THE USE OF DAYTIME RUNNING LIGHTS (DRL) IN THE NETHERLANDS

Methods of analysis to link user data to accidents and a description of the use of DRL in the Netherlands from November 1, 1989 to October 31, 1990

R-91-37

J.E. Lindeijer & F.D. Bijleveld

Leidschendam, 1991

SWOV Institute for Road Safety Research, The Netherlands

SUMMARY AND RECOMMENDATIONS

Summary

During the period November 1989 to October 1990, monthly measurements were carried out to study the use of daytime running lights (DRL) by motor vehicles at 26 different locations in the Netherlands. The measurements were taken between sunrise and sunset. 1,057,547 motor vehicles were observed, subdivided on the basis of the following vehicle categories:

- 945,052 passenger cars, 26.3% of which with DRL;
- 84,488 lorries and vans, 36.6% of which with DRL;
- 10,437 motor cycles, 81.0% of which with DRL;
- 17,570 mopeds, 25.2% of which with DRL.

An analysis of the first twelve months of measurement justifies the following conclusions:

- Based on the use of DRL, it is possible to select DRL-related accidents from the accident data. DRL-related accidents are classified as accidents occurring in the daytime and involving at least two parties, one of which is a motor vehicle.
- The light intensity appears to be the principal variable (for a large group of drivers) explaining variations in the measured use of DRL. The accident data does not record this variable. Therefore, the light intensity during accidents will have to be estimated with the aid of a formula to calculate the altitude of the sun.
- Aside from the light intensity, weather, visibility and road surface conditions also affect the use of DRL. The poorer these conditions, the greater the percentage of DRL measured, also in the middle of the day. When linking the use of DRL to accidents, it is not possible to distinguish between different dry weather and visibility conditions as can be done on the basis of the gathered use of DRL. As a result, different weather conditions should be combined.
- During the winter months (November to January), the hours during which the lowest percentages of DRL (based on hourly totals) were measured during dry weather were between approx. 10.00 a.m. and 3 p.m. and from February to October between approx. 9.00 a.m. and 5 p.m., with the exception of July and August (between 7 a.m. - 8 p.m. and 8 a.m. - 6 p.m., respectively).

The percentages measured during these periods (based on hourly totals) vary from approx. 4% to 22%, with the exception of January, when these percentages varied between approx. 20% and 24% (between 10.00 a.m. - 1 p.m.).

- In addition, factors influencing the use of DRL appear to be location related. Examples of differences include: on roads inside versus outside the built up area, type of road, geographic area and working day versus weekend day, as well as the influence of interactions between these variables.
- Extra measurements have established that the use of DRL on polder roads differs from the use of DRL on 80 km/hr roads included in the measurement system. It is therefore recommended that polder roads be included in the set measurement programme.
- In October and November, 1990, speed measurements were conducted on 80 km/hr roads outside the built up area, whereby in a reasonable number of cases a distinction was made between vehicles with and without DRL. In dry weather, the cumulative speed distributions of both categories were found to be identical. Differences measured during wet weather may be explained by location-related factors. In addition, the distributions of the weighed percentages of DRL on these control roads would indicate that they correlate reasonably well with the distributions measured on the 80 km/hr roads during the DRL survey.

Recommendations

It was decided, on the basis of previous experience and "common sense" considerations, to set up the measurement network in such a way that those variables which were expected to influence the use of DRL would be included.

Based on the results of the analysis, it can now be concluded that it would not have been wise to exclude even one of the selected variables, or to combine variables or restrict their measurement. More significantly, there are indications to suggest that the use of DRL on polder roads (as a result of additional measurements, supplementary to the measurement programme) deviates significantly from the use of DRL on the 80 km/hr roads included in the measurement network. Should this inclusion exceed the budget allowance, then a choice based on the following considerations is recommended. The collection of data on the use of DRL is primarily intended to ensure a sound evaluation study.

This means that it is not only necessary to assess the relevance of a variable in the use of DRL, but also to judge the importance of a variable in relation to accidents.

If the introduction of a compulsory DRL measure is considered, it would be advisable to plan the date of commencement for the end or beginning of the year.
In order to realise the greatest possible response, it would be advisable to plan the information campaign leading to the introduction of DRL for September.

CONTENTS

FOREWORD

Prior to the possible introduction of a measure related to the use of daytime running lights (DRL), the SWOV was asked by the Transportation and Traffic Research Department (DVK) of the Ministry of Transport to measure the use of DRL. The study commenced in November 1989. This assignment represents part of an evaluation study into the effect of a DRL measure, as described in an earlier report: Daytime running lights; A master plan for an evaluation study in the Netherlands (SWOV R-89-49).

The effect of DRL in terms of a reduction in the number of accidents must be investigated. In addition, it must be established to what degree and for what type of accidents and/or groups of road users DRL contributes to road safety. This means that the data collected on the (current) use of DRL must be linked to accident data. The measurements were conducted by a permanent group of ten observers at all times of year, under all weather conditions and from sunrise to sunset. As a result of the perseverance and dedication of this group, the reliability of the collected material is great; this was confirmed on the basis of simultaneous measurements. Over a period of twelve months, over one million vehicles were observed.

Based on a description of the use of DRL in the Netherlands from November 1, 1989 to October 31, 1990, an explanation is given of the variables selected. This is followed by a discussion of the analytical problems associated with linking the measured use of DRL to accidents, and how and with which techniques these problems can be overcome.
This report was written by Mrs. J.E. Lindeijer. The analysis of measurement data was conducted by Mr. F.D. Bijleveld.

1. INTRODUCTION

1.1. General

From November 1, 1989, monthly measurements were carried out to assess the use of daytime running lights (DRL) at various locations distributed throughout the Netherlands (see also Appendix I). The measurement data collected during the period November 1989 to October 1990 were analysed. The set-up of the measurement programme was based on the assumption that the use of DRL would be influenced by various factors or variables, such as:

- The light intensity: at twilight and when it is 'dark', drivers will switch on their lights. For this reason, the measurement times were distributed over the day as much as possible, where the day commences at sunrise and finishes at sunset.
- Weather and visibility conditions: For many years, the use of DRL during poor weather conditions has become a matter of course for many drivers.
- The seasons: This variable can be considered as a derivative of the light intensity. Nevertheless, it is expected that the seasons exert their own influence, independent of the light intensity. One assumption, for example, is that people are more likely to switch on their lights in winter than in summer, even with similar light conditions.
- Other variables, such as: type of road, type of day and hour of the day; it is assumed that people's lighting behaviour (lights on/off) is also influenced by considerations other than the light intensity and weather conditions. To gain an insight into this factor, measurements were conducted:
- on various types of road outside the built up area, such as motorways, secondary roads (100 km/hr) and other roads (80 km/hr);
- on roads inside the built up area, such as through roads and local roads (in residential areas);
- on different days of the week;
- at different hours, distributed throughout the day.

In practice, the abovenamed variables often manifest themselves in particular combinations, but in principle, different situations and different conditions will lead to the measurement of different user percentages. Data on the use of DRL are used for the following purposes:
- to describe the use of DRL in the Netherlands;

- the accident study (evaluation study);
- evaluating the influence of information campaigns on the use of DRL (untill now no information campaigns have been held).

For the sake of clarity, the set-up and execution of the measurement programme, analysis results of the reliability of the data collected and tables and diagrams have been included separately.

1.2. Description of the use of DRL

Chapter 2 offers a description of the differences in the use of DRL in the Netherlands in various situations and under various conditions. The description shows that the variables selected with the set-up of the measurement network (based on assumptions about the degree of influence on the use of DRL) all exert their own influence on the use of DRL.
The differences in the use of DRL will be illustrated on the basis of percentages measured during bright daylight, subdivided according to dry and wet weather (see also par 1.3). Why and how these percentages were arrived at is described in Chapter 3 to 6.

1.3. General problem of analysis

Everyone uses their lights at night, but as the light intensity increases, each driver decides when to turn his lights off (or on, when it becomes darker). The principal motivation is therefore the 'light intensity'. But even in broad daylight, some drivers will switch on their lights, regardless of the light intensity. In other words, it is possible to distinguish between two driver categories (populations), i.e. the group which (mainly) uses lights as a function of the light intensity and the group which uses lights independently of this factor, i.e. based on motivations other than the light intensity. For example, some people will use DRL on motorways but not on 80 km/hr roads, or during overcast conditions outside the built up area, but not inside the built up area under the same weather conditions, etc.
This latter group is an important one for the accident study, when trying to establish the effects of the use of DRL in specific situations and/or under specific circumstances (for more information on the 'analysis of specific effects', see Lindeijer et al., 1990). In addition, this group is

also important in order to describe the differences in the use of DRL and to evaluate the influence of information campaigns.
However, this creates a problem with the analysis of the material. The collected material offers 'DRL distributions as a function of the light intensity', which must then be subdivided on the basis of the principal factors of influence affecting lighting behaviour. In other words, the distributions are composed of two populations, distinguished according to whether or not their lighting behaviour is influenced by the light intensity. An analysis method must be selected which 'estimates' what proportion of the total DRL distribution measured represents the group that acts independently of the light intensity. It must be established what situations and/or circumstances influence this group with regard to the resultant use of DRL. The estimations must be carried out on the basis of the collected material. This material consists of observations over a five minute period. In the course of the measurement year, over 45,000 five-minute time units were collected, in which over 1,000,000 vehicles (= observations) were counted. The smallest unit of time on which calculation of a user percentage can be based is therefore five minutes. However, it does happen that during such a five minute period, only one, two or even no vehicles are counted. Low intensities are primarily found during the period before seven a.m. in the morning and after 7 p.m. at night, in the summertime. Even in the middle of the day, the intensities measured are significantly less than those recorded during peak times. An analysis method must therefore be found that can cope with the problem of large fluctuations in the available material. The most suitable method proved to be the analysis method offered by the PROBIT model. Practical application of this model then demonstrated a technical processing problem (Bijleveld, 1991). The massive quantity of data proved to be an obstruction. Halving the quantity (by combining raw data to give observations over a ten-minute period) proved to be an adequate solution. This choice also reduced the number of time units with a minimum number of observations. Chapter 3 will discuss the backgrounds to the choice of an analysis model, following by discribing the method of analysis in greater detail.

1.4. Processing and linking problems

Aside from the overall analysis problem, the following difficulties may also be defined:

- The <u>transformation</u> of the variable 'light intensity' for the purposes of the accident study. The light intensity was shown to be the principal explanatory variable for the use of DRL on a voluntary basis. However, the light intensity as such is not recorded in the accident data. The accident study must estimate this factor on the basis of substitute variables that are given in the accident data, e.g. hour of the day and date. Chapter 4 describes how this problem was solved.
- The <u>selection</u> of DRL-related accidents for the accident study. DRL-related accidents are accidents which have occurred (and do occur) in the daytime, where it is expected that the use of DRL is an influential factor. If a significant drop in accidents can be established, the greatest probability of this occurring is anticipated during those times of day when the use of DRL has risen most markedly following introduction of the (compulsory) DRL measure. It is important for the evaluation study to make the greatest possible distinction between times of day when the use of DRL was lowest (where factors of influence other than the light intensity play a role) and times of day where use is already quite high (e.g. during twilight), using user data from the preliminary period. Previous evaluation studies into the effect of the use of DRL on accidents (conducted in Scandinavian countries) did not make such a distinction, partly due to lack of proper preliminary measurements, which weaken the conclusions drawn and enables alternative explanations for the measured effect in retrospect. The problem of selection is discussed in greater detail in Chapter 6.
- The <u>combination</u> of types of weather and visibility conditions for the purposes of both the accident study as well as the description of the use of DRL in the Netherlands. Weather conditions are important variables, which, in addition to the light intensity, clearly influence the use of DRL on a voluntary basis. It is therefore important to make the greatest possible distinction between different types of weather, conditions of visibility and whether the road is wet or dry. This information is covered in less detail in the official accident registration, when compared with the user data collected during the study.

In order to ensure that the description of DRL use in the Netherlands did not become unnecessarily complicated, it was decided to divide the database into two sub-categories, i.e. dry and wet weather. Chapter 5 also explains how the choice for this combination came about.

1.5. Data on the use of DRL and measured speeds

It is often said that with regard to the use of DRL on a voluntary basis (as is the case at present), it is particularly the 'fast drivers' that switch on their lights in the daytime. As the months of October and November 1990 included speed measurements on 80 km/hr roads outside the built up area, this offered a unique opportunity to investigate to what extent this opinion was founded in truth.
In addition, these roads are comparable to the 80 km/hr roads in the measurement network, so that the figures can be regarded as control figures; they offer an insight into the extent to which the 80 km/hr roads included in the measurement network are representative of that category.
During part of the speed measurements, the speed of motor vehicles using DRL was noted separately. The data was analysed and the results are presented in Chapter 7.

2. USE OF DRL IN THE NETHERLANDS

2.1. General

This relates to a description of the use of DRL as collected during the first twelve months (November 1989 to October 1990) of the measurement programme. The material was collected at 9 types of location per region. The Netherlands were subdevided in 4 regions beside Amsterdam. At a number of measurement sites, two types of location could be combined. For example, in some cases a measurement location was found inside the built up area, where both traffic on a through route and on a local route could be observed. In this way, the number of measurement locations could be reduced. For this reason, the total number of required measurement sites was sometimes less than the number of locations. Outside the monthly measurement programme, extra measurements were taken on a number of polder roads and on Texel island. In order to establish the reliability of the collected data, simultaneous measurements were regularly performed (see also Appendix I).
Within a measurement period of one hour, the number of vehicles observed were recorded at five minute intervals, and the light intensity was measured with the aid of a lux meter (see Appendices I, II.2 and II.3). In total, 1,057,547 motor vehicles were counted, subdivided as follows:

Vehicle category	Light on	Light off	Total	% On/Total
Passenger cars	248,413	696,639	945,052	26.3%
Lorries	30,887	53,601	84,488	36.6%
Motor cycles	8,418	2,019	10,437	81.0%
Mopeds	4,435	13,135	17,570	25.2%
Total	292,153	765,394	1,057,547	27.6%

From January 1, 1990, it was also noted how many passenger cars using DRL drove with a defective light. The percentage over 10 months was almost 1% (N = 1806). The monthly figure also proved to lie close to 1%.

As already stated (see para. 1.3), the description will mainly rely on user percentages. These percentages are usually indicated in the following paragraphs as 'C values' or 'C%'. This is understood to mean: the percentage of motor vehicles using DRL, independent of the light intensity. For example, many motor cycles always use DRL, even in broad daylight when the sun is shining. Aside from motor cycles, a fairly constant percentage of drivers of passenger cars and lorries were also found to use DRL at all times. Partly because the lights automatically go on when the engine is switched on (e.g. Volvo and Saab) and partly for as yet unknown reasons. For the purposes of the information campaigns (and therefore the government) this group of DRL users offers a particularly good gauge to help establish to what extent the imposition of a compulsory measure would be complied with.

Reference to diagrams given in the following paragraphs will often show 'DRL distributions as a function of the light intensity', where the y axis generally represents the calculated sun altitude. Why this form of presentation was chosen is explained in Chapter 4.

The introduction also discussed the influence of weather and visibility conditions on the use of DRL. The following paragraphs often compare the use of DRL during 'dry' weather versus 'wet' weather. Chapter 5 sets out which weather types and road visibility conditions were combined under dry or wet weather categories.

The Introduction also stated that the overall analysis problems related to the selection of a time unit, based on which percentages of the use of DRL could be calculated. The time unit which allowed a reliable estimation of C values proved to be 10 minutes. The presented percentages are in most cases calculated with the aid of the analysis method of the PROBIT model and in some cases, deduced from the diagrams. Further information on the method of analysis used can be found in Chapter 3.

2.2. Use of DRL according to vehicle category

The following table offers an overview of the estimated C values and the associated standard deviations (s.d.).
For the reader's convenience, the table includes the limits of reliability (= 2 x s.d.) at a 95% reliability, rather than giving the standard deviation.

Vehicle category	Dry weather		Wet weather	
	C%	2 x s.d.	C%	2 x s.d.
Passenger cars	6.5%	1.0%	34.6%	3.4%
Lorries	9.9%	1.4%	39.9%	10.6%
Motor cycles	60.5%	27.0%	86.9%	5.6%
Mopeds	7.7%	3.6%	13.8%	15.4%

While the DRL percentage of passenger cars based on the annual total was 26.3% (see para. 2.1), this table demonstrates how large the differences for the use of DRL in the various categories are, even when we are only considering the influence of a single variable.
It is expected that a fairly large percentage of motor cyclists also uses DRL, regardless of the light intensity. The user percentage of this category can offer an indication of the anticipated percentage of DRL users if DRL is recommended for all motorised traffic. Due to the small number of motor cycles within the observation units of 10 minutes, the standard deviation is great.
During dry weather, the estimated C values for lorries (including vans), passenger cars and mopeds do not differ very much (approx. 10%, 7% and 8%, respectively), but during wet weather, the C value for mopeds (approx. 14%) is significantly less than that for the two remaining categories (approx. 40% and 35%).

Diagrams 1 to 4 show the distributions in the use of DRL during dry and wet weather as a function of the measured light intensity for the various vehicle categories, after an observation period of one year.

In a number of cases, it will be shown that the light intensity leads to different results in the use of DRL. The use of DRL is then described by indicating at what light intensity 50% of drivers still (or already) uses their lights. For example, the following table presents the estimated light intensities (expressed as the logarithms of the measured lux values), at which 50% of drivers, subdivided according to vehicle category, use lighting, with the associated standard deviation, during dry and wet weather.

In order to give an impression of what these lux values represent, the following can serve as an example: In the months of December and January, in the middle of the day during clear sunny weather, none of the lux values measured will exceed 20,000 lux. In the summer, these values, under the same conditions, increase to over 100,000 lux.

Vehicle category	Log-lux values at 50% use of DRL			
	Dry weather		Wet weather	
	mu	sigma	mu	sigma
Passenger cars	3.23	0.36	3.45	0.31
Lorries	3.41	0.35	3.64	0.38
Motor cycles*	-	-	-	-
Mopeds	2.63	0.77	3.08	0.71

* The relatively small number of motor cycles per time unit in the observations do not allow a valid estimation with the aid of the analysis method.

This table shows that moped riders are the first to respond to an increase in light intensity (they sooner switch off their lights or fail to use their lights), or respond more slowly to a decrease in light intensity than do other vehicle categories.
Drivers of lorries and vans keep their lights switched on the longest.

The large proportion of passenger cars in the observations makes it possible to describe the use of DRL according to various sub-classifications, without leading to extreme distributions due to, for example, a too-limited number of observation units at a given light intensity. The following paragraphs, 2.3 to 2.9, will therefore only relate to the category of passenger cars.

2.3. Use of DRL according to month

The importance of the light intensity was already pointed out. For this reason, we must assess to what degree the light intensity is of influence from month to month. For example, will the use of DRL as a function of the light intensity differ between summer and winter?

The table below shows the light intensities per month (in estimated log-lux values) at which 50% of passenger car drivers still have their lights switched on during dry or wet weather.

Month	Log-lux values at 50% use of DRL			
	Dry weather		Wet weather	
	mu	sigma	mu	sigma
November 1989	3.23	0.27	3.49	0.25
December 1989	3.04	0.27	3.11	0.24
January 1990	3.17	0.39	3.92	0.32
February 1990	3.12	0.31	3.83	0.42
March 1990	3.41	0.30	3.83	0.52
April 1990	3.50	0.39	3.71	0.50
May 1990	3.22	0.51	4.14	0.43
June 1990	3.46	0.39	3.67	0.30
July 1990	3.19	0.34	3.31	0.28
August 1990	3.07	0.38	3.24	0.16
September 1990	3.37	0.42	3.69	0.56
October 1990	3.31	0.35	3.98	0.53

During dry weather, the average light intensity at which 50% of drivers still uses their lights is lowest in December and August; i.e. during these months, people switch their lights off sooner or switch them on later (at comparable light intensities) than they do in other months. In March, April and June, in contrast, the lights are switched on for longer periods or switched on sooner than in other months.
For all months, it can be said that at light intensities between 1000 (log-lux = 3) and 10,000 lux (log-lux = 4), during both dry and wet weather, approx. 50% of passenger cars uses DRL, with the exception of May, during wet weather conditions.
Whether these differences are coincidental or structural (do they occur every year in the same months) cannot be answered here (as yet).

To what extent the estimated C values (percentage of DRL use, independent of the light intensity) differ <u>from month to month</u> within one vehicle category is shown in the next table, for the group of passenger cars. The table shows that in the months of April and May, during dry weather, the C values were lowest, namely between 0% and 5% in April and between 0% and 3% in May. The greatest variance outside the estimated C values is found in January, namely between 0% and 33%.

Month	Log-lux values at 50% use of DRL			
	Dry weather		Wet weather	
	C%	2 x s.d.	C%	2 x s.d.
November 1989	9.5%	3.0%	17.6%	8.4 %
December 1989	7.3%	4.3%	55.6%	7.4 %
January 1990*	13.9%	18.8%	-	-
February 1990*	8.2%	5.4%	-	-
March 1990*	5.0%	6.4%	-	-
April 1990*	0.5%	4.4%	-	-
May 1990*	0.3%	2.6%	-	-
June 1990	5.7%	2.2%	26.5%	12.8%
July 1990	7.5%	1.0%	47.7%	5.8%
August 1990	5.1%	1.8%	38.7%	3.8%
September 1990	6.1%	6.2%	22.5%	30.6%
October 1990*	4.3%	3.0%	-	-

* During these months, the analysis method of the PROBIT model did not allow a reliable estimation of C value during wet weather.

During the months that the C values could be estimated during wet weather, large differences are found between the estimated C values per month, with variations between, on average, approx. 18% and 56%. The overview shows that it is important to be able to follow the development of the use of DRL from month to month.

Diagrams 5 to 16 indicate the distributions of the weighed percentages of DRL use during wet and dry weather, as a function of the calculated sun altitude. The number of observations are aggregated and then given as an average value for each degree of sun altitude (see Chapter 4 for further information on the sun altitude).

2.4. Use of DRL according to working day and weekend day

Not location-related variables alone affect the use of DRL. The purpose of travel (ride motivation) also shows a difference in the use of DRL. Here, the variable of ride motivation is 'translated' (operationalised) into the variables working day and weekend day. It is anticipated that in the weekends, most travel has a recreational purpose, whereas on working days, measurements will largely relate to commuting traffic.
Based on the yearly total, the differences in the use of DRL (C values) between working days and weekend days, subdivided according to dry and wet weather, are as follows:

Type of day	Dry weather		Wet weather	
	C%	2 x s.d.	C%	2 x s.d.
Working days	6.6	0.8	23.1	5.6
Weekend days	5.7	1.1	44.4	6.4

While the C values during dry weather agree quite well between working days and weekend days, DRL is clearly used more frequently on weekend days during wet weather. The extent to which annual percentages during dry weather distort the differences from month to month is shown by the table on the next page.

The weekend traffic during the months of March to August was greater than in the winter months, which affects the degree of variance of the estimated C values. If only the average C values for the working and weekend days are used for comparison (seen separately from the distribution), the following differences can be seen:
- During working days in the months of November 1989 to February 1990 and in the months of July and September, the C values are higher than the annual total, while in the months of April and May, the C values are significantly less.
- During weekend days, the C values for the months of March, June, July and August 1990 are greater than the annual total, while for working days this is only true for the month of July.
- In March, June, July and August, the use of DRL during weekend days is

somewhat higher than during working days. For the remainder of the year, DRL use during those days is less than during working days.

Month (dry weather)	Working day C%	 2 x s.d.	Weekend day C%	 2 x s.d.
November 1989	9.9	2.2	0	7.4
December 1989	10.1	3.2	0	5.4
January 1990	7.2	13.2	-	- *
February 1990	8.4	3.4	0	4.8
March 1990	5.8	3.0	7.3	3.8
April 1990	0.9	3.4	0	1.6
May 1990	0	3.0	1.7	2.6
June 1990	6.1	2.2	6.3	2.4
July 1990	7.2	1.2	9.1	1.6
August 1990	3.7	1.4	8.4	1.4
September 1990	8.5	5.4	3.5	11.2
October 1990	3.8	2.4	0	7.4
Annual total	6.6	0.8	5.7	1.1

* Within time units of ten minutes and comparable light intensities, the percentages of DRL use differ too markedly to allow a reliable estimation of the C value with the aid of the analysis method of the PROBIT model.

The combination of 'month' and 'type of day' has been found to offer important information, which is useful for the accident study.

2.5. <u>Use of DRL according to inside or outside the built up area</u>

If we only consider the use of DRL inside versus outside the built up area on an annual basis, the differences in C values are found to be irregular.

Built up area	Dry weather C%	 2 x s.d.	Wet weather C%	 2 x s.d.
Inside the built up area	5.1	0.6	24.7	4.2
Outside the built up area	9.0	1.4	46.2	7.4

On roads outside the built up area, DRL is used almost twice as often as inside the built up area, during both dry and wet weather.

In addition, the influence of the light intensity on the use of DRL is different inside and outside the built up areas. Both during wet and dry weather, on average, motorists outside the built up area continue to drive for longer with their lights switched on at an increasing light intensity, or will sooner switch on their lights with a drop in light intensity, than is the case inside the built up area.

2.6. Use of DRL according to inside or outside the built up area, per road type

In every town, two measurement locations were chosen to distinguish between through traffic (main routes) and traffic in residential areas (local routes). These choices were regarded as an operationalisation of the variable for 'ride length'.
Outside the built up area, a distinction was made per region with regard to:

- motorways (max. speed 120 km/hr)
- secondary roads (max. speed 100 km/hr)
- other roads (max. speed 80 km/hr).

Based on the annual totals, the following table offers an overview showing the differences in the use of DRL inside and outside the built up areas. The estimated C values and the reliability limits (2 x s.d.) are subdivided according to dry and wet weather.

Both during dry and wet weather, DRL is used least in residential areas, i.e. 4% and 19% respectively.
A difference in the use of DRL is found between local and through routes. During dry weather, there is hardly any difference in use noted between 80 km/hr roads and secondary roads outside the built up area, compared to through roads inside the built up area. The use of DRL during dry weather is greatest on the motorways (approx. 13%).
Both on roads inside and outside the built up area, more use is made of DRL during wet weather conditions, but with greater variations, i.e. a minimum of 13% (local roads), compared to a maximum of 69% (motorways).

Built up area/type of road	Dry weather		Wet weather	
	C%	2 x s.d.	C%	2 x s.d.
Inside the built up area (total)	5.1	0.6	24.7	4.2
local route	3.3	0.6	19.3	6.0
through route	6.7	0.8	30.4	5.6
Outside the built up area (total)	9.0	1.4	46.2	7.4
motorway	12.8	2.6	48.6	20.6
secondary road	7.4	3.0	44.9	10.4
80 km/hr road	6.0	1.0	47.2	5.4

Here, too, it can be noted that the variable 'road type' shows a marked difference in the use of DRL.

2.7. Use of DRL according to region

Three provinces were combined per region, where the classification often used by the Central Bureau of Statistics (CBS) was adhered to. The regions are grouped as follows:

- North: Groningen, Friesland and Drenthe;
- East: Overijssel, Gelderland and Flevoland;
- West: Utrecht, North and South Holland;
- South: Zeeland, North Brabant and Limburg.

The top table on page 24 indicates the estimated C values and associated reliability limits per area for the category of passenger cars, subdivided on the basis of dry and wet weather.
During dry weather, the C values are highest for the Northern region (between 9% and 12%), followed by the Eastern region, with values between 8% and 10%. The Western and Southern regions demonstrate the lowest percentages, i.e between 3% and 6%.

Region	Dry weather		Wet weather	
	C%	2 x s.d.	C%	2 x s.d.
North	10.6	1.8	43.2	6.0
East	8.9	1.2	35.2	6.8
West	4.1	1.0	14.4	7.6
South	4.5	1.0	40.6	9.0

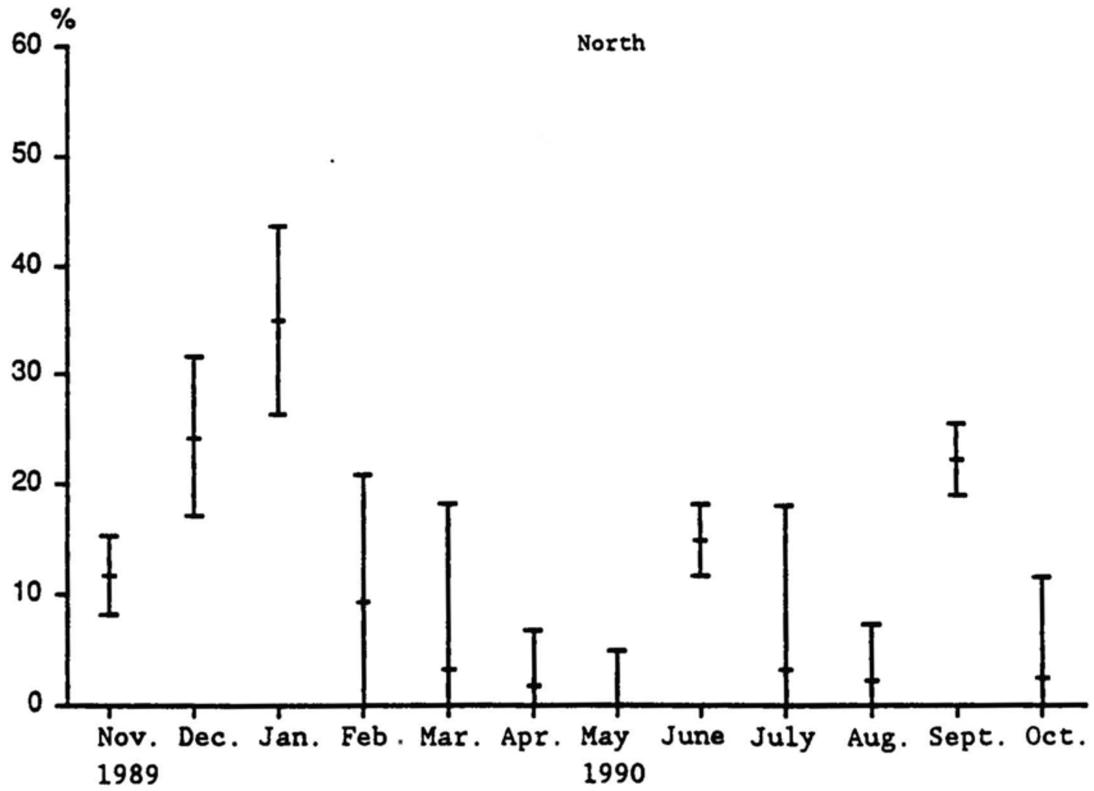
During rainy conditions, the Western region shows the lowest percentages, ie. between 7% and 22%, while the percentages for the rest of the Netherlands vary from a minimum of 29% in the East to maximally 50% in the South. The use of DRL therefore differs per region on an annual basis. The following table shows the differences per month. The estimated C values are given for dry weather per month and per region, with the associated reliability limits (2 x s.d.) for the category of passenger cars.

Month	North		East		West		South	
	C%	2 x s.d	C%	2 x s.d	C%	2 x s.d	C%	2 x s.d
November 1989	11.7	3.4	12.3	3.8	7.0	2.2	11.3	3.2
December 1989	24.3	7.2	10.4	5.4	6.5	2.8	0.0	4.4
January 1990	35.0	8.6	16.6	13.2	26.3	26.6	13.3	24.0
February 1990	9.2	11.6	14.3	6.6	4.7	3.8	4.4	5.2
March 1990	3.3	14.8	7.7	3.2	2.7	3.2	4.0	7.2
April 1990	1.6	5.0	0.0	2.8	6.4	2.0	2.6	1.4
May 1990	0.0	5.0	5.3	3.4	0.4	1.8	1.2	2.0
June 1990	14.9	3.2	8.4	3.2	3.2	1.8	0.0	2.4
July 1990	3.2	14.8	9.0	3.2	3.5	0.6	6.7	1.0
August 1990	2.2	5.2	9.0	1.0	3.0	1.0	3.3	2.0
September 1990	22.3	3.2	1.4	33.8	4.4	5.2	6.7	4.4
October 1990	2.4	9.0	0.0	3.4	8.2	1.6	4.2	4.6

For the sake of clarity, only the C values are given, without taking spread into account.

During the months December 1989 and January 1990, the highest C values on average were recorded in the North (approx. 24% and 35%, respectively), followed by the Eastern region with approx. 10% and 17%. In the Western and Southern regions, the measured variance was so great that a C value could not be given.
It is evident in this case, also, that the use of DRL is high in January, albeit with a large variance.
In keeping with expectations, the use of DRL drops markedly after February and remains low up to and including October, with the exception of June and September in the Northern region, with approx. 15% and 22%, respectively.
For the distribution of estimated C values during wet weather, we refer to Table 2.
It is again pointed out that the number of time units incorporated under 'wet weather' conditions is fairly low, so that when estimating percentages, the variance outside the estimated values was sometimes great, or the analysis method of the PROBIT model did not allow an estimation.

The diagram below illustrates yet again how different the use of DRL is over time, and how great the variance outside the calculated C values can be. A graphic representation of the use of DRL in the Northern region was chosen. For the other areas, please refer to Diagram 35 to 38.



2.8. Use of DRL according to region, inside or outside the built up area

The previous paragraphs offered an overview of the differences between the various regions and between inside versus outside the built up areas. This paragraph deals with the differences in the use of DRL when the influence of other variables is taken into account. In other words, in what way do both variables influence each other with regard to the use of DRL?

The table below offers an overview of the influence of the light intensity on the use of DRL. The table give the estimated log-lux values at which 50% of drivers still uses DRL, subdivided according to dry and wet weather.

Region/built up area	Log-lux value at 50% use of DRL			
	Dry weather		Wet weather	
	mu	sigma	mu	sigma
North				
inside the built up area	3.27	0.35	3.43	0.29
outside the built up area	3.69	0.31	3.58	0.37
East				
inside the built up area	3.13	0.34	3.43	0.35
outside the built up area	3.62	0.30	3.87	0.24
West				
inside the built up area	3.11	0.38	3.46	0.36
outside the built up area	3.21	0.28	3.73	0.41
South				
inside the built up area	2.85	0.32	3.31	0.40
outside the built up area	3.42	0.34	3.51	0.32

During dry daytime conditions, half the number of drivers in the Southern region will more readily use (with increasing light intensity), or will continue to use (with a drop in light intensity), DRL than in the rest of the Netherlands. During wet weather, drivers in the East and West continue to drive with DRL for longer periods as the light intensity increases, or will sooner switch on their lights when the light intensity drops.

The percentage of DRL use during dry and wet weather inside and outside the built up area are represented according to region in the following table.

Region/built up area	Dry weather C%	Dry weather 2 x s.d.	Wet weather C%	Wet weather 2 x s.d.
Total inside the built up area	5.1	0.6	24.7	4.2
Total outside the built up area	9.0	1.4	46.2	7.4
North				
inside the built up area	8.4	1.6	39.9	5.8
outside the built up area	15.7	3.2	53.6	13.8
East				
inside the built up area	6.5	1.1	25.6	8.6
outside the built up area	15.6	2.4	44.5	12.1
West				
inside the built up area	3.9	1.1	22.4	8.1
outside the built up area	4.5	1.5	3.3	13.0
South				
inside the built up area	2.5	0.6	16.3	9.4
outside the built up area	6.5	2.1	58.3	9.5

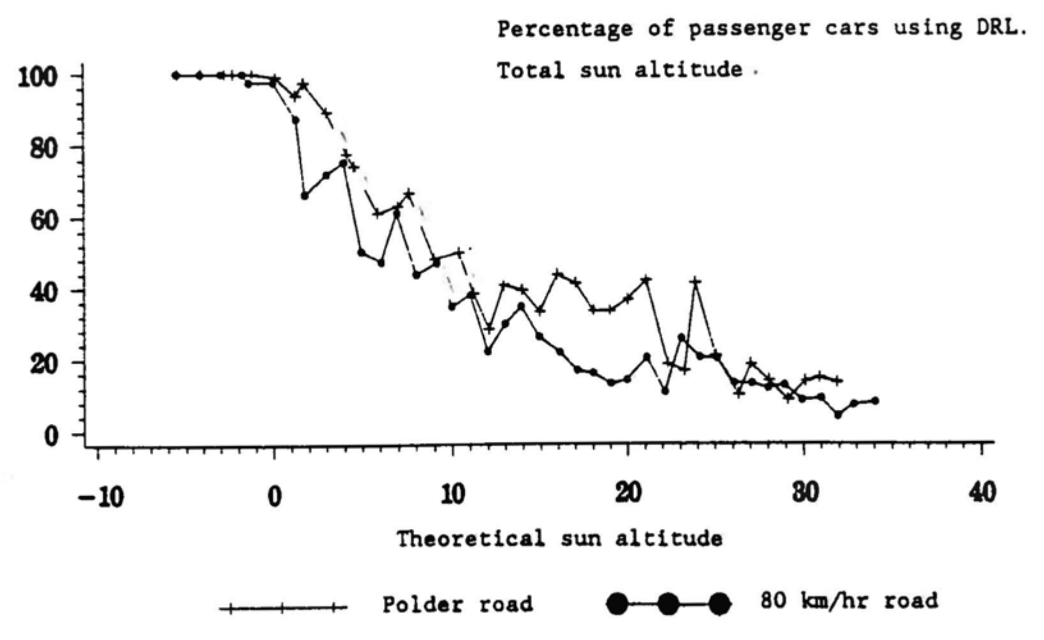
During dry weather, the principal differences are:
In the Northern and Eastern regions, during dry weather and clear daylight conditions, an equal number of people will use DRL outside the built up area on average, i.e. approx. 16%. The average percentage is clearly greater than the national average of approx. 9%. The Western and Southern areas show an average value below the national figure, i.e. approx. 5%.
On roads inside the built up area, the percentage for the North and East is approx 7%, the national figure is approx. 5% and in the West and South, approx. 3%.
Therefore, none of the calculated percentages deviate greatly from the national average.

During wet weather, the principal differences are:
In the Eastern and Western regions, during wet weather inside the built up area, daytime measurements show that approximately the same number of people uses DRL on average, i.e. approx. 24%, which corresponds reasonably well with the national average of approx. 25%, albeit that the variance outside the percentages is greater for the regions than is the case on a national basis.

The percentages for the North (approx. 40%) and in the South (approx. 17%) are the most extreme, both with regard to each other and with regard to the national percentage. Strangely enough, the user percentages during wet weather outside the built up area in the Northern and Southern regions not only correlate reasonably well (approx. 56%), but are also higher than the national average of approx. 46%. For the East, the user percentage under such conditions is approx. 45%, and therefore agrees quite well with the national average, while the West, with percentages between 0% and 13%, deviates most markedly from that figure.

2.9. Use of DRL on polder roads

The financial means available did not allow all types of road to be included in the study. Therefore, it was decided to conduct incidental measurements on roads not included in the measurement network, supplementary to the set measurement programme. One of those types of roads is the category of polder roads. Measurements were conducted on a through road (comparable to an 80 km/hr road) in the North-East polder and one in the Beemster. It has already been stated several times that small numbers make it difficult to estimate C values. This problem is certainly manifested in this case. In addition, the incidental measurements happened to occur more often during wet weather conditions. For this reason, a C value could only be calculated for wet weather. On the polder roads, it is evident that during wet weather, approx. 53% of motorists uses DRL, compared to approx. 31% on 80 km/hr roads, albeit that a far greater variance was found in this case. To illustrate this further, a diagram is shown here of the distributions on polder roads versus 80 km/hr roads during dry weather.



3. ANALYSIS METHOD AND TECHNIQUES

3.1. General

If the use of DRL is made compulsory, the measure can be evaluated. In order to establish the effect on a scientifically sound basis (in terms of a reduction in the number of accidents), the use of DRL must be known for both the preceding and the follow-up period. For this reason, the user measurements as described were performed, amongst others. In practice, it is impossible to measure the use of DRL at all locations where accidents occur. In order to carry out an 'analysis for specific effects' (Lindeijer et al., 1990), the use of DRL will have to be estimated for those specific situations and under those specific conditions where accidents have occurred.
In addition, it must be estimated what proportion of DRL distributions is represented by the group of drivers that use DRL for reasons other than the light intensity (see also para. 1.3). This chapter will explain the analysis methodology used.

3.2. Basic model

The aim of the analysis is to gain an insight into the following questions: what differences are seen in the use of DRL, in what situations, under which circumstances and how can user data be linked to accidents? This insight helped to construct the foundation for the theory formulation required to restrict the number of parameters with which the use of DRL could be described. With the aid of these parameters, the influence on information campaigns can also be established.

Prior to formulating the theory, a number of assumptions were made on the basis of the available material, in order to arrive at an ordered principle with which to describe the results. These assumptions <u>and</u> the ordered principles together represent the basic model of the use of DRL. The assumptions are set out as follows:
- The light intensity, expressed in lux, will be an important factor with which to describe the use of DRL.
- The decision whether or not to switch lights on or off is to a large degree determined by the light intensity as experienced by the driver.

- Each driver has his own limit for the light intensity (= threshold value) below which lights are switched on and above which lights are switched off.
- When taken together, all individual threshold values (expressed as a logarithm of the light intensities) will be normally distributed, on the whole.
- The average log-lux (mu) value and its standard deviation (sigma log-lux) represent the parameters of this distribution.
- The influence of other factors on the use of DRL (seasonal, inside or outside the built up areas, weather condition and the like) can be expressed through these parameters.

Therefore, the light intensity is considered to be the principal intermediate variable in the basic model.

Furthermore, it is known that a proportion of drivers of motor vehicles already uses DRL at all times (e.g. motor cyclists). This means that the distribution of the use of DRL will not run from 100% to 0%, but rather from 100% to C% (= percentage of DRL use regardless of the light intensity).
The measured light intensities (lux values) are converted to log-lux values, so that a factor 10 in the lux values agrees with a difference in the log-lux to a value of 1 (Bijleveld, 1991). This distance between two successive log-lux values is divided into equal categories. Within each category, both the lux values and the number of observations are first added up (total value) and then given as an average value.

3.3. Analysis model

3.3.1. General

The first step in the analysis is to choose a suitable time unit, based on which the use of DRL can be estimated. The raw data consists of vehicles counted during a five minute period (intensity per unit of time), subdivided according to vehicle category, and whether they were or were not using DRL within that category. In particular, in the early morning (before 7 a.m.) and after 7 p.m., in the summer months, many time units showed no, or extremely low, intensities. In other words, there are large fluctuations with regard to the total intensity per five minute time unit, which affects the feasibility of estimating the use of DRL (based on the collected material).

Clearly, an optimum compromise must be found between intensity and time unit, in order to estimate the most reliable percentage possible, while approximating reality as closely as possible.

To estimate the use of DRL, the analysis uses the analysis method of the PROBIT model. This model assumes that an object (driver), influenced by an increasing dosage (=light intensity), is subject to a threshold value where the administered dosage leads to the desired effect (DRL on/off). The model is derived from Biometrics (Cox et al. 1984), and was assessed for its applicability to this material and the purpose for which data was collected (Bijleveld, 1991). First, it was empirically established at what unit of time the model can offer good estimations. This was already shown to be possible at time units of 10 minutes.

3.3.2. Method of analysis for the PROBIT model

The PROBIT model makes it possible to choose from a number of functions, two of which can be used. These functions describe the relationship between log-lux and the anticipated percentage of DRL use. With regard to form, they are similar to that of a normal distribution or to that of a logistic distribution, but do not compare with the stochastic of such distributions.

In other words, based on the empirical material, it was found that no choice can be made as to which of the two realistic functions is best under all conditions. These functions, which indicate the relationship between the use of DRL and the light intensity (expressed as a logarithm of the measured lux value) closely approximate the form of the cumulative distributive function of the normal or the logistic distribution.

The distributive function in this case varies from 100% to C%, where C% is the proportion of road users that always uses lights, regardless of the light intensity. Using the PROBIT analysis, the use of DRL as a function of the light intensity can now be described in a simple manner, by specifying three parameters: the average, the variance and the C value. For example, the estimation method of the PROBIT model allows the lowest user percentage of DRL per vehicle category (C%) to be estimated as a of the light intensity during dry and wet weather, with the associated standard deviations (s.d.). The estimation method allows an estimation of C values, which are assumed to have an asymptotic, normally distributed error, with an associated standard deviation. This means that the limits of reliability (at a 95% reliability level) of the estimated C values will lie between the standard deviation, times two (for further information, see: Bijleveld, 1991).

4. THEORETICAL LIGHT INTENSITY

It has been empirically established that the light intensity is indeed the principal explanatory variable, as was assumed in the basic model. Using the light intensity in the accident analysis (to estimate the use of DRL), a problem manifests itself. The light intensity during accidents can only be estimated on the basis of data from the accident itself, because it is not specified as such. The major predictor of the light intensity that can be derived from the accident data is: position of the sun (= combination of time of day, time of year and geographic location of the accident site).

Therefore, a formula was developed to calculate the altitude of the sun for the purposes of this study (described in Lindeijer et al, 1990). Using this formula, the use of DRL as a function of the theoretical light intensity per accident can be estimated. The question to be answered is: is there a loss in explanatory validity if the use of DRL is estimated as a function of the theoretical light intensity (rather than the actually measured light intensity)?

To answer this question, the explanatory percentages for both the measured and the estimated light intensity were calculated per month for the category of passenger cars. The percentages per month are as follows:

Month	Measured light intensity	Estimated light intensity
November 1989	0.6878	0.7450
December 1989	0.5794	0.4630
January 1990	0.2472	0.2692
February 1990	0.4269	0.4267
March 1990	0.5440	0.5814
April 1990	0.6069	0.6279
May 1990	0.5579	0.5543
June 1990	0.6206	0.6114
July 1990	0.5404	0.4256
August 1990	0.6567	0.6363
September 1990	0.4113	0.3641
October 1990	0.5096	0.5332

The table shows that the light intensity estimated on the basis of the sun's altitude offers a comparable explanatory percentage for four months of the year, and an even greater explanatory percentage for five of the twelve months. One possible reason for this is: in the daytime, the light intensity varies markedly within five minute categories. For example, during clear, slightly overcast weather the lux values vary from over 100,000 lux to less than 30,000 lux. However, it is known that the human eye (at this degree of brightness) can hardly distinguish between this degree of fluctuation. It may therefore be assumed that the large distribution in the light intensities does not influence lighting behaviour (turning lights on and off) in these situations; people probably respond to an average light intensity.
It is striking to note the low explanatory percentage in the month of January, both on the basis of the measured and the theoretical light intensity. In the months of December and July, also, the explanatory percentage based on the estimated light intensity was found to be approx 11% less than that based on the measured light intensity. A likely explanation for this phenomenon is not possible at this stage of the analysis. It is still too early to establish whether this difference is a structural one for these months or varies from one year to another, and can therefore be attributed to coincidence.

Based on this comparison, it can be concluded that the use of the formula for the sun altitude to estimate the light intensity implies a loss of information (fluctuations in the light intensity over a short period of time). There is, however, no reason to assume that such a loss is in most cases essential to explain the use of DRL. On that basis, it can be seen that the estimated light intensity will in some cases offer an even greater explanatory validity than the measured light intensity, not even considering the accuracy of the measured light intensity (see Appendix I).
In the months of December 1989 and July 1990, the estimated light intensity showed a less significant explanatory validity than did the measured light intensity. Both the estimated and the measured light intensity for the month of January 1990 demonstrated a noticeably low explanatory validity.

5. COMPOSITE "WEATHER" VARIABLE

5.1. General

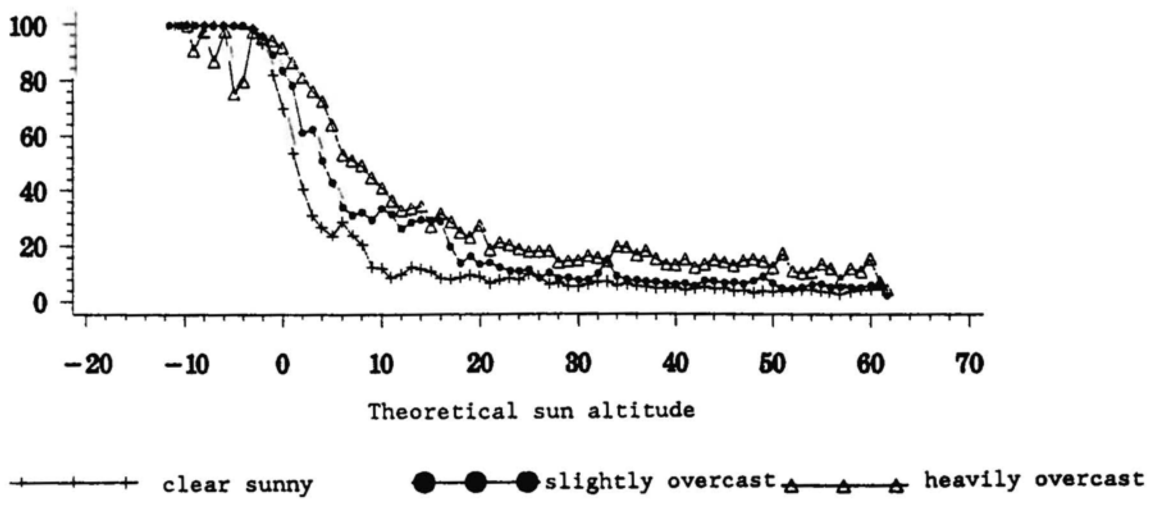
The previous chapter dealt with the analytical problem surrounding the "light intensity" variable. This chapter offers an explanation as to why and how the different types of weather, the visibility conditions and the state of the road surface were combined as independent variables influencing the use of DRL, to form two composite sub-variables.

5.2. Weather conditions and the use of DRL

It has been empirically established that the use of DRL is also affected by weather conditions.
Types of weather are assessed by the observers during five minute periods at the measurement locations. The subdivision of the various types is as follows:
Dry weather: clear and sunny (23.8%); slightly overcast (35%); dry/heavily overcast (31.5%).

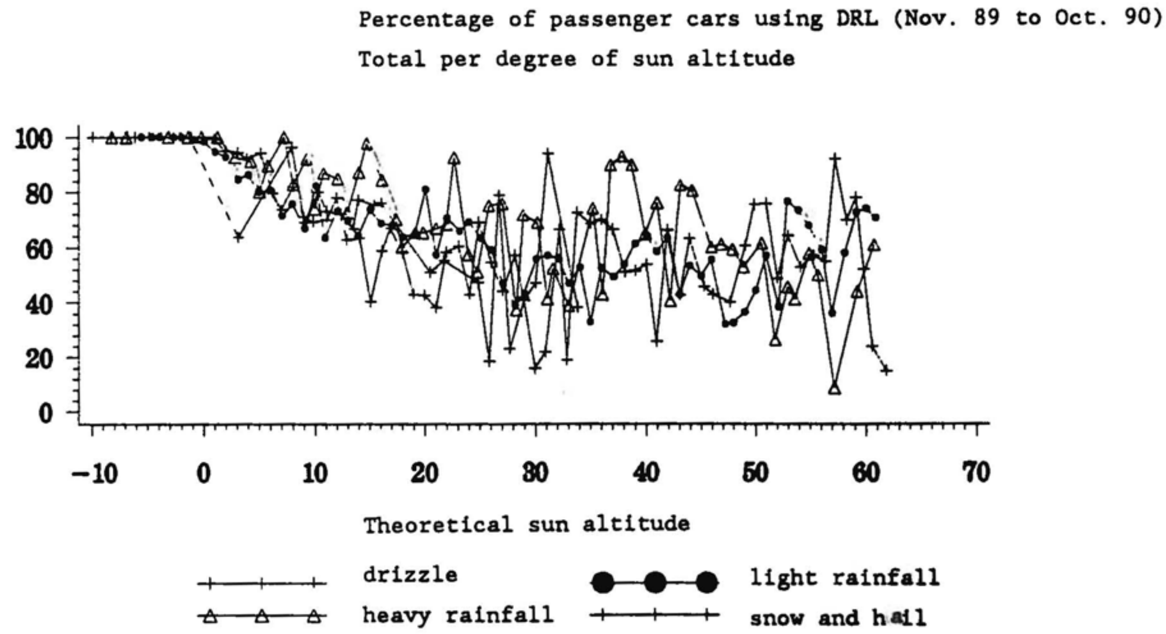
The diagram below indicates the distributions of the weighed percentages of DRL as a function of the theoretical sun altitude, given per dry weather type with a dry road surface. Why this condition was selected here will be discussed later.

Percentage of passenger cars using DRL (Nov. 89 to Oct. 90)
Total per degree of sun altitude

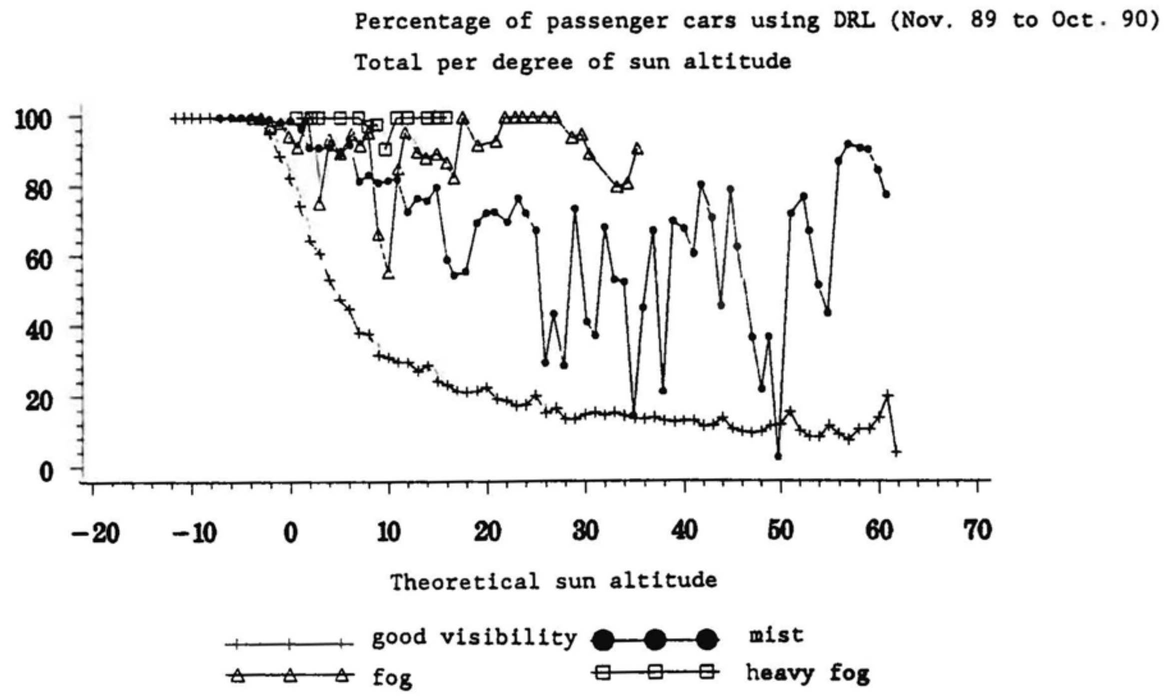


- Wet weather: drizzle (3.0%); light rainfall (5.5%); heavy rainfall (1.0%); snow and hail (0.2%).

The distribution of the weighed percentages DRL with these types of weather and a wet road surface as a function of the theoretical sun altitude are represented below.



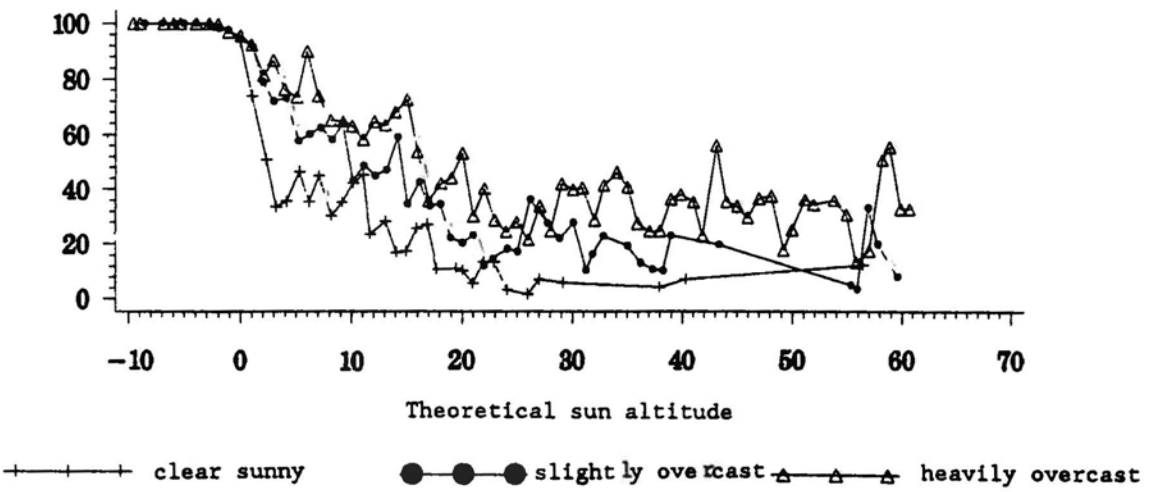
At five minute intervals, the observer assesses the 'visibility'. This is established subjectively, based on the personal interpretation as driver.



Observations were performed during the following visibility conditions: good visibility (94.7%); mist (4.1%); fog (1.2%); heavy fog (between 50 and 100 m; 0.1%).
Under different conditions of visibility, the use of DRL also varies, as the previous diagram shows.

Aside from weather and visibility conditions, the road surface proved to be 'wet' during 17.3% of the observed time. In other words, while the weather conditions were noted as 'dry' for part of the observations, the road surface was still wet. It is expected that when the rain stops, but the road surface is still wet, the measured use of DRL is different than would be the case if both the weather and the road surface were dry. This prediction is based on the assumption that many drivers will switch on their lights as a result of rainy weather, and will not immediately switch their lights off when the rain stops while the road surface is still wet. This shows the following distribution:

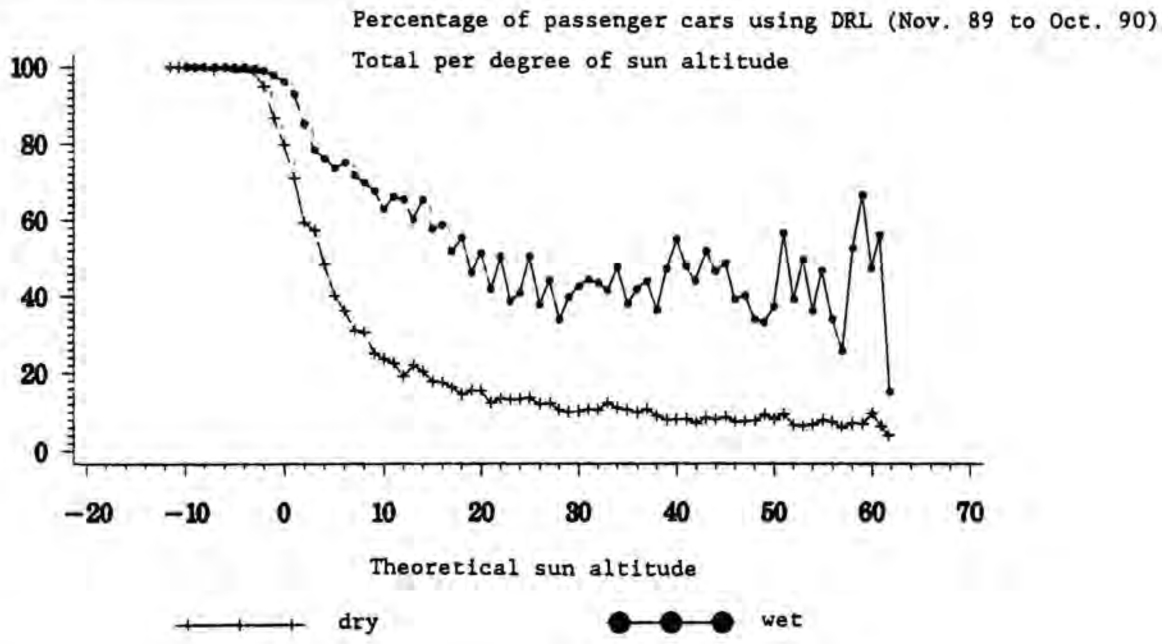
Percentage of passenger cars using DRL (Nov. 89 to Oct. 90)
Total per degree of sun altitude



In other words, the previous diagrams show that when relating the use of DRL to accidents, a maximum distinction must be made according to weather, visibility and road surface conditions. On the other hand, the degree to which a distinction can be made is limited by the less specific differentiation made by the police with regard to these variables when

registering accidents, i.e. the police distinguish between: dry; rain; snow and hail; fog; and wet/dry road surface.
Clearly, when linking user data to accidents, a 'translation' of the subdivisions made by the observers and those made by the police is necessary. In order to describe the development in the use of DRL in the Netherlands (see Chapter 2), it was decided to use two sub-categories on the grounds of practical considerations, i.e.:
- Use of DRL during <u>dry</u> weather (= clear and sunny, slightly and/or heavily overcast). This relates to 78.1% of all 10-minute observations (N = 16,275).
- Use of DRL during <u>wet</u> weather (= light and heavy rainfall, (dense) fog, drizzle, mist, snow and hail, wet road surface). The total number of 10-minute observation in this case amounts to 4,560, or 21.9%.

The annual distribution of the weighed percentages of DRL as a function of the theoretical sun altitude for both categories is shown as follows:



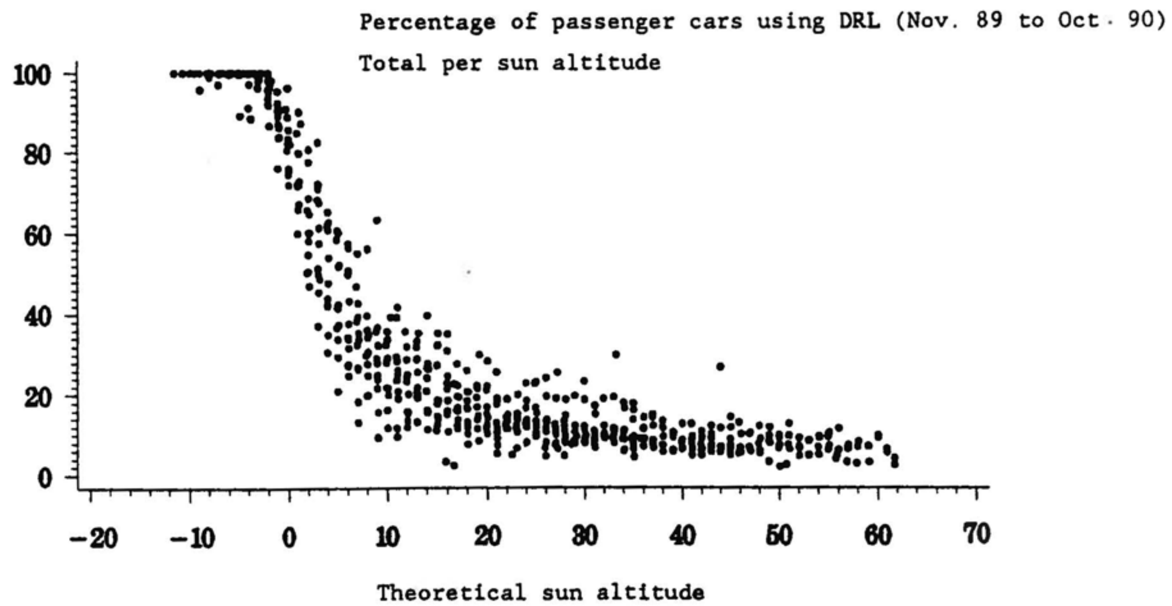
6. SELECTION OF DRL-RELATED ACCIDENTS

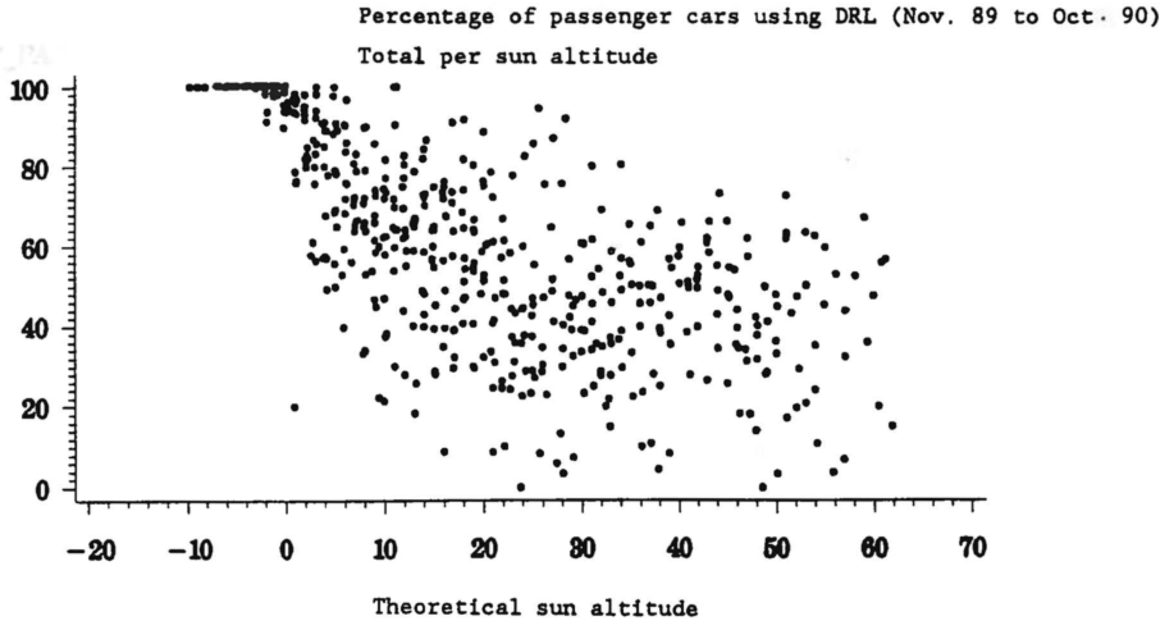
6.1. General

If DRL is to be introduced as a compulsory measure, any derived effect on road safety will only relate to accidents occurring during the daylight, in which at least one motor vehicle is involved, i.e. so-called DRL-related accidents. Here, two selection problems can be distinguished, i.e. establishing the distinction between night and day and between daylight and twilight, based on the use of DRL.

6.2. Distinguishing between night and day on the basis of DRL use

Using the theoretical altitude of the sun, it is now possible to subdivide the accidents into those occurring at night (all motor vehicles use lights in the preliminary period) and during the day, based on the use of DRL. During dry weather, the distinction for passenger cars is made with the sun at approx. 2° below the horizon. During wet weather, this boundary shifts somewhat, being approximately 0° for passenger cars.
In the next two diagrams, all observations are first totalled per month and per sun altitude - subdivided according to dry and wet weather - after which the percentage of DRL is calculated. In other words, each dot represents the weighed percentage of DRL per degree of sun position per month. The first diagram shows the distribution of weighed percentages of DRL for passenger cars per month during dry weather, as a function of the theoretical sun altitude.





This shows the distribution of weighed percentages of DRL per month during wet weather, as a function of the theoretical sun altitude.

Oddly enough, the months and the associated seasons do not appear to exert an influence on the decision of almost all drivers as to whether or not to switch their light on or off. Based on the use of DRL, a fairly clear distinction can be made between DRL-related and non-DRL related accidents; between accidents occurring at night or during the day. However, these diagrams do show that the light intensity during the twilight periods and in the middle of the day lead to differences in use (see also para. 2.2).

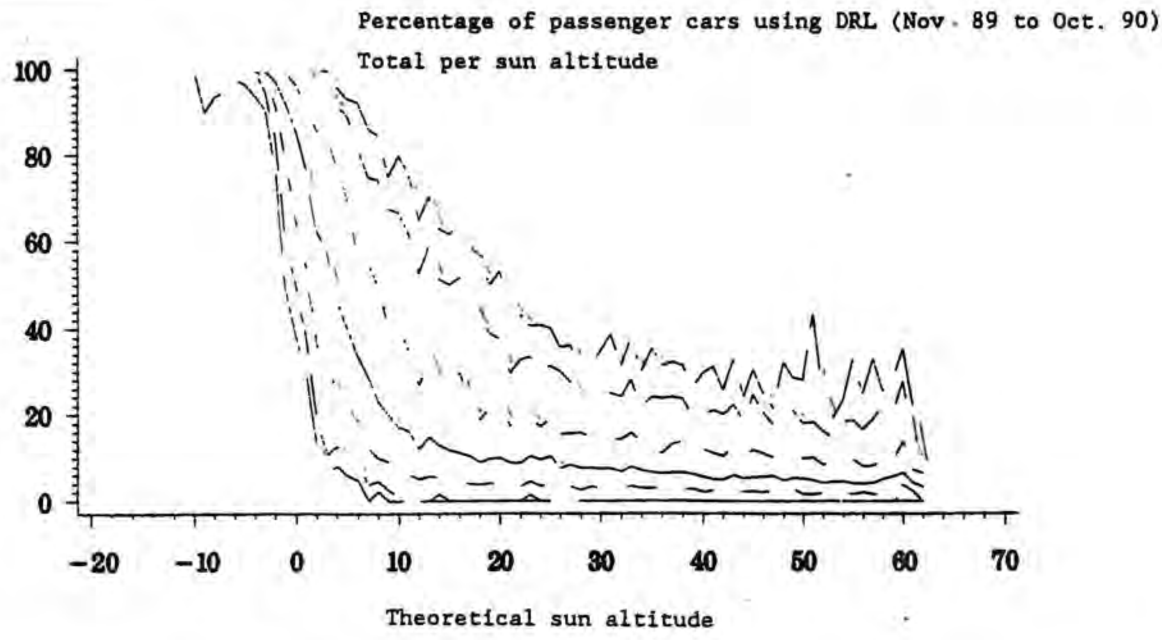
6.3. Distinguishing between daylight and twilight, based on DRL use

During twilight (with increasing or decreasing light intensity), each driver will determine for himself when to switch lights on or off (see basic model, para. 3.2). With regard to the use of DRL, the twilight period can thus be defined as the period where the most marked drop or rise in the use of DRL occurs as a function of time. During wet weather, the percentages are so widely distributed, regardless of the position of the sun, that these situations can only be represented by average percentages. An estimation of the use of DRL under these circumstances therefore remains fairly inaccurate.

For the accident study, this means that the greatest probability of demonstrating an effect - in terms of a reduction in the number of accidents - as a consequence of the increased use of DRL is found during the times of day when the lowest user percentage is measured over the preliminary period, during dry weather conditions. For further information on this subject, please refer to Lindeijer et al. (1990).
The periods during which the use of DRL was found to be fairly constant will be characterised as daytime periods. All other circumstances are designated as twilight, where the concept of 'twilight' is used in a much broader sense here than it would be under normal circumstances.

In order to make a well-founded choice between twilight and daylight periods, the following questions must be answered:
- at what position of the sun is there question of a marked rise or fall in the use of DRL (= twilight period)?;
- at what position of the sun can one speak of a fairly constant percentage (C values during daylight periods)?
It is anticipated that during a marked rise or fall in the use of DRL, the differences (to be further referred to as the variance) between the measured percentages per ten-minute unit of time are great during the twilight period, but small during the remainder of daytime hours. This principle makes it possible to formulate the following study question for the purposes of the analysis: How great is the distribution between the different measured percentages within one degree of sun altitude and in comparison to other degrees of sun altitude?

The following diagrams visualise the distribution per degree of sun altitude with the aid of a number of percentile values, i.e. 95% (upper boundary), 90%, 75%, 50%, 25%, 10% and 5% (lower boundary). The upper boundary in the diagrams (per degree of sun) therefore demarcates the area below which 95% of the individual percentages per degree of sun relate to the category of 'DRL on'. The lower boundary demarcates the area below which only 5% relates to the category 'DRL on'. To perform this analysis, use was made of those time units of ten minutes where at least nine passenger cars were counted.
The diagrams do not indicate the weighed distribution of percentages per degree of sun altitude. For example, the 95 percentile value of a random sun degree may be based on one time unit, but may also be based on 100 time units, for example.



This diagram shows how great the variance per degree of sun altitude is during dry weather for the category of passenger cars. The drop in distribution in relation to the increase in the light intensity is evident here.

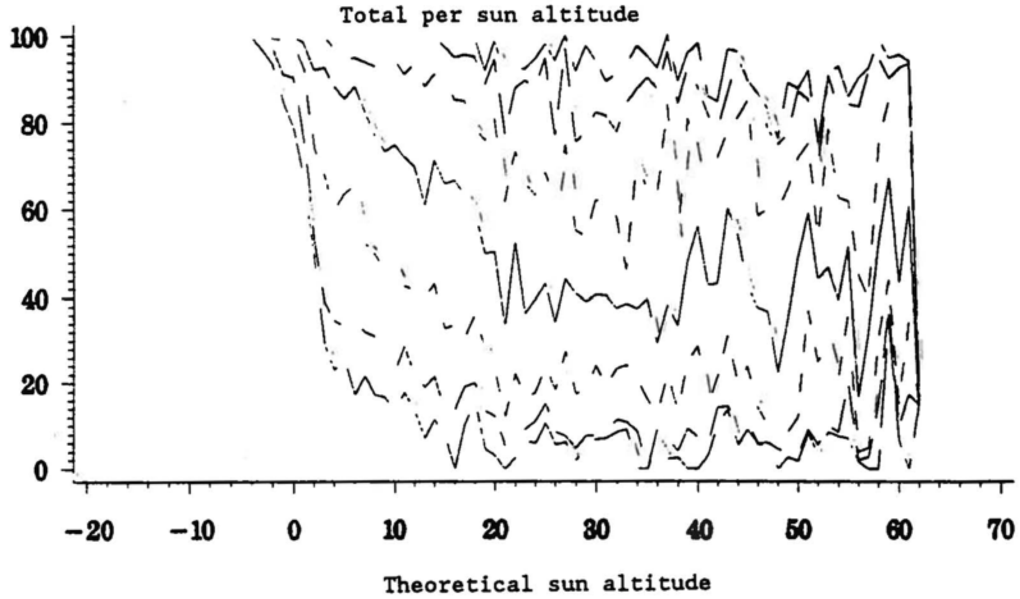
To illustrate this point, the following approximations of user percentages were read off the diagram at a sun position of 10° and 30° for different percentile values.

Percentage DRL per 10 min. observation period	Percentage 'lights on' sun position 10°	sun position 30°
95% of the percentages	approx. 78% or less	approx. 35% or less
90% of the percentages	approx. 68% or less	approx. 28% or less
75% of the percentages	approx. 40% or less	approx. 15% or less
50% of the percentages	approx. 15% or less	approx. 10% or less
25% of the percentages	approx. 10% or less	approx. 5% or less
10% (can no longer be noted)		

Here it can be seen, for example, that at 95% of the percentages, the measured relationship between the use or non-use of DRL was maximally 78%, approx. (but usually less) at a sun altitude of 10° above the horizon, while at a sun altitude of 30°, this was maximally 35%, approx. In contrast, 50% of these percentages were found to indicate a maximum of approx. 15% and approx. 10%, respectively.

The marked difference in variance between sun altitudes during wet weather conditions is shown by the following diagram. It must be remembered, however, that the total number of observation units during wet weather only represent approx 20% of the total number of observation units (see par. 5.2).

Percentage of passenger cars using DRL (Nov. 89 to Oct. 90)
Total per sun altitude



During the accident study, a restriction in the number of 'useful' daylight periods may lead to a problem with regard to the number of suitable accidents available. To illustrate this fact, the monthly daytime periods are indicated in hours, showing the lowest percentages of DRL use for passenger cars measured within those periods and based on hourly totals (all observations noted within one hour were first totalled up, after which the percentage of DRL was calculated). The values in the table were derived from Diagrams 17 to 28.

Month	Daylight periods	Use of DRL in %
November 1989	10.00 - 15.00	8% - 15%
December 1989	10.00 - 15.00	9% - 22%
January 1990	10.00 - 13.00	20% - 24%
February 1990	9.00 - 16.00	8% - 20%
March 1990	9.00 - 16.00	8% - 20%
April 1990	9.00 - 17.00	8% - 16%
May 1990	9.00 - 17.00	4% - 12%
June 1990	9.00 - 17.00	8% - 16%
July 1990	7.00 - 20.00	5% - 20%
August 1990	8.00 - 18.00	5% - 9%
September 1990	9.00 - 16.00	8% - 16%
October 1990	9.00 - 15.00	8% - 16%

If, during the course of the accident study, it is found that the number of accidents in the period of the day indicated in the above are too small to demonstrate a significant difference, it must be decided whether, and in what way, a distinction can be made between day and twilight. In other words, a definite choice between twilight and daylight accidents, based on the use of DRL, will be made in conjunction with the available accident material.

It would be reasonable to assume that the use of DRL in January would be comparable to December or even be somewhat lower, as the daylight periods are becoming longer (and the light intensity is increasing) with respect to December. This might be expected to influence lighting behaviour as a function of the light intensity (see para. 3.2). However, the opposite is true! One likely explanation is that people experience the light intensity as being 'darker' than it is in reality. This would also explain why the light intensity as an explanatory variable scores lowest in the month of January (see Chapter 4). Another explanation can be that people still act out of habit in January.

7. USE OF DRL AND THE DRIVING SPEED

7.1. General

Studies have shown that people estimate the speed and/or distance of cars with DRL as being greater than it is in reality. This could explain the frequently heard opinion (hypothesis I) that people using DRL during clear daylight conditions are 'fast drivers'. This value judgement could express the feeling of lack of safety people experience when seeing cars using DRL during bright daylight. In addition, experts who adhere to the risk compensation theory (homeostasis) believe that if people consider the use of DRL to be a safety feature, they will compensate by driving faster, on average (hypothesis II). As far as we know, no studies have been carried out in practice into the relationship between the use of DRL on a voluntary basis and the speeds driven (to test hypothesis I); neither were speed measurements conducted in the preliminary and follow-up periods in countries where DRL is now compulsory (to test hypothesis II).
Given the growing interest in DRL as a promising road safety measure, their is a great need at both a national and an international level to learn more about a possible relationship between DRL and speed.

In October and November of 1990, the SWOV was asked by the Transportation and Traffic Research Department of the Ministry of Transport to conduct speed measurements on roads outside the built up area (80 km/hr roads). These measurements were performed for the purposes of another study, unrelated to the DRL study described here.
In the interest of an evaluation study into the effect of DRL and in the interest of information campaigns (in the event DRL is made compulsory), the SWOV therefore decided to take advantage of the opportunity offered by the planned speed measurements. One of the radar meters used allowed observers to read the speed measured for each vehicle. Aside from measuring speed, one of the observers also noted the following:
- the use of DRL and weather and visibility conditions;
- the individual speed of vehicles using DRL.

With these extra data, the SWOV has two aims in mind, i.e.:
1. To gain an indication of the degree to which the use of DRL on the four 80 km/hr roads selected (and included in the random test of the DRL

study) agrees with and/or is representative of the use of DRL on the same types of road where speed measurements were conducted (to be referred to as control roads in the following).
2. To obtain a preliminary indication about the relationship between speeds measured and the use, or otherwise, of DRL outside the built up area on 80 km/hr roads.

7.2. Comparability between control and random counts

The speed measurements were carried out in the twelve Dutch provinces, on roads outside the built up area (see Appendix II.1). They were performed for three quarters of an hour at a time and distributed throughout the day, during the months of October and November, 1990. For the purposes of the DRL study, a total of 35 x 3/4 hours was observed, recording the use of DRL and the associated speeds. In total, 13,084 motor vehicles were observed and measured (lorries, vans, buses, passenger cars and motor cycles), of which 2,855 were using DRL (= 21.5%). This percentage agrees well with the DRL percentage of 23.5, obtained from the national measurements total (see para. 2.2; excludes the moped category).

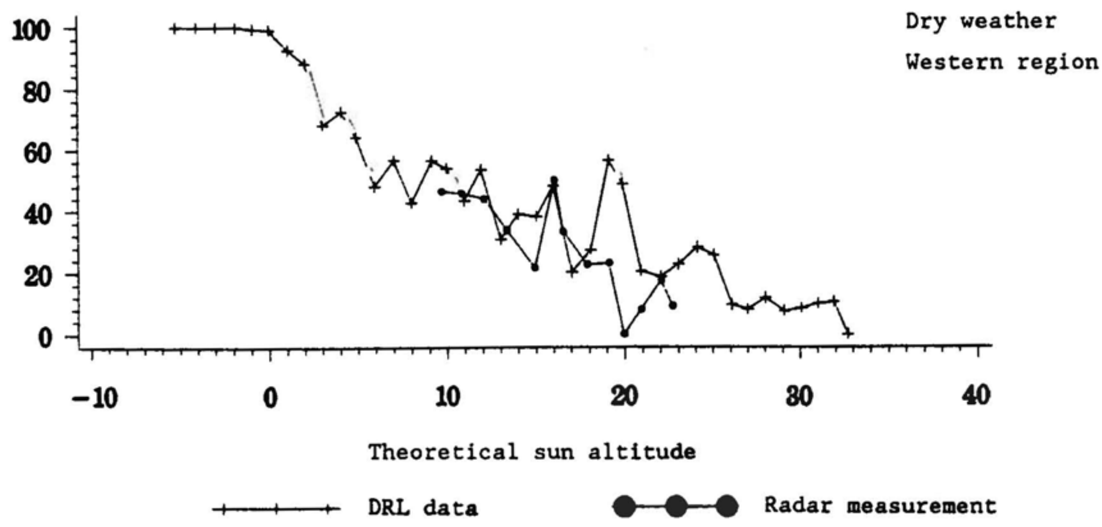
The differences in the number of observations were great from one province to another. The table on page 47 gives the absolute values, subdivided on the basis of dry and wet weather. The category of 'region' indicates how many control roads were used to allow comparison per region.

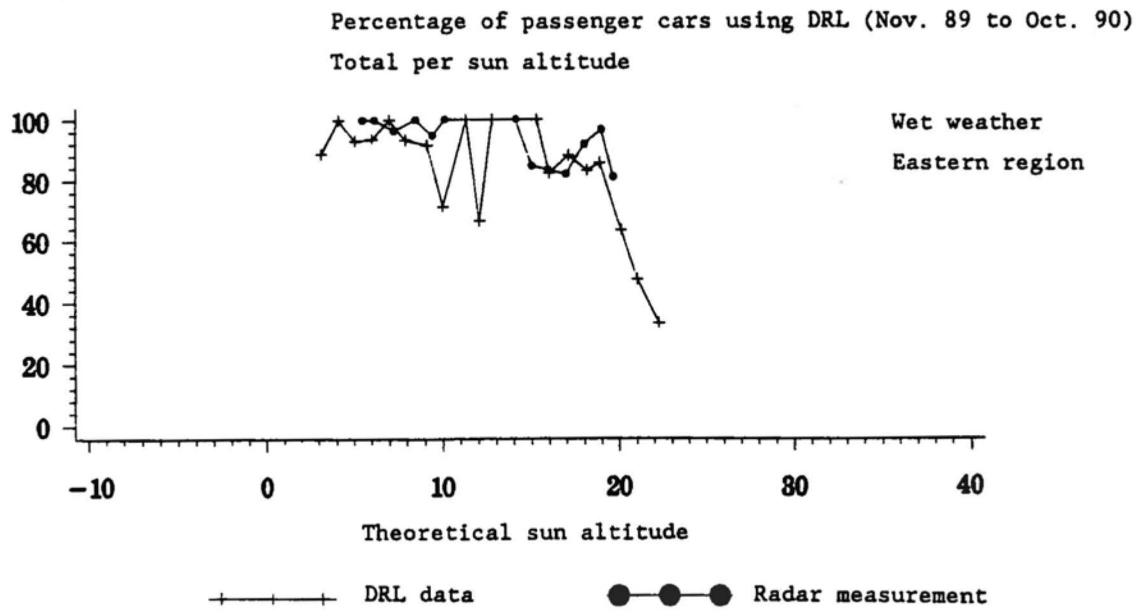
The previous chapters have already indicated the problem of insufficient numbers, causing a large variance in the distributions of the weighed DRL percentages. This problem is also apparent here. In order to still gain an impression of the comparability of the use of DRL between control roads and 80 km/hr roads in a region included in the random test, it was decided to compare the distribution of the weighed percentages of DRL for the control roads within one region against the distribution per region as a function of the theoretical sun altitude, taking into account dry and wet weather. The theoretical sun altitude was selected in this case, because while the speed was being measured, it was not possible to also measure the light intensity at five minute intervals, as was done during the DRL measurements. However, the observation time could be noted for each car observed, while the geographic position of the measurement locations was also known (see also Chapter 4).

Province (Region)	Dry weather		Wet weather	
	DRL	total	DRL	total
Groningen (North)	175	812		
Friesland (North)	44	166	100	124
Drenthe (North)	62	314		
Overijssel (East)	166	644		
Gelderland (East)	119	447	212	271
Flevoland (East)	243	645		
Utrecht (West)			354	358
North Holland (West)			222	279
South Holland (West)	748	8161	166	339
Zeeland (South)	22	145		
North Brabant (South)	167	287		
Limburg (South)	55	92		

In order to illustrate this, two diagrams are shown below. The dry weather distribution in the Western region and the wet weather distribution in the Eastern region were chosen, because the greatest number of observations were noted under these particular conditions in each region.

Percentage of passenger cars using DRL (Nov. 89 to Oct. 90)
Total per sun altitude





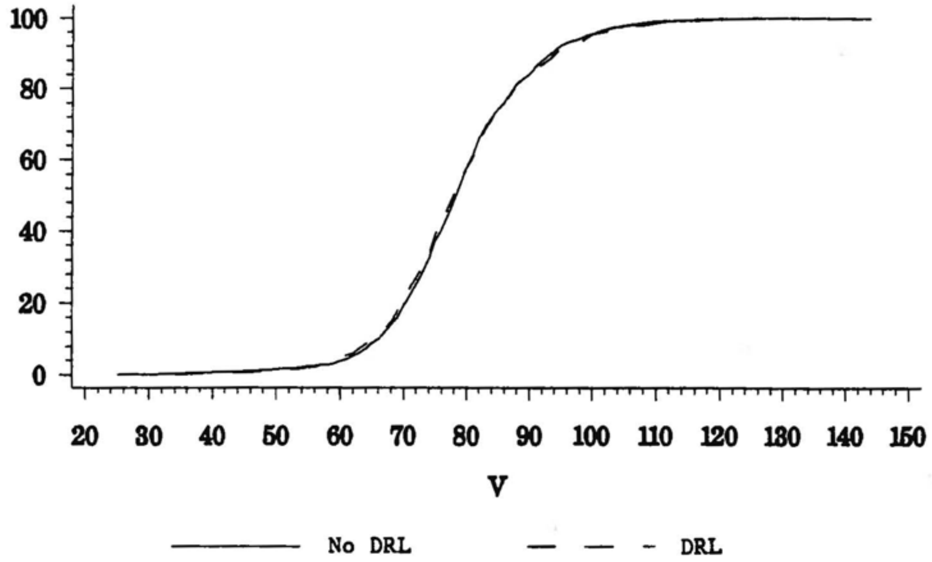
The diagrams show that the distribution of the weighed percentages of DRL comparable reasonably well with the regional distributions. For the sake of completeness, the diagrams for the other regions are included as Diagrams 29 to 34.

7.3. Use of DRL and measured speeds

The diagram on page 49 shows the cumulative speed distributions between vehicles with and without DRL during dry weather conditions.
During dry weather, the speed distributions of both groups were shown to be identical (see hypothesis I, para. 7.1).

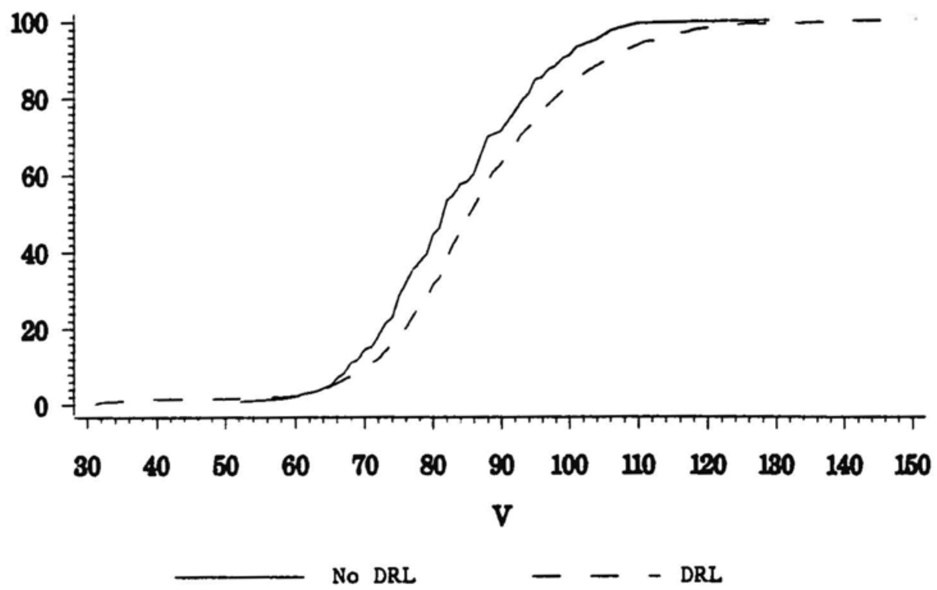
The previous chapters have established that there is a strong interaction between location-related factors and the use of DRL, in addition to light intensity and weather conditions. This is also shown with regard to differences noted with speed distributions.
For example, it was found that people on average drive faster with DRL than without DRL during wet weather. This could be explained, however, by the fact that all measurements taken in the Flevopolder occurred during wet weather, and that it was precisely on those roads that a higher average speed distribution was found than elsewhere in the Netherlands (Van de Pol & Oei, 1991).

Cumulative percentages for speed measurements, without Flevoland - Dry weather

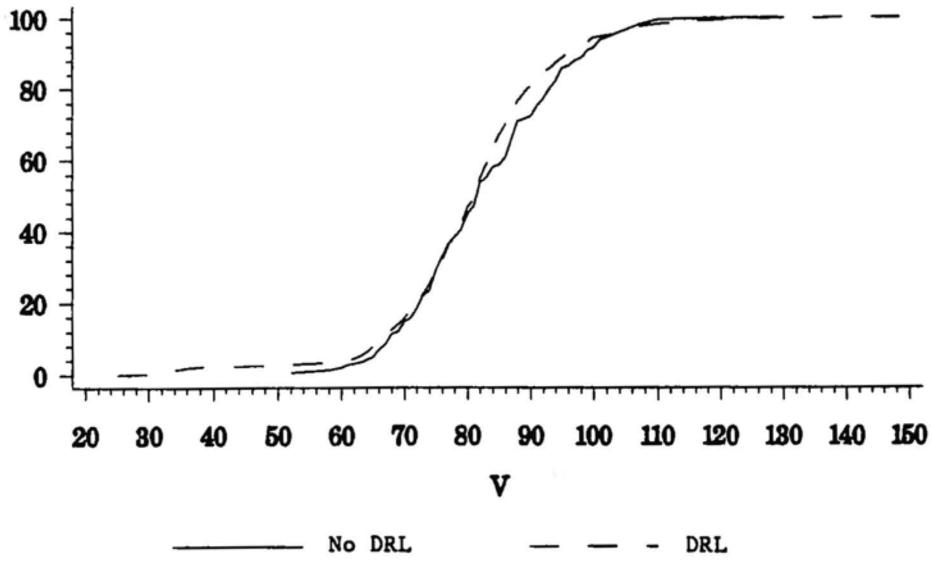


The first of the following diagrams relates to all measurements taken during wet weather. The second diagram excludes the measurements taken in Flevoland.

Cumulative percentages for speed measurements - Wet weather



Cumulative percentages for speed measurements, without Flevoland - Wet weather



Based on the preceding information, it can be concluded that there is as yet no reason to assume that a relationship exists between the voluntary use of DRL and higher speeds, neither during dry weather nor during wet weather. The combined percentages concerning the use of DRL on control roads also indicate that the 80 km/hr roads included in the measurement network provide a reasonably good impression of the use of DRL on this type of road, outside the built up area.

BIBLIOGRAPHY

- Bijleveld, F.D. (1991). Toegepaste statistische methoden gebruikt bij de analyse van gegevens over het gebruik van motorvoertuigverlichting overdag, SWOV. (In preparation).

- Cox, D.R. & Oakes, D. (1984). Analysis of survival data. Chapman and Hall, London, 1984.

- Lindeijer, J.E. (1989). Daytime running lights (DRL); A master plan for an evaluation study in the Netherlands. R-89-49. SWOV, Leidschendam, 1989.

- Lindeijer, J.E.; Bijleveld, F.D.; Oppe, S. & Polak, dr. P.H. (1990). Design of a study into the effects of DRL on accident rate; Methods of analysis and evaluation techniques. R-90-38. SWOV, Leidschendam, 1990.

- Van de Pol, W.H.M. & Oei, H.L. (1991). Rijsnelheden op 80 km/uur-wegen in Nederland II (Driving speeds on 80 km/hr roads in the Netherlands II). R-91-24. SWOV, Leidschendam, 1991.

DIAGRAMS 1 TO 38

Diagram 1. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for passenger cars (November 1989 to October 1990).

Diagram 2. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for lorries and vans (November 1989 to October 1990).

Diagram 3. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for motor cycles (November 1989 to October 1990).

Diagram 4. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for mopeds (November 1989 to October 1990).

Diagram 5. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in November 1989.

Diagram 6. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in December 1989.

Diagram 7. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in January 1990.

Diagram 8. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in February 1990.

Diagram 9. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in March 1990.

Diagram 10. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in April 1990.

Diagram 11. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in May 1990.

Diagram 12. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in June 1990.

Diagram 13. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in July 1990.

Diagram 14. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in August 1990.

Diagram 15. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in September 1990.

Diagram 16. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in October 1990.

Diagram 17. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in November 1989, according to hour of the day.

Diagram 18. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in December 1989, according to hour of the day.

Diagram 19. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in January 1990, according to hour of the day.

Diagram 20. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in February 1990, according to hour of the day.

Diagram 21. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in March 1990, according to hour of the day.

Diagram 22. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in April 1990, according to hour of the day.

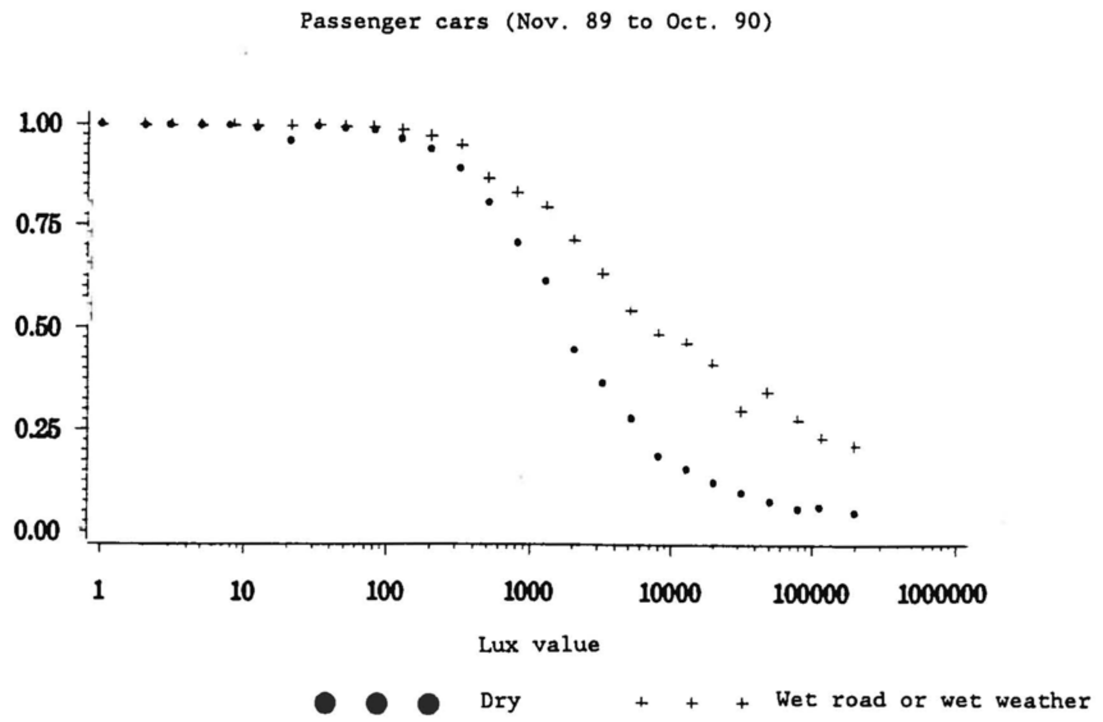
Diagram 23. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in May 1990, according to hour of the day.

Diagram 24. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in June 1990, according to hour of the day.

Diagram 25. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in July 1990, according to hour of the day.

Diagram 26. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in August 1990, according to hour of the day.
Diagram 27. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in September 1990, according to hour of the day.
Diagram 28. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in October 1990, according to hour of the day.
Diagram 29. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Northern region during dry weather.
Diagram 30. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Northern region during wet weather.
Diagram 31. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Eastern region during dry weather.
Diagram 32. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Western region during wet weather.
Diagram 33. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Southern region during dry weather.
Diagram 34. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Southern region during wet weather.
Diagram 35. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Northern region.
Diagram 36. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Eastern region.
Diagram 37. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Western region.
Diagram 38. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Southern region.

* percentage DRL use, independent of the light intensity



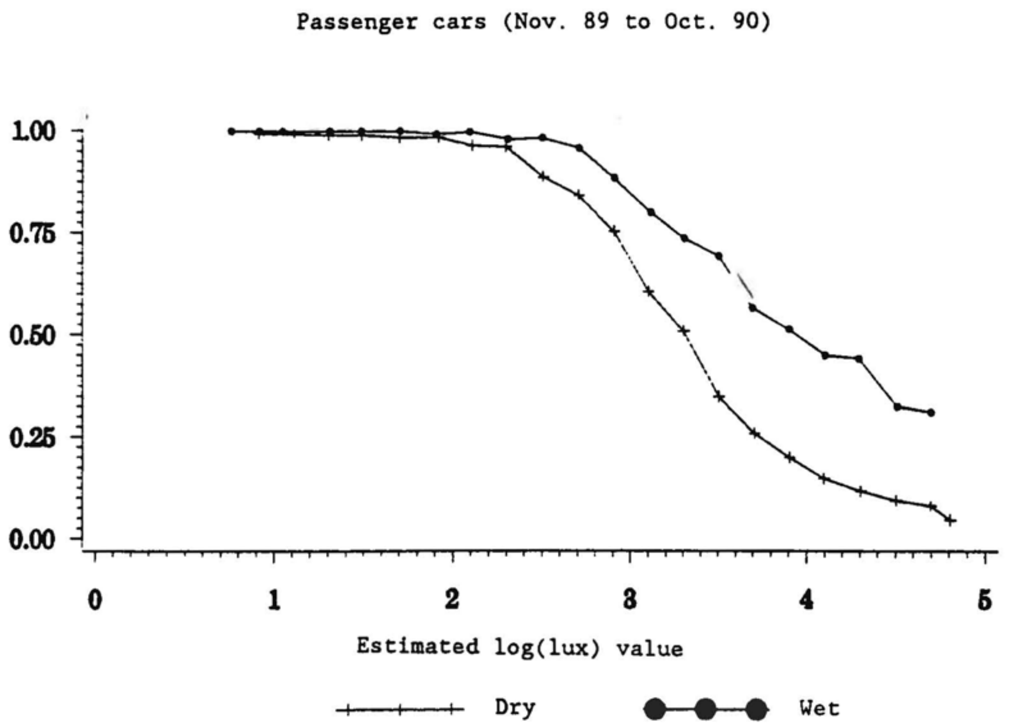
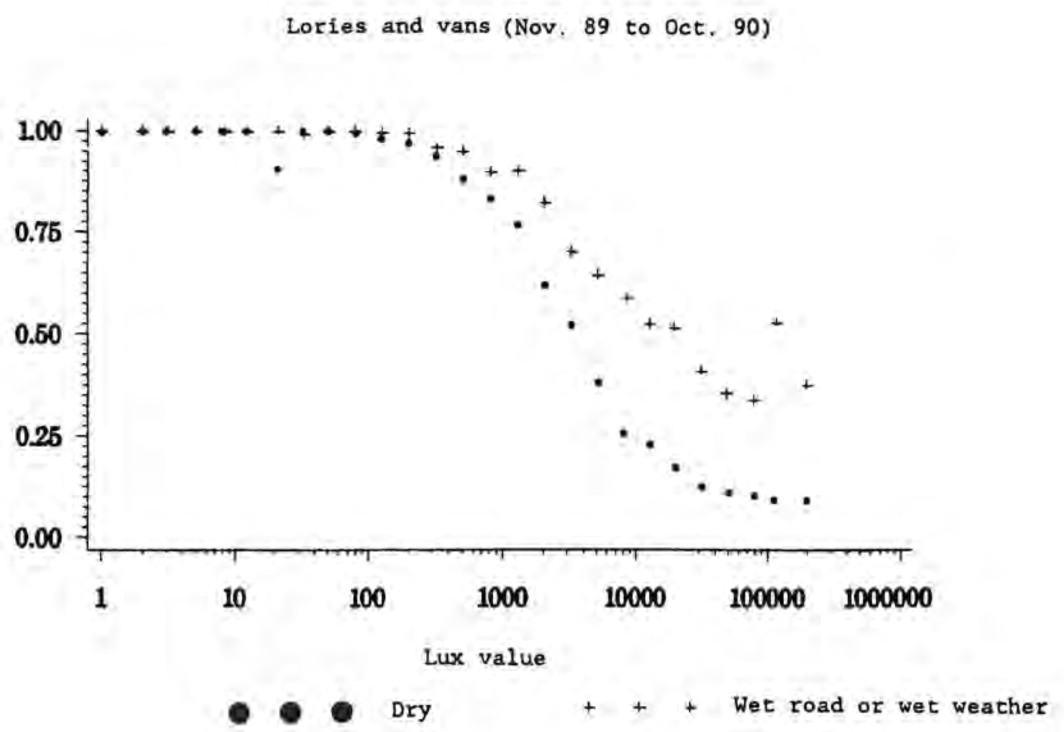


Diagram 1. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for passenger cars (November 1989 to October 1990).



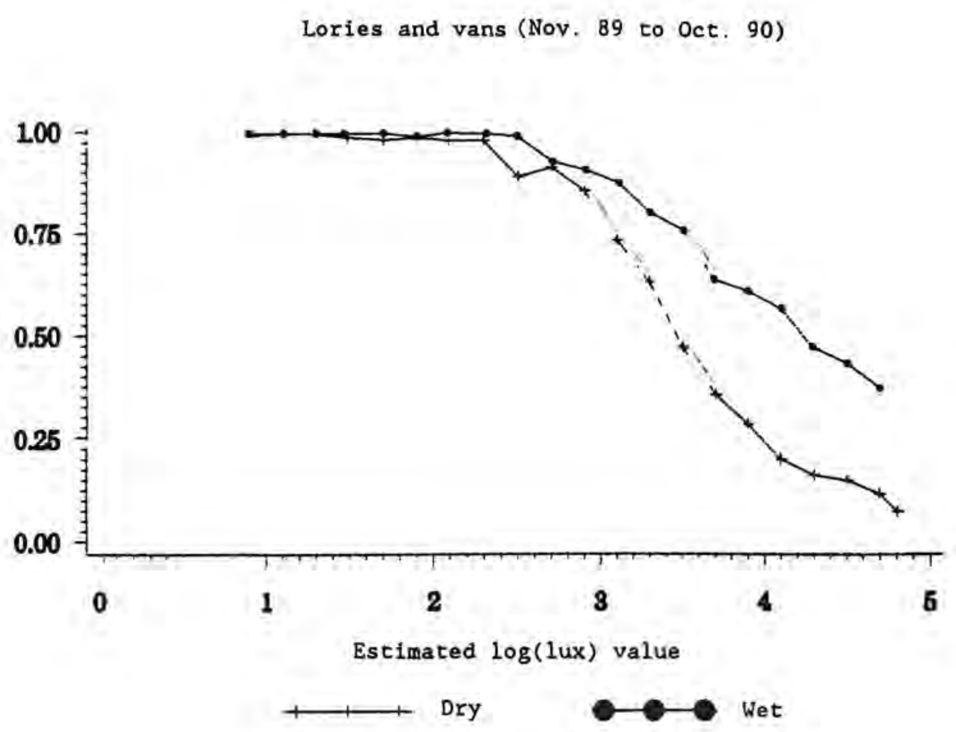
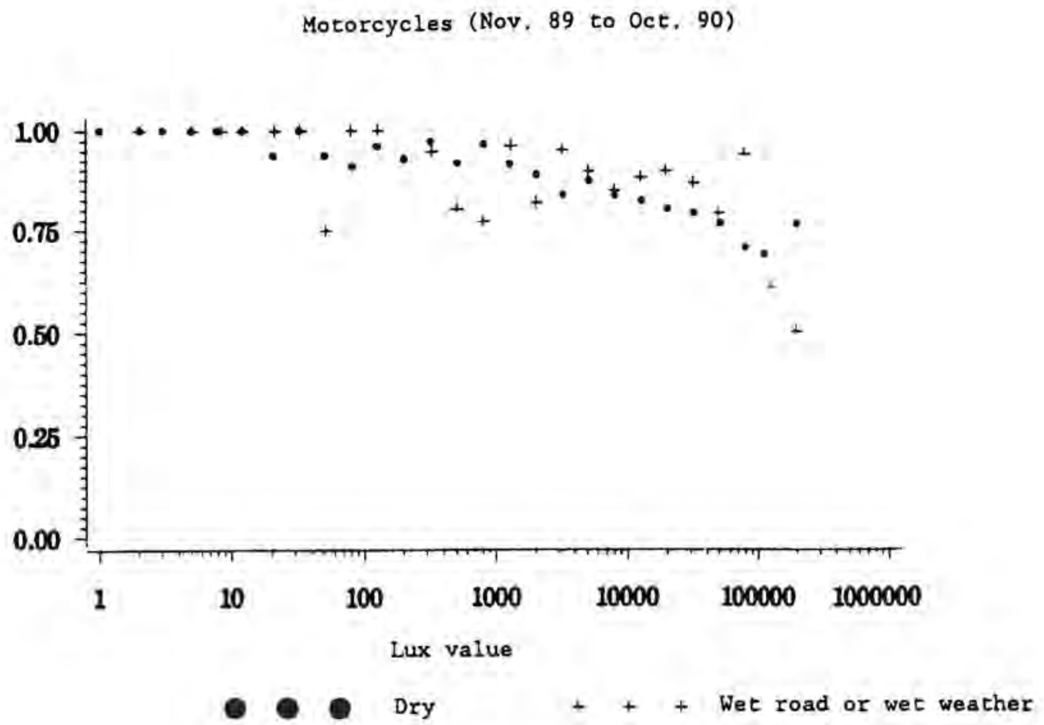


Diagram 2. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for lorries and vans (November 1989 to October 1990).



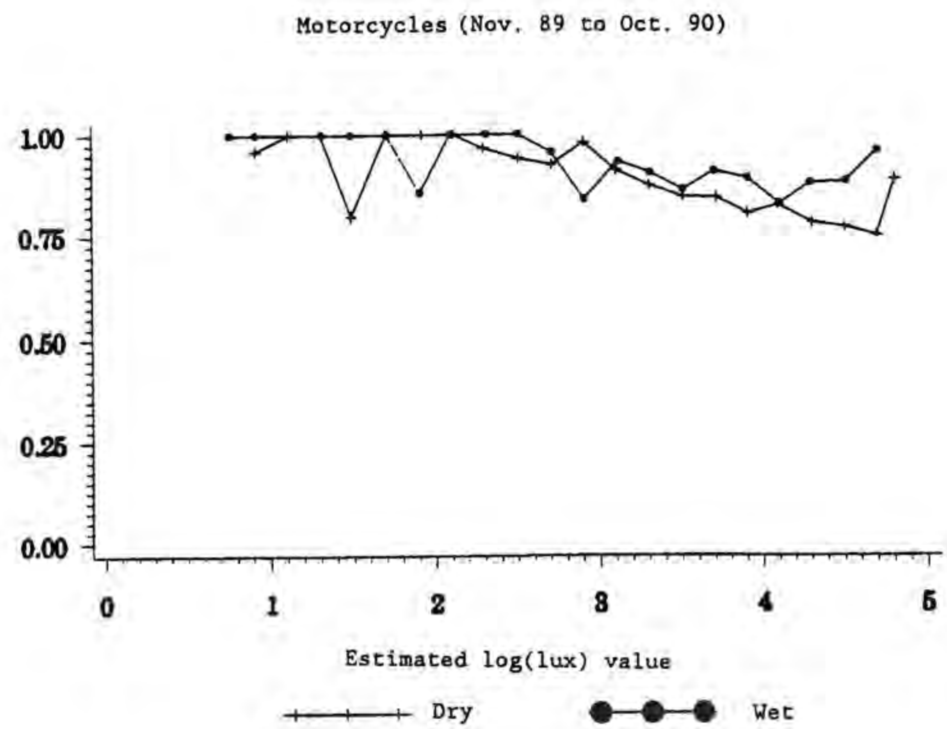
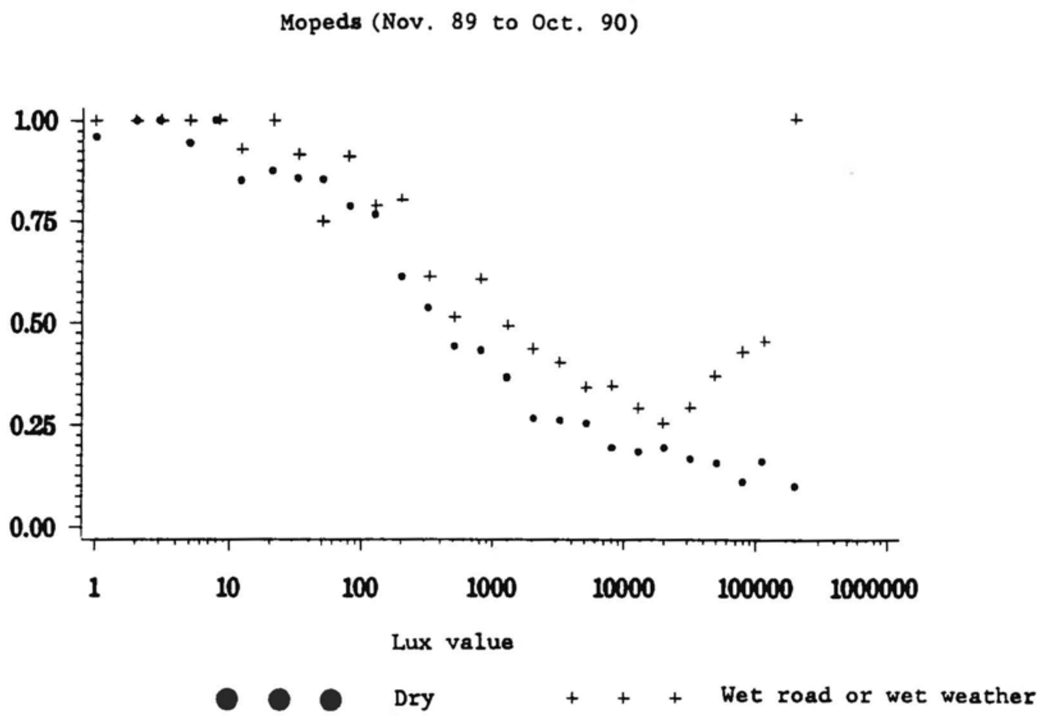


Diagram 3. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for motor cycles (November 1989 to October 1990).



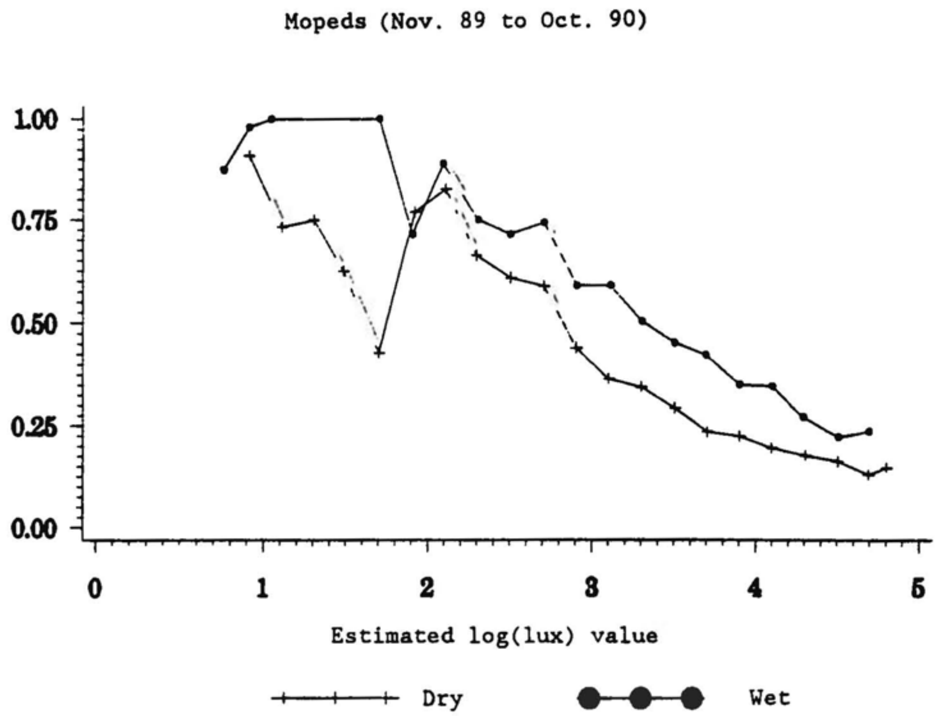


Diagram 4. Distribution of the use of DRL during dry and wet weather at measured lux values and the estimated log(lux) values for mopeds (November 1989 to October 1990).

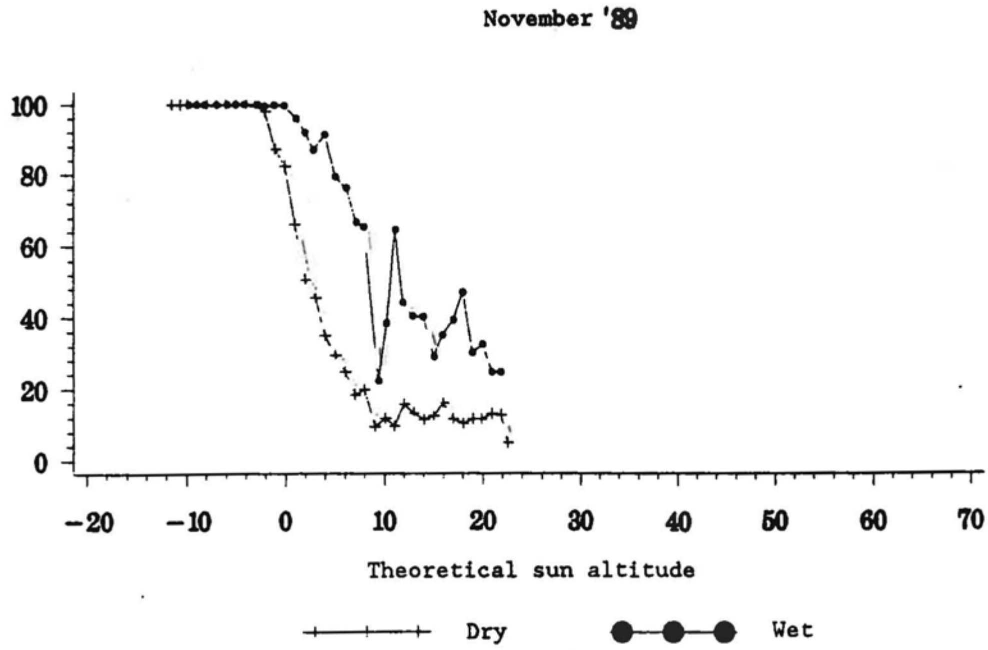


Diagram 5. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in November 1989.

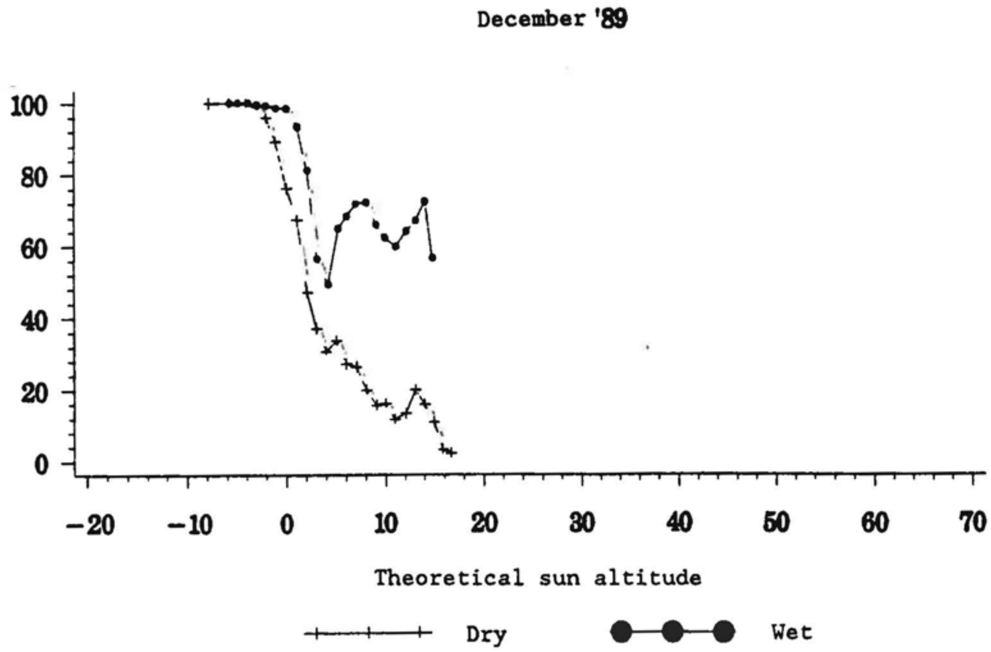


Diagram 6. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in December 1989.

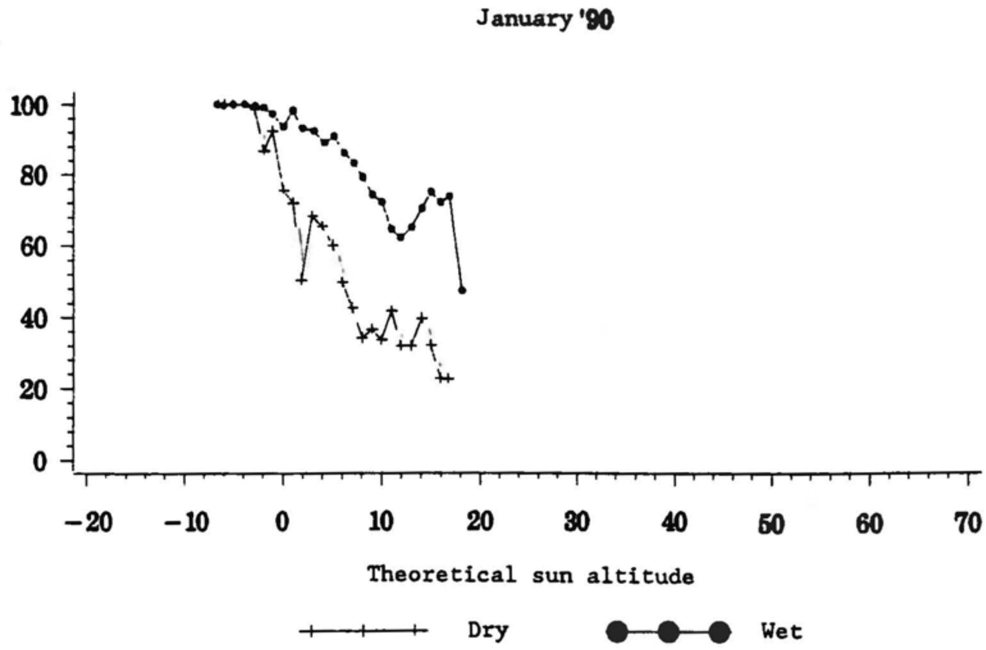


Diagram 7. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in January 1990.

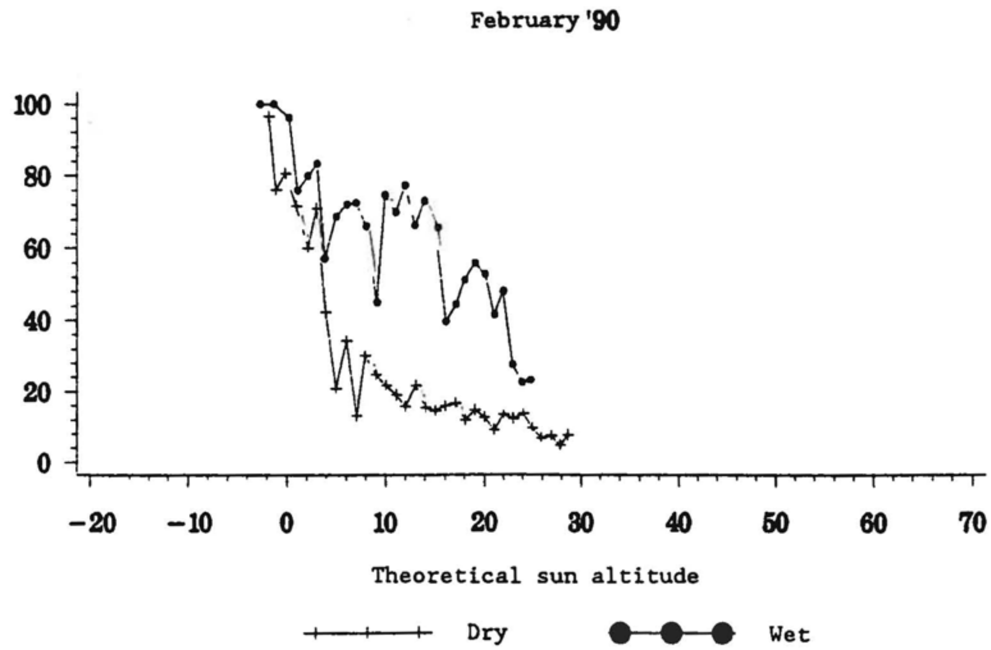
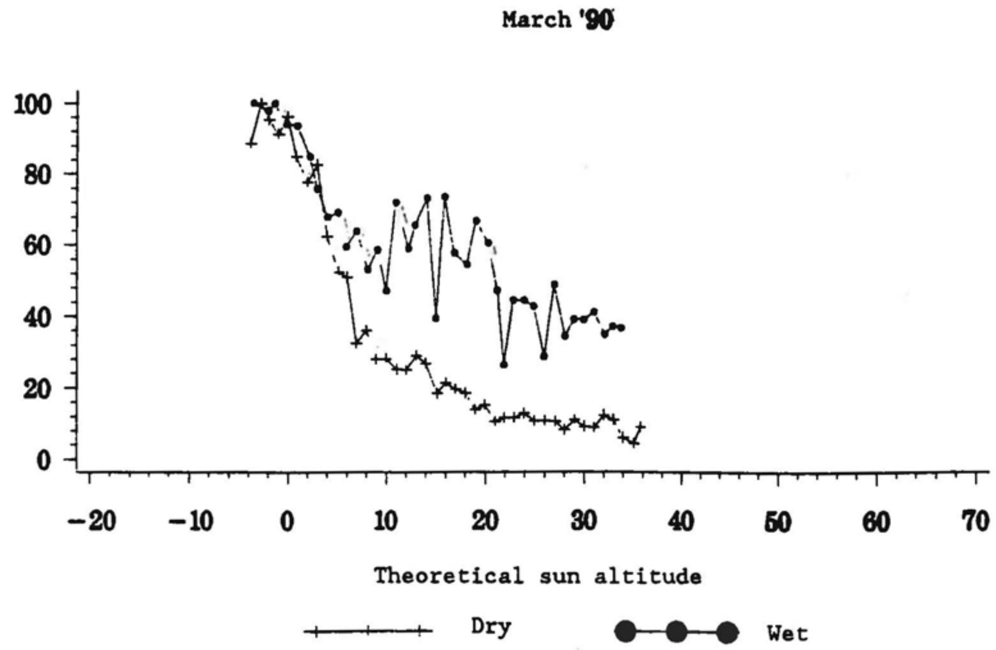
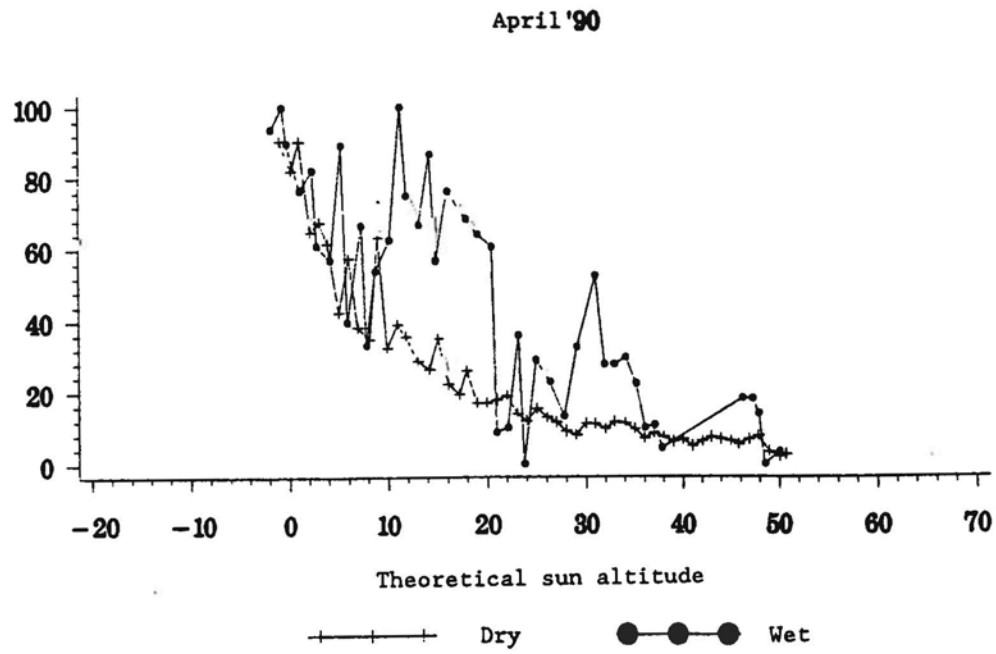


Diagram 8. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in February 1990.



<u>Diagram 9</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in March 1990.



<u>Diagram 10</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in April 1990.

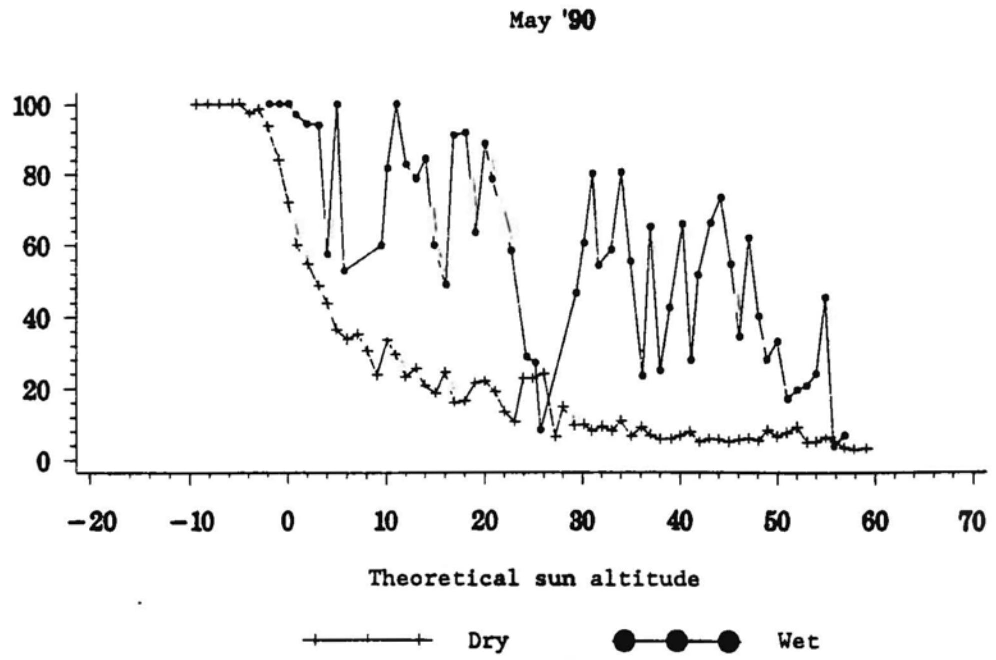


Diagram 11. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in May 1990.

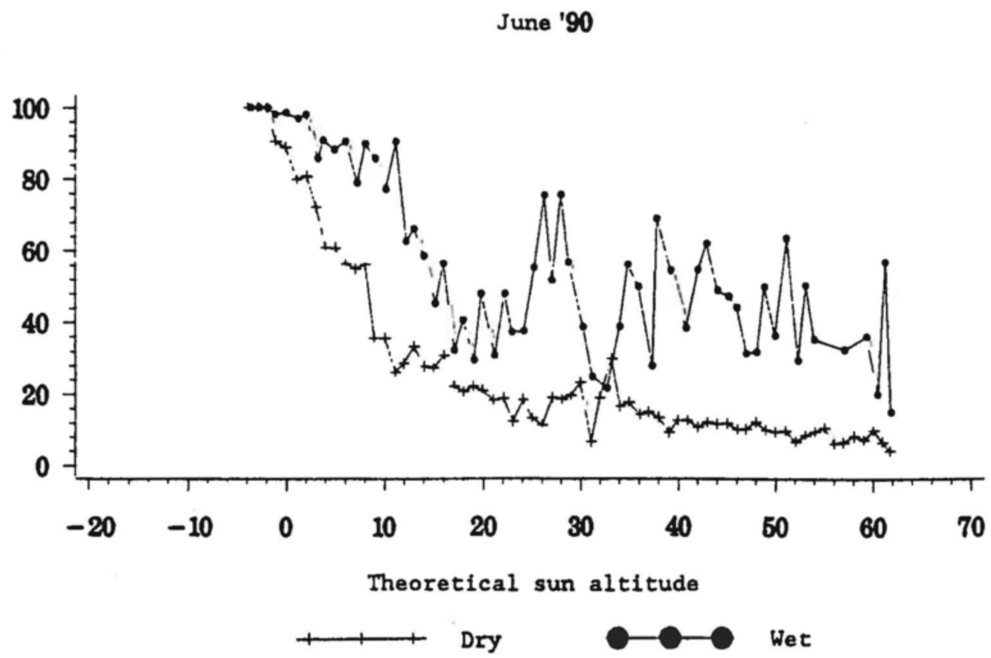


Diagram 12. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in June 1990.

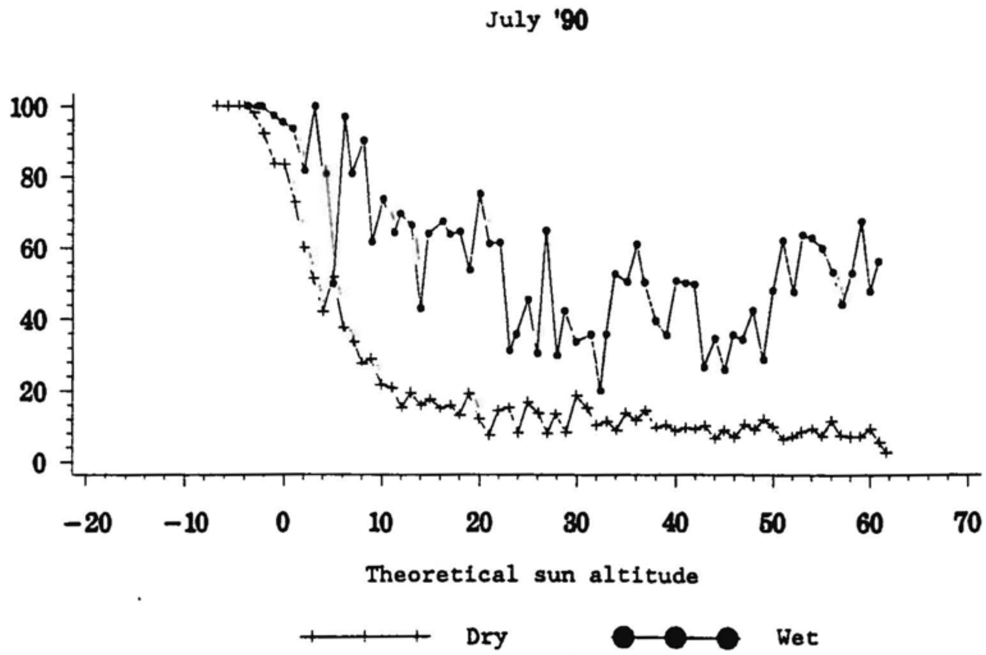


Diagram 13. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in July 1990.

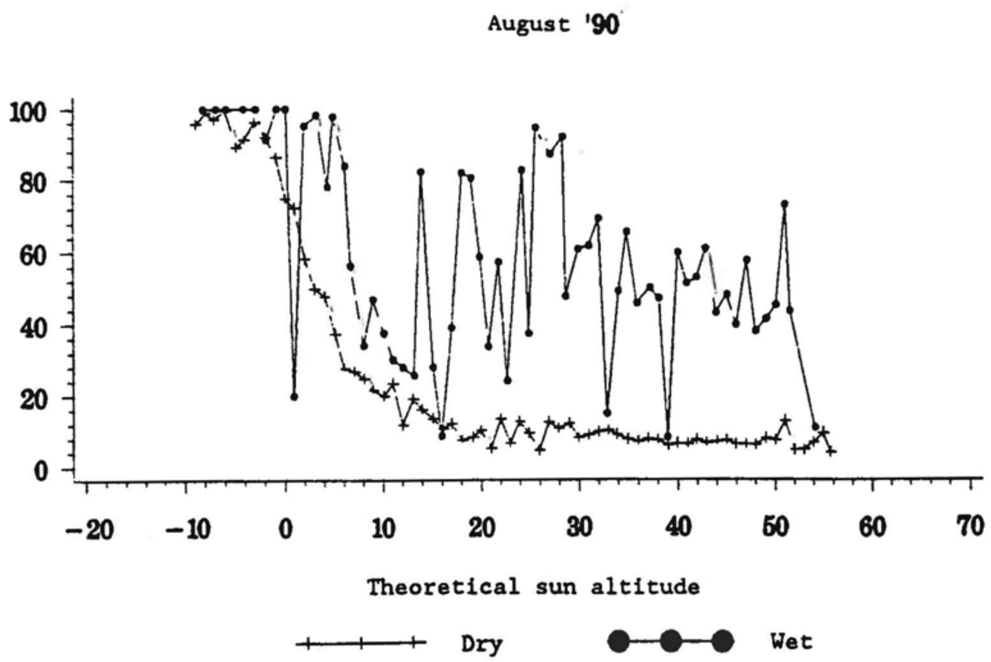


Diagram 14. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in August 1990.

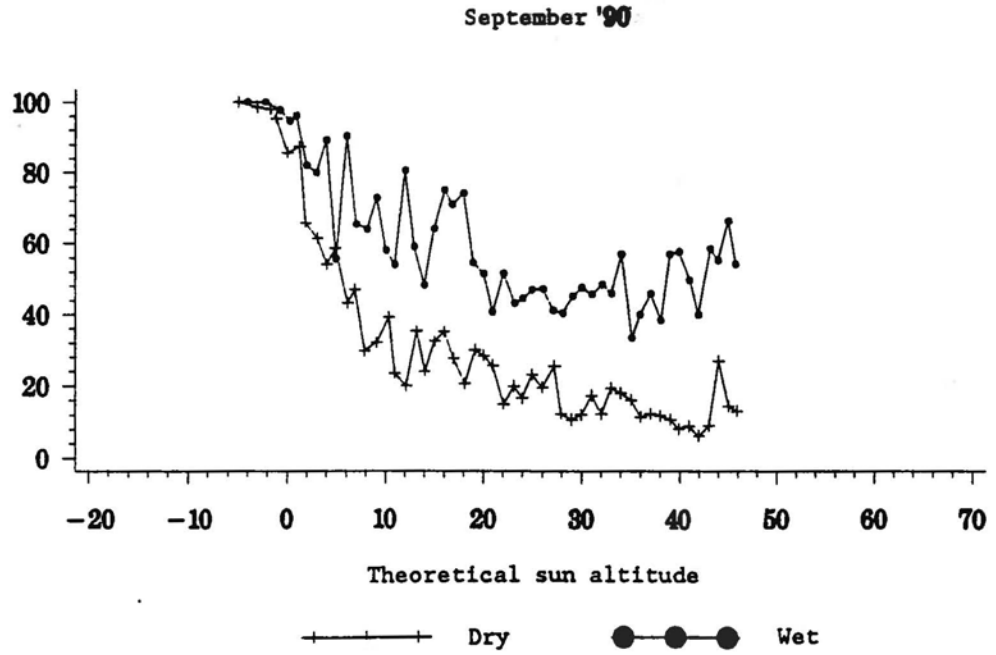


Diagram 15. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in September 1990.

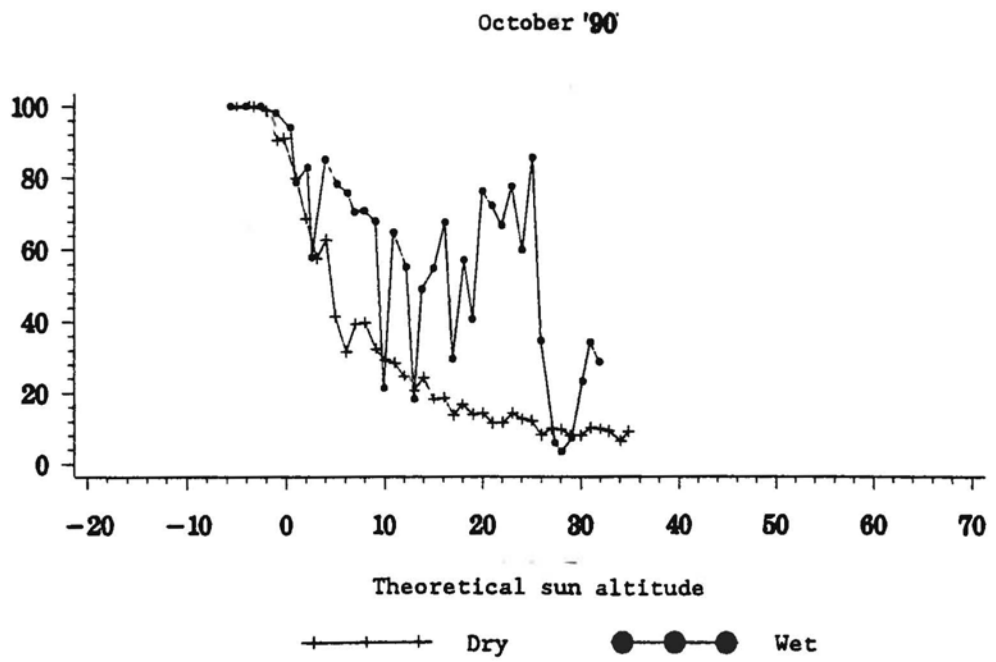
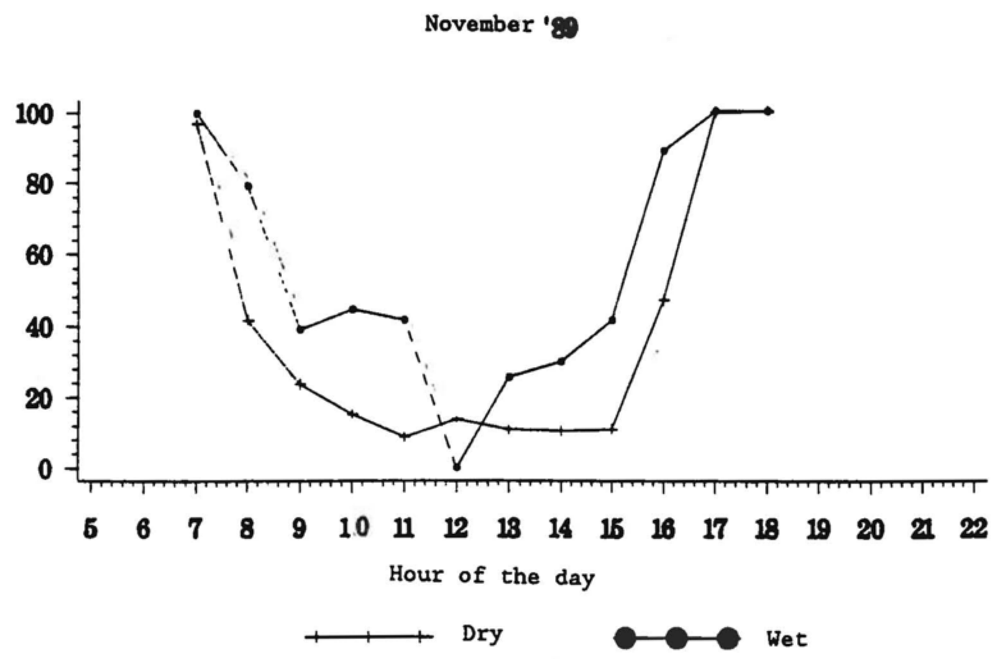
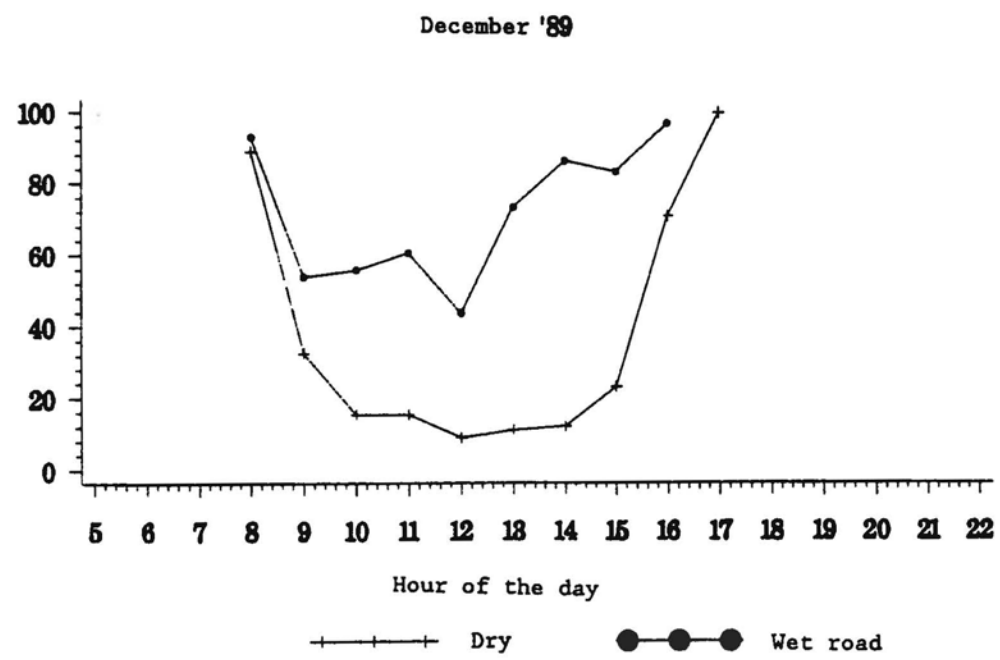


Diagram 16. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude, in October 1990.



<u>Diagram 17</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in November 1989, according to hour of the day.



<u>Diagram 18</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in December 1989, according to hour of the day.

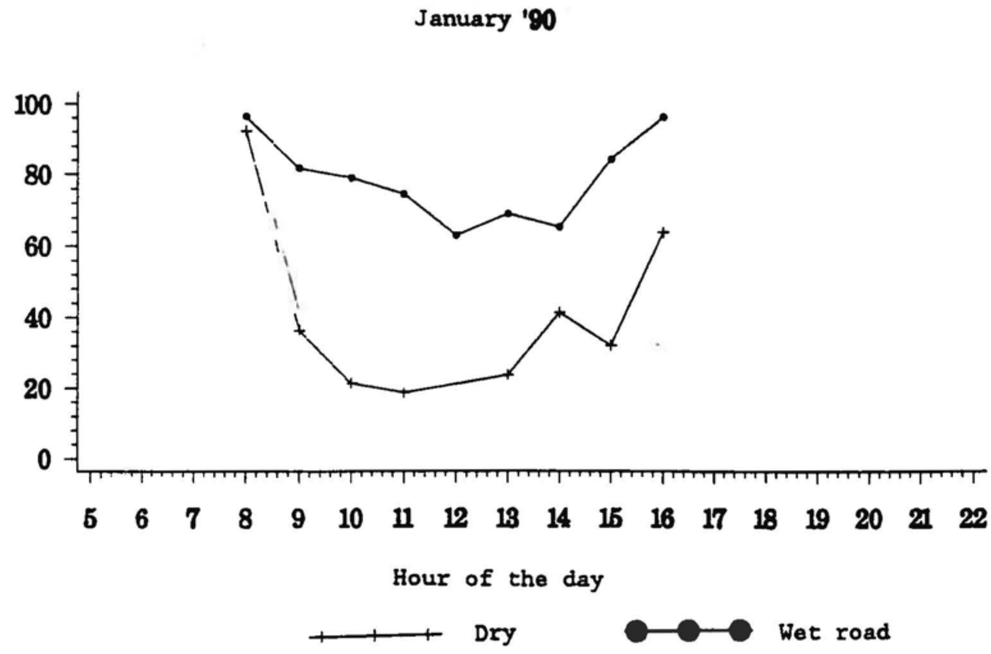


Diagram 19. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in January 1990, according to hour of the day.

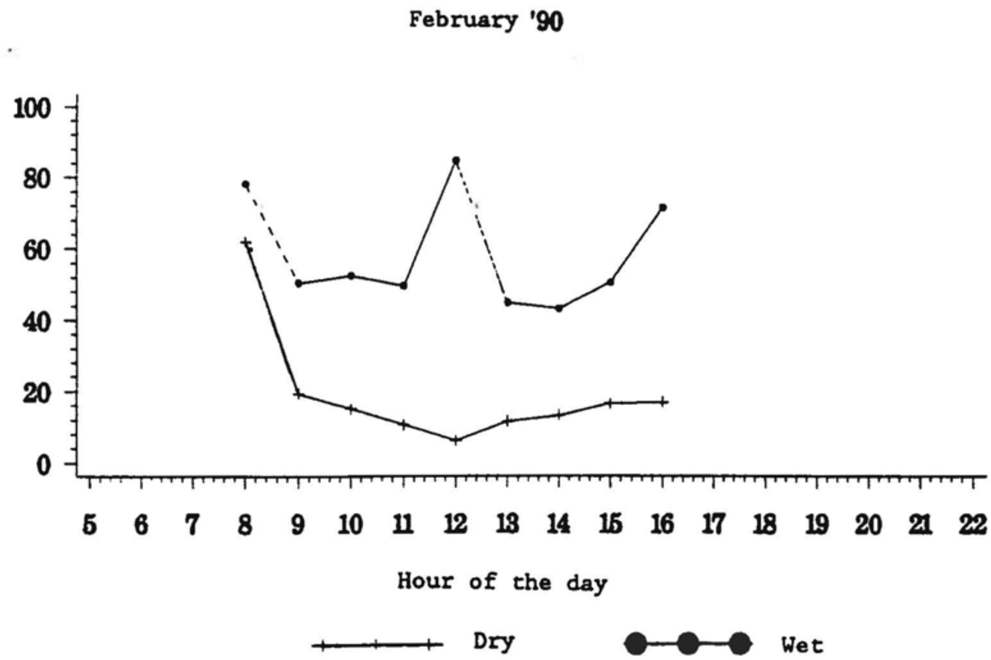
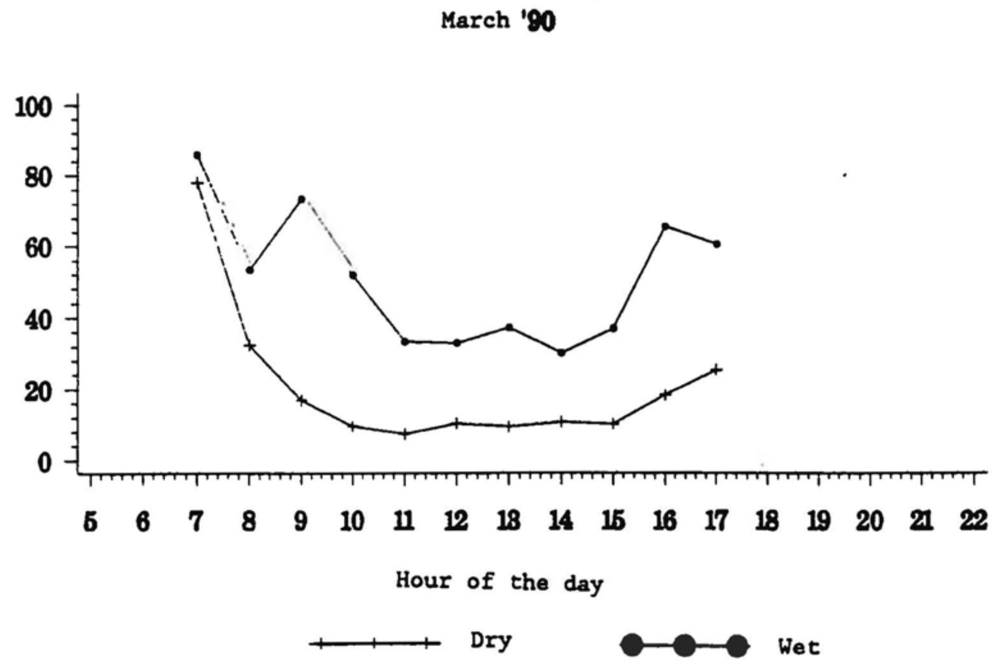
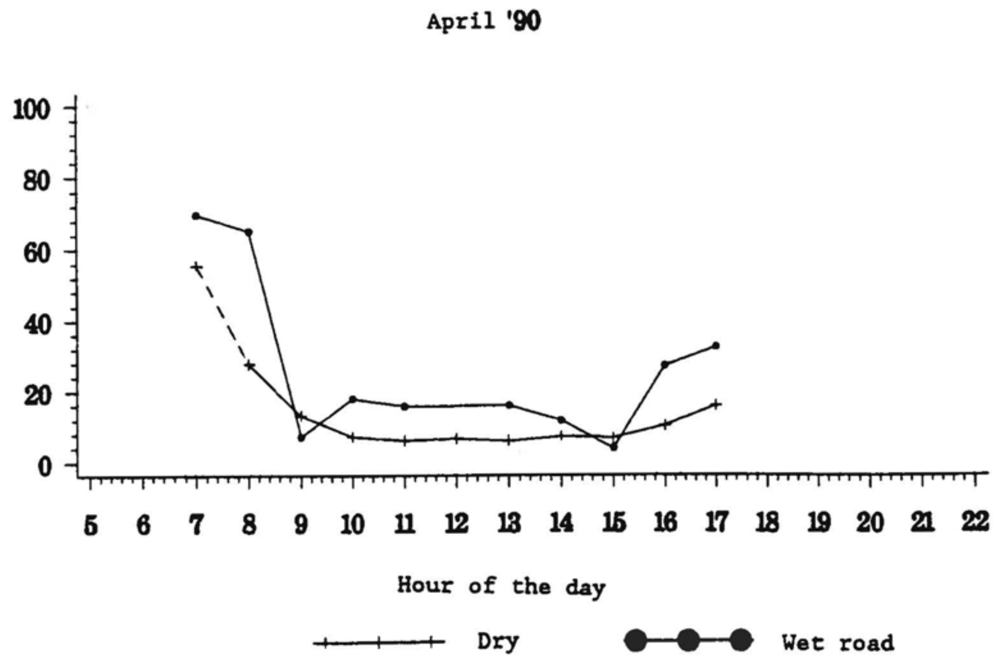


Diagram 20. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in February 1990, according to hour of the day.



<u>Diagram 21</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in March 1990, according to hour of the day.



<u>Diagram 22</u>. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in April 1990, according to hour of the day.

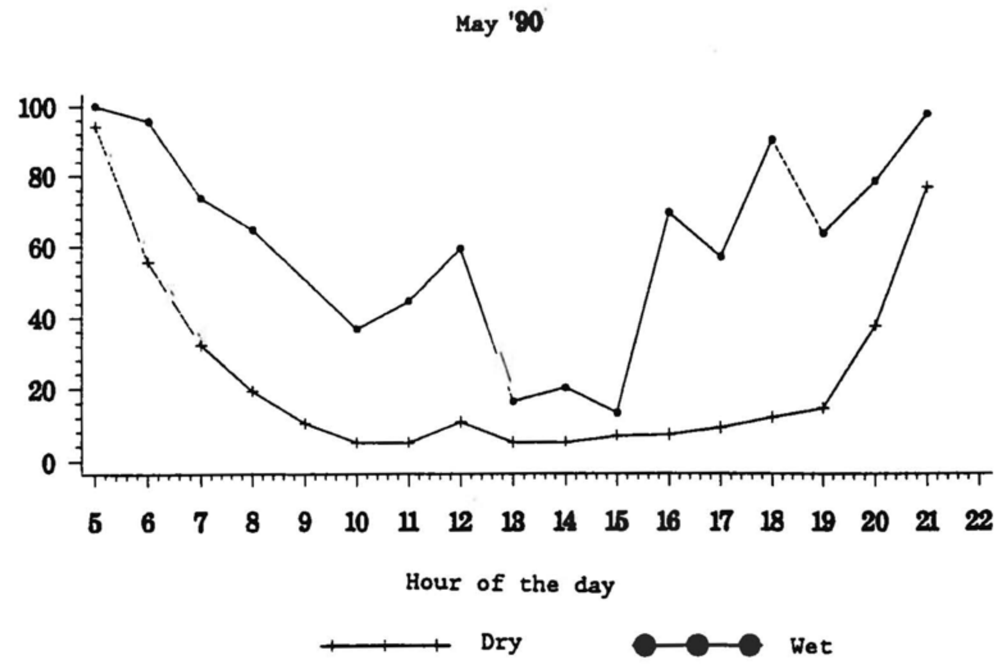


Diagram 23. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in May 1990, according to hour of the day.

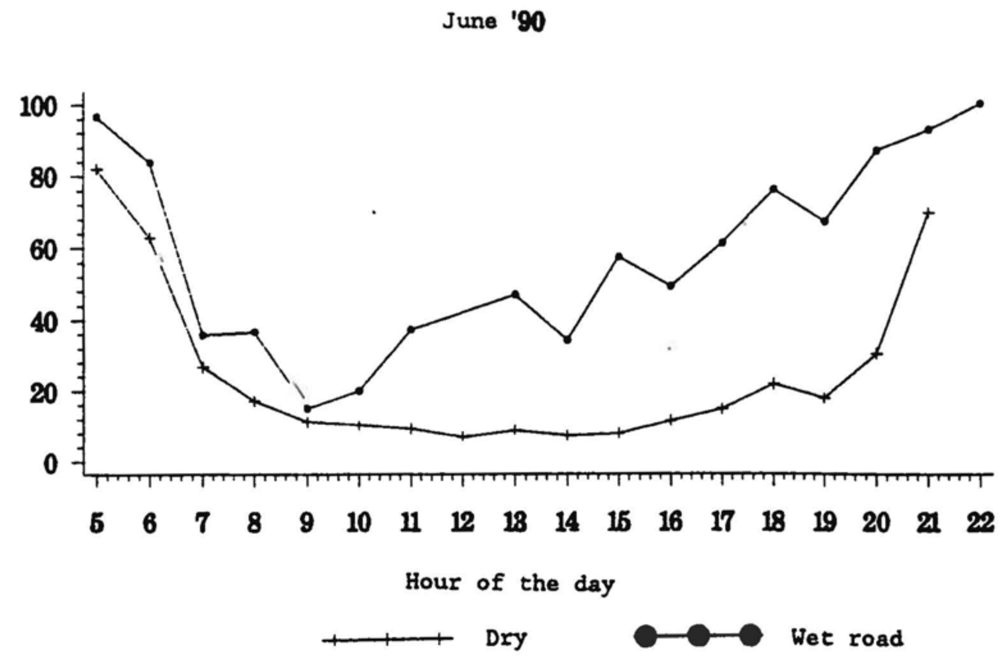


Diagram 24. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in June 1990, according to hour of the day.

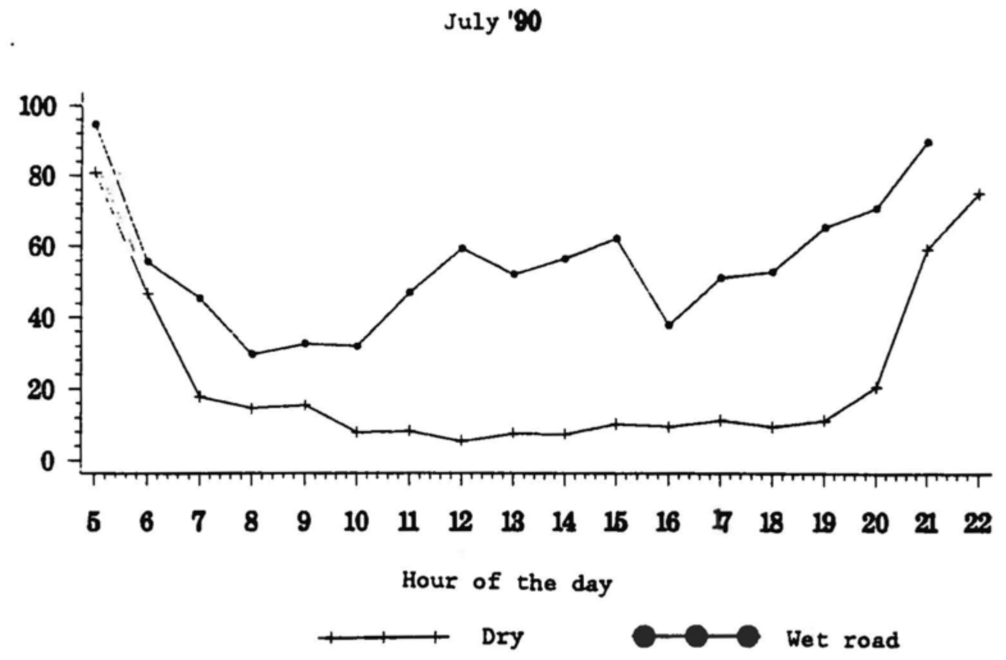


Diagram 25. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in July 1990, according to hour of the day.

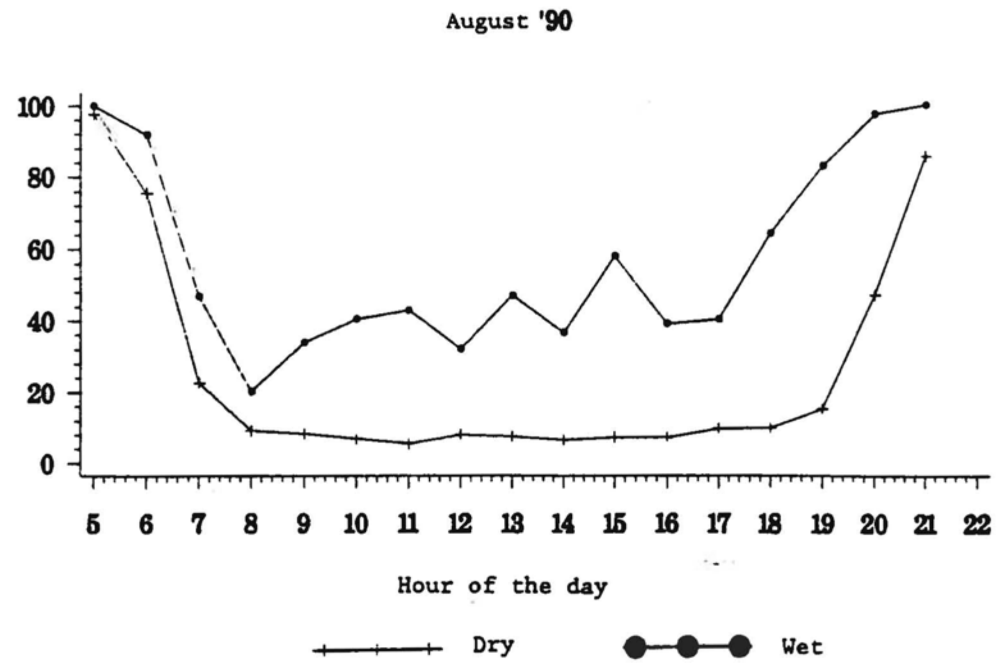


Diagram 26. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in August 1990, according to hour of the day.

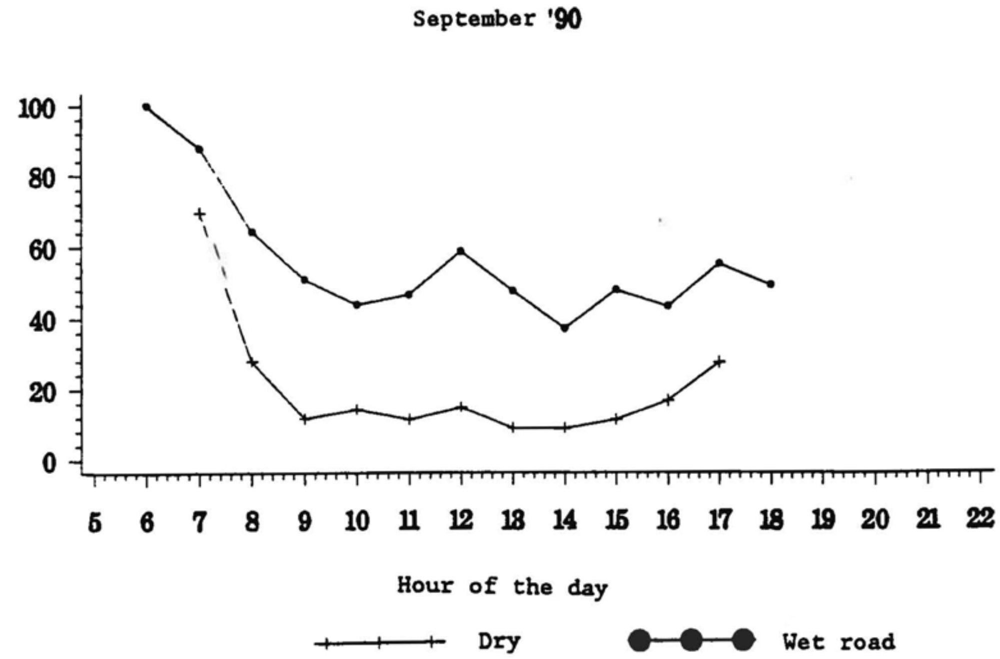


Diagram 27. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in September 1990, according to hour of the day.

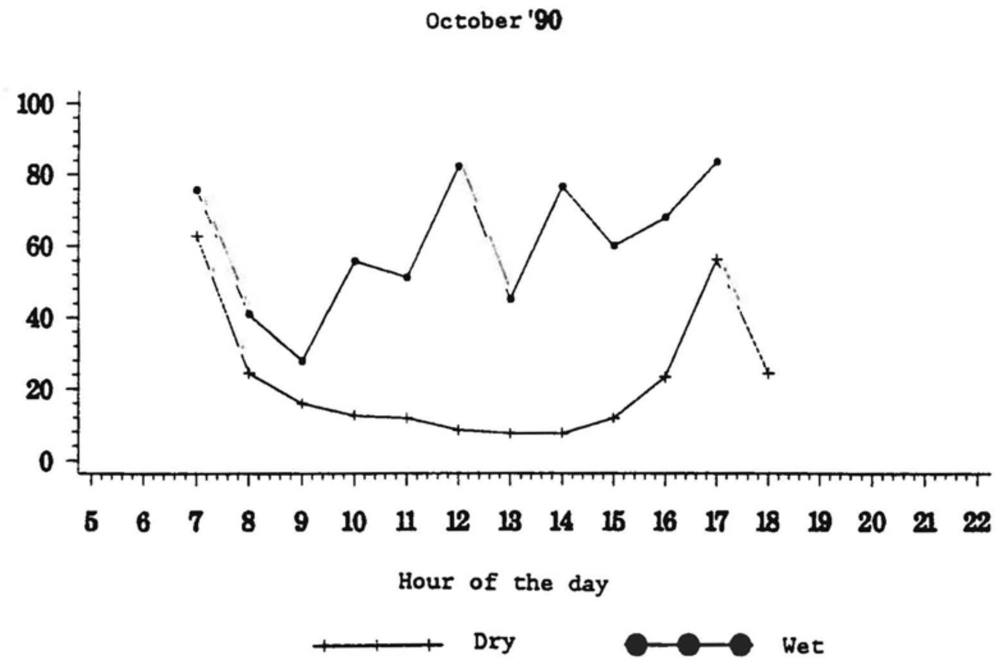


Diagram 28. Distribution of the weighed percentages of DRL use by passenger cars during dry and wet weather as a function of the calculated sun altitude in October 1990, according to hour of the day.

Region North - Dry weather

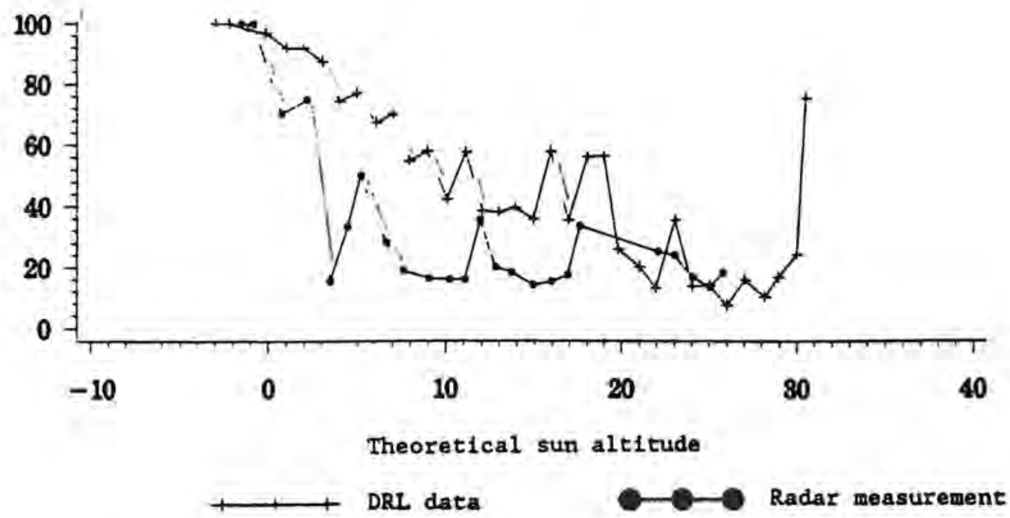


Diagram 29. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Northern region during dry weather.

Region North - Wet weather

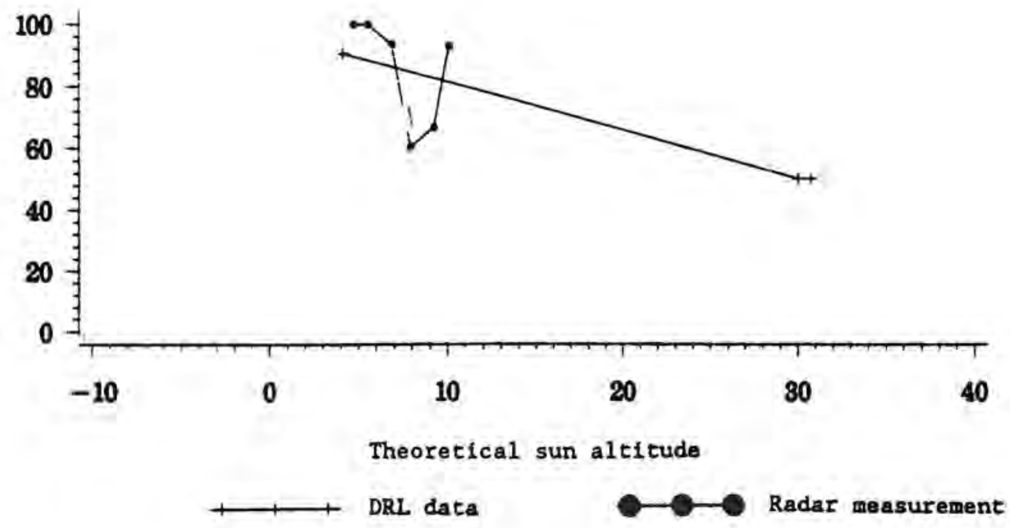


Diagram 30. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Northern region during wet weather.

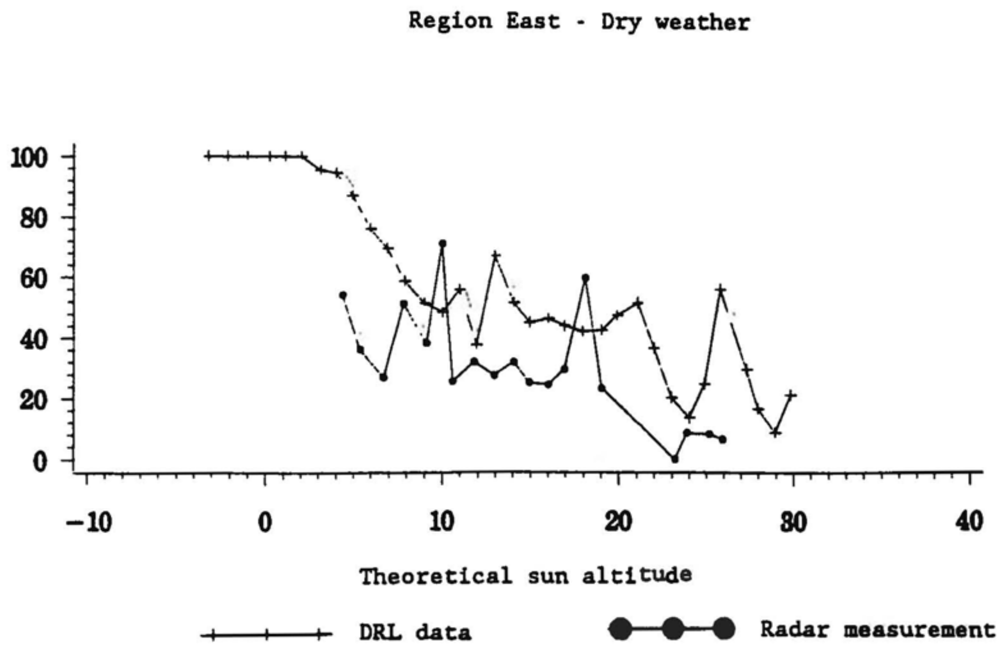


Diagram 31. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Eastern region during dry weather.

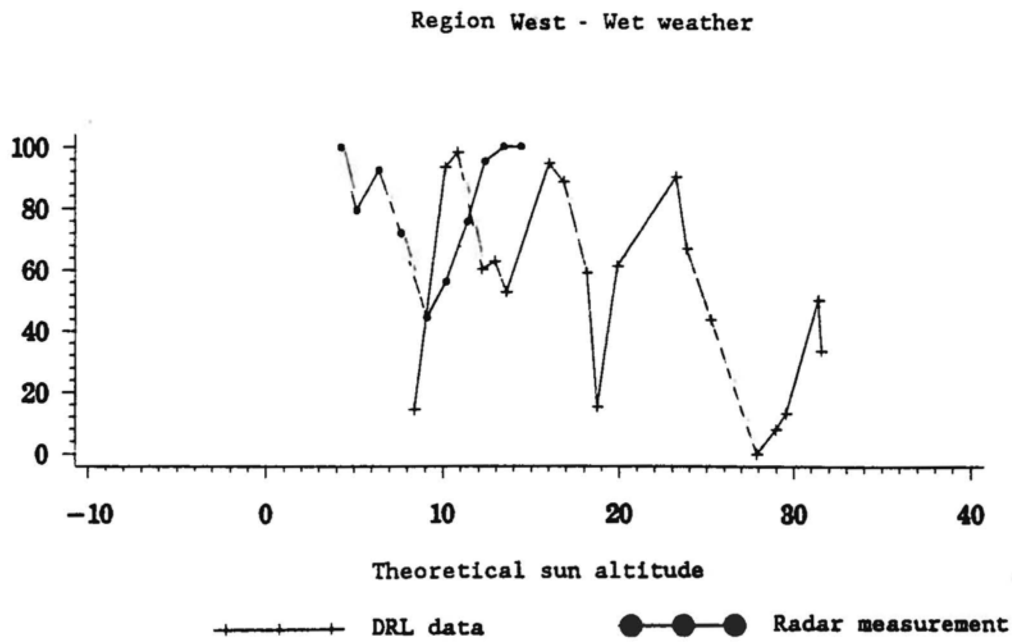


Diagram 32. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Western region during wet weather.

Region South - Dry weather

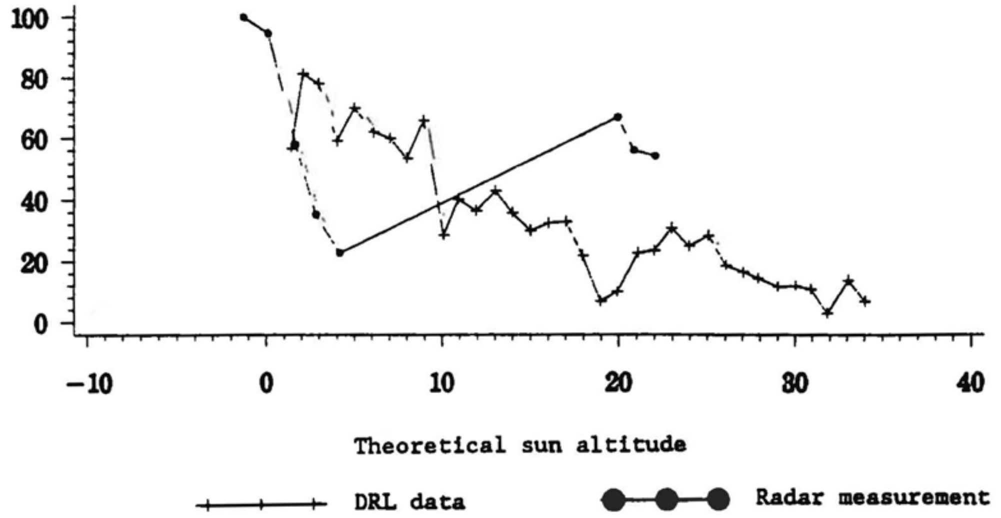


Diagram 33. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Southern region during dry weather.

Region South - Wet weather

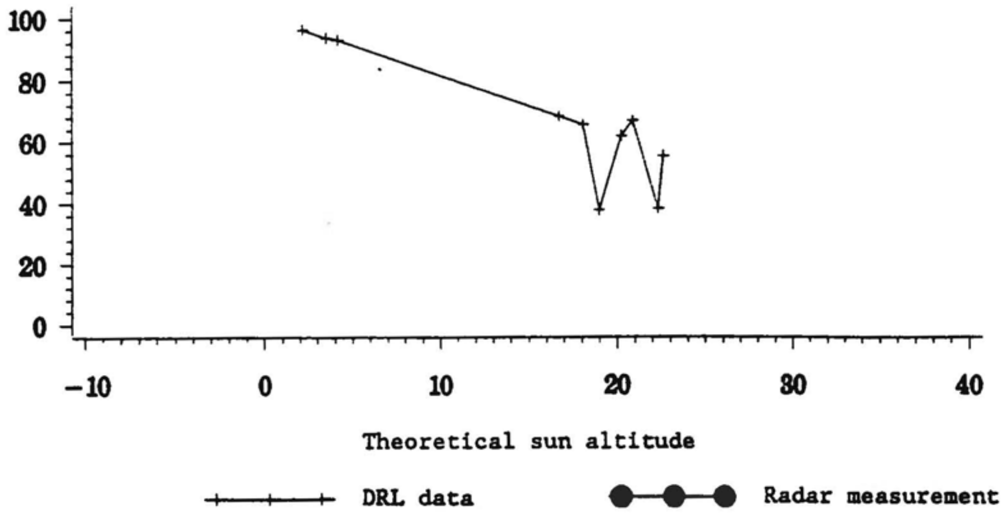


Diagram 34. Distribution of the weighed percentages of DRL by passenger cars for control versus random counts in the Southern region during wet weather.

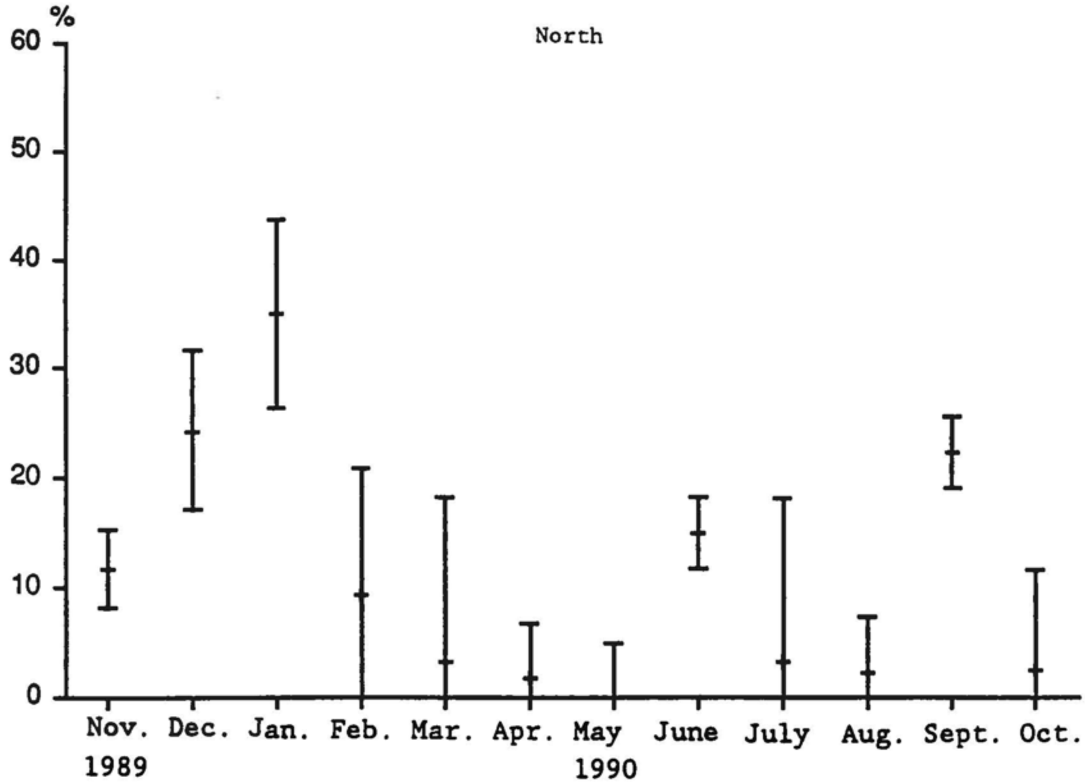


Diagram 35. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Northern region.

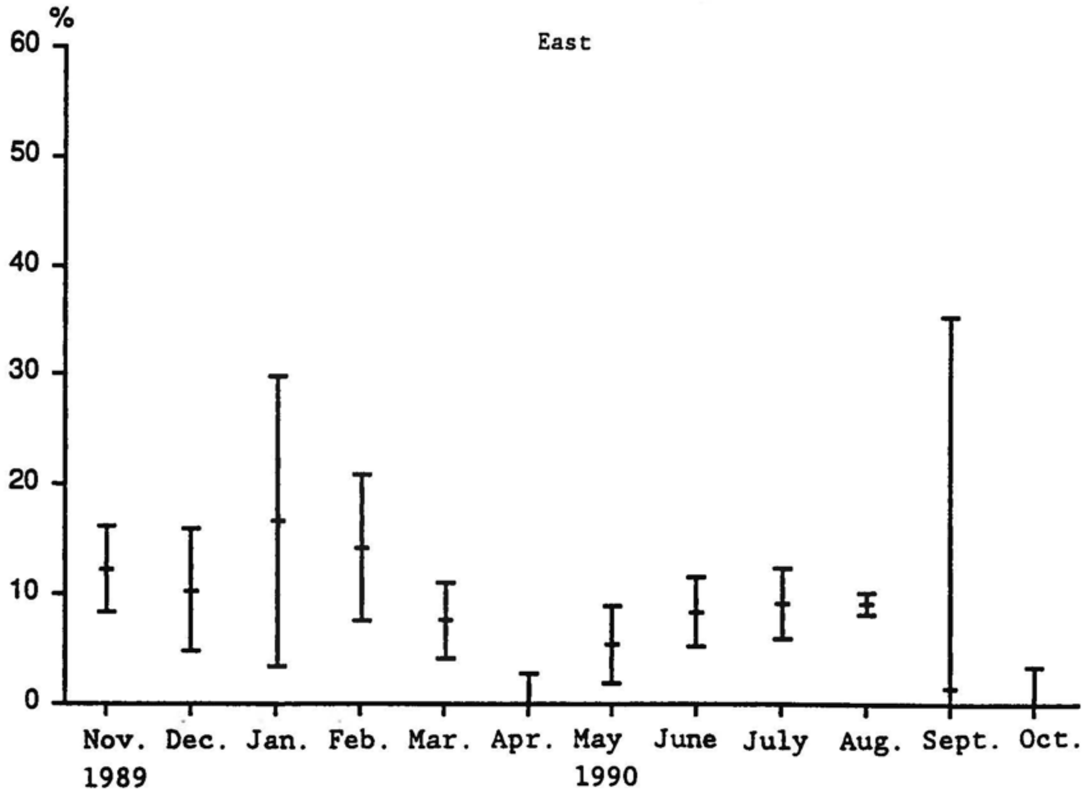


Diagram 36. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Eastern region.

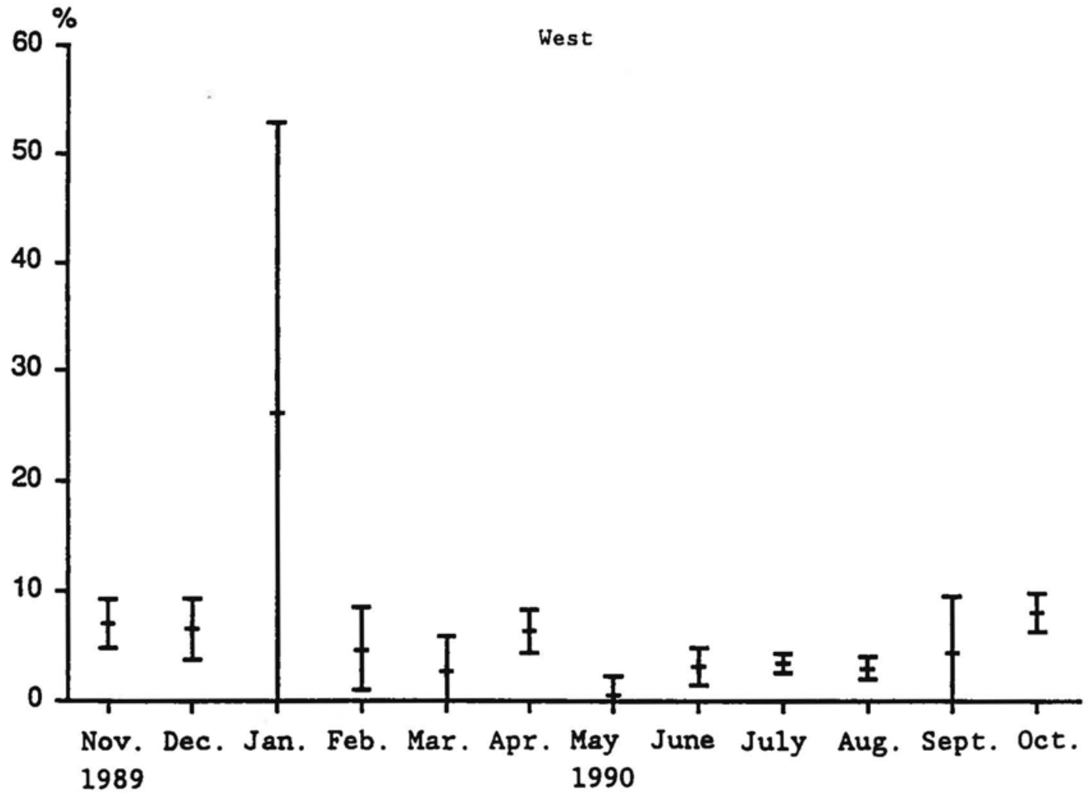


Diagram 37. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Western region.

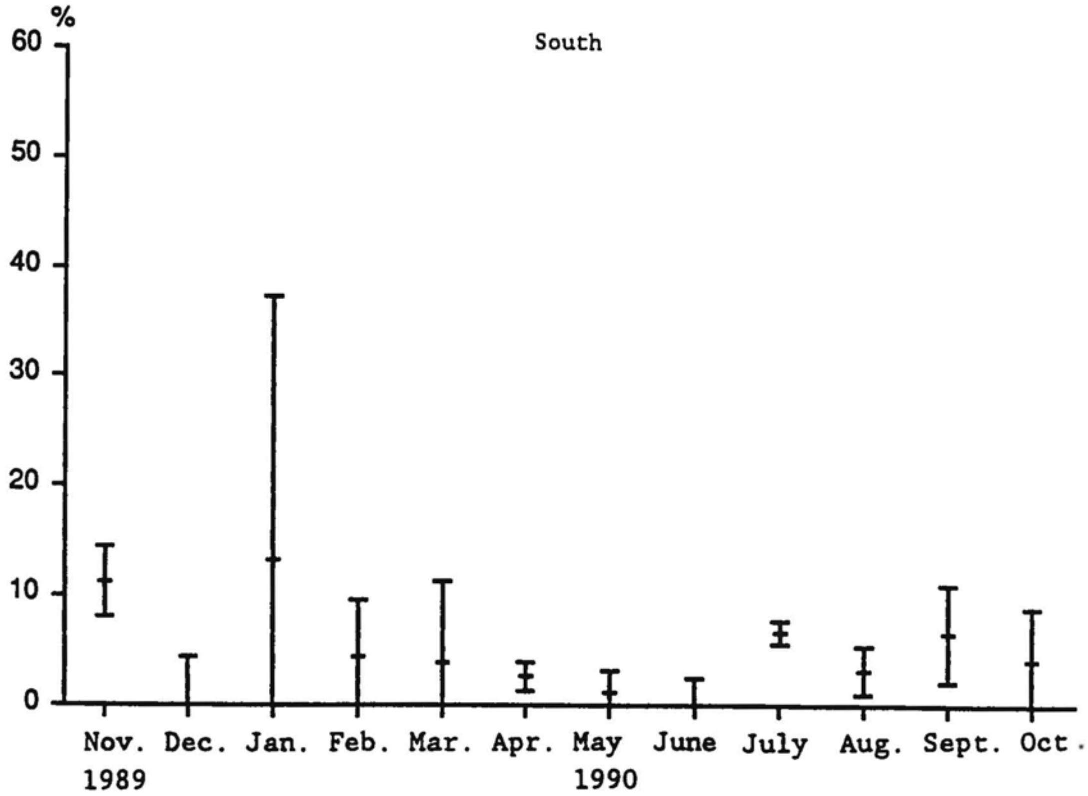


Diagram 38. Estimated C values* for DRL use by passenger cars and the variance (2 x s.d.) in the months November 1989 to October 1990 during dry weather in the Southern region.

TABLES 1 to 6

REGION	WEATHER	MU	SIGMA	C	SD	LNLIKE
noord	Droog [1)]	3.41339	0.36083	0.10649	0.009125	-50440.69
noord	Nat [2)]	3.51738	0.31640	0.43239	0.030205	-18203.60
oost	Droog	3.22704	0.36444	0.08941	0.005908	-86585.01
oost	Nat	3.49351	0.31801	0.35197	0.033877	-32987.53
west	Droog	3.15197	0.34046	0.04073	0.004789	-81709.59
west	Nat	3.59590	0.39259	0.14399	0.037969	-32222.31
zuid	Droog	3.13976	0.37333	0.04472	0.005547	-56623.94
zuid	Nat	3.43428	0.33242	0.40559	0.045432	-27171.86

1) dry; 2) wet

Table 1. Logistic distribution (November 1989 - October 1990)

MONTH	REGION	WEATHER	MU	SIGMA	C	SD	LNLIKE
januari	noord	Droog	3.02863	0.25171	0.34961	0.04310	-1920.04
januari	noord	Nat	3.47600	0.35381	0.75564	0.00000	-821.23
januari	oost	Droog	2.90167	0.33787	0.16649	0.06550	-5484.38
januari	oost	Nat	3.58172	0.18740	0.35762	0.14441	-1350.93
januari	west	Droog	3.44572	0.22848	0.26308	0.13312	-2994.65
januari	west	Nat	3.68676	0.32237	0.39517	0.13159	-4293.77
januari	zuid	Droog	2.93421	0.33755	0.13309	0.11977	-1838.59
januari	zuid	Nat	3.82023	0.24584	0.00000	0.22250	-2192.88
februari	noord	Droog	3.54340	0.29244	0.09179	0.05828	-2570.59
februari	noord	Nat	3.56094	0.29493	0.11163	0.11935	-2395.89
februari	oost	Droog	3.05486	0.22929	0.14261	0.03280	-4734.69
februari	oost	Nat	4.07442	0.55973	0.00000	0.47946	-3138.13
februari	west	Droog	3.23206	0.26726	0.04708	0.01900	-3722.04
februari	west	Nat	3.74011	0.35318	0.00000	0.10573	-3735.27
februari	zuid	Droog	2.94293	0.37369	0.04358	0.02582	-3217.61
februari	zuid	Nat	3.74642	0.15765	0.33798	0.13284	-525.97
maart	noord	Droog	3.48574	0.43328	0.03334	0.07449	-3898.01
maart	noord	Nat	4.24893	0.38982	0.00000	0.77217	-874.25
maart	oost	Droog	3.50880	0.24734	0.07704	0.01556	-6118.94
maart	oost	Nat	3.50932	0.41677	0.10962	0.08851	-4104.94
maart	west	Droog	3.30645	0.25899	0.02675	0.01558	-6157.55
maart	west	Nat	2.98815	0.07246	0.38257	0.04602	-985.09
maart	zuid	Droog	3.50168	0.33587	0.03952	0.03598	-5176.81
maart	zuid	Nat	3.76084	0.35012	0.27425	0.20589	-1215.99
april	noord	Droog	3.56570	0.37015	0.01642	0.02519	-3847.54
april	noord	Nat	3.77264	0.25129	0.36784	0.17448	-293.92
april	oost	Droog	3.58501	0.51008	0.00000	0.01417	-6582.12
april	oost	Nat	3.86783	0.14213	0.14180	0.10659	-592.08
april	west	Droog	3.13056	0.30080	0.06369	0.01000	-4853.56
april	west	Nat	3.61747	0.60203	0.00000	0.12059	-2487.08
april	zuid	Droog	3.69550	0.20030	0.02623	0.00666	-2853.98
april	zuid	Nat	3.54353	0.46486	0.00000	0.09813	-674.71
mei	noord	Droog	3.67753	0.62440	0.00000	0.02520	-5875.13
mei	noord	Nat	4.29073	0.35164	0.11952	0.24497	-660.95
mei	oost	Droog	3.15704	0.42676	0.05250	0.01696	-8888.81
mei	oost	Nat	4.11126	0.52282	0.00000	0.18184	-2707.78
mei	west	Droog	3.14658	0.44777	0.00352	0.00919	-8257.90
mei	west	Nat	2.96339	0.08644	0.65350	0.05322	-573.76
mei	zuid	Droog	3.17260	0.41433	0.01223	0.00951	-4458.73
mei	zuid	Nat	3.58108	0.33513	0.02138	0.03615	-675.37
juni	noord	Droog	3.59660	0.32133	0.14881	0.01582	-7138.65
juni	noord	Nat	3.52094	0.12582	0.50764	0.05022	-750.25
juni	oost	Droog	3.50960	0.33431	0.08393	0.01564	-9592.03
juni	oost	Nat	4.01247	0.38048	0.00000	0.18338	-405.93
juni	west	Droog	3.30886	0.38806	0.03248	0.00899	-8168.76
juni	west	Nat	3.53504	0.27400	0.20509	0.06798	-1995.29
juni	zuid	Droog	3.58756	0.53113	0.00000	0.01226	-7130.27
juni	zuid	Nat	4.10398	0.42752	0.00000	0.19359	-2742.98
juli	noord	Droog	3.69542	0.55279	0.03162	0.07394	-4584.95
juli	noord	Nat	3.71285	0.56641	0.33015	0.16827	-2823.84
juli	oost	Droog	3.49581	0.35957	0.09002	0.01571	-11373.46
juli	oost	Nat	3.64731	0.11642	0.36656	0.02475	-4831.07
juli	west	Droog	3.17827	0.29882	0.03477	0.00338	-8677.89

Table 2. Logistic distribution (November 1989 - October 1990)

REGION	PLACE	WEATHER	MU	SIGMA	C	SD	LNLIKE
noord	binnen	Droog	3.26677	0.35114	0.08355	0.007867	-28543.32
noord	binnen	Nat	3.42861	0.28482	0.39920	0.029327	-11324.47
noord	buiten	Droog	3.69433	0.30807	0.15716	0.015642	-20001.06
noord	buiten	Nat	3.58438	0.36811	0.53601	0.068580	-6542.25
oost	binnen	Droog	3.12584	0.34435	0.06510	0.005424	-53977.93
oost	binnen	Nat	3.43347	0.34552	0.25594	0.042943	-22373.53
oost	buiten	Droog	3.62175	0.29978	0.15614	0.011829	-28447.41
oost	buiten	Nat	3.86958	0.24456	0.44520	0.060509	-8797.02
west	binnen	Droog	3.11062	0.37630	0.03909	0.005393	-49618.44
west	binnen	Nat	3.45891	0.36153	0.22373	0.040854	-17218.35
west	buiten	Droog	3.21247	0.28055	0.04534	0.007505	-31904.48
west	buiten	Nat	3.73474	0.41207	0.03315	0.065241	-14919.49
zuid	binnen	Droog	2.84595	0.32452	0.02522	0.003127	-16927.77
zuid	binnen	Nat	3.30793	0.40082	0.16293	0.047474	-10328.75
zuid	buiten	Droog	3.42099	0.33915	0.06537	0.010747	-35636.76
zuid	buiten	Nat	3.51068	0.32265	0.58272	0.047633	-14159.20

1) inside built-up area; 2) outside built-up area

Table 3. Logistic distribution (November 1989 - October 1990)

ROAD	WEATHER	MU	SIGMA	C	SD	LNLIKE
snelweg 1)	Droog	3.43807	0.27861	0.12712	0.01283	-49740.70
snelweg	Nat	3.60583	0.39849	0.48604	0.10294	-15393.38
autoweg 2)	Droog	3.18648	0.39059	0.07370	0.01506	-27575.85
autoweg	Nat	3.43286	0.33623	0.44906	0.05188	-12372.26
80 km 3)	Droog	3.45566	0.34518	0.06000	0.00569	-45241.04
80 km	Nat	3.53567	0.27867	0.47175	0.02746	-18790.08
doorgaand 4)	Droog	3.13776	0.35081	0.06668	0.00425	-99015.68
doorgaand	Nat	3.42864	0.31365	0.30423	0.02821	-37936.93
lokale 5)	Droog	3.01481	0.37001	0.03289	0.00326	-52101.76
lokale	Nat	3.39258	0.39258	0.19303	0.03013	-23693.56

1) motorway; 2) secundary road; 3) 80 km/hr road; 4) through; 5) local

Table 4. Logistic distribution (November 1989 - October 1990)

PLACE	WEATHER	MU	SIGMA	C	SD	LNLIKE
binnen	**Droog**	**3.09631**	**0.36216**	**0.05077**	**0.003131**	**-152247.02**
binnen	**Nat**	**3.43541**	**0.35674**	**0.24685**	**0.020933**	**-61923.81**
buiten	**Droog**	**3.38960**	**0.32927**	**0.08981**	**0.006671**	**-123501.42**
buiten	**Nat**	**3.54911**	**0.34579**	**0.46197**	**0.036801**	**-46761.36**

Table 5. Logistic distribution (November 1989 - October 1990)

DAY	WEATHER	MU	SIGMA	C	SD	_LNLIKE_
werkdag	**Droog**	**3.21350**	**0.35752**	**0.06584**	**0.003728**	**-214451.95**
werkdag	**Nat**	**3.59007**	**0.37310**	**0.23078**	**0.028411**	**-74173.47**
weekend	**Droog**	**3.14202**	**0.40264**	**0.05728**	**0.005705**	**-66228.64**
weekend	**Nat**	**3.42405**	**0.29298**	**0.44439**	**0.032768**	**-36861.98**

Table 6. Logistic distribution (November 1989 - October 1990)

APPENDICES I AND II

Appendix I. Account of the set-up and execution of the measurement programme examining the use of DRL in the months November 1989 to October 1990.

Appendix II.1. General map of the Netherlands showing areas where speed measurements were conducted.

Appendix II.2. Overview of measurement locations per region.

Appendix II.3. Example of a counting record as used by the observers.

APPENDIX I

ACCOUNT OF THE SET-UP AND EXECUTION Of THE MEASUREMENT PROGRAMME EXAMINING THE USE OF DRL IN THE MONTHS NOVEMBER 1989 TO OCTOBER 1990.

I.1. Random survey of measurement locations

In order to collect reliable data on the use of DRL at a national level, the Netherlands was subdivided into the following sub-populations on the basis of anticipated differences in DRL behaviour:
According to types of road (through roads and local roads) inside the built up area, taking into account the degree of urbanisation of the towns within an area:
- large towns (> 100,000 inhabitants);
- medium-sized towns (> 30,000 and < 100,000 inhabitants);
- small towns (< 30,000 inhabitants).

According to road types outside the built up area:
- motorways and secondary roads;
- other road types

Aside from the given locations, the region itself is also included as a variable. Each region includes all given location types once (a total of nine). The four regional areas are represented by the following provinces:
Region: North - Groningen, Friesland and Drenthe;
Region: East - Overijssel, Gelderland and Flevoland;
Region: West - Utrecht, North and South Holland;
Region: South - Zeeland, North Brabant and Limburg.

Based on the subdivisions as given in the above, the roads and towns in each region were allocated a number; one number for each location type was then taken at random. If it was found that the types of location were located too close to each other (so that it was likely that the same traffic would be observed), then a new number was drawn.

A suitable measurement site was then chosen for each location. The measurement site could not be situated close to any tunnels, as it is compulsory to switch lights on upon entering. When people exit the tunnel, they may 'forget' to switch off their lights. Measurement of this radiating effect had to be avoided, otherwise it would have influenced the interpretation of the use of DRL. In order to measure the light intensity as accurately as possible, the measurement site had to be 'free', i.e not situated in the shadow of trees or large buildings. When a suitable measurement site was found, the local police force was informed about the proposed study.

I.2. Restrictions and consequences

In order to stay within the financial budget, a number of restrictions were imposed on the execution of the measurement programme with respect to the original set-up (Lindeijer, 1990), in consultation with the Transportation and Traffic Research Department (DVK) of the Ministry of Transport. These restrictions included:

- Within the built up area, measurements alternated between traffic on a through road for half a day and traffic on a local road for the other half of the day. This was also done for measurements on motorways and secondary roads. Therefore, two months were required to collect data for one full working day per measurement location. This has also led to a comparison between working days per measurement site only being possible after a period of ten months.
- Rather than taking measurements on one weekend day per measurement site each month, only half the measurement sites were included during one weekend day per month. This led to the 80 km/hrs roads being measured during one full Saturday and one full Sunday after four months, while measurements were completed at all other measurement sites after eight months only (see previous explanation).
- By combining measurements, measurements were often only taken for one hour, rather than two hours, per period of the day and per measurement site (the months of November and December 1989 and January, February, March and April 1990 were divided into four day periods). In order to perform sufficient measurements for each day period, a minimum of two months per measurement location was required.

I.3. Representative value

The measurement programme was set up such that the greatest possible distribution of measurement sites over the Netherlands was realised. In addition, the measurement hours are well distributed over the entire measurement day, which enhances the chances of conducting sufficient measurements during rainy weather. It is also necessary to spread measurements out over the day in order to divide the 'motor vehicle' population into sub-populations on the basis of 'destination'. In addition, it was attempted as far as possible to distribute the working days and weekend days over all measurement locations for each month. In this way, a maximal spread of the measurement programme was achieved within the confines of the financial budget, so that the measurements are expected to offer a reasonably representative picture of the use of DRL in the Netherlands for the principal factors of influence. One location type per region (being representative for all comparable locations within the region) is not enough from a statistical point of view. Therefore, it is not possible to speak of a representative value in the statistical sense of the word. In order to deal with this problem, additional measurements were carried out. These are incidental measurements (which were not a fixed item in the measurement programme). The results of these measurements were used to assess to what extent the use of DRL at a particular location in the random survey agrees with comparable (control) locations in the same region. These measurements have shown that the use of DRL on polder roads is different from the use on 80 km/hr roads in the same region. It was therefore decided that, after January 1, 1990, two polder roads would be included in the measurement programme. Another way of establishing the comparability of the different locations is to 'accompany' other studies. This opportunity presented itself during speed measurements on 80 km/hr roads in the Netherlands (see also Chapter 7).

I.4. Reliability of the observations

The significance of the evaluation study increases if, within the group of DRL-related accidents, a distinction can be made according to situations/circumstances where the measured increase in the use of DRL is greatest. The significance is also enhanced if, with regard to the use of DRL, experimental conditions were distinguished. Therefore, the value of the study is strongly associated with the degree to which the measurement of DRL is reliable.

I.4.1. The material used

During the first several months (November 1989 to May 1990), six lux meters with a range of 200,000 lux, three lux meters with a range of 20,000 lux and one photometer were used.
During a measurement day, light values and lux values were noted simultaneously. It was possible to convert the values of the photometer to lux values with sufficient accuracy. From June 1, 1990, the photometer was replaced by a lux meter with a range of 200,000 lux, while the range of the lux meters with a range of 20,000 lux was extended to the same range (200,000 lux). From that date onward, all lux meters could therefore measure light intensities up to 200,000 lux. One of the lux meters was used as a test meter.
When counting motor vehicles, the observers used counters for the categories of passenger cars (DRL on/off) and lorries/vans (DRL on/off). Only vans with double back wheels were counted as freight traffic. The idea here is that drivers of such vans can be regarded as belonging to the category of 'professional drivers', for whom DRL behaviour is expected to differ from that of passenger car drivers.
For each measurement hour, the position of the counter (cumulative) was noted at five minute intervals (= measurement unit) on a counting record, and a light measurement was performed (see Appendix I.3). Motor cycles (DRL on/off) and mopeds (DRL on/of) were counted and totalled at five minute intervals. This method led to the least number of mistakes/incorrect recording.

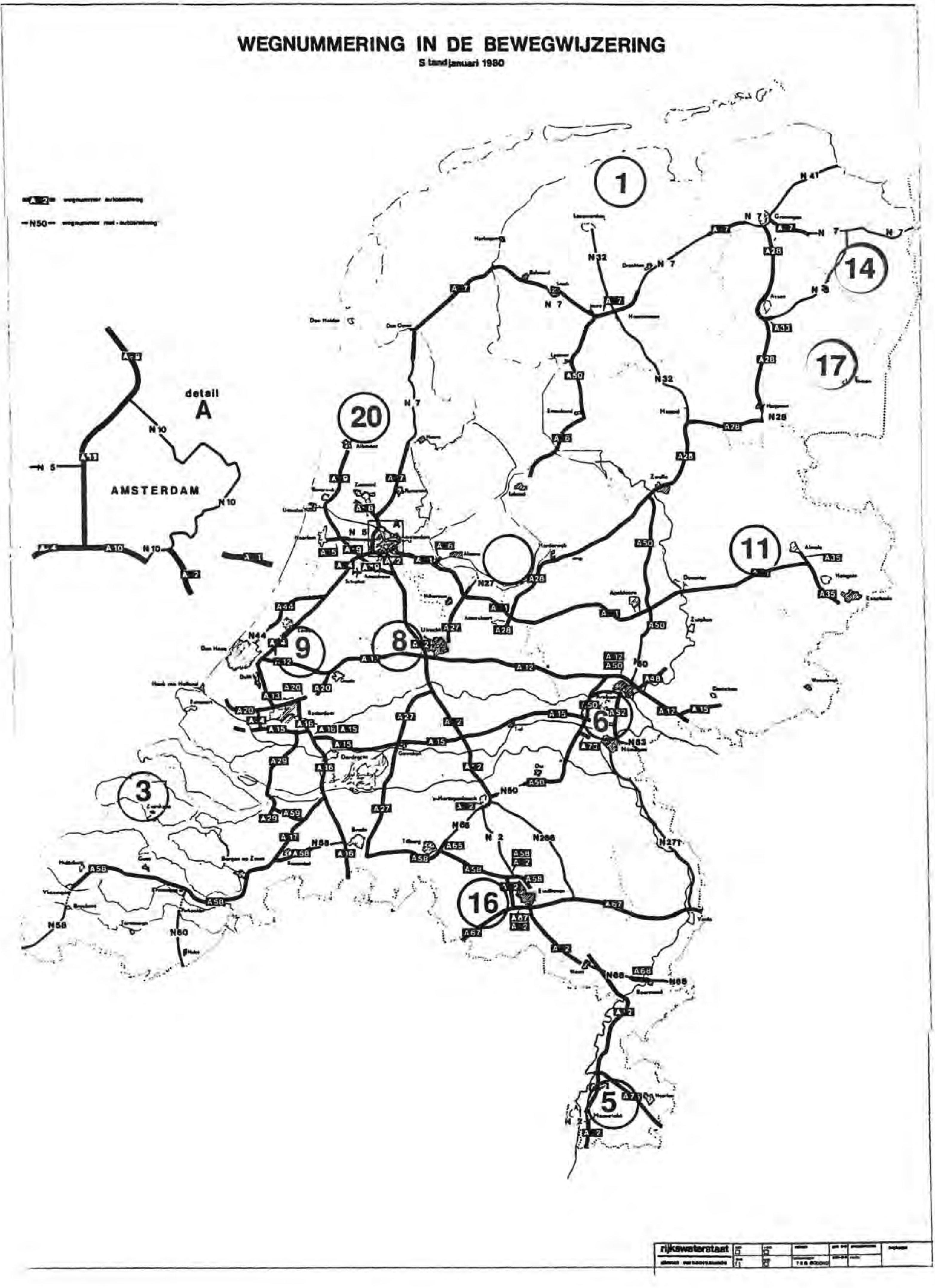
I.4.2. Simultaneous measurements

To establish the reliability of observations, it is necessary to demonstrate that:
- the observer measures the use of DRL consistently;
- the measurement of light intensity are sufficiently consistent;
- the lux meters are calibrated.

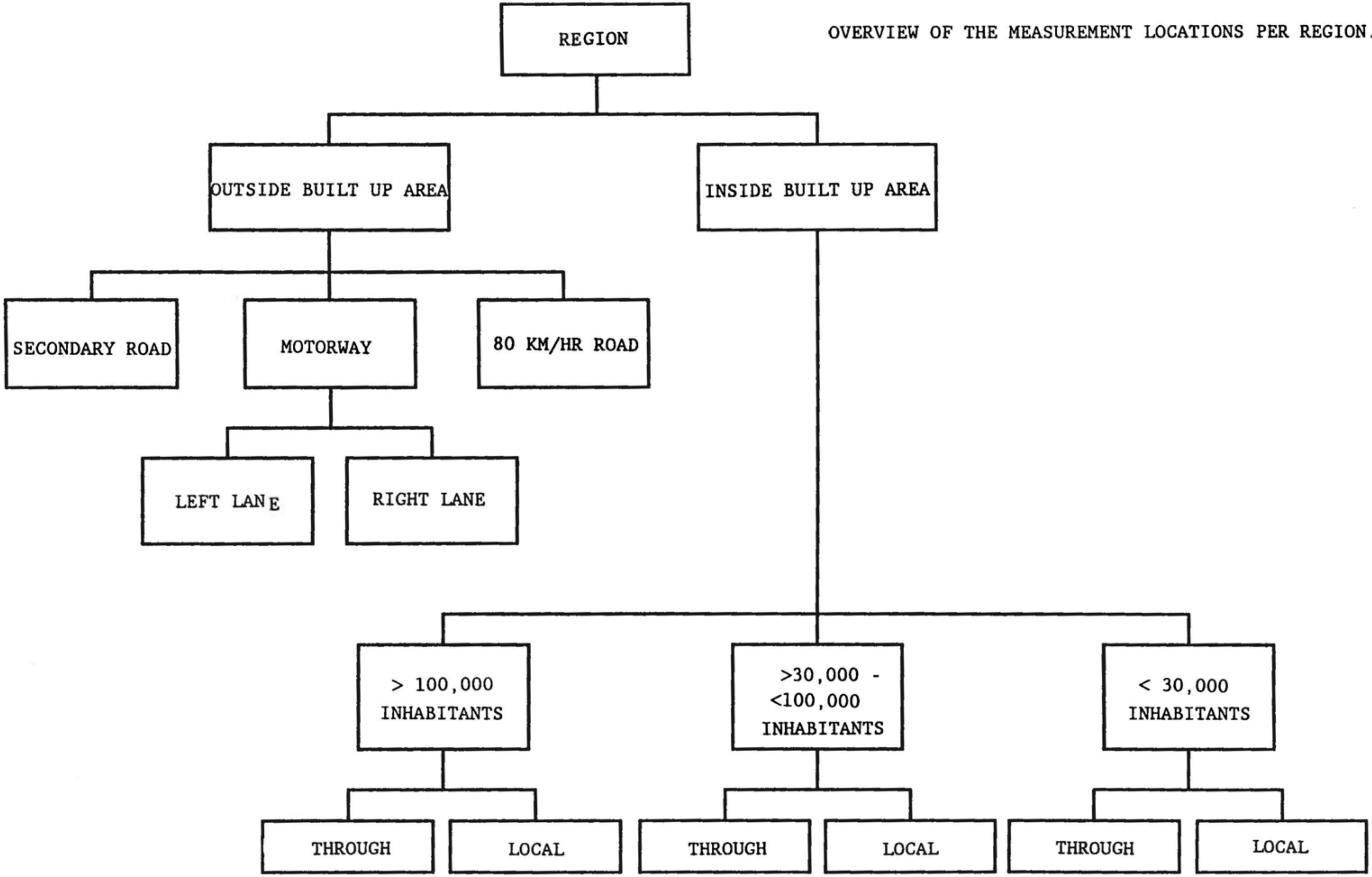
The reliability of the observed use of DRL and the measured light intensity was determined on the basis of simultaneous measurements. These measurements were performed per observer, without his knowledge. The results of the simultaneous measurements and the 'normal' measurements were compared. The degree of consistency determined the degree of accuracy of the observations. The simultaneous measurements were performed by the same observer, using the test lux meter. The following table shows the degree of correlation (correlation coefficient) for the various vehicle categories.

Vehicle category	DRL	Total
Passenger cars	0.99	0.91
Lorries (vans)	0.97	0.83
Motor cycles	0.79	0.83
Mopeds	0.81	0.90

Once a year, all lux meters are calibrated with reference to the test meter. The degree of consistency between measurements and the light intensity is tested on a statistical basis.


WEGNUMMERING IN DE BEWEGWIJZERING
Stand januari 1980
detail A
AMSTERDAM
1
3
5
6
8
9
11
14
16
17
20
rijkswaterstaat

OVERVIEW OF THE MEASUREMENT LOCATIONS PER REGION.



WEER:
- helder-zonnig = 1
- licht bewolkt = 2
- droog/zwaar bewolkt = 3
- motregen = 4
- lichte regen = 5
- zware regen = 6
- sneeuw/hagel = 7

ZICHT:
- goed zicht = 1
- nevel = 2
- mist = 3
- dichte mist = 4

WEGDEK:
- droog = 1
- nat = 2

OPENB. VERL.:
- geen = 0
- brandt = 1
- brandt niet = 2

openbare verlichting ☐

WAARNEMER: MEETPLAATS: RIJSTROOK: DATUM: . **TIJD:........................**

					verlichting AAN					verlichting UIT			
tijd	weer	zicht	wegdek	luxw.	personenauto	K*	bestel/vracht	motorfiets	bromfiets	personenauto	bestel/vracht	motorfiets	bromfiets

K* = kapotte lampen personenauto's

Appendix II.3.