rather late to start even now. Daytime running lights already got a lot of publicity and one can expect this publicity to change the use of lights by daytime. Moreover, a number of municipalities will introduce the stimulation of daytime running lights in the framework of the "Action -25%". This "Action -25%" gives governmental premiums to municipalities decreasing the number of traffic accidents by at least 5% a year.

The necessary data are related to three aspects: accidents, use of daytime running lights, and behaviour. VOR-data will probably give enough information on the accidents.
Data on running lights, however, are not systematically collected, but this will have to be done. They have to be representative for the actual situation in the Netherlands and for of the changes. It means that the measurements will have to be widely spread over the country to eliminate regional differences, especially if municipalities start their stimulation of daytime running lights. They must be spread in time, season, and weather circumstances to know the influences of variations in (meteorological) visibility. They must also be spread over vehicle types (lorries, cars, motorcycles) and over different types of roads to know the influences of the quantity of traffic and its composition and of the different roads themselves ((non) built-up areas e.g). Because there are no data on accident-involved vehicles with or without their lights on, no direct relationship can be determined, only a general one, between the use of daytime running lights and being involved in an accident.

For the measurement of behaviour and its changes several aspects are involved: speeds, priority, approach of junctions and crossings for cyclists and pedestrians, and conflict observations. To measure the spread in time and place the same requirements are valid as for the measurement of the use of lights. It appears to become an extensive research, but the need for it follows from the foreign research, which always was set up too narrowly in order to come to, to reach generally valuable results.

Many drivers have their light switched on by day; the choice to do so is mainly founded on two factors: the overall light level (horizontal illumination in the open field) and the (meteorological) visibility. It is different from country to country though. These two factors are not always weighed equally. Rumar (1981) notes Swedish results proving that the influence of the light level is great, but especially important with bad sight. This was also found in the Netherlands (Blokpoel & Mulder, 1986).

Rabideau & Bhutta (1977) are cited by Atwood (1981), as having found that the light level has a greater influence than sight. Allen & Clark, 1964) and Hisdal (1973) are cited by Atwood (1981) as having found the opposite.

On the relation between using lights by car drivers and the illumination level some Dutch data are available. In the framework of research on the condition and the use of lighting devices on pedal bicycles, the use of lights by motorized vehicles was also registered. The picture we have seen before appears from the count: a long time before it is compulsory most drivers switch on their lights. The use of daytime running lights by cars depends on the level of daylight.

Daytime running lights have already become widely used on a voluntary basis. There are important differences between the various countries. The decision of road users to use lights by day is mainly based on the illumination level of the daylight and the meteorlogical visibility on the spot. From the last fact it might be deduced that road users see the lights as a means to be visible for other road users, and not only as a means to see better. Voluntary use of daytime running lights can be considerably promoted by information and education campaigns, as is found in Canada and in Sweden (Gale, 1985; Hart, 1985; Nicholson, 1985; Rumar, 1981). The compulsory introduction of daytime running lights will not have a great influence on the use of lights under these circumstances then. This might strongly influence the conclusions on the safety effect of the measure especially if it is not taken into account that there are differences in using the lights by day under different circumstances of daylight and visibility.

Sweden has a special place with respect to daytime running lights. In 1967 left-hand traffic was changed into right-hand traffic and this change was coupled to the advice of using running lights by daytime. The advice was widely followed and led obviously to habit making obviously. When daytime running lights were considered in Sweden to be introduced they appeared to be widely in use already.
Data are given in Rumar (1981) and Andersson & Nilsson (1981, Chapter 2). The influence of the differences in using the lights under different circumstances in the 'before-period' is mentioned, but not taken into account

in the quantative analysis of accident data (Andersson & Nilsson, 1981, p. 7). This is of importance for the definite judgment on the effect of the measure in Sweden (see Polak, 1986). As indicated before this is one of the main reasons to urge a complete research on the use of lights by day in the Netherlands, research to be started well ahead of the compulsory introduction of daytime running lights.

10.2. Ways of introducing daytime running lights

In Chapter 4 it is shown that there are four variables for the technical execution of daytime running lights:

- standard side lights (parking lights)
- standard low-beam headlamps
- "dimmed" low-beam headlamps
- separate lamps ("attention lights").

The photometric characteristics of daytime running lights in Sweden are very much alike to those of "improved sidelights" or "town beams" i.e. adapted and stronger sidelights, which are excellent lights to be used in the dark on roads with a good street lighting. It is recommended to consider the introduction of this sort of light when introducing daytime running lights too.
It is recommended to take over the Swedish standard and to permit the use of the existing lamps (sidelights, or low-beam headlamps) as daytime running lights only during a transition period. The other possibilities are less suitable, though the dimmed headlights in Canada get a favourable judgment (Anon, 1985). With respect to the Swedish (separate) lights they do not have any advantage (not even in price), only disadvantages, so they should not be introduced.

10.3. Rear lights

Until now only lights at the front of the car have been discussed. Another question is whether the rear lights should be used by day. As almost all research was directed at the front lights it is hard to give an opinion. Probably rear lights will give information on speed and direction of cars in front.

The experience in Sweden does not give a clear indication. Originally the use of running lights by daytime was limited to the front, but because a lot of errors were made by drivers driving without rear lights in the dark, the rear lights have become compulsory too. There is only one disadvantage and that is the use of energy for lorries and busses carrying a great number of rear lights (Rumar, 1981).

An analysis of the accidents does not give a solution. None of the changes found of the numbers of head-tail collisions (coincident directions) appear to be on a 5% statistically significant level. Sometimes the changes are positive, sometimes negative.
Inside built-up areas this kind of collision decreased in summer and increased in winter; outside built-up areas it was the opposite (Andersson & Nilsson, 1981, p. 28).

If sidelights or low-beam headlamps are used for daytime running lights the rear lights are automatically switched on. But then most other light are working too, even if they do not have a function by daytime: number plates, instrument panel etc. This may lead to a considerable increase of energy use, even for private cars and to a higher number of defective lamps. If special lamps are used for daytime running lights it is technically not so difficult to switch on only front and rear lights by day. It may be considered to combine this special switch with another suggestion to use reinforced rear lights, especially when the sight is bad. This may replace the actual fog lamp, which is often misused. Further research still seems desirable (Schreuder, 1976).

The conclusion is that it is not very clear yet whether it is advisable to switch on rear lights by day, but that there is a preference to use 'ordinary' rear lights as part of the use of daytime running lights.

11. CONCLUSIONS

From the discussion on the possible introduction of daytime running lights in the Netherlands the following conclusions can be drawn:

1. The use of daytime running lights seems to be effective in Sweden: there is a decrease of (relevant) accidents after the introduction. An analysis of the Swedish data justifies the expectation that it will also be effective in the Netherlands. On the basis of a further analysis of the differences between the Netherlands and Sweden (geographical latitude, degree of urbanisation, and quantity of "slow traffic") it is to be expected that the effectiveness of such a measure would not be smaller, but possibly higher in the Netherlands than in Sweden.

2. It is hard to judge the cost-effectiveness of the measure. The costs are dependent on the chosen option. The profits depend on the extent of daytime running lights were already used before it became compulsory.

3. The effectiveness of daytime running lights is not equal for all road users. A detailed analysis of the Swedish data and of the results of research justify the expectation that especially cyclists and pedestrians will have an advantage of the measure. There is no reason to expect a shift within these groups regarding the risks of subgroups. Motorcycle riders will loose their exceptional position but are not expected to run a higher risk because of the measure.

The conclusions are based on an analysis of available data, both of accidents and of research. In a number of cases supplementary research is needed to confirm or put into more detail the conclusions:

- knowledge on the use of daytime running lights and its course in the Netherlands now, before using daytime running lights measure is officially discussed;
- knowledge on the level of costs and their compositions of various options of introduction and various ways of providing vehicles with daytime running lights;
- knowledge on the conspicuousness of 'other' road users (bicyclists, pedestrians, and motor riders) close to cars with their lights on;
- knowledge on the behaviour of drivers and changes in connection with the use of daytime running lights;

- knowledge on the fundamenteal aspects of perception in traffic more in particular on the connection between conspicuousness and recognition of traffic participants in (complex) situations;
- knowledge on the processes of perception of the 'tableau' and the reconstruction, of its visual selection and the making of the (correct) priorities for perception;
- knowledge on the possibilities and restrictions of (international) nature to introduce the measure in the Netherlands.

12. RECOMMENDATIONS

On the basis of the foregoing report the following recommendations are made:

1. In the Netherlands compulsory of daytime running lights should be introduced for all motorized vehicles. It remains compulsory to use lights in the dark and other circumstances, explicitly described.
2. Compulsory daytime running lights should include the rear lighting of motorized vehicles.
3. It is recommended to change the requirements for the equipment of motorized vehicles in such a way that the lights are automatically switched on when the vehicle is started and the lights to be used at night are not switched on.
4. It is recommended to supplement the requirements for the equipment of motorized vehicles that all vehicles will be equipped at the front with special lamps to be used by day. The lights should meet requirements that are yet to be formulated.
5. The standards for the running lights to be used by daytime should be equal to the Swedish ones, regarding colour, light intensity, and its distriction for the front side of motorized vehicles, and also the way to switch them on.
6. Compulsory of daytime running lights should be introduced as soon as possible.
7. The measure should be introduced step by step. The first step might be to immediately recommend the use of daytime running lights and state the standards. The second step might be to make of daytime running lights compulsory as soon as legislation (national and international) is possible. The use of sidelights or low-beam headlamps should be permitted. The third step might be to compulsory change the equipment of motorized vehicles, in such a way that new vehicles can only be admitted if complying with the standard, with a transition period in which the use of side lights and low beam headlamps is permitted.
8. The introduction of the daytime running lights should be monitored by research which may also serve as evaluation research.
9. Further research on the subjects mentioned in this report should be executed in time that the definite measure is in preparation.

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Comparative studies in the USA		Effect
Cantilli (1965, 1970)	238 modified vehicles compared to control group	-18%
Allen & Clark (1964) (Greyhound Bus)	One year 24 hours lights on compared to preceeding year	USA -12% Canada -24%
Attwood (1981) (AT&T LongLines)	One year 24 hours lights on compared to preceeding year	Average -32%
Attwood (1981) (Checker Cab)	Taxicabs with 24 hours lights on compared to other taxicabs	-7.2%
Stein (1984)	More than 2000 vehicles with automatic attention lights compared to control group	-22%
Before-and-after studies in countries with DRL-obligation		
Finland (Andersson et al., 1976)	Before and after DRL-obligation in winter outside built-up areas	about-25%
Sweden (Andersson & Nilsson, 1981)	Before and after universal DRL-obligation	-11%

Table 1. Accident reduction found in comparisation fleet-owner studies and before-and-after studies in countries with DRL-obligation (after Polak, 1986).

	Average latitude	Effect	Remarks
Finland (60°-70°)	65°	-25%	Winter outside built-up areas
Sweden (55°-68°)	61°	-11%	DRL usage from 55% to 98%
Canada (41°-70°)	55°	-24%	Busses
New York (40°)	40°	-18%	Port authority vehicles
USA (29°-49°)	39°	-18%	Four fleet owners

Table 2. Accident reduction for DRL-use according to geographical latitude.

	Summer		Winter		Total
	in	out	in	out	
Conflict between motor vehicle					
head-on	-13	-8	-8	-11*	-10
side	-12	+25	-13	-15	-9
rear-end	-2	+4	+6	-16	-2
Conflict vehicle vs bicycle	-25*	-19	-10	-18	-21
Conflict vehicle vs pedestrian	-27*	+7	-7*	-9	-17
Total	-19	-3	-8	-13	-13

* significant at 5% level

Tabel 3. Changes in accidents according to accident type (in %) according to urbanisation (in: winter built-up areas, out: outside built-up areas). After Andersson & Nilsson, 1981, p. 28, Table 11.