Daylight Running Lights in Sweden

Pre-Studies and Experiences

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Published as SAE Technical Paper Series No. 810191, Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, USA.
Daylight Running Lights in Sweden—Pre-Studies and Experiences

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International Congress and Exposition
Cobo Hall, Detroit, Michigan
Since most of the information acquisition in road traffic is made by the visual channel the correlation between accidents and visual performance of involved drivers should be high. Furthermore the most common explanation that is heard at traffic courts as explanation to accidents is "I did not see him in time". It is therefore amazing that in spite of numerous studies only very low correlations (r<.1) are reported (1, 2). One explanation is that we are not studying the relevant visual functions. What then are the relevant visual functions? During the history of man we have been both hunted and hunters. In those two roles the detection of moving creatures (attacking or escaping) in the peripheral visual field was a matter of life and death. And according to Darwin what was important to survival soon became a characteristic feature of the species. The attacking and escaping animals in the history of man were really moving - jumping, running, flying etc. However, in present road traffic the "attacking" vehicles are not really moving. They are silently and without any inherent motion sneaking up on us at a very high speed. Therefore this inherited talent of ours does not function in the fight for survival in traffic. We have to replace the historic motion by something that gives the same type of peripheral conspicuity to vehicles. This is in fact the general background to the introduction of daylight running lights in Sweden.

CONSPICUITY

From psychophysical point of view the detection of a visual target is determined by its
- contrast against background (brightness and colour)
- angular size
- motion

The size of a vehicle cannot be increased just to increase its conspicuity. Some suggestions have been put forward how real motion could be introduced to vehicles - e.g. on the front of trains to scare reindeers in the northern areas where this is a real problem.

*Numbers in parantheses designate References at end of paper.

ABSTRACT

The usage of daytime running lights in Sweden started at the end of the 60:ies. The behavioural studies of various measures to improve vehicle daylight conspicuity started at the same time. The conspicuity of oncoming vehicles was analyzed for drivers in real traffic. Brightness and colour contrast were found to be the most common causes to detection. The effect of different vehicle colours and lighted low beams on detection time was studied.

The low beam condition was in all situations as good as the best colour. Many field experiments of peripheral detection as a function of running light intensity were carried out. Various types of running light systems were developed. The costs of a running light were calculated. A running light specification (intensity: 300 - 800 cd) and a law concerning its use (1 Oct. 1977) were written. The accident analyses indicate a very favourable effect of daylight running lights on collision accidents in daylight.
But for motor vehicles on the roads this is no realistic method. Consequently, what remains to manipulate is contrast. A considerable number of studies have been carried out to study the contrast sensitivity of the human visual system. Blackwell (3) is the largest and most well known. What has been done in the Scandinavian countries is mainly to study directly or indirectly the safety effects of changes in contrast between vehicle and background. The lower the illumination level the higher the contrast has to be to reach the same conspicuity. There are special Nordic reasons for trying to increase the contrast between vehicle and background. We have a generally lower level of ambient illumination due to comparatively low altitude of the sun. In December the sky illumination in Washington is five times that of Stockholm. In June the dawn and dusk periods in Stockholm are about three times as long as in Washington. The proportion of overcast daylight hours per year is in Washington 43% and in Stockholm 56%. The effect of overcast is larger when the sun is low. Low standing sun is also a considerable glare source that may decrease contrasts in the visual field (4).

NORDIC STUDIES

As mentioned before the studies of safety can be direct (effects on accidents) or indirect (behavioural). The direct methods seem very accurate with several decimals in the figures. But the results have to be treated with great caution. Accidents as a criterium is not too reliable. There are a great many factors behind an accident, and it is really difficult to isolate the effect of a single cause.

The indirect (behavioural) studies can be split up into
- calculations based on laboratory data
- laboratory experiments
- full scale experiments
- real traffic observations

All four types have been used in the Nordic studies. The drawback with the indirect studies are that the obtained effect is very difficult to translate into real safety figures.

First an account is given of the use of lights on during daylight hours in Sweden before the law. Thereafter the behavioural studies are described. Then the few studied technical and economical aspects are reviewed. Finally the results of the accident analyses, the usage after the law and some practical experiences are reported.

PRELAW USE OF DAYTIME LIGHTS ON

Sweden changed over from left to right hand traffic in 1967. In that specific situation it was considered important to have high peripheral conspicuity on vehicles since road users would probably often look in the wrong direction.

Therefore the use of low beam during daylight was promoted by road safety organisations. However, the usage was never very high - only about 2% in clear weather (5). In the summer of 1974 the usage in clear weather was up to 10%, in the autumn of 1976 the corresponding figure was 25%. At that time the official promoting campaign was quite intensive and both Volvo and Saab were equipping their new passenger cars with standard running lights (see below). The figures were of course very dependent on the level of ambient illumination. In figure 1 the proportion of vehicle lighting is given as a function of weather condition and sky illumination in Sweden the winter 1975/76 (6). Just before the law (1977) the usage was about 50%.

The Swedish Railways introduced daytime lights on all their locomotives already in 1966/67. In 1967 the Swedish Police made low beam during daylight hours compulsory on all their cars except for cars on special missions. The Swedish Defence Forces introduced compulsory low beam on all their vehicles in 1969 (with the exception for war and manoeuvres!). Several separate trucking and bus companies introduced the same rules at the end of the 60:ies. All experience reported was in favour.

Fig. 1 - Usage (%) of daytime running lights in Sweden 1975/76 as a function of sky illumination (lux) for various weather conditions
and those who introduced the rule kept it until the law was introduced in 1977. However, no real follow up studies were made - not of effects on accident nor of effects on vehicle costs. Official and other road safety organisations, the large motorist organisation and a majority of the public were during this prelaw period very positive to the concept of lights on during daytime in order to increase vehicle conspicuity. One prominent ophthalmologist (7) and several other individuals thought the idea completely crazy - dangerous due to glare and very costly due to increased petrol and bulb consumption.

In Finland the situation was comparable up to 1968. After that the Finnish authorities moved faster concerning daytime lights on and already in 1969/70 the usage was as high as about 50%. Norway on the other hand has moved slower and in spite of some official campaigns the usage 1975/76 was only about 2%. In Denmark no official campaigns were carried out and the usage in 1975/76 was very low.

BEHAVIOURAL STUDIES

At the end of the 60:ies Dahlstedt & Rumar (8) carried out a study of causes for the detection of oncoming vehicles in rural traffic. Colour slides and verbal descriptions were taken at the moment of detection in real traffic. Their results show that brightness contrast (colour, silhouette, flashes, headlights) is the dominating single factor (> 80%) both during summer as well as winter. Colour contrast occurred in some cases at high levels of general illumination (~ 15%). Motion was the smallest single cause (5 - 10%). When headlights (low beam) were on this was invariably the cause for detection.

On the basis of these results Dahlstedt & Rumar made some laboratory studies of the conspicuity of 16 various car colours with and without headlights against some common traffic backgrounds. The subjects were to detect "the vehicle" on a colour picture projected for a very short time in front of them. Detection time was the criterium. The results show that optimal colour for conspicuity changed with background. But as soon as the background was not the sky or a snow field, headlights on gave the same effect as the best colour. After these results the study of car colour was abandoned, and the following studies of vehicle conspicuity were made with lights.

Rumar and Hörberg have in several studies (9, 10, 11, 12) systematically investigated the central and peripheral conspicuity of oncoming vehicles as a function of vehicle lighting intensity, surface and colour and as a function of level of ambient illumination and peripheral angle. Other smaller studies with related purposes are also reported (13, 14, 15).

The results show that central vision vehicle conspicuity is improved even by very weak lights (~ 50 cd). But as Rumar argues (12) it is the peripheral conspicuity that is important. It is in situations when a vehicle appears where it is not expected (fixated) that the issue may be critical that the situation may develop to an accident.

In 60° peripheral vision a considerably higher intensity (> 400 cd) is needed to improve vehicle conspicuity between 3 000 and 6 000 lux sky illumination. At 30°, an intensity of 400 cd almost doubles the detection distance of a car compared to the same car without lights (see figure 2). At 20° the detection distances are improved by running lights of 100 - 300 cd at about 1 000 lux sky illumination or lower (see figure 3).

No real difference between lighting colour (white and yellow) and lighting surface (70 and 200 cm²) was obtained. A correctly aimed standard European low beam gives 350 - 450 cd into the eyes of an oncoming driver on a flat straight road. On uneven roads, curves, hillcrests, by misaimed headlights etc., the intensity levels might be several times higher. No real differences in estimated distance to vehicles with and without low beam as observed in rear view mirrors were reported (14).

Hisdal (16) has tried to calculate on the basis of the contrast sensitivity of the eye

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**Fig. 2** - Detection distances (m) of oncoming vehicles for two peripheral angles (30°, 60°) as a function of running light intensity (cd)
The probability to miss during a one second observation at a distance of 100 m, in dawn/dusk illumination, an oncoming vehicle with and without low beams. According to Hisdal the risk for a miss would be about 12% for an oncoming vehicle without light and almost none for a vehicle with low beams.

One of the arguments against daytime lights on has been the possible masking of braking lights by the rear position lights. In a Swedish study (17) this was tested at peripheral angles 2°, 5° and 10° with reaction time as a criterium and no masking effect was found.

In the discussion of suitable intensity levels of a daylight running light the possible use of the running light during darkness within lighted areas (city beam) has been a complication. Hörberg & Rumar (9) argue for a daytime intensity in the interval 1 000 – 500 cd and a nighttime intensity in the interval 100 – 50 cd. They suggest an area of at least 70 cm² and a yellow or white colour. In their later study (11) they seem to favour a lower intensity. Hisdal (18) considering a double use (day and night) argues for an intensity of about 1/5 of the low beam. Hörberg & Rumar (9) suggest as a compromise day and night intensity ~ 200 cd and an area of 50 cm².

RUNNING LIGHT ALTERNATIVES

The daytime running light alternatives that have been discussed in Sweden are standard low beam (incandescent or halogen), special running lights, fortified position lights, reduced low beam, reduced high beam, standard or reduced front curve and fog head-lights, cornering lights. The standard low beam has always been and will probably in the future be accepted.

The other solutions are still under discussion but accepted.

Special running lights to place on or under the front bumper are presently mounted on about 15% of the cars. After a long discussion a Swedish standard mainly dealing with light distribution was accepted in 1978 (19). The standard (see figure 4) corresponds to ECE Regulations on e.g. front position lights but the illuminating surface should be ≥ 40 cm² and the central intensity should be ≥ 300 cd and < 800 cd. The colour could be white or yellow but is in practice yellow. These special running lights cost about $ 20 and normally use 21 w long life lamps.

Fortified parking lights was the solution chosen by Volvo when they in 1975 introduced the running light as standard equipment on their passenger cars. The bulb has two filaments 5 w (position light) and 21 w running light: (both filaments). This running light gives 300 – 400 cd straight ahead and has very good conspicuity at large angles.

Reduced low beam was the initial solution of Saab when they introduced their standard running lights in 1975. A resistor of about 4Ω is inserted in the circuit and this reduces the luminous output with about 50%. The life time of the bulb will be about ten times as long (4). Initially there was a fear that since lowered voltage destroys the halogen process in the bulb this would create a problem. However, both laboratory and field experiences show that even if some blackening of the bulb takes place this is reversible and disappears when full voltage is applied again.

Reduced high beam has been sold to a small extent as auxiliary equipment. As mentioned above the halogen bulb does not appear to be any problem. But the conspicuity at large angles and the reddish colour due to large voltage reduction are problems. This solution will probably be prohibited in Sweden.
Standard and reduced curve lights have not really been used to any extent. Cornering lights combined with running lights and parking lights were introduced by Saab as a standard in 1977.

RUNNING LIGHT COSTS

The costs for various alternatives of day-light running lights have been calculated in various ways. The method used in Sweden (20) was to split it up into installation costs (old and new cars) and running costs (bulbs and petrol).

The calculations of installation costs gave the following results ($).

<table>
<thead>
<tr>
<th></th>
<th>new</th>
<th>old</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard low beam</td>
<td>manual</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>automatic</td>
<td>3</td>
</tr>
<tr>
<td>Reduced low beam</td>
<td>manual</td>
<td>7</td>
</tr>
<tr>
<td>(12V+10V)</td>
<td>automatic</td>
<td>8</td>
</tr>
<tr>
<td>Special running lights</td>
<td>automatic</td>
<td>25</td>
</tr>
</tbody>
</table>

The theoretical calculations of yearly running cost are based on an increased burning time of 150 hours, the simultaneous use also of the other lamps on the passenger car, a petrol price of about 50 cents per liter and a petrol consumption of .09 litres for production of 100 w electrical effect per hour.

The results were the following ($).

<table>
<thead>
<tr>
<th></th>
<th>Bulbs</th>
<th>Petrol</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard low beam</td>
<td>Incandescent</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Halogen</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Reduced low beam</td>
<td>Incandescent</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>(12V+10V)</td>
<td>Halogen</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Spec. running lights</td>
<td>Incandescent</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Special empirical tests of petrol consumption with and without running lights (21) resulted in a difference of about 1%.

Using an expected life time of the car of 14 years, an average driving distance per year, and an interest of 8% makes it possible to capitalize the costs as follows (in figures for comparison).

<table>
<thead>
<tr>
<th></th>
<th>Incandescent</th>
<th>100 (norm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard low beam</td>
<td>Halogen</td>
<td>150</td>
</tr>
<tr>
<td>Reduced low beam</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Spec. running lights</td>
<td></td>
<td>116</td>
</tr>
</tbody>
</table>

As can be seen the reduced low beam is the economically most favourable solution.

The conclusion is that the introduction of a compulsory daylight running light would result in an increase of automobile costs for the individual car owner of about 1%. It should be remarked that critics of daytime running lights have presented calculations that are considerably larger.

ACCIDENT STUDIES

Some studies of the effect of daytime running lights on accidents have been carried out in the Nordic countries. The first one carried out by the Swedish Road & Traffic Research Institute (VTI) in cooperation with Finnish authorities (22) concerns the Finnish situation 1968 - 1974. From 1968 to 1970 there was a general campaign for daytime low beam. This resulted in a usage of about 50%. 1970 an official recommendation was issued to use low beams outside built up areas from October 1 to March 31. The usage increased to about 85%. Finally, from 1972 - 1974 (and still) the use of low beam during the same time and the same area was compulsory. The usage now went up to over 95%.

The hypothesis tested was that the greater use of low beams should reduce multiple accidents in daylight but leave single accidents in daylight and both multiple and single accidents in darkness unaffected.

A linear regression analysis of the accident development from 1968 - 1974 gave the following results:

- Multiple accidents in daylight (MD) decreased by 32%
- Multiple accidents at night (MN) decreased by 4%
- Single accidents in daylight (SD) decreased by 4%
- Single accidents at night (SN) increased by 6%

In an effort to balance the possible effect of other measures than daytime low beam the ratio Δ was formed

\[
\Delta = \frac{MD}{SD} = \frac{MN}{SN}
\]

Standardized this way

- Multiple accidents in daylight decreased by 15% from the campaign to the recommendation period and by a further 6% to the compulsory period.

It should be noted that this large effect was obtained by an increase of daytime low beams from about 50% (not from 0%) to 95%.

The Swedish law concerning daytime running lights was introduced October 1, 1977 for cars and motorcycles and 1980 for tractors, working machines, and mopeds. The law was general - that is to say concerned all vehicles at all times everywhere in Sweden.

In a first study of the effect of the daytime running light law on accidents in Sweden the preperiod 1975 - 1977 was compared to the afterperiod 1977 - 1978 (23). The same statistical technique was used as in the Finnish study (22). However, this time it was possible to separate between rural and urban areas,
between winter and summer and between some weather conditions.

The change in usage between the prelaw and postlaw periods varies a great deal with time of year and weather condition. The usage increased:
- in clear weather during winter from 55% to 95%
- in clear weather during summer from 25% to 90%
- in overcast during winter from 80% to 95%
- in overcast during summer from 35% to 95%
- in snow or rain during winter from 90% to 100%
- in rain during summer from 70% to 95%

The results based on the same type of ratio (Δ) as in the Finnish study were the following (none of them statistically significant):

- Multiple accidents in daylight decreased
  - by 20% during winter in urban areas
  - by 17% during winter in rural areas
  - by 12% during summer in urban areas
  - increased by 3% during summer in rural areas
- The weather conditions gave no clear cut results

The winter effect seems quite stable while the summer effect shows considerable variation. Again it should be noted that these results were obtained by comparison between two high usage periods (roughly 50%) and a very high usage (about 95%). Both the usage figures and the obtained effects on accidents coincide well with the results from the Finnish study.

Presently, also the effect during the second year after the law (1978-1979) is studied. Some modifications of statistical analyses have been introduced. The preliminary results (24) indicate lower but more stable effects.

The Swedish Road Safety Office (TSV) has also studied the effect of the running light law on Swedish accident statistics (25). The method corresponds closely to the VTI-method, but as a control TSV has been using rear end accidents instead of single accidents. They have also split up the multiple accidents into various types (overtaking, turning, oncoming etc.), finally they have been using a longer prelaw period (1970-76). This technique has given larger and significant results in favour of daytime running lights.

The conclusion is that daytime running lights reduce daytime collision between motor vehicles and other types of road users. The size of the reduction seems to be 5-15%.

GENERAL EXPERIENCES

The public attitude to a running light legislation the year before the legislation was very good (26). Among those already using daytime lights on, about 90% were in favour, among those not using lights, 30-40% were in favour. The number of young drivers and drivers driving long distances were overrepresented in the lights-on-group. After the law the general attitude is still very good. An indication of that is the still very high usage - close to 95% except for large cities where the usage is about 85% (27).

The criticism has come from bus and truck companies who claim that the increased costs due to increased bulb exchanges and petrol consumption are substantial since they have a large number of vehicles. One of the reasons for their criticism is that at the time of introduction only the front lights were compulsory. Due to misuse in dawn and dusk periods this was later changed and now also the rear lights are compulsory. Especially for trucks with trailers and side marker lights this makes a large difference.

In Sweden headlight cleaners are compulsory on cars built 1976 or later. This means that running lights of type low beam, reduced low beam or reduced high beam are constantly kept clean. On the other hand the other types of running lights - especially the low mounted special running lights often get very dirty. They often have only half or less of the original intensity. Another argument that also goes in favour of the main headlights is that since they are also used for night driving any faults (e.g. a burned out bulb) are quickly corrected.

In Finland there are proposals to make the limited daytime running light law general, that is to extend it over the whole year and also include urban areas. In Norway the authorities are discussing for and against a daytime running light law. Denmark has a general daytime running light law for motorcycles and presently there is no intention to extend it to other vehicles. The main argument against a law is of course the energy shortage.

The Swedish authorities are presently preparing to make a suggestion to ECE (UN) concerning an international regulation for a daytime running light. The idea is to coordinate the effort with the Finnish authorities which among other things probably would mean that the suggested acceptable intensity level will be somewhat higher than 300-800 cd.

The general conclusion is that daytime running lights by compensating the low visual peripheral sensitivity for oncoming vehicles, do function as an effective accident countermeasure.

REFERENCES
