POSSIBILITIES OF A DRL-EXPERIMENT IN THE NETHERLANDS: NORTHERN LIGHTS CAMPAIGN

Account of an analysis to enable statements concerning the duration and scope of an experiment on daytime running lights (DRL) in the northern provinces of the Netherlands

R-90-37
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Leidschendam, 1990
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SUMMARY

The Transportation and Traffic Research Department (DVK) of the Dutch Ministry of Transport has submitted three questions to the SWOV. They concern the duration and scope of a DRL experiment in the northern provinces of the Netherlands, the reliability of statements made on the basis of an evaluation study of the experiment and the possibility of assessing the effect of DRL in relation to road safety for slow traffic, taking into account that the use of DRL would be voluntary for this experiment.

The analysis is based on strict statistical requirements - stricter than the usual norm employed for various probability calculations.
The success of the experiment depends on the degree to which drivers will cooperate by using DRL. What this implies for the duration of the experiment and the scope of the experiment is shown in the table below (based on an estimation of a 10% drop in multiple daytime accidents involving at least one motor vehicle). The table includes the percentage of DRL use, given an 80% probability that an effectiveness of 10% can be demonstrated and that the minimal number of multiple daytime accidents recorded in the after period is 90% certain. Furthermore, a three-year experiment is not considered a realistic option.

Test area (provinces)	One year	Two years
Groningen, Friesland and Drenthe	approx. 65% DRL	approx. 55% DRL
Groningen, Friesland, Drenthe, plus Overijssel	approx. 55% DRL	approx. 50% DRL

Rounded off at 5%

- The percentage of DRL use under dry, clear conditions is presently 14% (approx.) in the northern provinces. This percentage is considerably higher than in the west of the Netherlands (approx. 2%). It is therefore reasonable to assume that the stimulation of DRL in the north would have a good chance of success.
- The accident analysis of the experiment should commence one year after the percentage of DRL use has risen to the percentage quoted in the table,

provided sufficient reliable measurements of DRL are reported in the test area and the transitional area before and during the experiment. These measurements must be conducted under situations and circumstances that represent the principal criteria for the accident analysis.

- The analysis will look at injury accidents and material damage only (MDO) accidents.
- By using selected accident groups in the analysis, based on DRL use over the before period, an effect must be demonstrable. This analysis approach is unique, because until now no other study (outside the Netherlands) could avail itself of extensive measurement data on the use of DRL during the before and after period.

Analysis results from this type of data permit forceful statements; the reliability of these statements is dependent on this approach and will therefore be considerable.

- The use of injury accidents and MDO accidents also offers sufficient opportunity to study the effect of DRL on the safety of cyclists and pedestrians, provided that DRL use in the built-up area reaches the minimum level necessary for analysis (and satisfies the annual percentage quoted in the table).

CONTENTS

FOREWORD

One of the ways to improve the visibility of motor vehicles is the use of daytime running lights (DRL). Based on the data available in 1986, the SWOV estimated what the effect would be for the Netherlands: a reduction of 4% to 5% in the total number of injury accidents if DRL were fully complied with. These considerations have led to a plan to made DRL compulsory in the Netherlands after November 1990. Since January 1990, the media has expressed a great deal of criticism about the set-up and methodology of studies conducted abroad. Doubt was also expressed about the status of unprotected road users after the introduction of DRL and the influence partial use of DRL would have on safety. These uncertainties have led the Minister of Transport to postpone the compulsory use of DRL. Instead, she intends to stimulate the use of DRL in a limited area in the north of the Netherlands (in order to study a number of uncertainties about its effectiveness) before deciding whether to introduce it on a nationwide scale.

The Transportation and Traffic Research Department (DVK) of the Ministry of Transport has asked the SWOV to calculate - taking into account increasing use of DRL in the test area - the length of time such a experiment should continue before reliable statements about the effectiveness of DRL can be made. In addition, it was queried whether the influence of DRL on the safety of pedestrians and cyclists could be determined, given a certain experiment period.
This report gives an account of the analysis conducted, which will form the basis of a recommendation on the value and reliability of statements to issue from an evaluation study conducted in the test area.

This report was compiled by J.E. Lindeijer; F.D. Bijleveld designed the computer programmes and performed the analysis.

1. INTRODUCTION

The Dutch Minister of Transport intends to stimulate the use of DRL in the northern provinces of the Netherlands on a voluntary basis. The Transportation and Traffic Research Division (DVK) of the Dutch Ministry of Transport has put the following questions to the SWOV:

1. What is the degree of reliability with which a statement can be made about the effect of DRL on road safety in lieu of the proposed campaign in the northern provinces, if DRL use in the test area varies between the present level and 100%?
2. To what extent can a statement be made about the effect of DRL on the safety of pedestrians and cyclists?
3. How long should the experiment continue to allow reliable statements about the effectiveness and the safety of other traffic participants (besides motor vehicles)?

In order to answer these questions, it must first be determined whether there is evidence of a trend - a drop or rise - in the number of DRL-related accidents. The number of DRL-related accidents anticipated over the after period can then be calculated for the test and control areas (Chapter 2). Based on the figures anticipated, the probability is then calculated that a degree of effectiveness can be demonstrated during the after period, given an increasing use of DRL in the test area and no rise in DRL use in the control area (Chapter 3). The report concludes with a reply to the questions put forward, based on the results of this analysis (Chapter 4).

2. PRINCIPLES OF THE ANALYSIS

Proving an effect

Previously formulated hypotheses concerning the expected effect will be tested in the evaluation study. Whether the effect can also be statistically proven (is significant) is very much dependent on the number of accidents for each group. If the number is too small, the effects may be great, but a statistical significance is difficult to prove. Therefore, the starting point of this analysis is to reach a compromise between the maximum number of accidents per subgroup and the greatest possible subdivision of accidents according to situations and/or circumstances and vehicle categories.

Options

In the analysis, the number of accidents in the after period is calculated on the basis of the figures for the before period, specifically injury accidents only and in combination with MDO accidents. In addition, the following options are taken into account:
- three or four provinces may be encompassed by the test area;
- the experiment may last one or two years.

Relevant and non-relevant accidents

A distinction has been made between accidents where it is assumed an increasing use of DRL will or will not have an effect.
Relevant accidents (in test and control area) include: multiple daytime accidents involving at least one motor vehicle.
Non-relevant accidents (in test and control area) include:
- nighttime accidents
- single daytime accidents
- daytime accidents not involving a motor vehicle.

Expected effectiveness

It is expected that the use of DRL will increase in the test area but not in the control area, therefore an effect is assumed to be noted only for the test area. Whether this will indeed be the case will have to be shown by measurements of DRL use in the control area; should these also show a rise, analysis will become more complex.

Furthermore, it is expected that the effect will not be of the same magnitude for all types of traffic and under all circumstances and situations. The greatest difference is expected to be in the number of collisions between fast traffic and slow traffic in the built-up area; the lowest between fast traffic on the motorways.
Any other measure, development or influence on road safety is assumed to exercise a similar influence on both the test area and the control area.

<u>Influences on the control area</u>
If external influences (excluding DRL) prove to have a different effect on the test area than on the control area, this factor will be corrected for, based on a comparison between non-relevant accidents in the test area and in the control area, i.e. the trend in the number of non-relevant accidents.
If additional campaigns for road safety are introduced in the Netherlands over the coming experiment period, or an active dissuasion policy in relation to (use of) the car is in force, it is assumed that these will have the most impact on the development of accidents in the west of the Netherlands (Utrecht, North Holland and South Holland). The Western Region forms part of the control area. It is expected, therefore, that non-DRL-relevant accidents will show a proportionately greater drop than will their counterpart in the test area. The probability of this development is taken into account in the analysis, on the basis of a 5% drop.

<u>Criteria for subdividing accidents</u>
Accidents can be split into daytime and nighttime accidents on the basis of accident data (day, twilight, night). This categorisation can be better subdivide with the aid of measured DRL use.
It has been shown that motor vehicles (aside from motorcycles) virtually all switch on their lights at a light level below 100 lux (Lindeijer & Bijleveld, 1990). It would be ideal if accidents could be categorised into daytime and nighttime accidents with the aid of this light level reading. Although the light level is not reported by the accident registration, it is possible to estimate this by using a formula for the sun altitude. This formula has been developed and tested as part of a nationwide evaluation study into the effect of DRL (see Annex).
Analysis of the user data has shown that DRL use varies widely for each group classed under the category of fast traffic.

For example, during clear, dry weather in the daytime, approx. 76% of motorcycles already use DRL, against approx. 6% of cars. DRL use for lorries and vans lies somewhere between these two values (Lindeijer & Bijleveld, 1990). This discrepancy must be corrected for in the evaluation study.

3. CALCULATION OF THE NUMBER OF ACCIDENTS IN THE AFTER PERIOD

3.1. General

Statistical requirement

There are annual fluctuations in the number of accidents (the 'noise' in accident data). In order to calculate the number of future accidents, this must be taken into account. Especially when it concerns a calculation where a drop in the number of accidents is anticipated. Given the 'noise' in these types of situations, the minimal number of accidents required is calculated in order to be able to demonstrate a true drop. In this connection, the probability of mistakenly attributing a measured drop to the effect - while in reality it is coincidental (the noise) - is usually set at 5% or 10% (alpha probability). On the other hand, there is a risk of unfairly attributing a measured drop to coincidental fluctuations, while in fact there is question of a true effect (the beta probability).
In fundamental research, an alpha probability of 1% to 5% is customary, but in empirical studies (as in this case) an alpha probability of 5% to 10% is more often used. Especially when differences are looked for, without there being a definite notion about the expected magnitude of these differences. The latter is to a certain extent true in this case. The effectiveness of DRL is expected to vary between various groups of traffic participants, but it is not certain how great those differences will be. The only assumption made is that the total difference for the relevant accidents will be approx 10% on the basis of a 100% use of DRL (Polak, 1987). Therefore, the analysis will take into account an alpha probability of 5% and 10%.

For a nationwide evaluation of the effect of DRL, it has been established that approx. 1000 accidents per cell (without distinguishing between test and control area) would be adequate to demonstrate a drop with 95% confidence provided DRL use is virtually 100% (Lindeijer, 1989). In the case of a DRL experiment on a voluntary basis, the method of probability calculus is much more complex. The requirement for 1000 accidents will only be used to determine whether the number of relevant accidents in the test area over previous years forms a reasonable basis for further analysis. However, it cannot be used to make statements about the duration and scope of the experiment.

Cross-table analysis

The evaluation of the experiment will require a before and a after study (= cross-table analysis), where the same number of years for each period is compared. Subdivisions are made according to relevant and non-relevant accidents in the test area and control area. It is the intention to differentiate between subgroups of accidents within these categories, e.g. according to type of collision, between fast traffic (corrected for DRL use), and fast traffic versus slow traffic, inside and outside the built-up area, etc.

In this way, the study set-up becomes more refined than if there is simply a question of a test area and a control area.

In order to give an impression of how the accident analysis will be conducted, an example of the simplest analysis model is shown:

		1988	1989	1990	1991
test area	multiple daytime accidents				
	non-relevant accidents				
control area	multiple daytime accidents				
	non-relevant accidents				

3.2. Trend development

The number of future accidents anticipated is calculated on the basis of statistics for previous years. Before the number of accidents for the after period of the test area can be calculated, it must be determined whether external influences in the control area and test area are likely to be relatively similar, to ensure that there is no question of a rising or declining trend.

In order to establish this, injury accidents from 1983 uptil 1989 were examined.

The relevant and non-relevant daytime or nighttime accidents have been subdivided according to the following study areas:
Northern Region (= Groningen, Friesland and Drenthe), Overijssel, Western Region (North Holland, South Holland and Utrecht) and the 'Rest' (remaining provinces, i.e. Gelderland, Flevoland, Zeeland, North Brabant and Limburg).
Per study area, these accidents are further categorised according to type of collision (side and frontal) versus the rest.
The results are represented by Figures 1 to 5. They show that there is hardly any difference from one year to the next with regard to the accident pattern, although the influence of the seasons is clearly evident. The graph produced did no give any cause to test for significant deviations.
Based on these results, it is acceptable to use the accident statistics for the before period as a basis for calculating the number of accidents in the after period, without having to correct for any trend fluctuations. However, to be on the safe side the ongoing analysis will take into account that retrospective differences may be found for the control area and not (or to a lesser degree) for non-relevant accidents in the test area.

3.3. Injury accidents and MDO accidents

The registration level of injury accidents is more comprehensive than the registration of MDO accidents. However, publications of the Central Statistical Office (CBS) show that the number of registered MDO accidents is about five times greater than the number of injury accidents. An assesment is made of the number of relevant injury accidents to be anticipated if policy were to remain unchanged (See Table 1). If it appears that the figures are fairly low - even if years are added together and/or several provinces are added to the test area - MDO accidents should also be included.

Notes to the table:
- Northern Region: Groningen, Friesland and Drenthe;
- Overijssel: can be added to the Northern Region;
- Gelderland and Flevoland will be used as transitional area if the test area is extended.

If only three northern provinces are included in the experiment, Over-

Study areas	1987	1988	1989
Northern Region	1427	1348	1531
Overijssel	1033	987	1005
Gelderland, Flevoland	1992	1975	2002
Western Region	7340	7019	7539
Southern Region	3754	3838	3989

Table 1. The numbers of relevant injury accidents in 1987, 1988, and 1989: multiple daytime accidents (based on a light level >100 lux) with at least one motor vehicle, categorised according to study area.

ijssel will represent the transitional area, in order to buffer the radiation effect resulting from stimulation campaigns and/or the in influence of crossing traffic on the development of DRL use in that (those) province(s).

- Western Region: North Holland, South Holland and Utrecht.
- Southern Region: Zeeland, North Brabant and Limburg are considered the most ideal control area for the experiment, as these provinces are furthest removed from the test area.

The initial orientation is based on a requirement for at least 1000 accidents (approx.) for a minimal frequency per cell (see para. 3.1). On the surface, the total number of injury accidents in the Northern Region over one year seems adequate to establish an overall effect. However, to investigate the effect of DRL on slow traffic this number seems less appropriate. The size of this group of accidents (fast traffic versus slow traffic in the built-up area) represents about half the total number of relevant daytime accidents. However, it will be possible to indicate the direction of any difference found; whether it is in fact significant is more difficult to prove. If the experiment were to continue for another year, the frequency per cell would be more favourable. Alternatively, Overijssel may be added to the Northern Region. This option would almost double the accident count in one year, although this number would continue to limit the analysis potential.

Therefore, Table 2 has added the injury accidents and estimated MDO accidents for the same study areas together. As stated, the number of registered MDO accidents is approx. five times greater than the number of injury accidents. The analysis is based on a more detailed method of categorising accident data. This means that less relevant daytime accidents will be selected than if use were made of the accident data for day or night. Therefore, the calculation multiplies the number of injury accidents by a factor of five. It is assumed that the same trend development has taken place for MDO accidents.

Study area	1987	1988	1989
Northern region	7135	6740	7655
Overijssel	5165	4935	5025
Gelderland, Flevoland	9960	9875	10010
Western region	36700	35095	37695
Southern region	18770	19190	19945

Table 2. The numbers of injury accidents and estimated MDO accidents in 1987, 1988 and 1989: multiple daytime accidents (based on a light level >100 lux) involving at least one motor vehicle, categorised according to study area.

The following considerations can now be expressed:
- The accident statistics over one year in the Northern Region seem to offer a feasible base for a statement about the significant difference in effect between the test area and the control area.
- Adding the province of Overijssel to the Northern Region improves the analysis potential on the basis of one year.

It is the intention to use the data on DRL to select accidents on the basis of DRL use in the before period. If accidents are selected on the basis of such types of conditions, the effect must be demonstrable and the likelihood of an alternative explanation small. Until now, this analysis method has not been used in any study (abroad), as specific user data for the before period was not available. It is precisely the outcome of this type of analysis which allows strong statements to be made and determines the reliability of such statements. The combination of injury accidents and MDO accidents appears to make this type of analysis possible.

The next phase in the analysis is to calculate the minimal number of accidents required to demonstrate a significant difference, based on an alpha probability of 5% and 10% and different drop percentages.

3.4. Calculation method

Analysis model

In order to calculate the number of accidents in the after period, the following method is used:

	Before period	After period
Test area	N_t	N_t (a = 5%/10%)
Control area	N_c	N_c

where:

N_t = number of accidents in the test area

N_t (a = 5%) = the calculated reduction in the number of accidents which can just show a significance at an alpha probability of 5% or 10%

N_c = number of accidents in the control area. As no trends have been noted, N_c in the before period forms the basis for N_c in the after period (with or without a drop of 5%).

The analysis contains a one-tailed test to determine at which (drop in the) number of accidents in relation to the before period it is still possible to demonstrate a significant difference for the test area. The one-tailed test is carried out with an alpha probabibility of 5% and 10%

The calculation is carried out for the following options:

- Groningen, Friesland and Drenthe (option I) with a constant number of accidents in the control area.
- Similar to option I, but with a 5% drop in the number of accidents in the control area (option II)

- Similar to option I, but with the addition of the province of Overijssel (option III).
- Similar to option II, but with the addition of the province of Overijssel (option IV).

Every option is based on a test of one or two years.

The probability that an anticipated effect would in fact be found with an increasing use of DRL in the after period was then assessed for each of the calculated options.

4. DRL USE AND EFFECTIVENESS

Until now, the analysis has not taken into account the changes in DRL use in the test area. The degree to which use of DRL will increase (and remain the same in the control area) will also determine the opportunity to actually demonstrate an anticipated effect, given the available number of accidents in the after period.
SWOV assumes an effect of 5% in relation to all accidents (DRL-relevant and non-DRL-relevant accidents). For the DRL-relevant accidents, a total effect of 10% is anticipated. This percentage is composed of the great and small effects anticipated for various categories of road users. Therefore, this analysis, which only looks at the relevant accidents, is based on an effect of 5%, 10% and 15%. These drop percentages have been selected quite arbitrarily, although they do fall within the expected drop for the various groups of traffic participants. For instance, on the one hand it is expected that the drop in the number of relevant accidents between fast and slow-moving traffic in the built-up area will be even higher than 15%. On the other hand, it is expected that this percentage will be relatively low or even entirely absent for multiple daytime accidents between fast traffic on the motorways.

Taking into account a percentage of 14% DRL use over the before period, the probability calculus is carried out for:

- The calculated number of injury accidents in the Northern Region only and in combination with Overijssel, at a duration of one and two years.
- Injury accidents and MDO accidents combined, in the Northern Region only and in combination with Overijssel, at a duration of one and two years.
- Taking into account the various options relevant to the control area (Southern Provinces only, or the Rest of the Netherlands).
- Based on an alpha probability of 5% and 10% for calculating the minimum number of accidents for the combinations described in the above.
- Based on whether a 5% drop occurs in the control area of the combinations nations described above.
- In order to determine the percentage DRL use required to demonstrate a significant effect in the number of daytime accidents between fast traffic and slow traffic, a separate probability calculus was performed for this type of accident.

For the benefit of the reader, a graph of every calculated combination is reproduced (Figures 6 to 45). In addition, a three-dimensional reproduction for one option has been included, showing the effectiveness per percent (from 1% to 15%) (Figures 46 and 47).
These graphs represent the probability that a particular effectiveness can be actively shown to be significant, given that a particular percentage of DRL use is measured over one or two years.
Only two extreme combinations are described here, in order to clearly define the boundaries within which probabilities and rising percentages of DRL use can vary.
These combinations are:
1. Injury accidents only after one year in a test area consisting of the three northern provinces versus a control area formed by the provinces of Zeeland, North Brabant and Limburg. This is the option with the smallest number of anticipated accidents; analytically speaking the least favourable situation (Figures 6 and 7).
2. Injury accidents and MDO accidents after one year in a test area including Overijssel versus the Rest of the Netherlands. From an analytical point of view, this option has the greatest differentiation potential, as even a small effect can soon be shown significant (Figures 40 and 41).

In order to make the requirement permitting statements as strict as possible, only the alpha probability is varied within the combinations, assuming that the beta probability must not exceed 20%.

<u>Combination 1</u>
Based on an alpha probability of 5% that the calculated number of accidents will be reached in the after period, the probability of showing a significant drop of 5% will be negative, even if DRL use should rise to 100%. The probability of showing a significant effect with a drop of 10% is approx. 50%, provided DRL use is around 90% for a period of at least one year. A significant drop of 15% can only be shown with a probability of 80% if DRL use is at least 85% for the same period.
If one bases calculations on an alpha probability of 10% DRL use (over a year) must be around 95% (10% effect) and 80% (15% effect) to show any significance. An effect of 5% cannot be regarded as significant within this combination, either.

Combination 2

Based on an alpha probability of 5% and an 80% probability of a showing significant effect, given the various drop percentages (5%, 10% and 15%), DRL use over a year must be approx. 80%, 60% and 50%, respectively.
If one bases calculations on an alpha probability of 10%, the DRL percentage may be lower, i.e. 80%, 55% and 45%, assuming the same conditions as described for an alpha probability of 5%.

If a significant effect is shown, in keeping with the requirements described in the above (a probability of 90% or 95% that a reduction in the number of accidents is found, and a probability of 80% that a 10% effectiveness is shown to be significant), then the requirements set for the more specific situations can be made more flexible. For example, a specific situation may be the accident category of fast traffic versus slow-moving traffic. Nevertheless, it was felt that a separate calculation should also be performed for this accident group, based on the principles described in the above. The calculation is only carried out for the second combination (test area including Overijssel, injury accidents and MDO accidents for one year). In addition, it was assumed that this accident category represents about half of the total number of relevant accidents. The probability calculus does take into account the three drop percentages cited, i.e. 5%, 10% and 15% (see Figures 42 to 45).
The graph shows that, at an alpha probability of 5%, the DRL percentage over a year should be around 100% (5% effect), 70% (at 10% effect) or 55% (at 15% effect), if the probability of showing a significant drop is put at 80%.
Based on an alpha probability of 10%, under the same conditions, DRL use over a year should be around 90% (5% effect), 65% (10% effect) or 50% (15% effect).

After establishing the significance of an effect (in accordance with strict definitions), analyses may be performed for specific situations and circumstances where statistical requirements do not need to be as stringent. The results may not all be significant, but if the sample results are in the same direction of the established significance, these results would represent a worthwhile supplement to the judgement of the effect of DRL.

5. CONCLUSIONS

The analysis is based on strict statistical requirements; stricter than normally applicable for various probability calculations.
The success of the experiment depends on the degree to which the use of DRL increases. What this means for the duration of the experiment and the scope of the test area is shown by the table below (based on a 10% drop in multiple daytime accidents, involving at least one motor vehicle, i.e. DRL-relevant accidents). The table includes the percentage of DRL use, given a probability of 80% that an effectiveness of 10% can be demonstrated and that the minimal number of accidents required for the after period can be reached with 90% certainty. Furthermore, it is assumed that a experiment spanning three years is not a realistic option.

Test area	One year	Two years
Groningen, Friesland and Drenthe	approx. 65% DRL	approx. 55% DRL
Groningen, Friesland, Drenthe, plus Overijssel	approx. 55% DRL	approx. 50% DRL

The northern provinces are considered most suitable as test area, as the percentage of DRL use under dry, clear conditions is already shown to be approx. 14%; this percentage is considerably higher that in the west of the Netherlands (= approx. 2%). It would therefore be reasonable to assume that the stimulation of DRL use in the North has a good chance of success. In other words, if DRL use were to rise approx. 35%, the experiment should span two years and the test area should comprise the three northern provinces and Overijssel. If the percentage rises approx. 50%, one year should be sufficient to stand a good chance to show a significant effect of 10% in the three northern provinces only.

Another problem is whether the significance found can be ascribed to DRL with reasonable certainty (the reliability of the statements).
Such an explanation for the differences found will be stronger the more the conditions under which DRL use has increased can be used as distinguishing features to select accidents.

Analysis of DRL user data shows that 'dry clear weather' inside and outside the built-up area represents one such condition. Analysis results based on this type of selection are more reliable than statements based on a found 'overall' effect, for example. The use of a combined accident database (injury and MDO accidents) offers a sufficient number of accidents to perform analyses on selected accident categories. The effect of DRL should be demonstrable for each of these categories. An effect demonstrated in this manner offers the least chance for alternative explanations, particularly if supported by a significant overall effect.
In other words, the reliability of the statements is determined by their strength. By applying user data for DRL from the before period, strong statements can be made with a high degree of reliability. The reliability of the statements is therefore very much dependent on the reliability of the user measurements.

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FIGURES 1 - 47

Figure 1. Number of DRL-related or non-DRL-related injury accidents according to month (1983 to 1989) and study area.

Figure 2. Number of DRL-related or non-DRL-related daytime injury accidents, excluding side and frontal collisions, according to study area.

Figure 3. Number of DRL-related or non-DRL-related daytime injury accidents according to side and frontal collisions, according to study area.

Figure 4. Number of DRL-related or non-DRL-related nighttime injury accidents, excluding side and frontal collisions, according to study area.

Figure 5. Number of DRL-related or non-DRL-related nighttime injury accidents according to side and frontal collisions, according to study area.

Figure 6. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

Figure 7. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

Figure 8. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of two years) is in fact found in the after period.

Figure 9. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents (based on a before period of two years) is in fact found in the after period.

Figure 10. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

Figure 11. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

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Figure 26. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

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Figure 42. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, is found to be significant with daytime injury accidents and MDO accidents between fast traffic and slow traffic, based on a 95% probability (alpha error = 5%) that the calculated number of accidents (based on a before period of one year) is in fact found in the after period.

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Figure 46. Three-dimensional graph showing the probability of demonstrating the significance of an effect (varying between 1% and 15%) for the Northern region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

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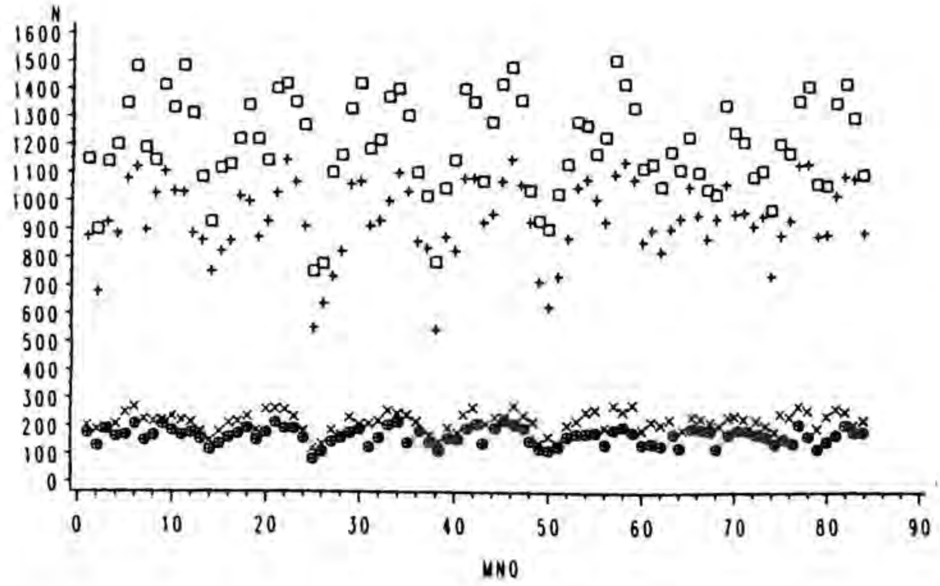
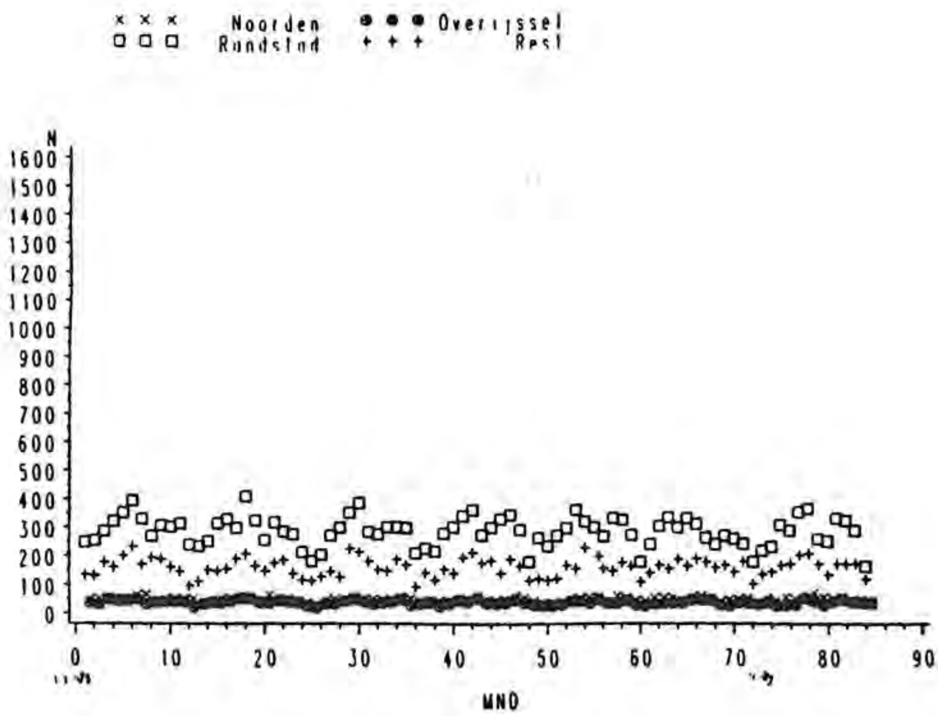
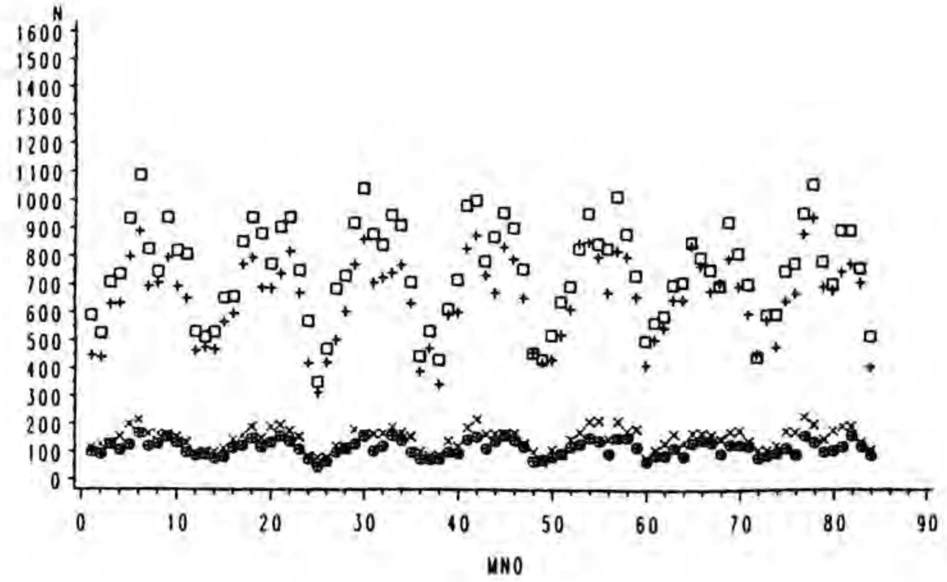


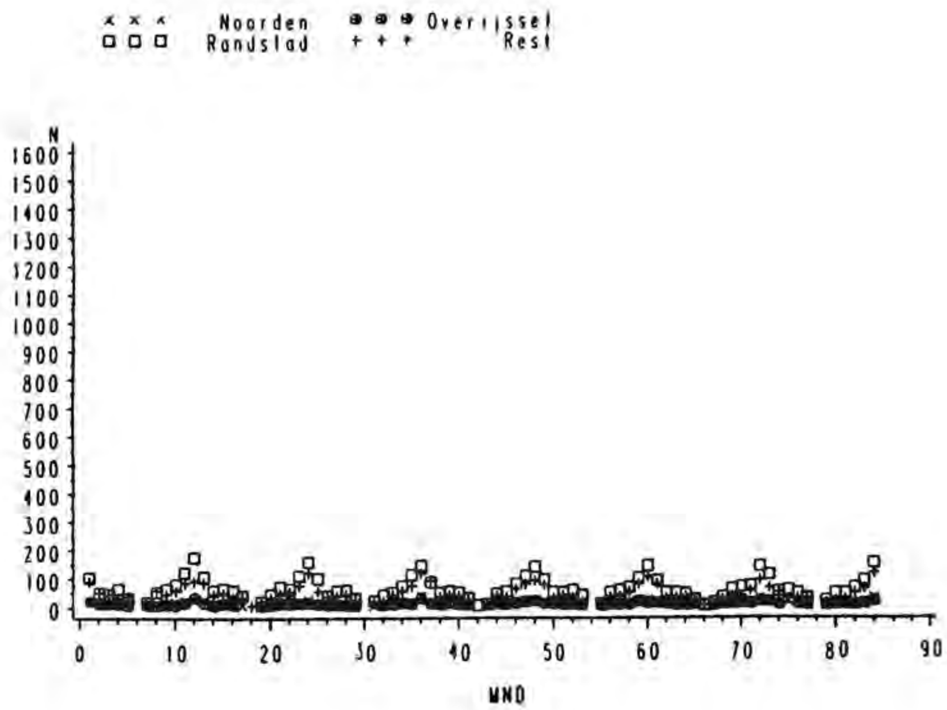
<u>Figure 1.</u> Number of DRL-related or non-DRL-related injury accidents according to month (1983 to 1989) and study area.



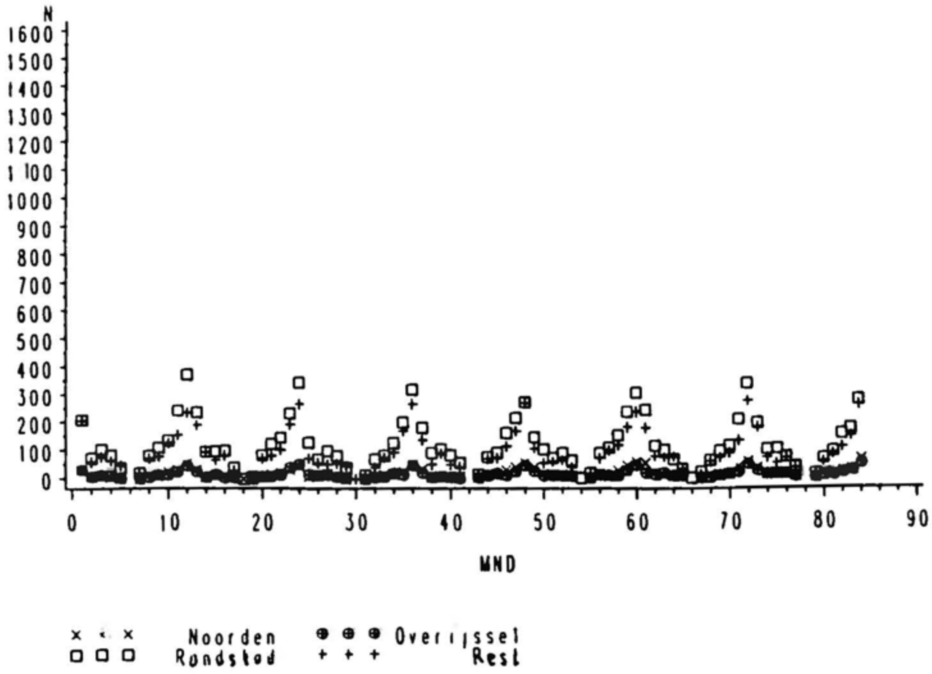
<u>Figure 2.</u> Number of DRL-related or non-DRL-related daytime injury accidents, excluding side and frontal collisions, according to study area.



<u>Figure 3.</u> Number of DRL-related or non-DRL-related daytime injury accidents according to side and frontal collisions, according to study area.



<u>Figure 4</u>. Number of DRL-related or non-DRL-related nighttime injury accidents, excluding side and frontal collisions, according to study area.



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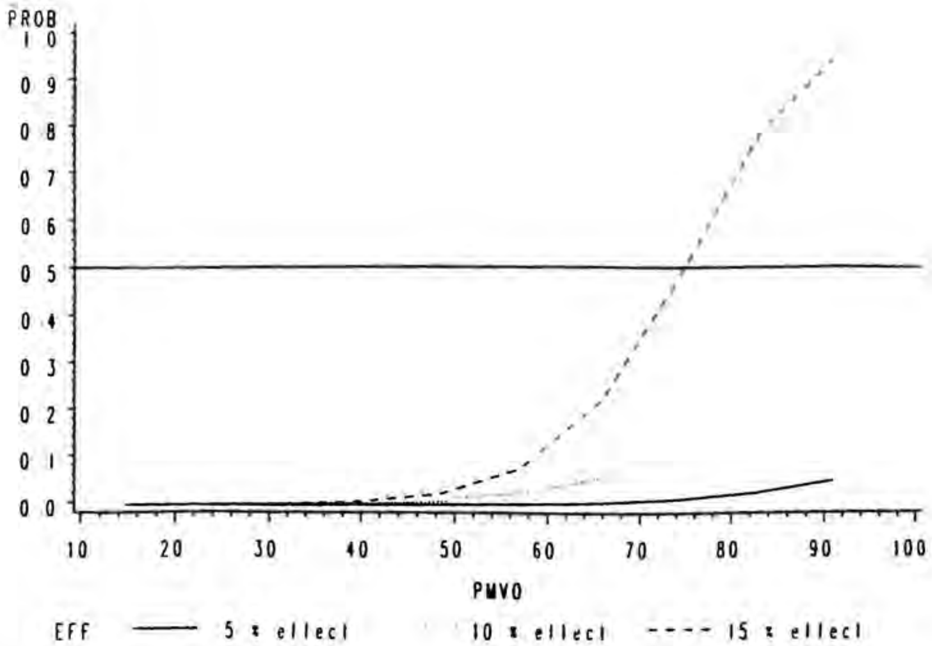
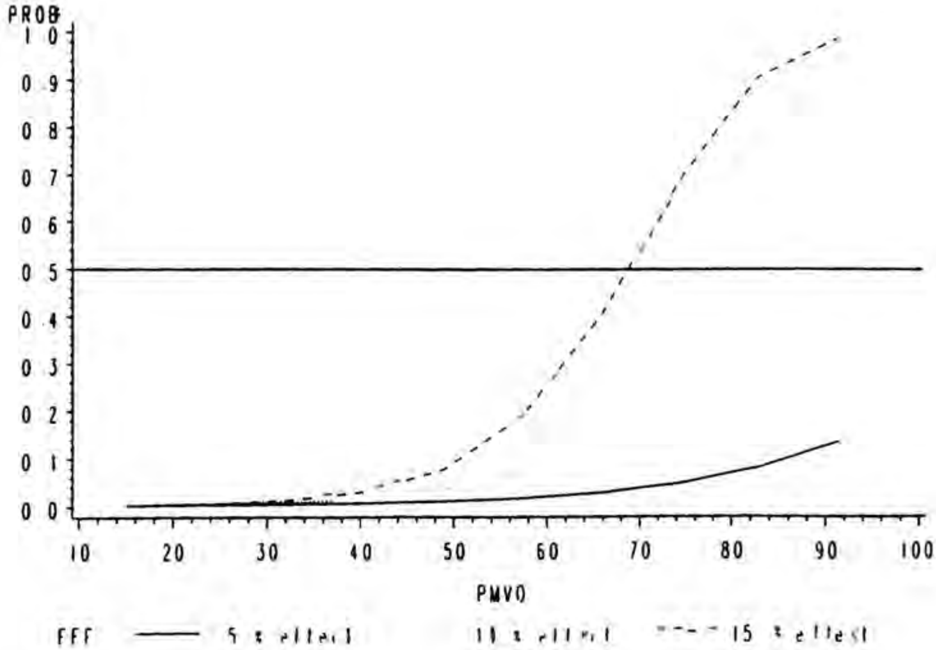


Figure 6. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.



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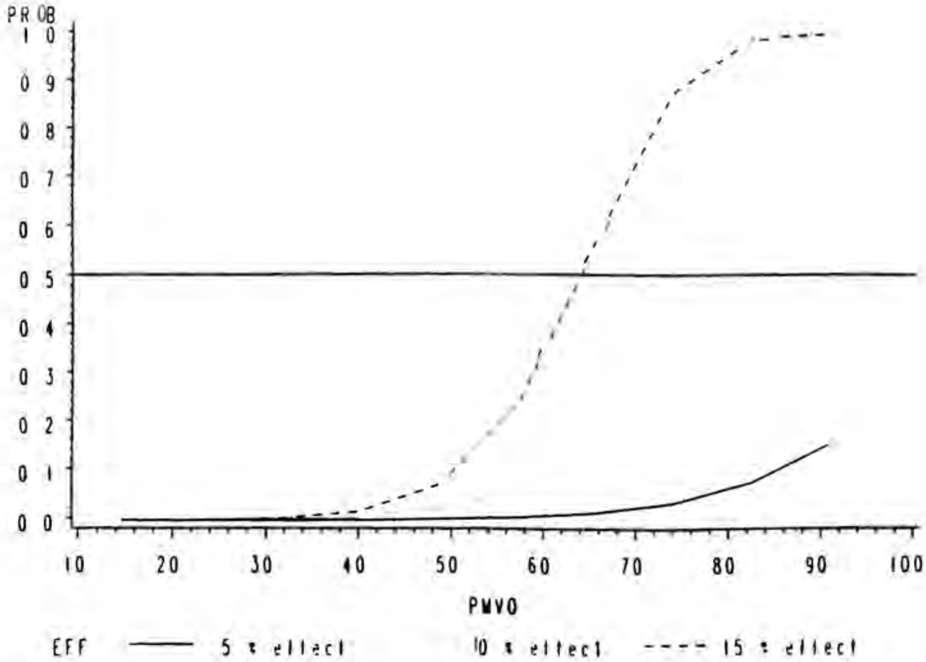

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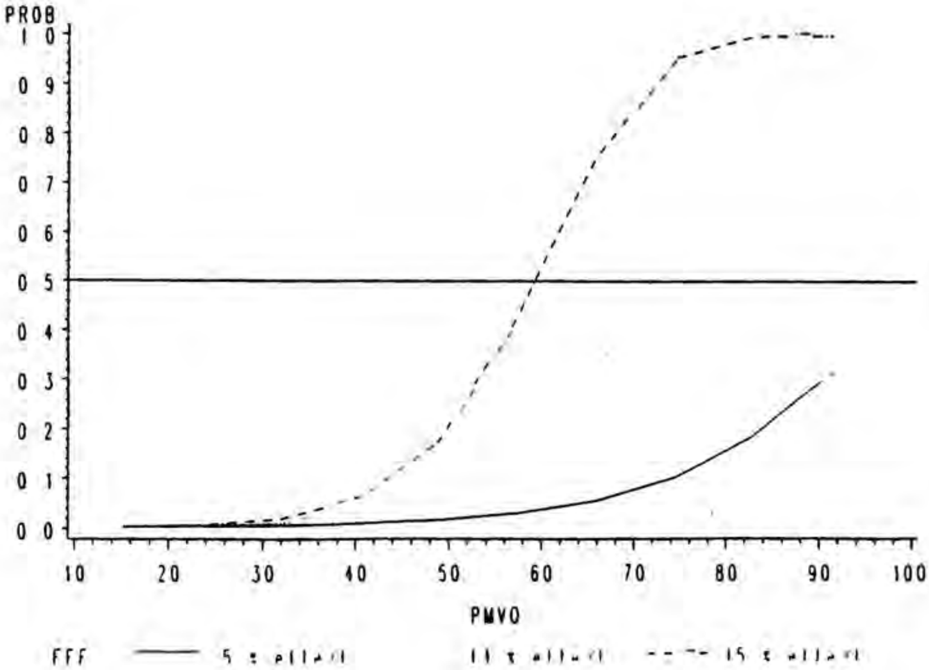

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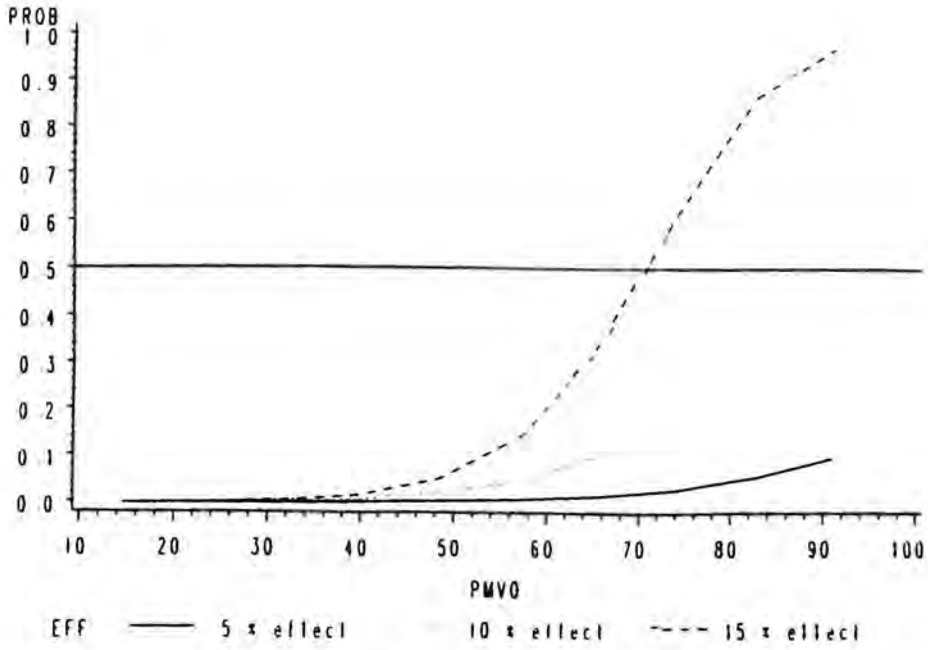

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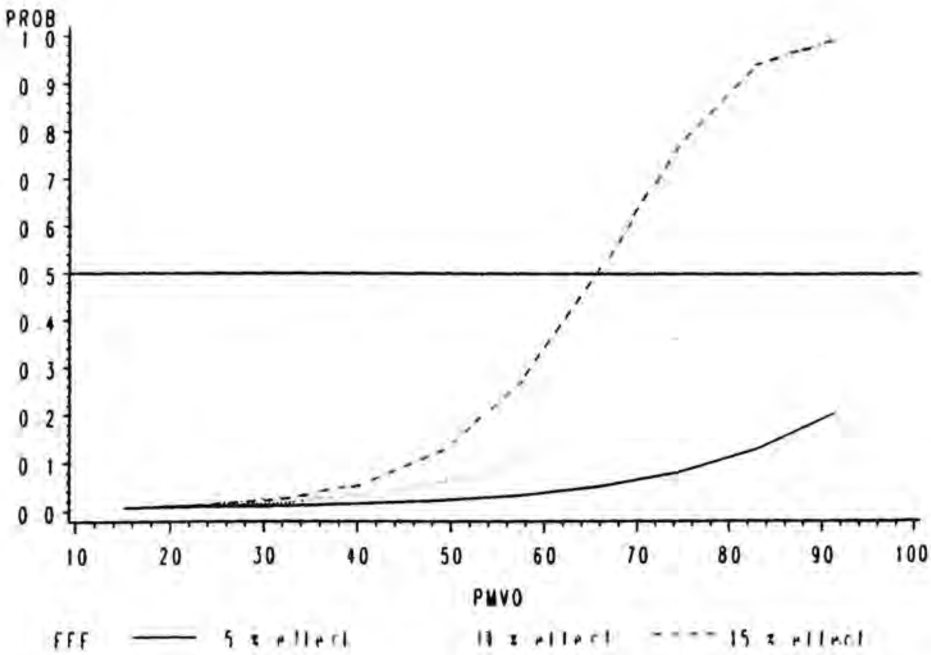

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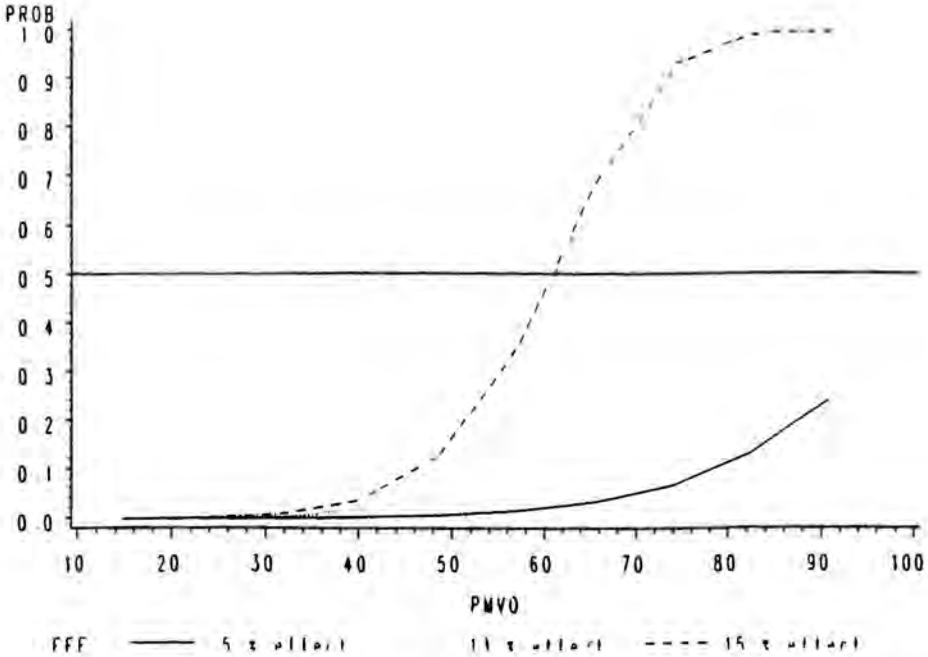

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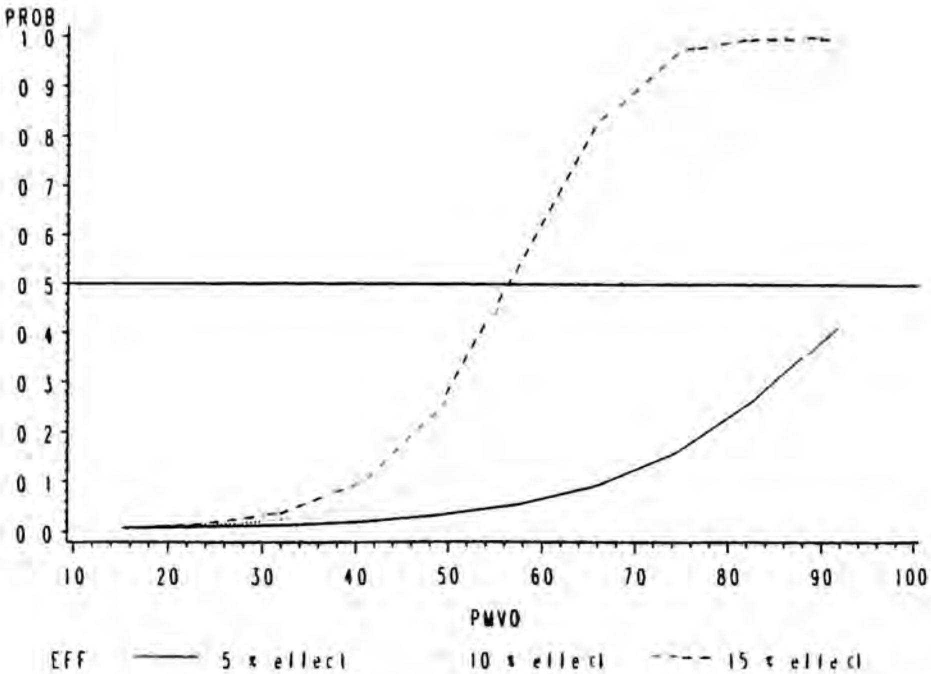

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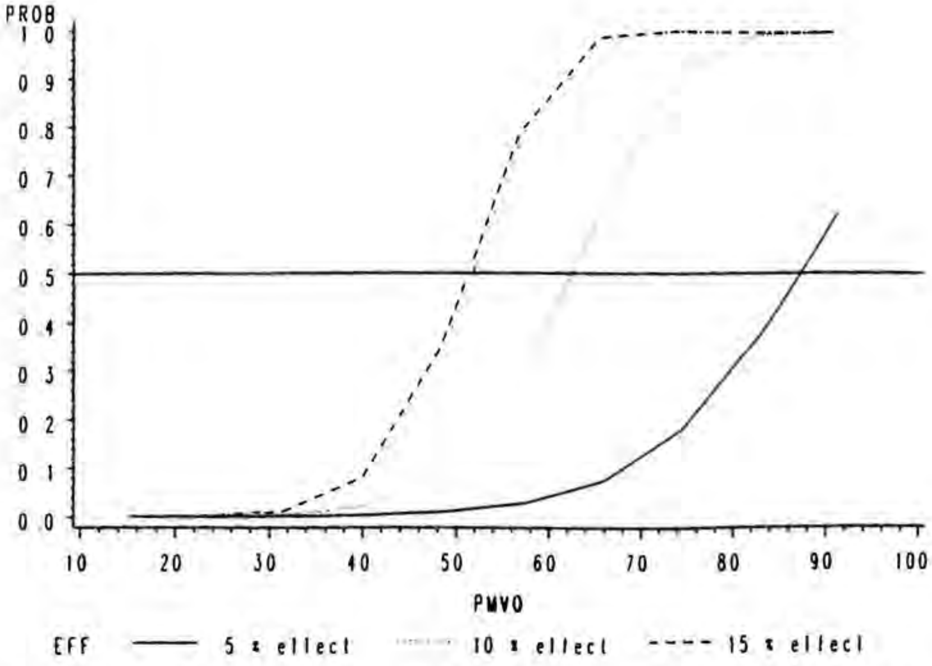

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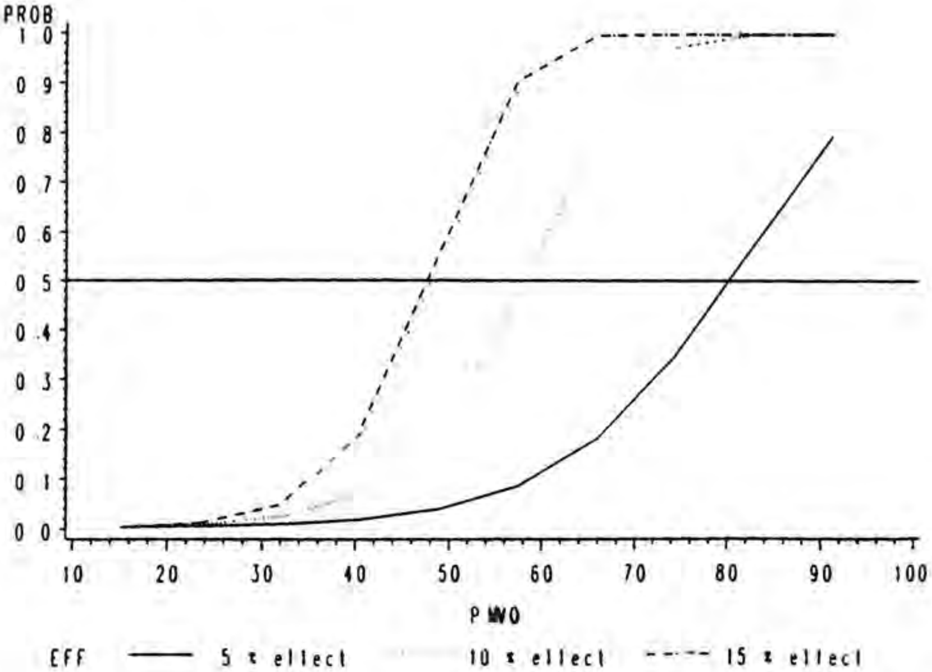

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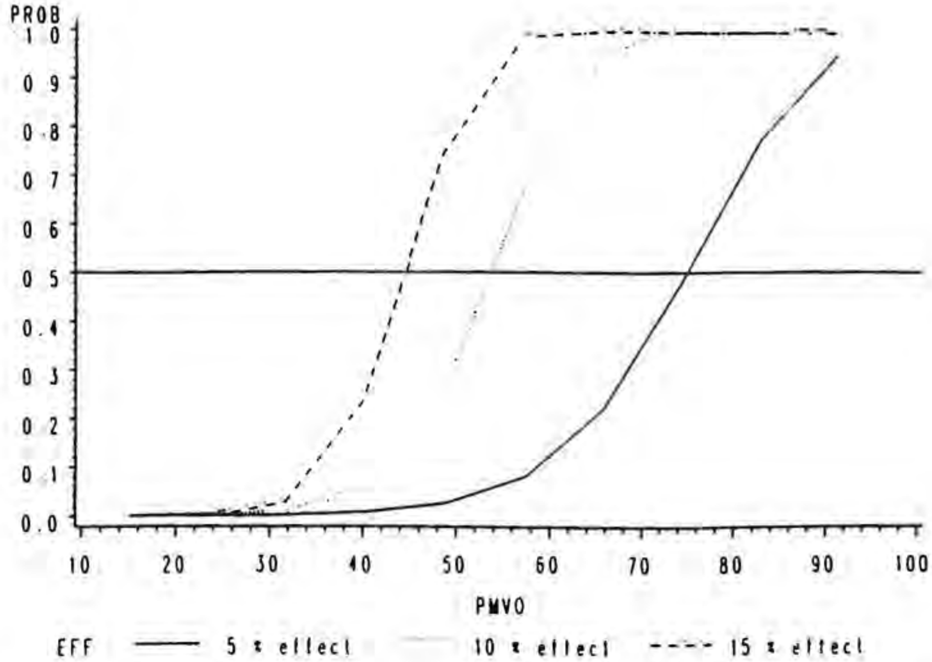

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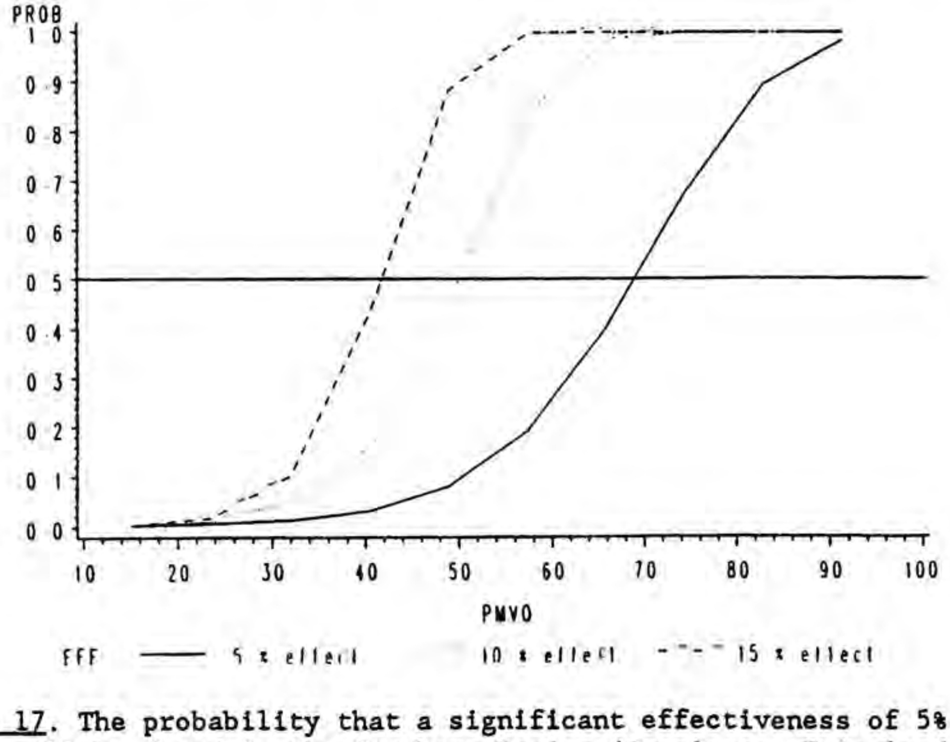

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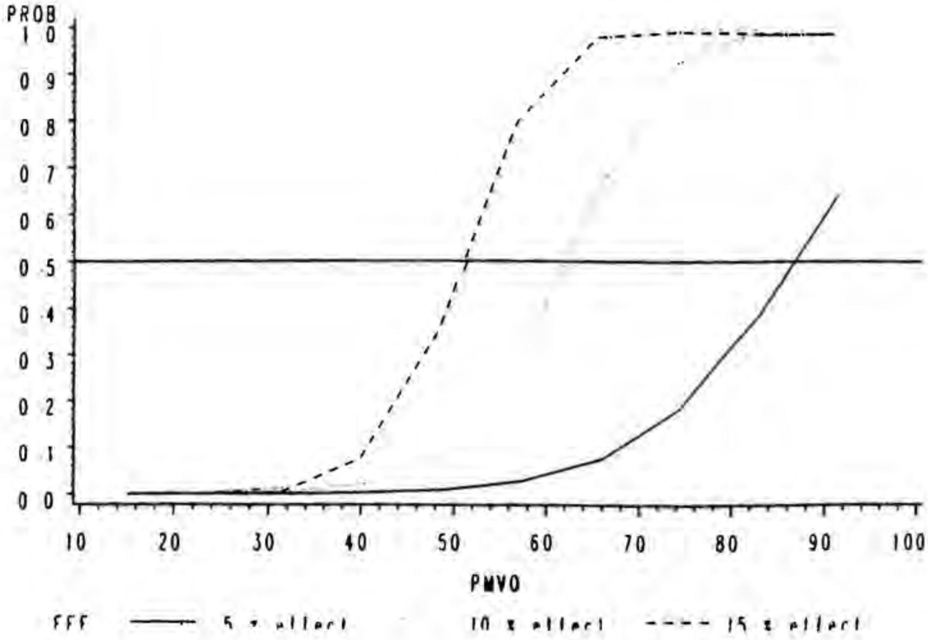

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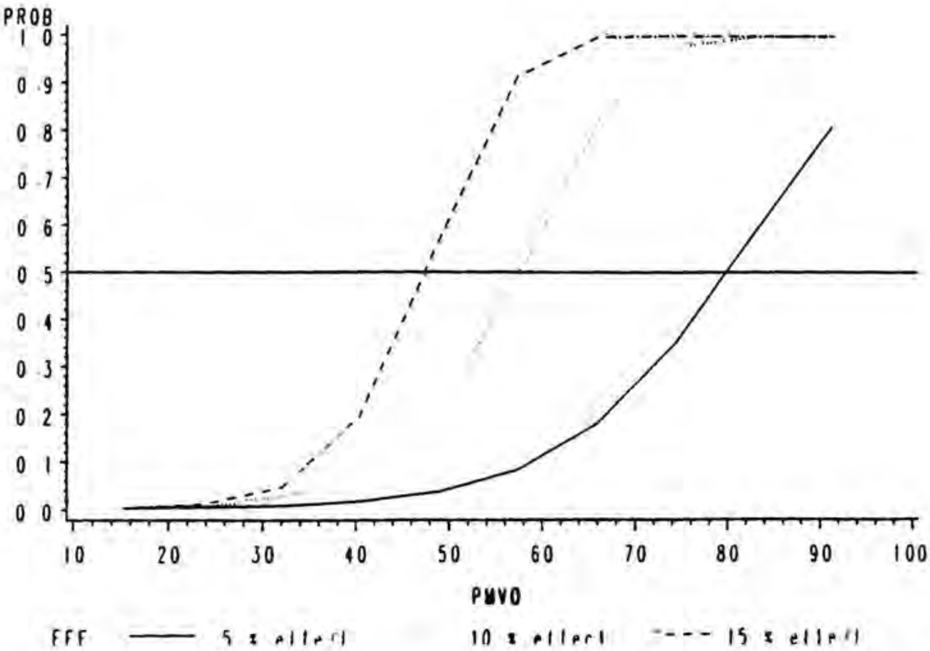

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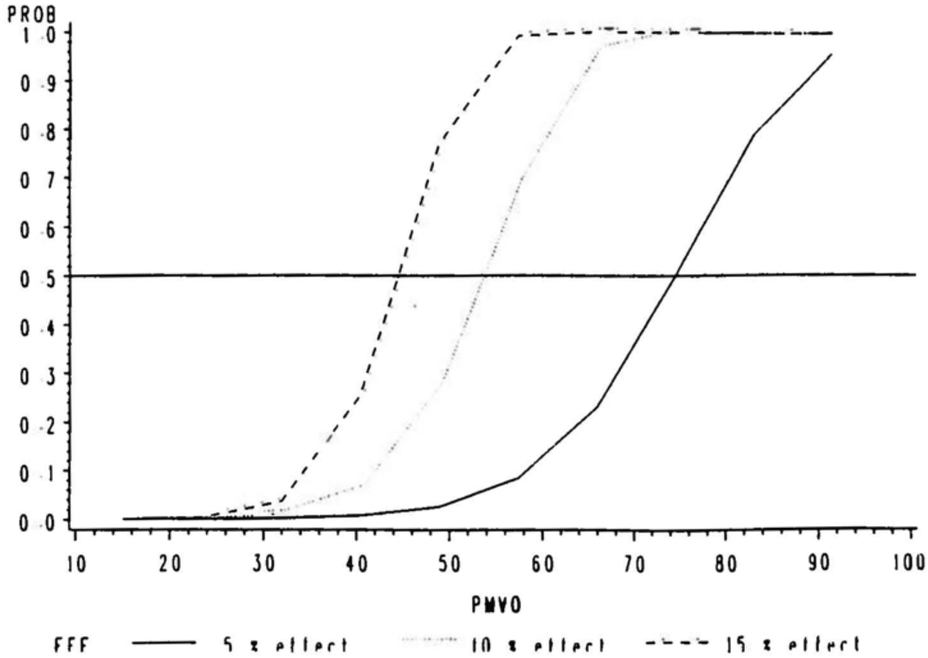

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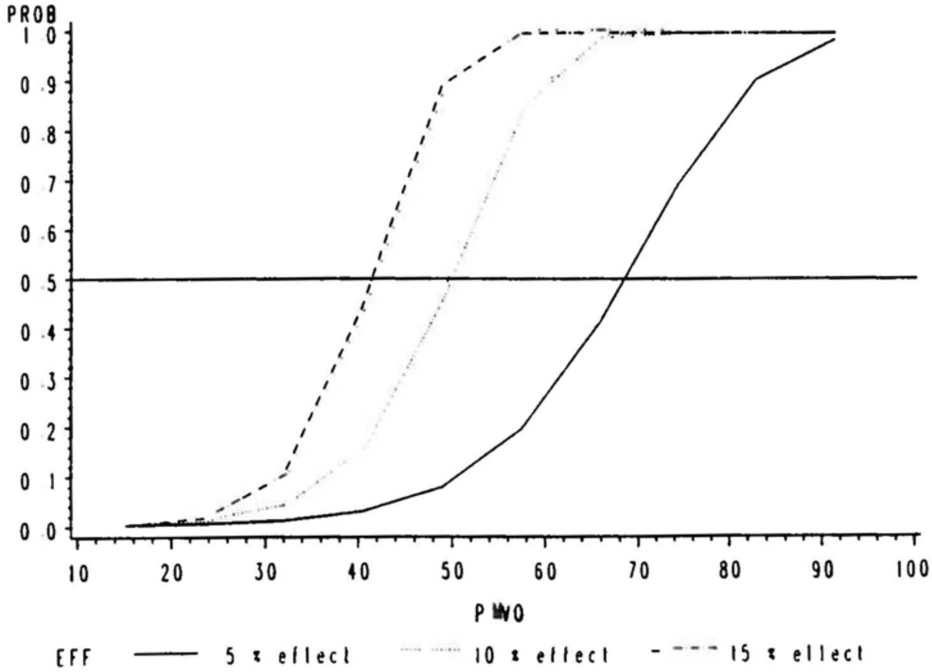
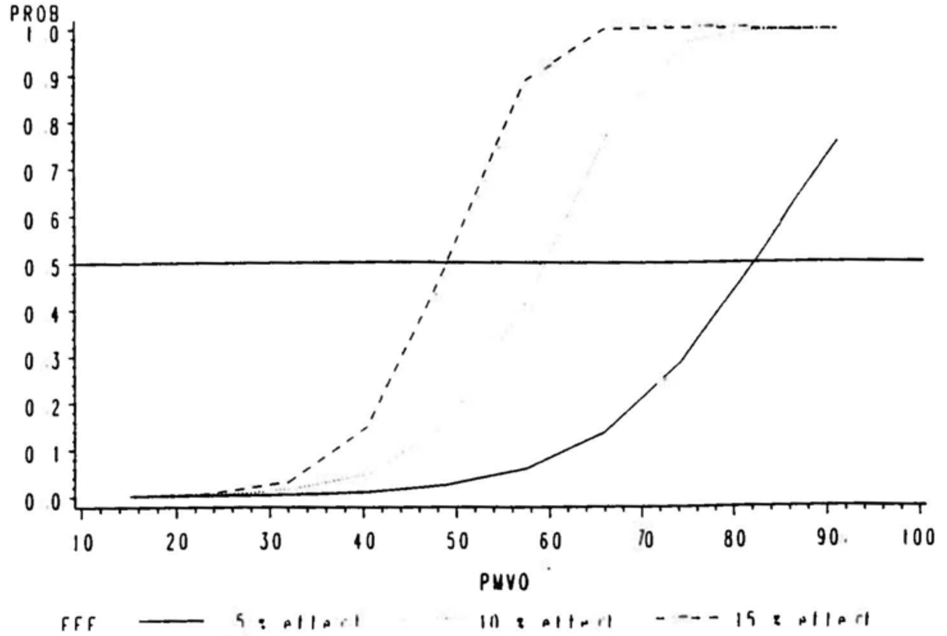
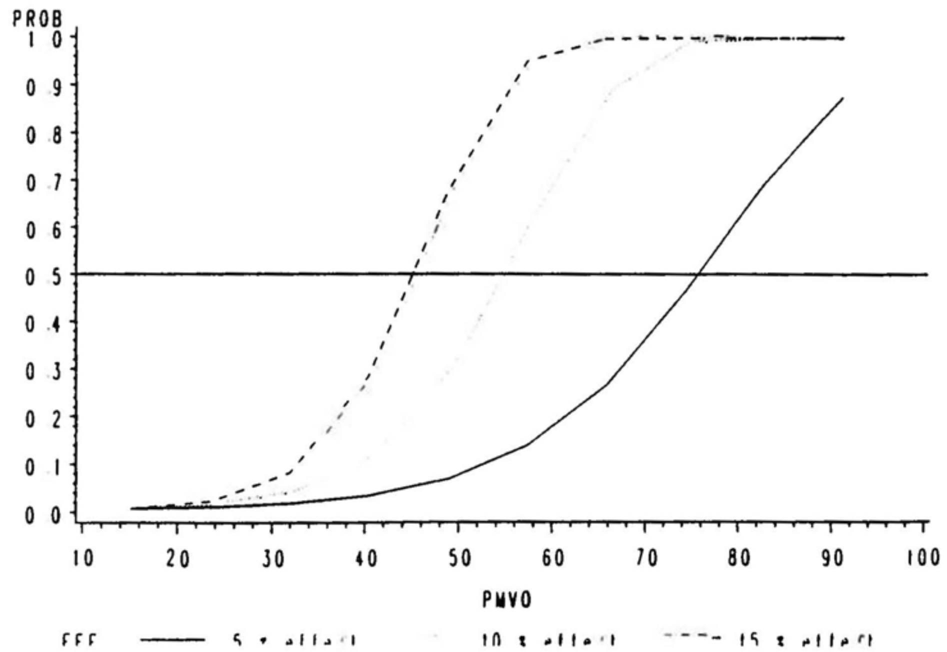


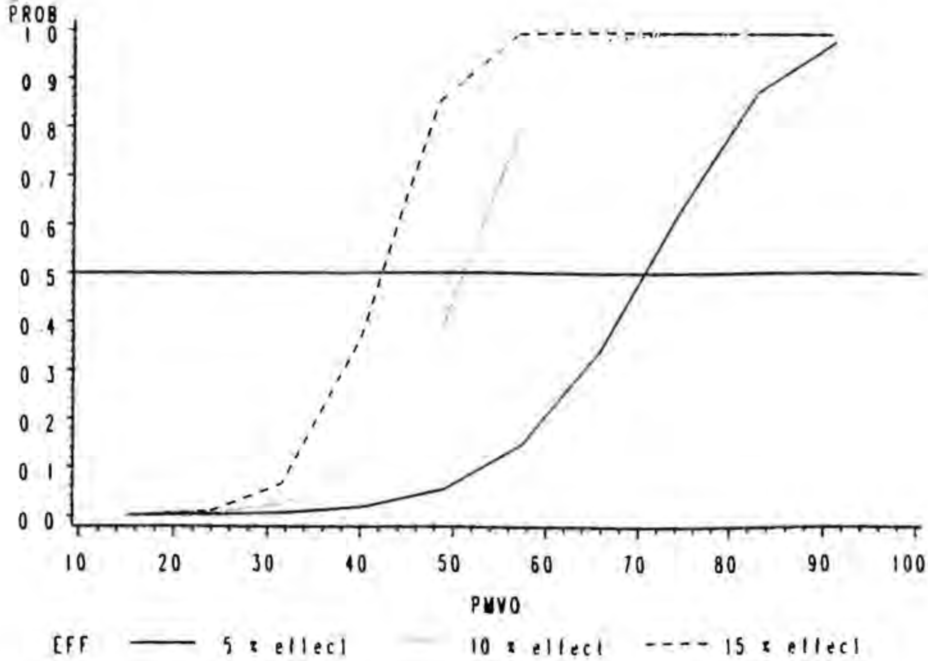
Figure 21. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.



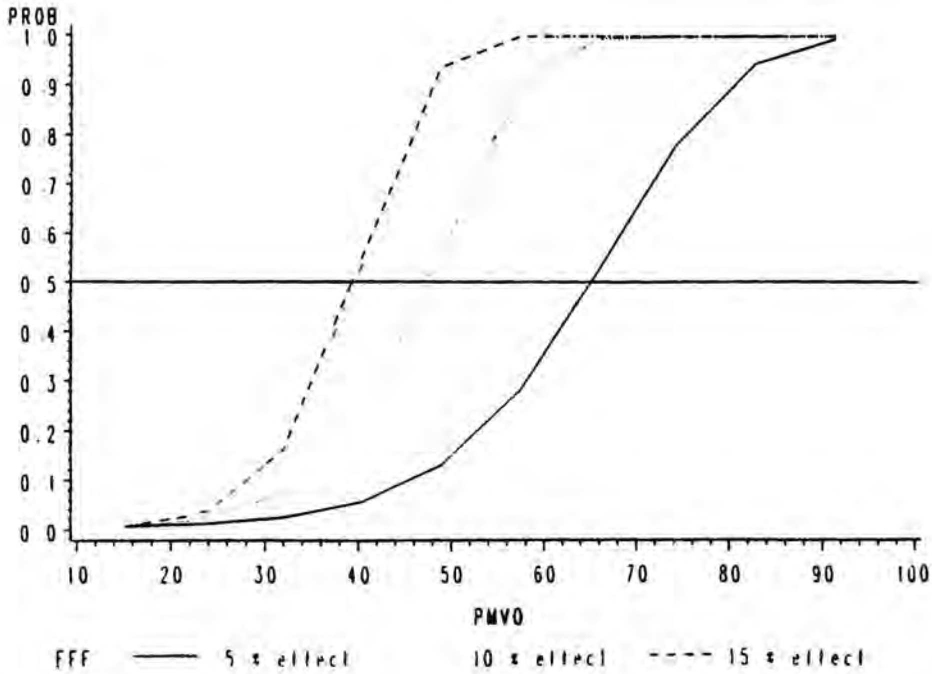
<u>Figure 22</u>. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.



<u>Figure 23</u>. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.



<u>Figure 24</u>. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.



<u>Figure 25</u>. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

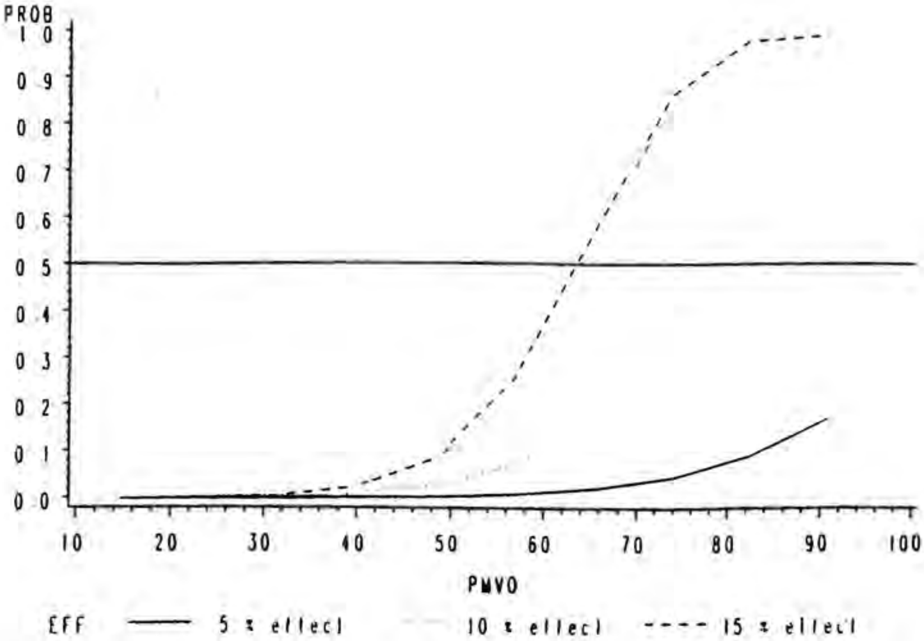


Figure 26. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

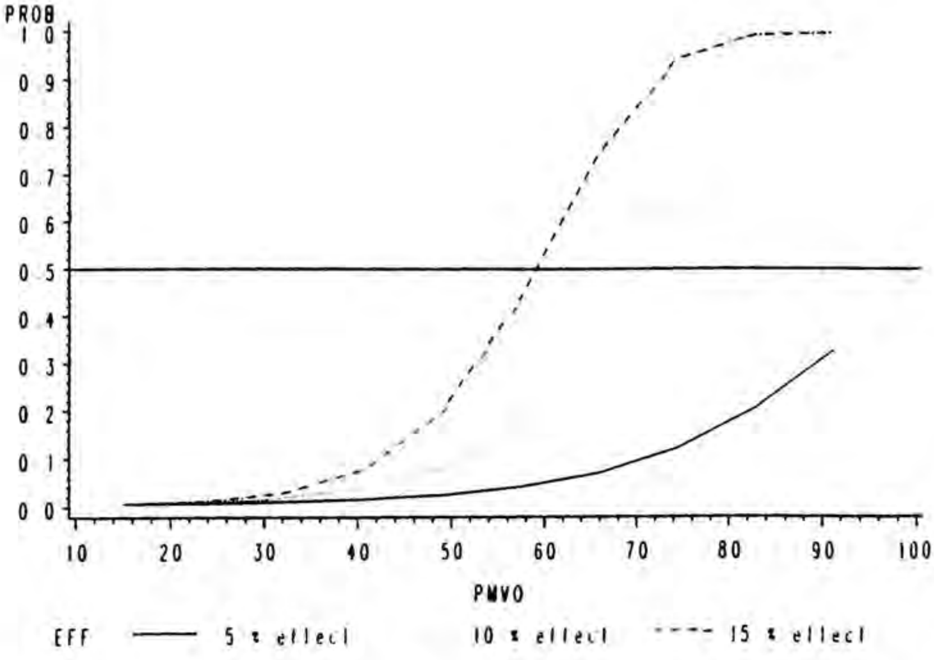


Figure 27. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents (based on a before period of one year) is in fact found in the after period.

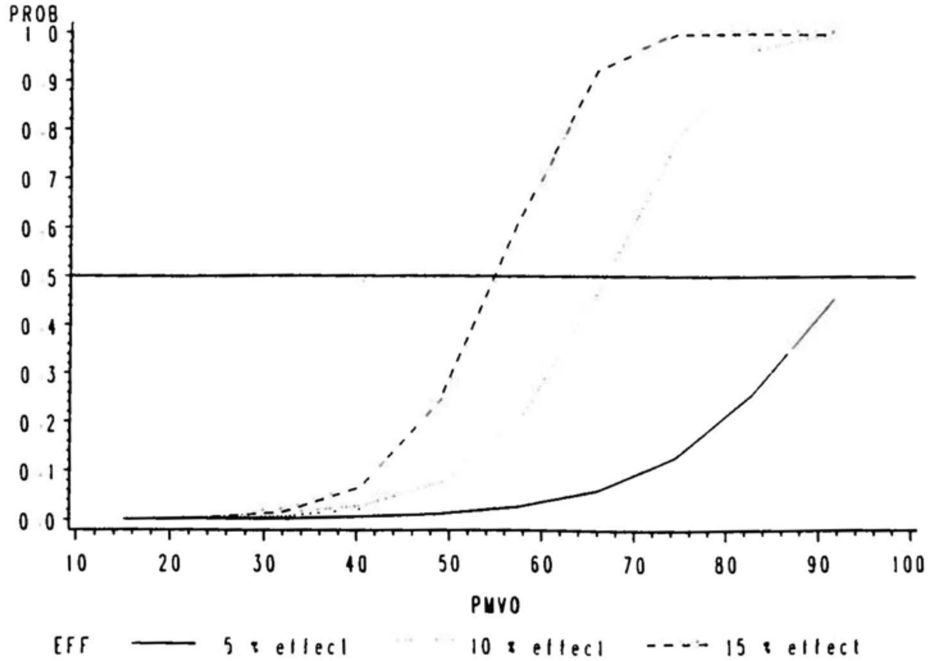


Figure 28. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents (based on a before period of two years) is in fact found in the after period.

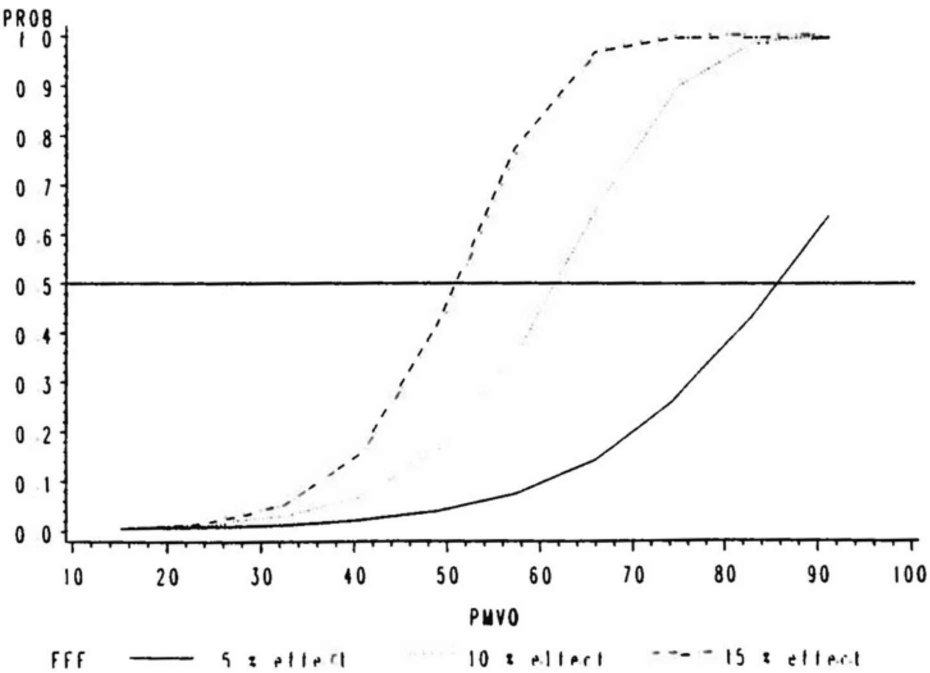


Figure 29. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents (based on a before period of two years) is in fact found in the after period.

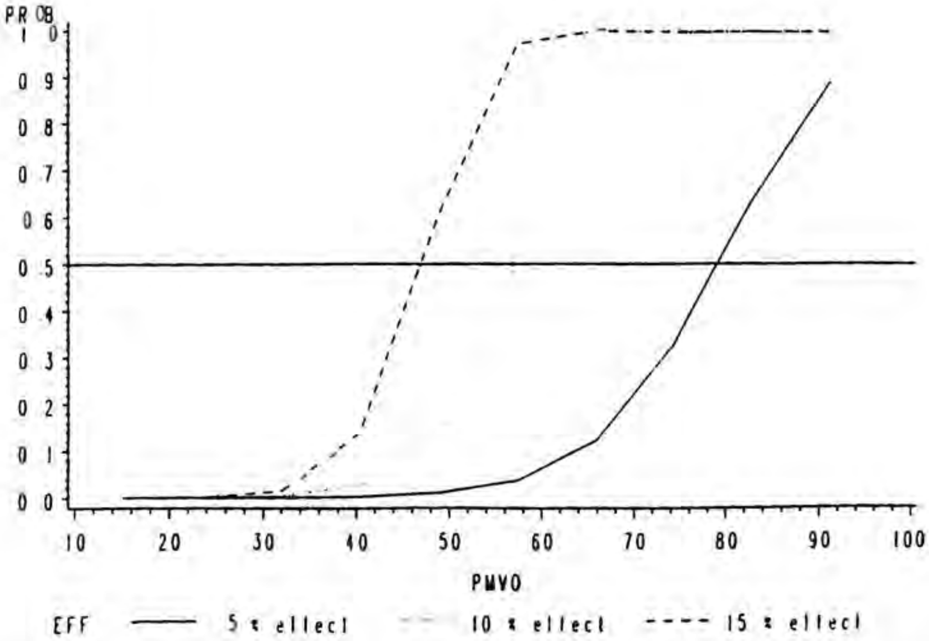


Figure 30. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

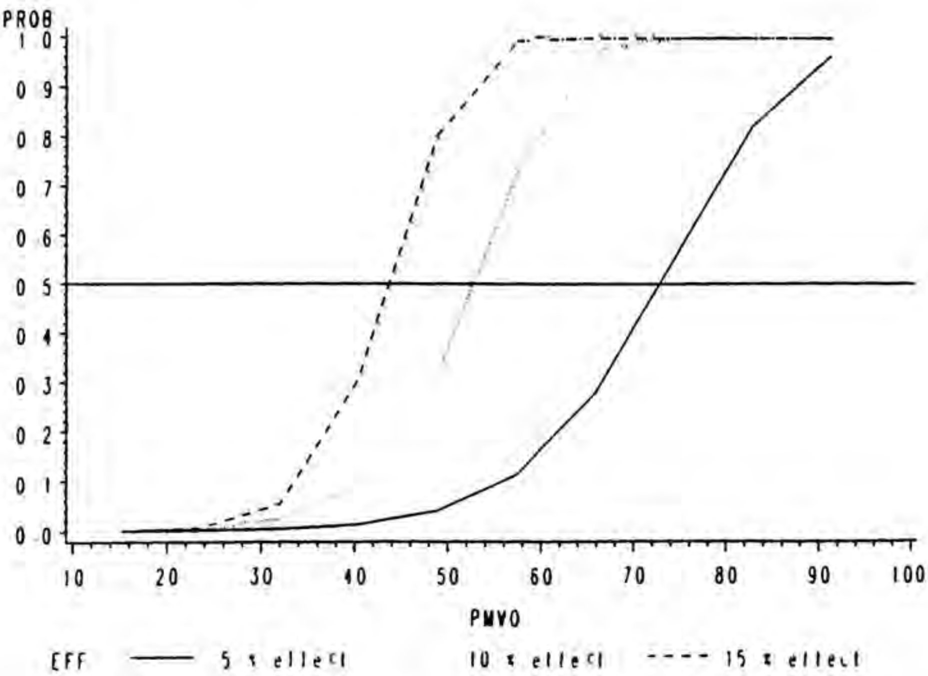


Figure 31. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

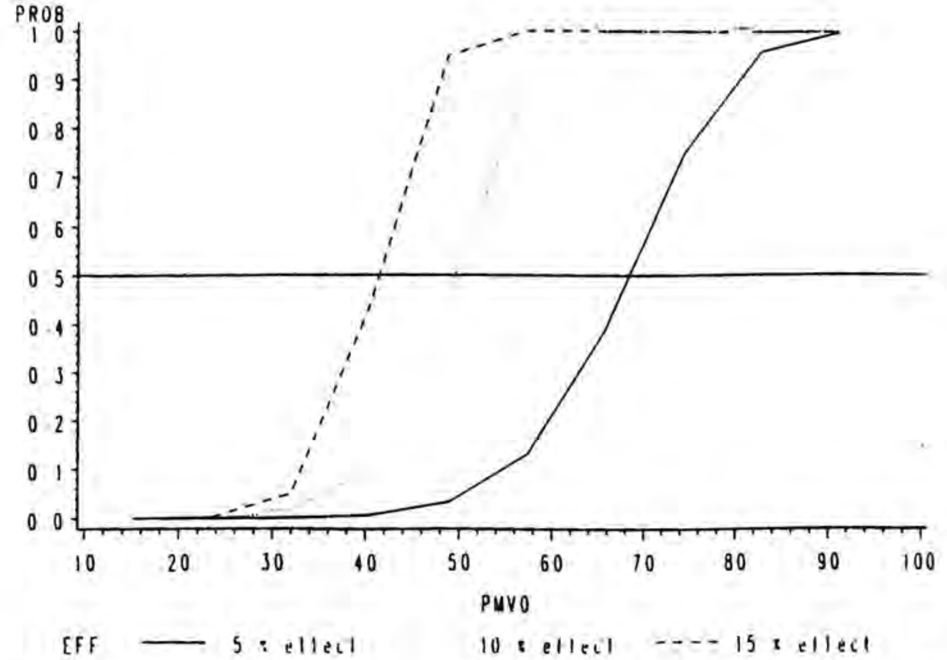


Figure 32. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

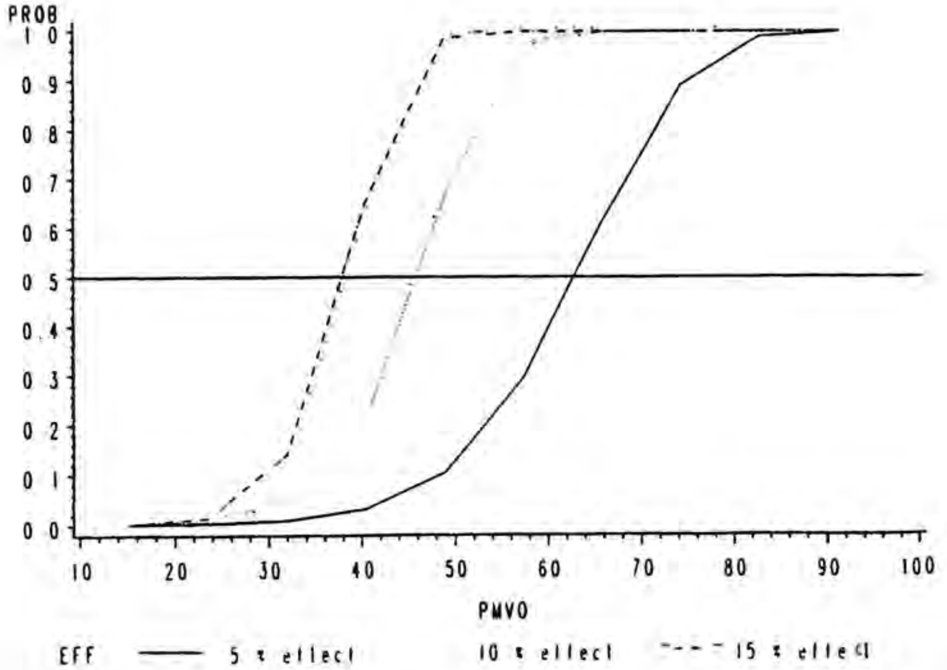


Figure 33. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, if the Southern Region (Zeeland, North Brabant and Limburg) is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

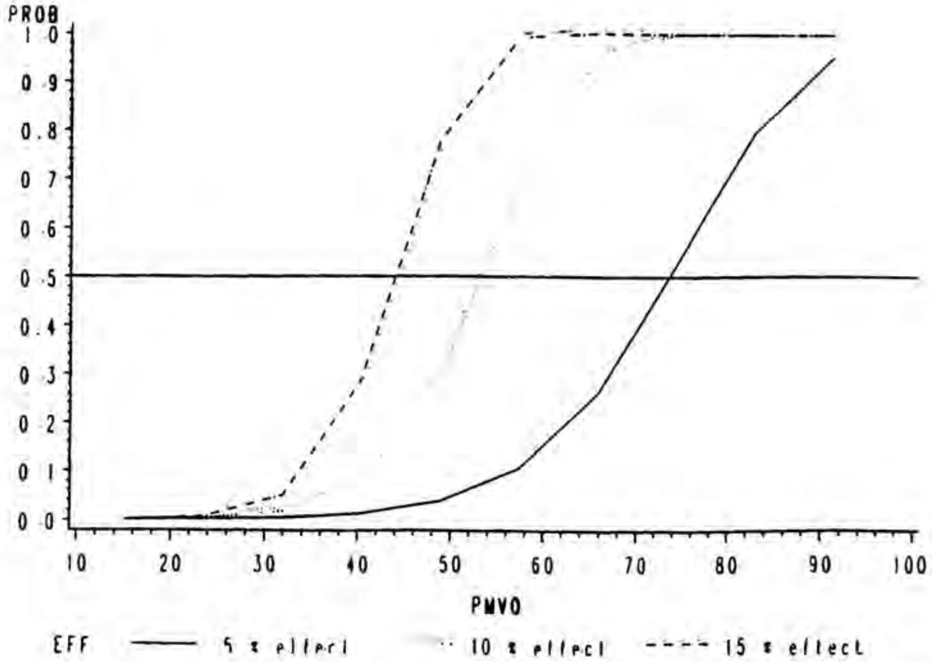


Figure 34. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area (taking into account a drop of 5% in this area), based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

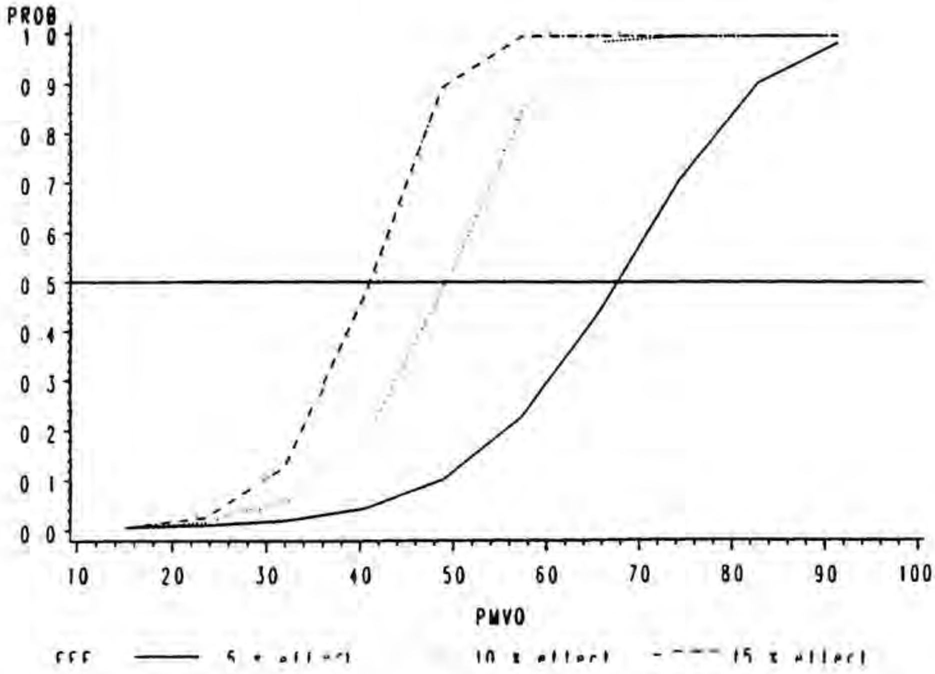


Figure 35. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area (taking into account a drop of 5% in this area), based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

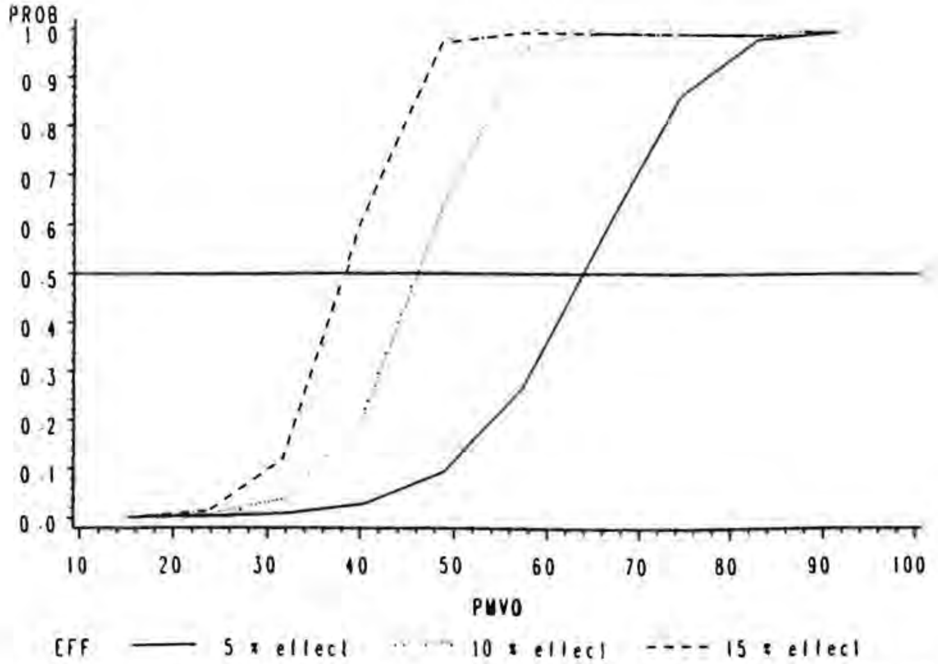


Figure 36. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area (taking into account a drop of 5% in this area), based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

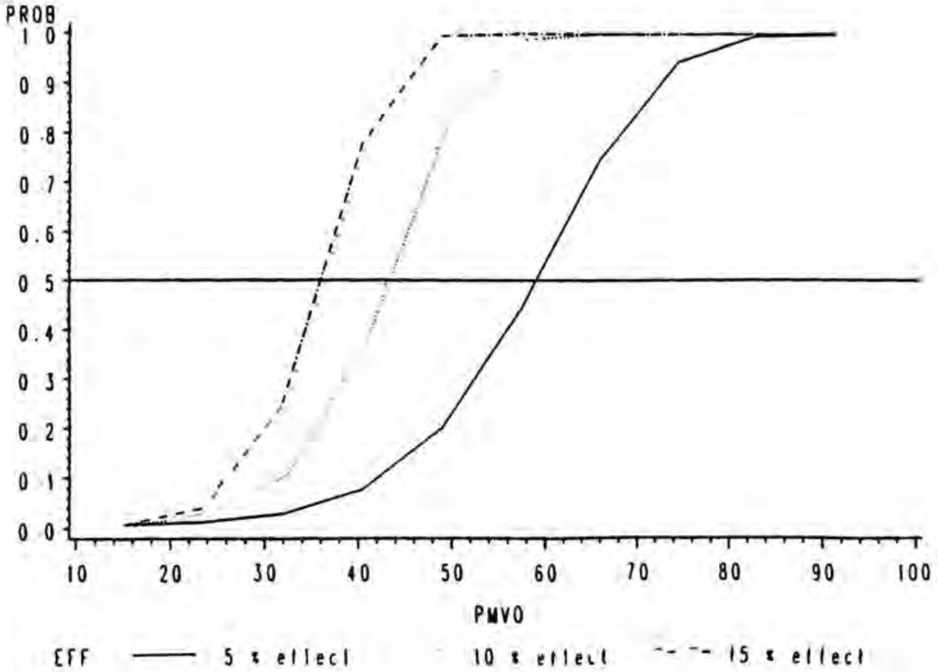


Figure 37. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area (taking into account a drop of 5% in this area), based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

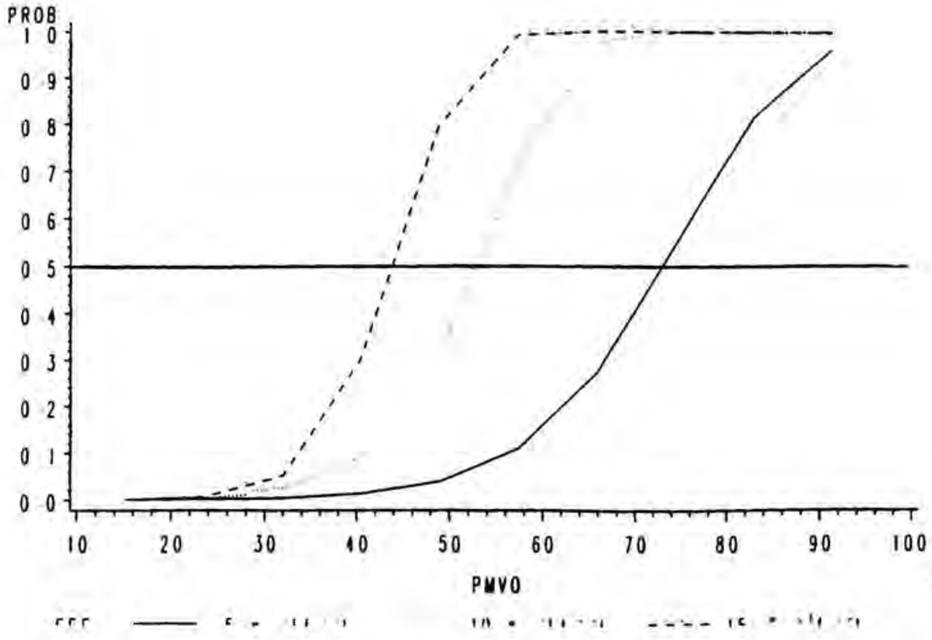
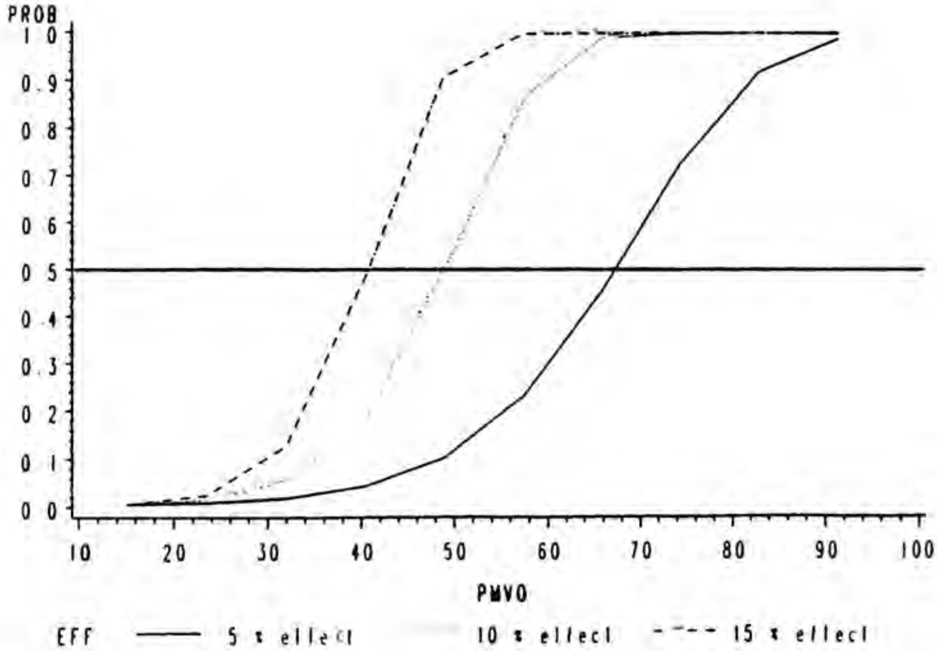


Figure 38. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.



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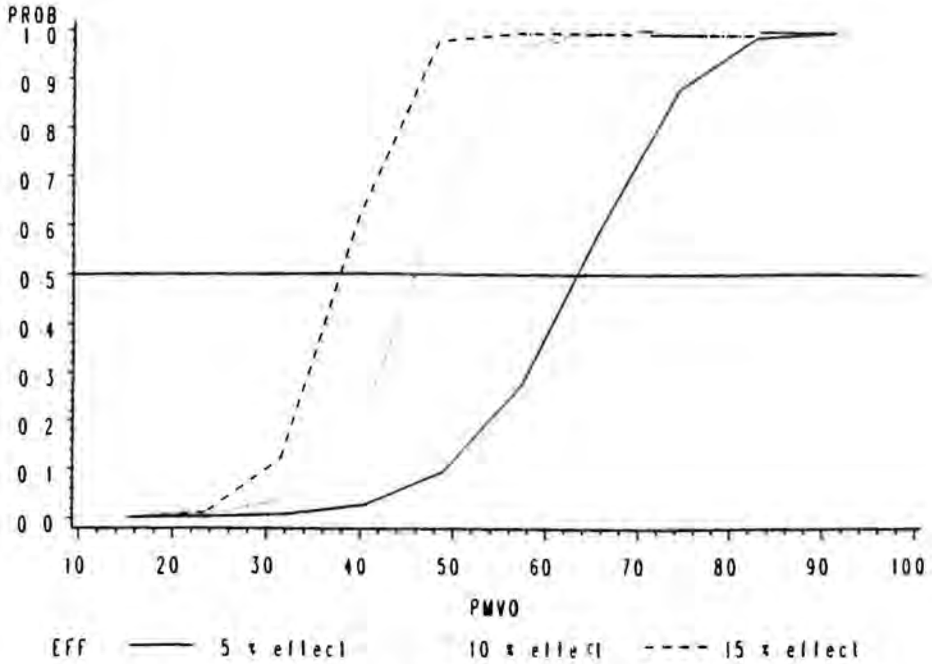

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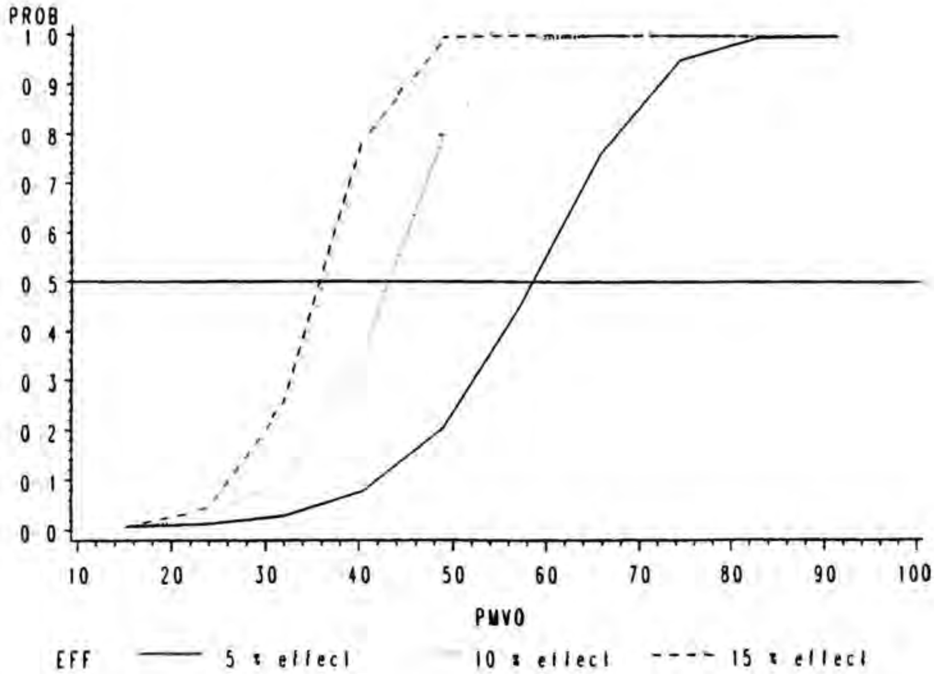


Figure 41. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is the control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of two years) is in fact found in the after period.

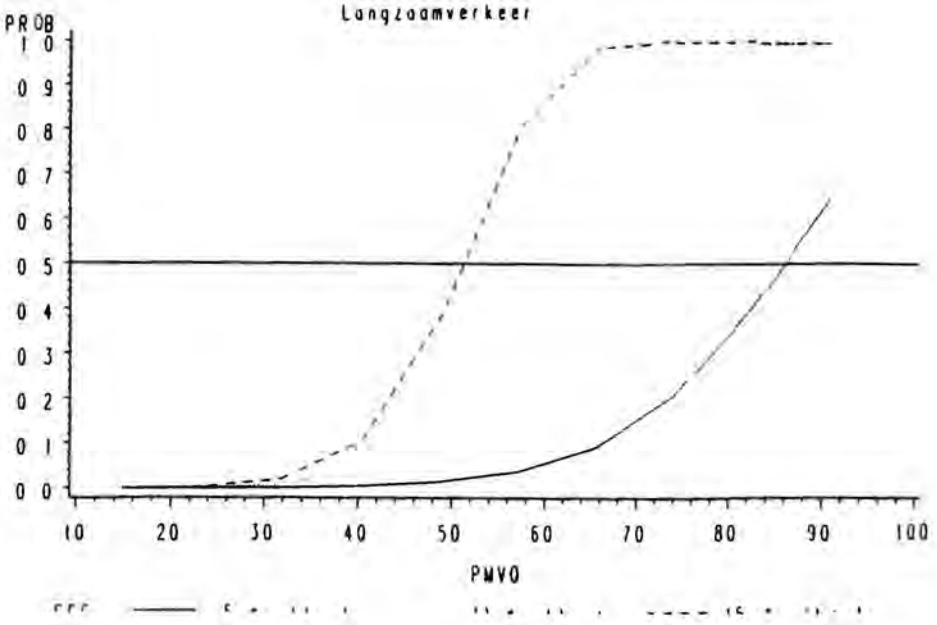


Figure 42. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, is found to be significant with daytime injury accidents and MDO accidents between fast traffic and slow traffic, based on a 95% probability (alpha error = 5%) that the calculated number of accidents (based on a before period of one year) is in fact found in the after period.

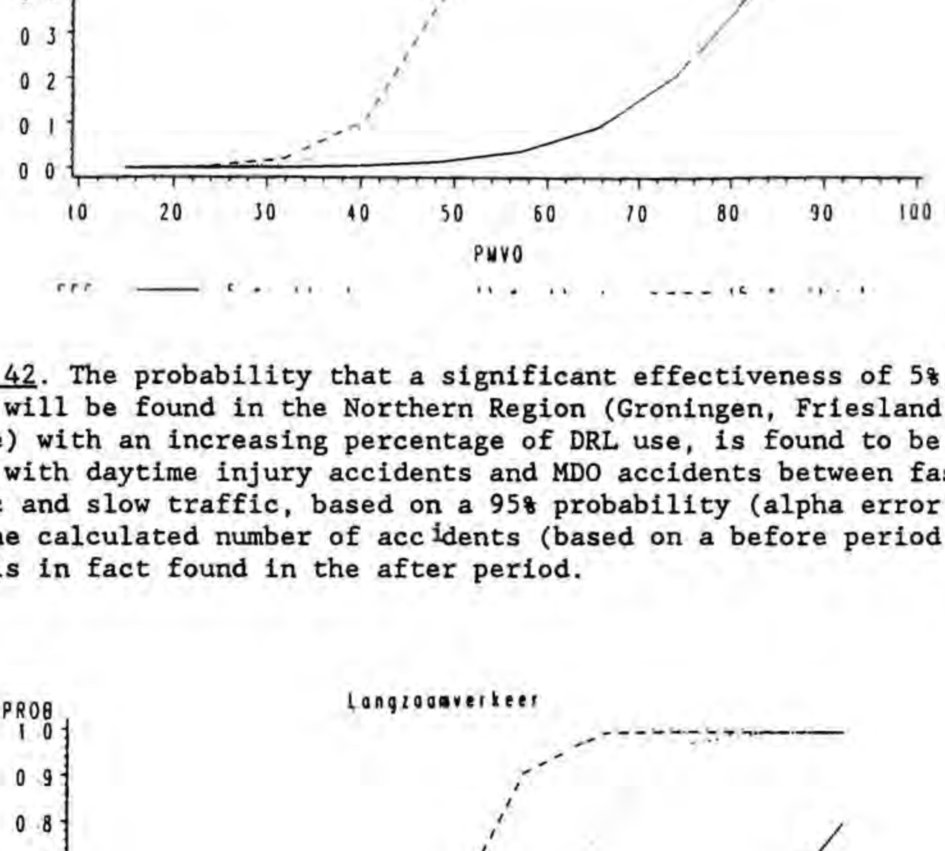


Figure 43. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, is found to be significant with daytime injury accidents and MDO accidents between fast traffic and slow traffic, based on a 90% probability (alpha error = 10%) that the calculated number of accidents (based on a before period of one year) is in fact found in the after period.

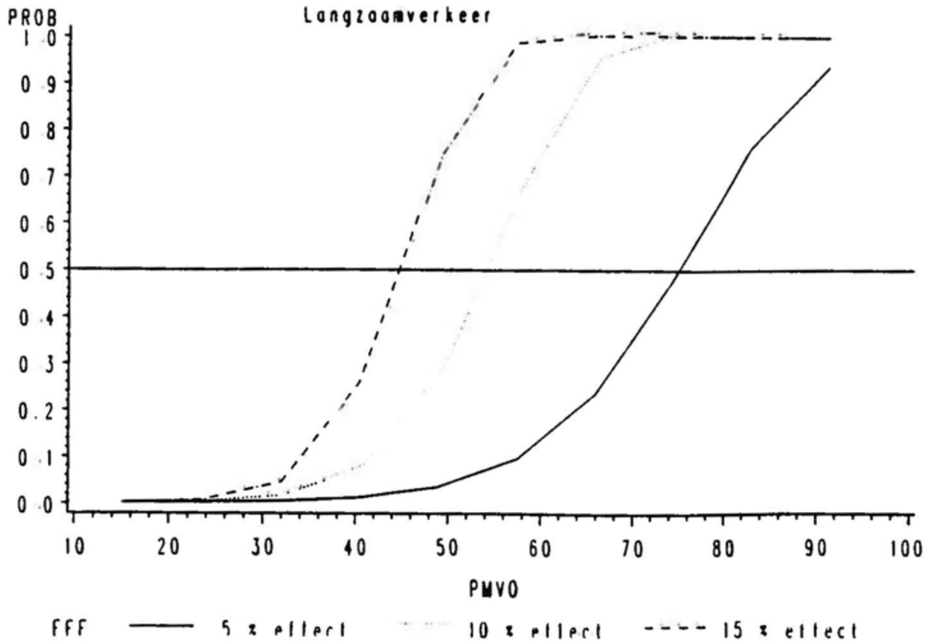


Figure 44. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, is found to be significant with daytime injury accidents and MDO accidents between fast traffic and slow traffic, based on a 95% probability (alpha error = 5%) that the calculated number of accidents (based on a before period of two years) is in fact found in the after period.

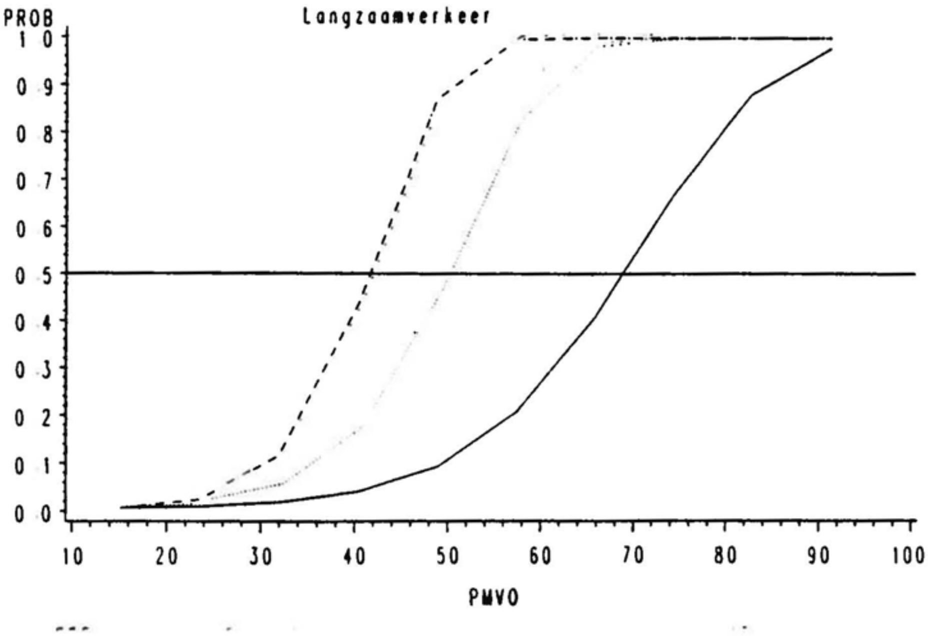


Figure 45. The probability that a significant effectiveness of 5%, 10% or 15% will be found in the Northern Region (Groningen, Friesland and Drenthe) with an increasing percentage of DRL use, is found to be significant with daytime injury accidents and MDO accidents between fast traffic and slow traffic, based on a 90% probability (alpha error = 10%) that the calculated number of accidents (based on a before period of two years) is in fact found in the after period.

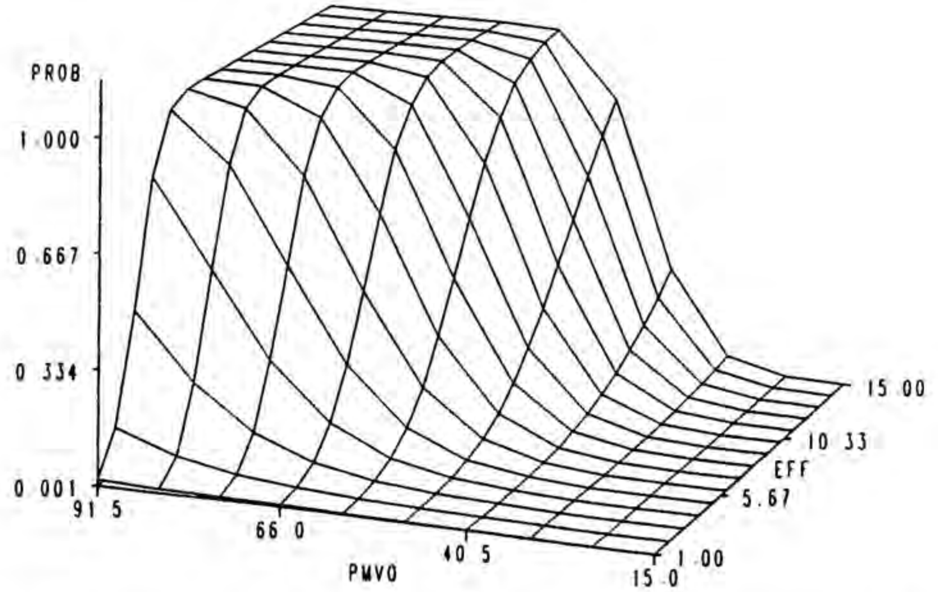


Figure 46. Three-dimensional graph showing the probability of demonstrating the significance of an effect (varying between 1% and 15%) for the Northern region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is control area, based on a 95% probability (alpha error = 5%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

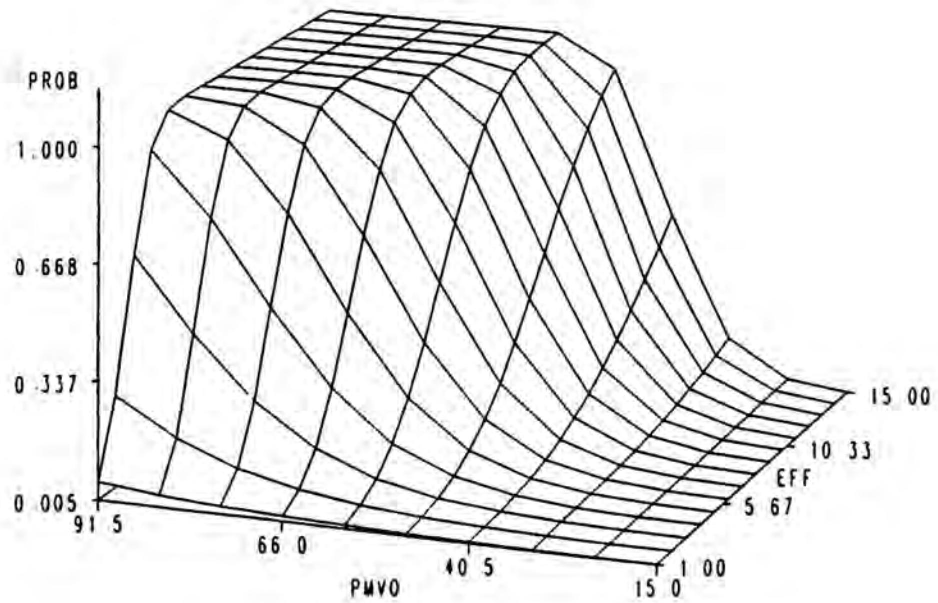


Figure 47. Three-dimensional graph showing the probability of demonstrating the significance of an effect (varying between 1% and 15%) for the Northern region (Groningen, Friesland and Drenthe) plus Overijssel with an increasing percentage of DRL use, if the Rest of the Netherlands is control area, based on a 90% probability (alpha error = 10%) that the calculated number of injury accidents and MBO accidents (based on a before period of one year) is in fact found in the after period.

ANNEX I

THE FORMULA USED TO CALCULATE THE ALTITUDE OF THE SUN

Dr. P.H. Polak, SWOV Institute for Road Safety Research

1. Introduction

An important factor in describing the DRL behaviour of road users is the light level at that time, which is strongly correlated to the sun's position. There was therefore need for an algorithm which could calculate the sun's altitude in degrees above or below the horizon on the basis of the day and time (EPOCH) and geographical location. In practice, this value is often calculated with the aid of tables and additional formulas, but this did not suit our purpose.
The principle is based on two tables from the Sterrengids 1990 (Astronomical Guide), published by 'de Koepel' Foundation.

2. The altitude of the sun

The altitude of the sun (A) varies at every location on earth, being a combination of a daily and an annual cycle. The annual cycle is expressed by the declination (D) and varies between +23°26' (June 21) and -23°26' (December 22). The daily cycle is linked to the time of day. For a particular location on earth, defined by its geographical latitude (La) and longitude (Lo) and by the true solar time (ST) and declination (D) at a particular EPOCH, the sun's altitude is calculated on the basis of the following spherical trigonometry formula:

$$\sin(A) = \sin(La)\sin(D) - \cos(La)\cos(D)\cos(ST*\pi/12) \qquad (1)$$

In order to apply this formula, one also needs the formula for the declination as a function of the EPOCH and the formula for the true solar time as a function of the EPOCH and the geographical longitude. With all these formulas, the angles must be expressed as radians, which is why the factor $\pi/12$ is used (so that ST may be converted from hours to radians).

3. The declination

The Astronomical Guide includes a table headed 'The Sun in 1990'; this lists the declination of the sun for every fifth day after January 1 1990 on the basis of 0^h Universal Time (UT), also known as Greenwich Mean Time. In order to interpolate between these values, a function is fitted to provide values with the same degree of accuracy as the table:

$$D = 0.40605 * \sin (0.0172028 * (EPOCH - 80.624) + 0.033 * \sin (0.0172028 * (EPOCH - 2.714))) - 0.00298 * \sin (0.0516084 * (EPOCH - 80.9)) \quad (2)$$

The first line represents the principal part, consisting of a sine with a period of one year (0.0172028 = $2\pi/365.242$, with 365.242 being the length of the tropical year in days), the second line represents a small asymmetry in the annual movement of the sun, caused by the elliptical orbit of the earth around the sun and the third line represents an even smaller correction whose frequency is three times that of the principal movement. The EPOCH variable is the time of sun observation, expressed in decimal days that have passed since January 1 1990, 00:00:00 hrs UT; it is calculated on the basis of the date and local time, by correcting for the time difference with UT in the Netherlands: less 1 hour during wintertime and less 2 hours during summertime. For example, 13.00 hours at 1-1-1990 is equivalent to EPOCH = 0.5000, while 19.00 hours at 31-12-1990 is equivalent to EPOCH = 364.75.

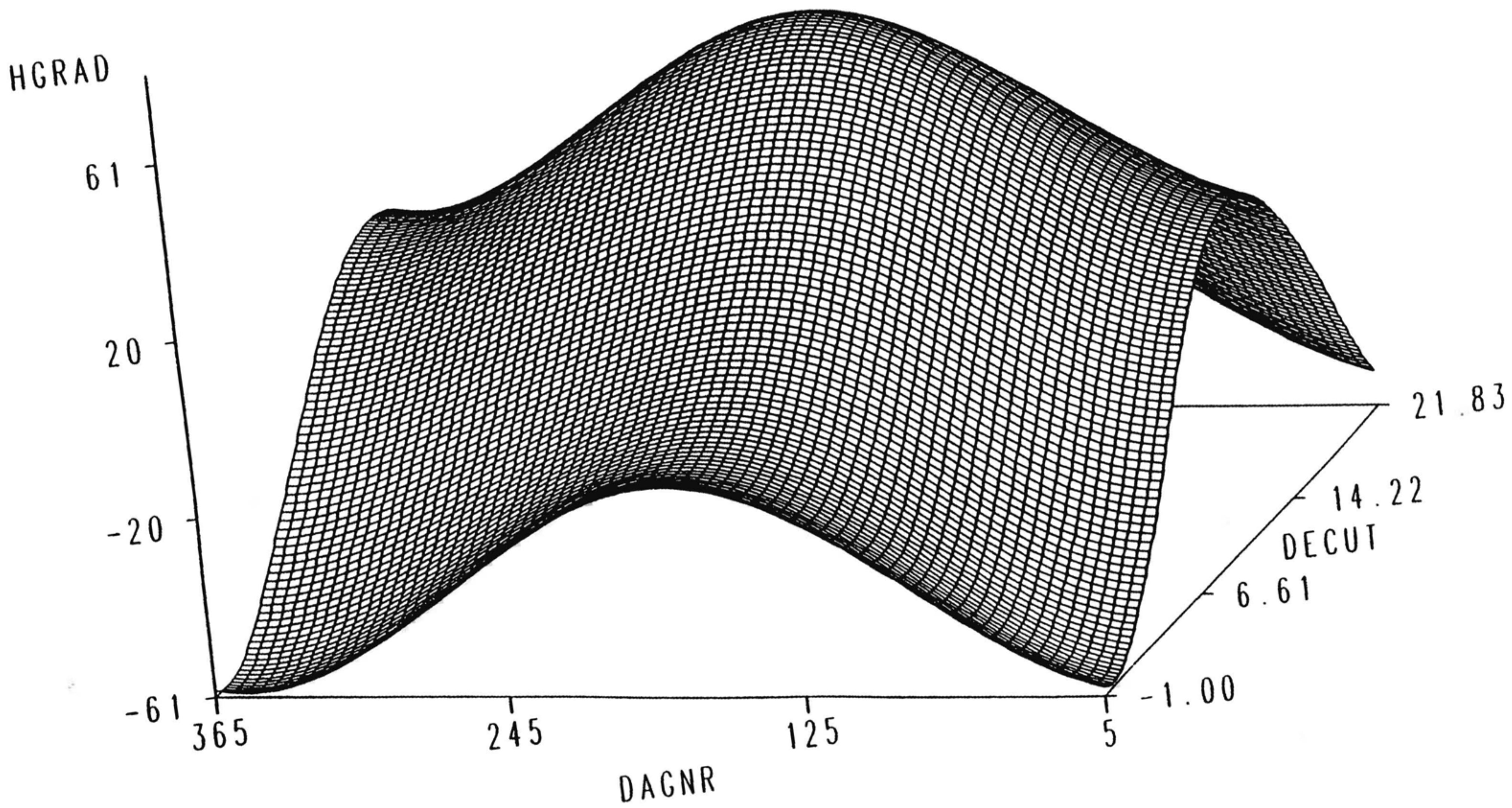
4. The true solar time

The daily movement of the sun for a particular location on earth is mainly dependent on the local time (LT). However, it must be remembered that in the Netherlands the same legal time is in force at any given location, i.e. the Middle European Time (the local time at a meridian of 15° eastern longitude), which is one hour later than UT (with a two-hour difference in the summertime). In order to convert to the local time of a given location, it is necessary to calculate back to UT and then calculate the time difference with UT from the eastern longitude:

$$LT = \text{legal time} - 1 + \text{eastern longitude}°/15° \quad (3)$$

TEST ZONNEHOOGTE

Lengte = 5 en breedte = 52



For summertime calculations, the 1 is substituted by 2. The formula provides the local (average solar) time in hours.
A second correction must be carried out for this local time, i.e. a time adjustment (Ad), which is also made necessary by the elliptical orbit of the earth around the sun. Therefore, the true sun will be ahead of, or behind, local time (up to approx. 15 minutes). This correction for time is also listed in the tables of the 1990 Astronomical Guide, and again an adjustment function has been fitted:

$$Ad = 0.1225 * \sin(0.0172028 * (EPOCH - 186)) + 0.165 * \sin(0.0344056 * (EPOCH - 80.8)) \quad (4)$$

The two terms are a sine with a period of one year and one with a double frequency. This gives us the true solar time, in hours:

$$ST = LT + Ad \quad (5)$$

After entering formulas 3 and 4 in 5, and 2 and 5 in 1, we obtain the sine of the sun's altitude, from which A can be derived. The sun altitudes calculated with the aid of this algorithm are compared with the table, the greatest deviations being approx. 0.1°.