Effectiveness of daytime motorcycle headlights in the European Union

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Summary

Motorcyclists are road users with a particularly high accident risk. In particular, motorcycle accidents are severe in nature, due to the relative lack of protection of motorcyclists once an accident takes place. Furthermore, given the young age of many victims, these accidents often result in a high loss of life expectancy for fatalities and high social-economic costs for severely injured motorcyclists. Therefore, even a moderate reduction in the number of accidents will result in relatively large benefits for the potential victims, and social-economic savings for society.

This report describes a research on the effect of the use of daytime running lights by motorcycles in the European Union. In particular attention is directed at Austria; in this country a new law has been introduced in 1982. Using a generalised linear model, it is found that this law has reduced the number of victimised motorcyclists in daytime multiple accidents by about 16%.

This result has been generalised in a rough manner for the expected effect of daytime headlights as a motor vehicle standard in the European Union, which predicts about 7% less fatalities and injured in the European Union.

Contents

1. Introduction

SWOV has conducted a research on the effectiveness of the obligatory use of headlights for motorcycles in contract with KeyMed Ltd. The project number is 69.862.

Motorcyclists are road users with a particularly high accident risk.
In particular, motorcycle accidents are severe in nature, due to the relative lack of protection of motorcyclists once an accident takes place.
Furthermore, given the young age of many victims, these accidents often result in a high loss of life expectancy for fatalities and high social-economic costs for severely injured motorcyclists. Therefore, even a moderate reduction in the number of accidents will result in relatively large benefits for the potential victims, and social-economic savings for society.

It is sometimes stated that the main reason for the high risk potential is the active risk taking of motorcyclists, but research has shown that a considerable number of motorcycle accidents is due to the fact that car drivers failed to detect their presence.
Because of this inconspicuity, motorcyclists themselves often use headlights during daytime. There is strong evidence for the effectiveness of this measure. Therefore, in a number of countries (e.g. Austria, Germany, Belgium, France, Spain and Portugal) daytime running lights for motorcyclists are compulsory. Because of the positive effect on detection by other road users, the daytime running light measure is even made compulsory for car drivers as well in a number of countries.
However, although a large majority of motorcyclists already use their headlight in daytime in countries where the measure is not compulsory, about 90% in the early nineties in the Netherlands, there is still potential for improvement of the effect, by raising the use up to 100%.

Arguments against such an obligatory use of daytime running lights are often a mix of factors such as the above mentioned feeling that motorcycle accidents are primarily caused by the risk seeking behaviour of the motorcyclists and economic or environmental arguments, related to extra battery usage, extra fuel costs or costs for light bulbs. Furthermore, it is argued that such measures should be taken at an European level.
In order to prepare legislation on a national as well as European level, it is important to describe the state of the art with regard to practice, effects on accidents and of the legislation in various European countries.

2. Aim of the study

The aim of the study is to give a synthesis of the state of the art of the (obligatory) use of running lights for motorcyclists during daytime.
This synthesis gives an overview for various European countries of the following issues:

- statistics on motorcycle accidents during day and night, and their severity;
- practice of headlight usage during daytime and the existing legislation;
- estimated effects of this use in reducing accident risk and the potential to improve this effect;
- a short discussion of the advantages and disadvantages of a general legislation on motorcycle daytime running lights and implementation aspects of such a (safety) measure.

3. Design of the study

3.1. Overview

In order to get a general insight in the scientific support of the measure and the national opinions and attitudes regarding it, a first short questionnaire is sent to a number of sister institutes of SWOV in Europe. This questionnaire is followed by a telephone interview.

In addition to this first overview, a literature study is performed to collect accident statistics on motorcycle accidents and their severity, as well as the reported effects of daytime running lights. This information supplements data from the questionnaire that is sent out during the first stage of the project.

The results of both research steps are integrated in a final report. This report also contains a discussion of the pros and cons and of the implementation of the measure.

3.2. Questionnaire

All European Union sister institutes together with Switzerland and Norway have been contacted both by mail and telephone in order to obtain information related to safety aspects of DRL for motorcycles together with information on relevant laws in each country. The questionnaire has been conducted at short notice; therefore SWOV has delivered the information already available and asked for checks and additions to make the job as simple as possible.

The survey consisted of questions on annual statistics about accidents, motorcycle and car road fatalities and injuries, a further distinction between day and night, and a distinction between single and multiple accidents and for the age groups of younger drivers, for example 18-24 year.

To supplement this information, information on exposure was asked also. More general information, like population figures are generally available in the IRTAD database.
Apart from these figures, DRL related information is needed. For instance information on a DRL law for motorcycles, whether it is implemented or not; whether such an introduction has been considered; if introduced, what was the effect and so on.
If no law was applied or is foreseen, it might be useful to know whether there is an official policy that promotes motorcycle DRL.

Finally it was asked whether or not information is available on the actual use of DRL by motorcyclists in traffic. It was not anticipated that separate reliable information was available on use of motorcyclist daytime running lights in accident situations.

4. Analysis of the results obtained from the questionnaire

Due to the fact that results still come available, this section may change. At the time of this writing, full data have been obtained from Great Britain, France, Denmark, Austria and The Netherlands. Partial data have been obtained from other countries. Any following analysis is based on the data of the above mentioned countries.

The results obtained from the questionnaire gave an insight in the current situation on the use of DRL by motorcyclists.
The use is obligatory in Denmark and France for the entire period of which data are available. The use has never been obligatory in both Great Britain and The Netherlands. This means that it is impossible to obtain an insight in the effectiveness of DRL for motorcyclists using data for those countries alone. We are in the fortunate position that the use of DRL for motorcyclists has become effectively obligatory in Austria since July 1982. In that year a new law was introduced on top of an older law that was not implemented in practice. The new law prescribed the installation of a device in all motorcycles (newly registered and existing ones) that automatically switches on headlights as the engine is started. It is said to have resulted in an almost 100% overall use of DRL.
No real world observations on the actual use of DRL are available, neither before introduction of the law nor afterwards. Therefore some assumptions on the development of the actual DRL use have to be made. It is likely that the 100% use of DRL is (was) reached after about 10 to 15 years.
The use of crash helmets has become compulsory for motorcyclists in Austria in July 1984. This will influence the number of victims and is therefore likely to interfere in the analysis.

The Netherlands have observed a change in the use of DRL for motorcyclists (among others) due to campaigns from 81% in 1990 (estimated from a sample of counts of size n = 9989) to 88% in 1993 (n = 9538). This fact might be used to indicate an effect of DRL for motorcyclists as well. Useful data are also available for France, showing similar use of DRL to the Netherlands. It is said that DRL use is as low as 60% in Great Britain, but no real observations are available.

Given the situation as described above, one option for research is to compare Great Britain to the others as the use of DRL is likely to be lower than in the other countries. In this case it should be considered that definitions of motorcycles differ between European countries as well as the (conditions of) use of motorcycles.

Other options include:

- Law/no law comparison. This would mean comparing data of countries that have a law with data of countries that do not. A possible problem with this approach might be that the actual use of DRL may not differ that much between countries in different conditions.
- The change in use in The Netherlands in the period 1989-1993 and (or) France. One problem with this approach is that it is known that the actual use of DRL differs between road types. The data available in this research do not allow for such an distinction.
- A before/after study for Austria, as the introduction of a law has taken place in the observed period. This is the ideal analysis situation and was first persued, although it only covers one country.

Unfortunately, the use of daytime running lights in normal traffic cannot be compared to the use of daytime running lights on motorcycles involved in accidents. An analysis using both sources of information would make an almost optimal design, but hardly any information on the use of daytime running lights on motorcycles in traffic is available and no information on the use of daytime running lights on motorcycles involved in accidents is available. Consequently, such an analysis can not be performed.

Given the options sketched above, any analysis can be best performed first for all age groups and all victims. If necessary, one can concentrate on fatalities (or injured) and (or) young road users.

Table 1 below summarizes the results of the questionnaire.

Country	Law	Accident Data	Data on use of Drl
Austria	Yes	Yes (All)	No
Belgium	Yes	Yes (Limited)	No
Denmark	Yes	Yes (All)	No
Holland	No	Yes (All)	Yes
Luxemburg	Yes	No (Not asked)	No
Finland	Yes	Yes (Limited)	No
France	Yes	Yes (All)	Yes
Germany (W/E)	Yes	No	No
Greece	No	No	No
Ireland	No	Yes (Limited)	No
Italy	No	No	No
Portugal	Yes	No	No
Spain	Yes	Yes (Limited)	No
Sweden	Yes	No (Not asked)	No
UK	No	Yes	No

Table 1. *Summary of the results of the questionnaire.*

5. Study of relevant literature

Issues regarding motorcycle conspicuity have been a subject of research for decades. This report is not intended to give an extensive synthesis of all results on this subject. The reader is referred to papers of Olson (1989), Wulf et al. (1989) and Cercarelli et al. (1991) and the references therein for much more detail. These papers focus on motorcycle conspicuity in general and formed the basis of the following survey of results of older research, together with some specific papers.
This report is however focused on the application of motorcycle daytime running lights, which is an option to increase motorcycle conspicuity. Although motorcycle daytime running lights is not the main issue in the papers used as a reference, it plays an important role in them.
A more recent study by Radin Umar et al. (1996) with a new accident analysis of a running lights intervention in Malaysia, is also included.

5.1. Classical results on (motorcycle) conspicuity

It is common sense that visual aspects and conspicuity in particular play an important role in traffic safety. It is sensible to investigate how and in what manner conspicuity issues influence traffic unsafety in order to find out how exactly traffic safety can be improved by (improving) conspicuity.

Probably the most fundamental research finding (for instance Dahlstedt, 1986; cited in Wulf's evaluation) is the fact that from in-depth accident studies it is found that in many cases people involved in an accident claim to have looked but have not noticed their accident partners in time to avoid an accident. Because these results come from post-accident interviews of offenders involved in accidents, it is possible that such an explanation of the cause of the accident may be more attractive than admitting not to have looked at all. Assuming that accidents are unintentional, it is likely that decreasing the chance of not seeing other relevant vehicles is likely to decrease the chance of an accident occurring in certain circumstances.

This phenomenon, 'looking without seeing' (Dahlstedt, 1986), is likely to be a cause for traffic accidents in general and motorcycle accidents in particular. In the case of motorcycle conspicuity the relevance of this hypothesis is supported by three other findings.

First it is found that in motorcycle accidents other vehicle drivers seem to be more often in error than motorcyclists (Cercarelli et al, 1991, Wulf et al., 1989). Hurt et al. (1981) found that "automobile drivers involved in accidents with motorcycles were generally unfamiliar with motorcycles". Weber and Ote (1980, also cited in Wulf's evaluation) found that 45% of all driver licence holders in West Germany also had a motorcycle licence while only 12.4% of all automobile drivers involved in an accident with motor-cycles also hold a motorcycle licence. From this it may be inferred that it is more likely that other road users overlook motorcyclists than vice versa and, more tentatively, vehicle drivers with experience with motorcycles tend to notice motorcyclist better than others. Unfortunately, it was not possible to find out whether vehicle drivers with experience with motorcycles were less often at fault in accidents with motorcycles than vehicle drivers without experience with motorcycles.

Secondly, an observation by Smith (1974) is that the ratio of other drivers' fault to motorcyclists' fault was higher in daytime than in nighttime. This finding supports the idea that there is something special about daytime accidents in which motorcyclists are involved.

Finally, another result (Olson, 1989) supporting the hypothesis of a conspicuity factor in motorcycle accidents is that from several accident studies (seen from right-hand driving) it is found that a substantial number of accidents occur when a car turning left, crosses the path of an oncoming motorcycle driving straight on. This number is far more dominant than the matching number in the cases when two cars are involved or the car drives straight on while the motorcycle is turning.
Olson (1989) analysed daytime car/car and car/motorcycle accidents in the year 1986 in the state of Texas. He reports that in 17.1% of all car/ motorcycle accidents, the car turned left and the motorcycle went straight, while 1.7% of all cases it was the other way round. 10.4% of all car accidents had the same manoeuvre. Adding together Dutch data for 1990 through 1995, about 14% percent car/motorcycle accidents can be found with manoeuvre left/forward while only 1.4% is forward/left. For cars the figure is 11%. At night the figures are 22%, 1.7% and 12% respectively.

The accident study in Cercarelli et al. (1991) did not indicate significant differences, but that analysis did not distinguish forward/left and left/forward accidents. Furthermore, its statistical method is questionable. An important remark to make is that it may not be correct to attribute all the 'looking without seeing' to general conspicuity issues. Conspicuity itself is sometimes divided into sensory conspicuity, inherent to the object (motorcycle) and cognitive conspicuity, dependent on the observer (for instance his or her expectations) (Engel, 1976). Obviously, running lights will only influence sensory conspicuity while 'looking without seeing' is dependent on both.
Another factor that may indicate an alternative to the influence of sensory conspicuity is the fact that the motorcycle has a small frontal profile compared to a car, so it may easily be that recognition is hampered or even impossible because the motorcycle is obscured by objects along the roadside or in the car. Related to this feature, Wulf et al. (1989) cite research by Leibowitz and Apelle (1969): "When the automobile driver turns his or her head to the left during performance of a left turn (...), low-conspicuity targets in the right periphery might have a relatively lower probability of being detected."
This phenomenon may partly explain the dominance of motor forward/car left turning accidents. It should also influence car forward/motor left turning accidents if this means that the 'conspicuity' of the forward moving object were of no influence. It may be true that the conspicuity of motorcyclists is below a certain level while the conspicuity of cars is above that level, so a car is more likely to be detected in the right periphery.

5.2. Daytime running lights as an option to improve (frontal) motorcycle conspicuity in daylight

The results outlined above seem to indicate that car drivers may have a problem noticing motorcycles in traffic. This problem may be reduced or solved by improving the way car drivers look for motorcyclists in traffic or by making motorcyclists more conspicuous, or both. The latter option seems to be most practical and is the prime interest in this report.

In order to improve motorcycle conspicuity combinations of a number of options are available:

1. Increase the profile of the vehicle, in particular the frontal profile. This can be achieved for instance by mounting (white) fairing to the vehicle. These fairings can then be used to attach other conspicuity enhancing devices.
2. Using retroflective or coloured materials. Retroflective or coloured materials can be fitted on the motorcycle as well as on the motorcyclists' garments and helmet. The latter two have the extra advantage that it may improve off-vehicle safety. Using retroflective or coloured materials has the disadvantage that its effect is relative to the background environment. That is, it is found that retroflective materials are particularly effective in dusk and obviously, white clothing may not be as effective in snow conditions.
3. Active lighting: running lights, dipped head lights, low-beam lights, high-beam lights, strobes, lights with rotating prisms and many more. See Wulf et al. (1989) for a large number of references. In practical terms dipped head lights seem to be the most practical solution as all technical material should be readily available on all motorcycles.

This report focuses on the latter option. Wulf et al. (1989) give a large number of studies that univocally conclude that daytime running lights (as well as other options) improve the motorcycles' conspicuity. All these studies share one common problem in this setting: they research the improvement of conspicuity in some setting rather than that the effect on unsafety is studied. In plain words this means that it was studied whether or not motorcycles were more easily seen, not whether they were safer. Used as a means to estimate the improvement of the motorcycle conspicuity those studies are not free from methodological problems either. Many studies use an experimental setting (either in an laboratory environment or on 'location') in which either the experimental subject may know the object of study is about motorcycles or motorcycles occur much more often than in practice. In any way the experiments at best approach real life traffic situations.

Following this it should be noted that it is likely that such research offers an insight into what measures are more effective than others in improving motorcycle conspicuity.

Some results show a possible positive safety effect of daytime running lights for motorcycles. Some studies found side effects of the use running lights by motorcyclists, probably most seriously wrong estimation of the speed of a motorcycle. In that case it is found that with headlights off, the speed of a motorcycle is estimated higher than when headlights are on (Shew et al., 1977). This phenomenon may (partly) counter positive effects of the use of headlights by motorcycles.

5.3. Accident studies

Many studies have been conducted to get an insight in terms of a reduction in the number of accidents (and sometimes fatalities or victims) when the use of daytime running lights is changed for some reason.

Such studies report diverse results. Even the survey studies used as a reference for this report seem to support different conclusions. Olson (1989) reviews studies reporting effects between 4% and 20%. Cercarelli et al.

(1991) reports a study (Zador, 1985, United States) with an effect of about 13% reduction in the number of fatal daytime (not just multiple daytime) accidents. Radin Umar et al. (1996) found an effect of about 29% and cites studies that showed effects of 20-25%. They acknowledge that in some studies no effect was found.
The review by Wulf et al. (1989) is more critical stating that: "In fact, the results of studies investigating the effectiveness of headlight-on laws, or campaigns to promote voluntary headlight use, in terms of change in motorcycle accident rates, are inconclusive." A small part of these differences may be attributed to the fact that in some of the studies conspicuity was the main object, whereas in others the research was directed towards finding a safety effect, this may have influenced the research settings.

Most studies seem to suffer from methodological problems, for instance small numbers of fatalities that may or may not be an explanation for nonsignificant 'effects'. In other cases the use of daytime running lights by motorcyclists may not differ all that much between conditions that are supposed to be different (viz. France in which the use of daytime running lights is obligatory and the Netherlands in which it is only highly advised, use in both countries does not differ very much). Campaigns may not change the use of headlights in an substantial manner in some cases and thus no big safety effects can be expected in those cases anyway.
Some other explanations are that only a short period is studied. No control group has been used. Other differences can be found when, as is done below, the effect on relevant daytime running lights accidents is studied, an effect on these accidents may be significant while no significant effect can be found when all motorcycle accidents are compared.

The recent study performed by Radin Umar et al. (1996) studies the effects of the introduction of a running lights law in Malaysia in 1992. In July 1992 a daytime running lights intervention was introduced in Malaysia; after a campaign its use became obligatory since September 1992. It changed the use of running lights from nil to 82%. A two year-long series of weekly data has been analysed. The study does not suffer from most of the problems sketched above. One problem it suffers from though, is the fact that it lacks a control group.
As the study is performed in Malaysia, its results cannot be generalised straight forward to the European situation. This regards more likely the estimated effect size than the effectiveness of daytime running lights.
The authors start with the statement that nearly 60% of all vehicles in Malaysia are motorcycles. This will mean that the general road user will have much more experience with motorcycles than a common European road user has. Lack of experience is sometimes indicated as a potential factor in motorcycle (un)safety (see above).
Secondly, it may be argued that if road users tend to look for motorcyclists more often, they can benefit more from their use of headlights. Another yet unfortunate advantage in the Malaysian situation is that quite a lot of people get killed as a motorcyclist. It is said that 2,307 fatalities were motorcycle riders or 'pillion' passengers in 1992 (51% of all cases). Therefore the small number problem counts less in this study.

The model used by Radin Umar et al. (1996) corrects for a trend in unsafety, assumed to be a result of the increase in traffic. Other disturbing factors include fasting in Ramadhan (which changes a substantial portion of traffic) and a local holiday phenomenon that was later found to be insignificant.

Besides these factors, a factor that corrects a change in accident registration was introduced together with an effect for the running lights law. Unfortunately, these two factors seem to cancel out almost entirely except for a small residual effect for daytime running lights. It therefore has to be assumed that the authors used other sources (e.g. control group) to check the effect of the change in the accident registration system. Besides this, the effect of the measure might have been more gradual.
Finally, no seasonal effect has been modelled, but there may not be a reason to do so in Malaysia.

Assuming that the change in registration was approximately the same for other types of accidents, the Radin Umar et al. (1996) study gives a clear indication of a positive effect of daytime running lights on motorcycle safety. The effect is found in a large population of motorcyclists who may have changed their use dramatically. It should be realised that if the population was smaller and the change in use was smaller in this case, it had been possible that no significant effect was found.
This fact, together with the fact that in this case a change from nil up to 82% use was observed compared to a change anticipated in Europe from about 80% upward, it seems wise not to use the effect found in terms of reduced numbers of victims in Radin Umar et al. (1996) as a yardstick for the expected reduction in numbers of victims in Europe, without an appropriate correction for prior use of DRL. But it is still clear that it indicates a positive effect of daytime running lights for motorcyclists.

5.4. Summary of literature

In summary it can be concluded that it is very likely that motorcyclists are sometimes not seen by car drivers or other traffic participants.
This phenomenon is likely to be caused by a number of factors, of which conspicuity related factors is one. This assumption is supported indirectly by a number of studies showing that an improvement of conspicuity has improved the safety record of motorcycle riders.

6. Analysis of accident data

6.1. Introduction

Part of the questionnaire consisted of a request for accident data. Data were received from a number of countries that were able to deliver easily, as was requested because of the time constraint. For the same reason, numbers of fatalities and injuries were requested rather than numbers of fatal accidents or injury accidents, as it was assumed that these numbers would probably be more easily available. It was further thought that, particularly for motorcyclists, those numbers would be reasonably comparable. Secondly, local definitions were requested, resulting in differences in definition of fatalities and injuries, day and night and motorcycles themselves.

At the time of this writing, not all countries were able to deliver all requested data. Fortunately, at least data from Austria were available, a country that introduced a technical law on motorcycle DRL and Denmark, a country that introduced a general law on DRL. As it turned out, in Austria a positive relative effect could be found. In line with theory, a negative effect on the relative advantage of victimised motorcyclists in daytime multiple accidents compared to other accident types (though not statistically significant) can be found in Denmark with a reduction in the total number of casualties following the introduction of a general DRL law (Hansen, 1994). In that case, other explanations may exist.

Sister institutes in Europe were requested to deliver data for as many years as possible, disaggregated in a number of levels. In practice, data of years back to 1976 were requested. Some countries were not able to go back that long anymore while still being able to make the requested disaggregation.

Data were to be disaggregated into fatalities and injuries, motorcycle riders or passengers and car drivers or passengers, day or night and multiple or single accidents. A separate table for victims aged between 18 and 24 was included.

This particular selection of data was based on the assumption that the conspicuity situation of the motorcyclist was reflected in the relative frequency of multiple daytime accidents. As the relative frequency of multiple daytime accidents may also be influenced by the traffic (volume) itself, comparable car accidents were also compared as a control. It was thus assumed that a relation exists between relative frequency of multiple daytime accidents and the conspicuity situation, expressed in terms of the use of daytime running lights by motorcyclists as well as cars. This is based on the hypothesis that the larger the proportion of DRL-use of motorcyclists is in comparison to cars, the relatively less motorcycles are involved in multiple daytime accidents with casualties.
In the special situation of Austria and Denmark, it could be investigated whether or not this relative frequency of multiple daytime accidents has changed at the time of the introduction of the law in these countries.
This would suggest that those changes result from the changes in the use of running lights due to the laws in those countries.
This latter assumption is the prime subject of the rest of this section.
This section proceeds with a discussion of the results found in Austria and Denmark.

6.2. Analysis of the Austrian data

6.2.1. *The Austrian situation*

Data are available for Austria starting with 1976. In July 1982 a new general motorcycle daytime running lights law became effective, in addition to the law of 1977. From then on motorcycles should have automatic daytime running lights combined with ignition, meaning that almost a 100% usage will be reached when all motorcycles are fitted with the equipment. Technical failures are assumed to be negligible. Unfortunately it is not known at what level use of daytime running lights was when the law was introduced, but it is unlikely that it was less then 60%, (a lot less then the estimate in France of 1988 of at least 75% (in cities) up to 89.7 % on 130 km/h highways, similar to results available for the Netherlands in 1989). Secondly, it is not known at what pace the actual implementation took place. It is likely that most motorcycles were fitted with automatic running lights at the time the law was introduced, but it is not known what part was not yet equipped and how long it took before usage reached it maximum.

The numbers of victims in Austria may have been influenced also by a decrease in motorcycle possession (and use), and a crash-helmet law in July 1984. The control group of cars will have been influenced by a seatbelt law in July 1984. Any model should account for such influences, in order to avoid attributing those effects to the DRL law. Because the effects of such influences are generally unknown, those effects should be estimated or partialled out by some model in order to correct the effect of the motorcycle running lights law.

A close inspection of the data (*Figure 1a*, *Figure 1b*, but best in *Figure 3a-h*) reveals that the number of victims in multiple day accidents dropped substantially over the years. However, not directly after 1982, but after the year 1985, one year after the introduction of the crash helmet law. It is tempting to attribute this change to that law, but the effects of this law should be similar for all types of motorcycle accidents. Inspection of the development of nighttime accidents shows that both single and multiple day accidents start a substantial decrease after the year 1984 of the introduction of the crash helmet law. It seems that the single day accidents show a peak in the years 1983 up to 1985. A peak is also visible in the number of daytime single accident victims in cars in the year 1983, and to a lesser extent in multiple accident victims in cars in the year 1983. This may indicate a particular day effect in 1983, the first year after the introduction of the running lights law, that obscures the effect for the first years after the law.

It is also notable that while the number of multiple daytime victims for cars is increasing, the number of multiple daytime victims for motorcycles has dropped since 1985. The number of single daytime victims for motorcycles has dropped since 1985 as well but less extensive as the multiple accidents. It is possible that this difference can be attributed to the running lights law of 1982, assuming that no other factor has influenced the relative decrease in multiple daytime motorcycle victims.

6.3. Statistical analysis

Giving the discussion in the preceding section, (victim) counts are to be analysed for a number of years under eight conditions. Starting for 1976 through 1995 counts of fatalities and injuries are available for Austria disaggregated as follows:

- Motorcycle (driver or passenger) versus car (driver or passenger).
- Daytime versus nighttime. Local definition is used to distinguish between night and day. This may differ among countries.
- Single accidents versus multiple accidents (against other driving vehicles).

As the series is about twenty years long and overall developments are of no interest here, it is likely that a time series analysis cannot be performed. Therefore the best option is to analyse the data using a Generalised Linear Model. In this case, the SAS procedure GENMOD is used, which is based on McCullagh and Nelder (1989). In order to acquire as large numbers as possible, the analysis is started using victims (= fatalities plus injured) for all age groups. It is assumed that (victim) counts are Poisson distributed and a 'log' link is used in the cited SAS-procedure.

Any feasible model should satisfy the following properties:
The model should allow for a general trend in the number of victims. Such a trend can be due to an increase or decrease of mobility or a development in population size or both. Of course, other explanations may apply.

Motorcycle victims may come at a different rate than car victims, as can be said of multiple accidents and daytime accidents compared to respectively single and nighttime accidents.

These properties ask for the cancelling out of main effects for year, motor, conflict type and day (respectively: 1976-1995, motorcycle/car, multiple accident/single accident and day/night). All these main effects should be included in the model as irrelevant factors for the DRL effect.

The effect of 'motor' (the relative proportion of motorcycle victims compared to car victims) may change over the years, due to a change in travel habits and, due to the introduction of a crash-helmet law and the seatbelt law in 1984.

Due to the level of congestion the relative proportion of multiple accidents may change, influencing the relative proportion of victims of multiple accidents compared to victims of single accidents, which should be accommodated by an interaction between year and type of accident (conflict type = multiple or single accident).
Due to avoidance of congestion or for totally other reasons, the relative importance of daytime travel may change, which should be accommodated by an interaction between year and daytime.

Among other reasons, it is more likely that one is involved in a single accident at nighttime than at daytime, hence an interaction between conflict type and day should be considered. It is also known that motorcycles are mostly used in daytime, thus an interaction between daytime (day) and road user type (motor) should be considered as well.

Based on the above it can be concluded that all factors up to the second order of the variables year (year of observation), motor (road user type, motorcycle or car), day (time of day, day and night) and conflict (accident type, multiple or single) should be included as irrelevant factors for the motorcycle DRL-effect.

Maybe to avoid traffic jams or just for recreational drives, the daytime use of motorcycles may change relatively, which points to an interaction between year, motor and day. Similar arguments can be used to include like year, conflict and day when the amount of nighttime travel changes which could have a different effect on single and multiple accidents. All other third order factors are included in the model as well as irrelevant factors for the motorcycle DRL-effect.

This leaves one effect, the development of the interaction between motor, day and conflict type over the years. This effect is precisely the effect of interest here, as it detects change in the relative proportion of daytime multiple motorcycle victims compared to others.

Changes in this last interaction are being attributed to the effect of daytime running lights by motorcyclists. All other changes are seen as irrelevant to this measure.

One of the alternative ways to look at this model is the following: it is assumed that the daytime running lights only affect the number of daytime multiple accidents for motorcyclists, thus the ratio (multiple day * single night)/(single day * multiple night) should decrease as a result of the measure. One problem with this design is that one has to assume or make sure that no other cell changes except multiple day. It is conceivable that, for instance due to a change in traffic volume one other cell is influenced as well. The current model compensates for this case when this effect influenced the same cell for cars as well, as our interaction is essentially the (multiple day * single night)/(single day * multiple night) for motorcycles divided by the same ratio for cars. In *Figure 5* both developments are drawn. Note that the dotted line, the ratio for cars, remains roughly stable while the ratio for motorcycles decreased. Its ratio is drawn in *Figure 4* except that the last ratio is subtracted from the other ratio's and the value of the ratio's are being multiplied by a constant.

$$\frac{R_{motor}}{R_{car}} = \frac{\dfrac{mmd \times msn}{msd \times mmn}}{\dfrac{cmd \times csn}{csd \times cmn}} \equiv \frac{mmd \times msn}{msd \times mmn} \times \frac{csd \times cmn}{cmd \times csn} \equiv$$

$$\frac{mmd \times cmn}{mmn \times cmd} \times \frac{msn \times csd}{csn \times msd} \equiv \frac{\dfrac{mmd \times cmn}{mmn \times cmd}}{\dfrac{csn \times msd}{msn \times csd}} = \frac{R_{multiple}}{R_{single}}$$

Consequently, a similar argument can be made comparing the ratios for multiple and single accidents as well as for daytime accidents compared to nighttime accidents. This interaction, whether or not expressed in terms of motorcycles compared to cars, day or night or comparing multiple accidents to single accidents is assumed to be influenced by motorcycle daytime running lights. All other combinations of effects are equally distributed over numerator and denominator. For instance, daytime accidents are in *mmd* and *csd* in the numerator while represented by *cmd* and *msd* in the denumerator. A change by a certain percentage in daytime accidents thus has no influence on the ratio. Single night accidents are represented by *msn* in the numerator and *csn* in the denominator, so no dependence on second order terms can be found as well.

It is assumed that this interaction remained the same for the years 1976 up to 1981 (including, which are six years preceding the intervention). The year of the intervention is best left out of the analysis entirely or at least, the number of victims on daytime multiple accidents for motorcyclists should be left out due to the fact that 1982 is neither a pre-intervention year nor a post intervention year, as the intervention took place in July. To check results, a separate analysis is performed without excluding 1982. With the exception of the gradual introduction model, similar models fitted substantially less though an effect could still be found.

Figure 4 shows the estimated interaction terms of year, motor, conflict and day, the coefficient for the multiple day motorcycle victims in the saturated model. No statistical smoothing is in place. The effect in the year 1995 was set to zero (1982 was left out) and the values are only of relative importance.

From this graph it can be inferred that in the pre-intervention period, the year 1980 produces a relatively high contribution to the mean level of the interaction term. The years 1978 (the year after the introduction of the first law) and 1981 have a relatively low contribution. It seems sensible to analyse the data additionally without one year in order to get an insight in the sensitivity of the conclusions to the choice of the years in the analysis. In this way one can exclude the possibility that an eventual effect found is only significant because of a relatively high contribution of that one year only. The year 1980 would suit these purposes well. The year 1983 has a similar effect in opposite direction.

The same graph also hints the idea that, if anything happened at all, the development is relatively stable starting in 1986. This option might be supported by the fact that the use of running lights slowly increased after a possible initial jump in the use of running lights. Another option is to assume that this effect is caused by an undocumented influence, not relevant to running lights. Finally one can investigate the option of a linear trend as a complete alternative to the intervention of running lights, but no sensible reasons for a linear time trend in this fourth order interaction term are present.

This observation leaves three possible models for the development of the effect to be considered:

1. One single effect for the after period.
2. One effect increasing up to 1986 and remaining stable afterwards.
3. One effect up to 1986 and one other effect after 1986.

The final model was estimated with and without the year 1980. Also the inclusion of 1983 was varied. In general it can be concluded that models fit better without the years 1980, 1982 and 1983. However, there is little support for the exclusion of the year 1983, except that it might have taken more time to introduce the law in Austria. The year 1982 can be excluded

for the reason that it is neither a pre-intervention year nor a post-intervention year. It has to be realised that 1980 is a genuine year and thus should always be considered, not completely left out.
After the saturated model was fitted, the fourth, highest order term was removed and DRL relevant term included:

6.3.1. *Model type 1 (One single effect for the after period)*

The first model type consists of a 0-1 DRL effect, a separate constant interaction term before intervention and a separate interaction term for the period after the intervention. This assumes that the effectiveness of daytime running lights on the number of victims is the same for all years after the intervention. This assumption may not hold, for instance when it took some time before the use of running lights reached its final level.

When studying the model using a 0-1 DRL effect, it is included in the model together with all the effects described in the previous section. When the results of the analysis become available, it is sensible the inspect the model fit first:

The Criteria For Assessing Goodness Of Fit in this case were:

Criterion	DF	Value	Value/DF
Deviance	17	40.6623	2.3919
Scaled Deviance	17	40.6623	2.3919
Pearson Chi-Square	17	40.6791	2.3929
Scaled Pearson X2	17	40.6791	2.3929
Log Likelihood	.	5954227.7105	.

Table 2.

When the year 1982 is included in the analysis:

Deviance	18	54.0482	3.0027

Table 3.

When the year 1980 is excluded from the analysis:

Deviance	16	30.9433	1.9340

Table 4.

In the first table a number of criteria are listed. In the sequel attention is restricted to 'Deviance'. For each model, the degrees of freedom is listed. The degrees of freedom decreases one when an additional parameter is estimated. Next the value of the criterion and the value divided by its degrees of freedom is tabulated. An ideal model has a ratio of deviance per degree of freedom of about one, or, the deviance should be about as much as the degrees of freedom in the model. Otherwise statistical tests should be adapted. More deviance than could be expected is called overdispersion.

From these results it can be seen that, restricting ourselves to the 'Deviance' measure of goodness of fit, the difference between the data and the model is most when 1982 is included in the model and the difference is least when

1980 is excluded from the model. The model does not fit very well and it seems sensible to correct statistics for overdispersion. This would widen confidence regions and makes test more conservative.

Some overdispersion is to be expected, because victim counts are analyzed, which are usually more dispersed than Poisson distributed counts. The fact that counts for car victims are more likely to be dispersed than motorcycle victim counts is ignored here. All deviances in the tables above would question the assumption of Poisson distributed counts at 5% level.

The next step would be to check whether the terms included in the model are really necessary to acquire the model fit or, in other words, it is checked whether the model can do without the terms. Correcting the statistics for overdispersion, which makes it 'more likely' that a term is deemed nonsignificant than when such a correction has not taken place, the significance of a term can be inferred from a type 3 analysis.

In a type 3 analysis, the significance of terms is inferred by comparing the fit of a model without that particular term and including a particular term. Anything else is held the same. If a model including a particular term does not fit sufficiently better than the model without the term, it could be concluded that the model can do without that term. However, some care must be taken.

The type III analysis (deviance over dispersion) reveals that all of the effects are significant. Using Pr>F and Pr>Chi, the significance of the terms listed under 'Source' can be read. Smaller number mean more significant. Depending on the preset value, values exceeding 0.05 are suspect.
As a result of this, the relevance of the term YEAR*CONF*DAY may be questioned. If excluded, this would mean that there is no change in for instance the proportion of single night victims (Motorcycle plus car) compared to others over the years. It turns out that, when the year 1980 is excluded from the analysis, the relevance of the term YEAR*CONF*DAY is not questioned anymore.

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
YEAR	19	17	105.1795	0.0000	1998.4114	0.0000
MOTOR	1	17	101759.731	0.0000	101759.731	0.0000
YEAR*MOTOR	19	17	89.0947	0.0000	1692.7986	0.0000
DAY	1	17	6593.6833	0.0000	6593.6833	0.0000
YEAR*DAY	19	17	26.8742	0.0000	510.6093	0.0000
MOTOR*DAY	1	17	2404.9569	0.0000	2404.9569	0.0000
YEAR*MOTOR*DAY	19	17	11.5971	0.0000	220.3454	0.0000
CONF	1	17	7580.9396	0.0000	7580.9396	0.0000
YEAR*CONF	19	17	6.6256	0.0001	125.8873	0.0000
MOTOR*CONF	1	17	133.8335	0.0000	133.8335	0.0000
YEAR*MOTOR*CONF	19	17	6.1630	0.0002	117.0979	0.0000
CONF*DAY	1	17	13658.9736	0.0000	13658.9736	0.0000
YEAR*CONF*DAY	19	17	1.9176	0.0915	36.4352	0.0093
MOTOR*CONF*DAY	1	17	88.7602	0.0000	88.7602	0.0000
DRL	1	17	7.5365	0.0138	7.5365	0.0060

Table 5.

In this setting, the effect of DRL is estimated as:

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
Drl law	1	-0.1770	0.0644	7.5460	0.0060 (With 1980)

Table 6.

An estimate of -0.1770 would mean an estimate of 1-Exp(-0.1770) (equals about 16%) decrease in the number of victims. This number could vary between 1-Exp(-0.1770+1.96 0.0644) (5%) and 1-Exp(-0.1770-1.96 0.0644) (26%).

6.3.2. *Model type 2 (One effect increasing up to 1986 and remaining stable afterwards)*

This model suggests a effectiveness of DRL reaching its maximum in 1986. The effectiveness starts to increase linearly from 1983 upwards.

Modelling the effect of DRL in this manner, the fit is:

Criterion	DF	Value	Value/DF
Deviance	17	24.0122	1.4125
Scaled Deviance	17	24.0122	1.4125
Pearson Chi-Square	17	23.9921	1.4113
Scaled Pearson X2	17	23.9921	1.4113
Log Likelihood	.	5954236.0355	.

Table 7.

Clearly, this improves the fit by a wide margin over the 0-1 model. There may not be a reason to correct for overdispersion, but it is done to be on the safe side.
The type III analysis reads:

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
YEAR	19	17	175.3633	0.0000	3331.9030	0.0000
MOTOR	1	17	172333.097	0.0000	172333.097	0.0000
YEAR*MOTOR	19	17	154.1851	0.0000	2929.5165	0.0000
DAY	1	17	11225.8910	0.0000	11225.8910	0.0000
YEAR*DAY	19	17	41.7088	0.0000	792.4679	0.0000
MOTOR*DAY	1	17	4099.3893	0.0000	4099.3893	0.0000
YEAR*MOTOR*DAY	19	17	18.7264	0.0000	355.8009	0.0000
CONF	1	17	12874.2146	0.0000	12874.2146	0.0000
YEAR*CONF	19	17	10.0178	0.0000	190.3390	0.0000
MOTOR*CONF	1	17	238.0366	0.0000	238.0366	0.0000
YEAR*MOTOR*CONF	19	17	6.7292	0.0001	127.8557	0.0000
CONF*DAY	1	17	23139.4635	0.0000	23139.4635	0.0000
YEAR*CONF*DAY	19	17	2.9967	0.0136	56.9372	0.0000
MOTOR*CONF*DAY	1	17	164.9047	0.0000	164.9047	0.0000
LDRL	1	17	24.5503	0.0001	24.5503	0.0000

Table 8. *LR Statistics For Type 3 Analysis.*

Clearly, all effects are significant. The effect YEAR*CONF*DAY is now significant in any way too. There is still some overdispersion in the model, but when 1980 is removed, this vanishes completely. Therefore, it does not seem reasonable to look for other terms to improve fit. As the contribution of DRL is significant in this model, and the model seems to fit the data sufficiently, it is concluded that DRL has a significant effect on the number of victims.

The effect of DRL is now:

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
LDRL	1	-0.2564	0.0518	24.5338	0.0000 (With 1980)

Table 9.

The results in terms of predicted numbers of victims are in graphed in figures 3a to 3h.

In section 6.3.4 sensitivity of this model to certain influences is studied.

6.3.3. *Model type 3 (one level of effectiveness in one period and another level afterwards)*

As an alternative, a two stage effect could be modelled. The effect of DRL is kept on one level up to (including) a year and on another level in the after period.

The fit statistics a listed in the following table:

Period	CRITERION	DF	VALUE	VALUE/DF
1983-1984	Deviance	16	27.2957	1.7060
1983-1985	Deviance	16	24.6667	1.5417
1983-1986	Deviance	16	29.0267	1.8142
1983-1987	Deviance	16	31.7140	1.9821
1983-1988	Deviance	16	30.9074	1.9317
1983-1989	Deviance	16	32.3606	2.0225
1983-1990	Deviance	16	30.1921	1.8870
1983-1991	Deviance	16	35.8014	2.2376
1983-1992	Deviance	16	35.4219	2.2139
1983-1993	Deviance	16	37.9023	2.3689
1983-1994	Deviance	16	39.6872	2.4805
1983-1995	Deviance	17	40.6623	2.3919

Table 10.

Comparing the linear trend (type 2) model reveals:

Deviance	17	24.0122	1.4125

Table 11.

Only 1983-1985 comes close to this fit but needs an extra degree of freedom (one for the after period). From this result it is suggested to favour the linear trend model over this two stage model.

The estimates of the effect of DRL are:

Period	Effect	DF	Estimate	STDERR	CHISQ	PVAL	MEST	LEST	UEST
1983-1984	Drl law	1	-0.0236	0.0771	0.0940	0.7591	0.02337	-0.13598	0.16037
1983-1985	Drl law	1	-0.0472	0.0655	0.5191	0.4712	0.04610	-0.08457	0.16102
1983-1986	Drl law	1	-0.0859	0.0666	1.6650	0.1969	0.08234	-0.04561	0.19463
1983-1987	Drl law	1	-0.1093	0.0667	2.6878	0.1011	0.10358	-0.02161	0.21343
1983-1988	Drl law	1	-0.1165	0.0638	3.3330	0.0679	0.10998	-0.00861	0.21462
1983-1989	Drl law	1	-0.1294	0.0637	4.1219	0.0423	0.12134	0.00447	0.22450
1983-1990	Drl law	1	-0.1316	0.0604	4.7485	0.0293	0.12327	0.01314	0.22110
1983-1991	Drl law	1	-0.1515	0.0647	5.4930	0.0191	0.14061	0.02450	0.24290
1983-1992	Drl law	1	-0.1560	0.0635	6.0433	0.0140	0.14445	0.03113	0.24451
1983-1993	Drl law	1	-0.1649	0.0651	6.4196	0.0113	0.15203	0.03665	0.25359
1983-1994	Drl law	1	-0.1722	0.0661	6.7970	0.0091	0.15820	0.04184	0.26043
1983-1995	Drl law	1	-0.1770	0.0644	7.5460	0.0060	0.16222	0.04944	0.26161
1985-1995	After effect	1	-0.2240	0.0570	15.4471	0.0001	0.20071	0.10623	0.28520
1986-1995	After effect	1	-0.2435	0.0558	19.0668	0.0000	0.21615	0.12561	0.29733
1987-1995	After effect	1	-0.2460	0.0625	15.5086	0.0001	0.21810	0.11625	0.30821
1988-1995	After effect	1	-0.2485	0.0677	13.4622	0.0002	0.22002	0.10930	0.31697
1989-1995	After effect	1	-0.2642	0.0698	14.3103	0.0002	0.23217	0.11954	0.33040
1990-1995	After effect	1	-0.2713	0.0755	12.9074	0.0003	0.23758	0.11598	0.34245
1991-1995	After effect	1	-0.3017	0.0782	14.8795	0.0001	0.26047	0.13793	0.36559
1992-1995	After effect	1	-0.2803	0.0941	8.8814	0.0029	0.24445	0.09150	0.37166
1993-1995	After effect	1	-0.3123	0.1080	8.3548	0.0038	0.26824	0.09564	0.40789
1994-1995	After effect	1	-0.3006	0.1318	5.2046	0.0225	0.25966	0.04147	0.42819
1995-1995	After effect	1	-0.2873	0.1884	2.3256	0.1273	0.24970	-0.08540	0.48134

MEST = 1-EXP(EST) is the 'real' effect
LEST = 1-EXP(EST+1.96 * STDERR) its lower limit
UEST = 1-EXP(EST-1.96 * STDERR) its upper limit

Table 12.

Note that the 1995 effect (-0.1770) should be the same as the effect of model type 1 above. Note as well that the initial DRL effect was only significant starting at 1989, thus when data up to the year 1989 was used. This year was 1986 when 1983 is omitted, with or without 1980. Leaving the 'After effect' out of the analysis (dropping the respective years from the analysis), a significant effect can only be found using data including at least up to 1991, eight years after the intervention. This effect increases when the year 1980 is omitted as well. Any possible significant effect depends in that case on whether to correct for overdispersion or not. This fact should be noted. Excluding 1983 as well reveals a significant effect using data including at least up to 1987. Note also that the after effect is never estimated to be at a lower level than the initial effect. This means that no 'novelty' effect can be found in this way.

6.3.4. *Perturbing the type 2 model (linear trend up to 1986 and stable after)*

The situation improves a lot when the linear increasing DRL effect is considered.

Leaving out the data of 1980 results in that case in a fit of:

Criterion	DF	Value	Value/DF
Deviance	16	16.7986	1.0499
Scaled Deviance	16	16.7986	1.0499
Pearson Chi-Square	16	16.7810	1.0488
Scaled Pearson X2	16	16.7810	1.0488
Log Likelihood	.	5936897.6036	.

Table 13.

This indicates a near optimal fit. The resulting differences between data and model is comparable to what could be expected from a Poisson model.

And an effect of DRL in this case:

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
LDRL	1	-0.2134	0.0476	20.1346	0.0000
LDRL (With 1980)	1	-0.2564	0.0518	24.5338	0.0000

Table 14.

As was expected, this estimate reveals a smaller decrease in the number of victims. It should be reiterated that no formal reason exists for excluding the data of 1980 except that it can be used to check the dependency of conclusions on the coincidental value of just one year.

The influence of the last observations on this model can be studied in this case as well. Including 1980 (and 1983) the following results can be found when analysing data of the Period:

Period	PARK	DF	EST	STDERR	CHISQ	PVAL	MEST	LEST	UEST
1976-1984	LDRL	1	-0.1726	0.2483	0.4830	0.4871	0.15852	-0.36912	0.48281
1976-1985	LDRL	1	-0.1585	0.1493	1.1272	0.2884	0.14658	-0.14352	0.36309
1976-1986	LDRL	1	-0.2067	0.1043	3.9296	0.0474	0.18678	0.00233	0.33712
1976-1987	LDRL	1	-0.2222	0.0855	6.7538	0.0094	0.19927	0.05316	0.32283
1976-1988	LDRL	1	-0.2127	0.0744	8.1672	0.0043	0.19158	0.06463	0.30129
1976-1989	LDRL	1	-0.2205	0.0668	10.8898	0.0010	0.19788	0.08564	0.29634
1976-1990	LDRL	1	-0.2128	0.0614	12.0081	0.0005	0.19171	0.08831	0.28338
1976-1991	LDRL	1	-0.2369	0.0614	14.8899	0.0001	0.21093	0.11003	0.30039
1976-1992	LDRL	1	-0.2366	0.0574	16.9873	0.0000	0.21072	0.11671	0.29473
1976-1993	LDRL	1	-0.2460	0.0558	19.4201	0.0000	0.21806	0.12766	0.29909
1976-1994	LDRL	1	-0.2528	0.0538	22.0382	0.0000	0.22334	0.13690	0.30113
1976-1995	LDRL	1	-0.2564	0.0518	24.5338	0.0000	0.22618	0.14354	0.30085

MEST = 1-EXP(EST) is the 'real' effect
LEST = 1-EXP(EST+1.96 * STDERR) its lower limit
UEST = 1-EXP(EST-1.96 * STDERR) its upper limit

Table 15.

It shows that a significant effect could be found based on 1976 though 1986 alone if 1980 and 1983 are included. The effect increases from 18% (MEST) upwards to 22% is all data up to 1995 are used.

As similar table can be generated without the use of 1980:

Period	PARK	DF	EST	STDERR	CHISQ	PVAL	MEST	LEST	UEST
1976-1984	LDRL	1	-0.0541	0.2045	0.0699	0.7915	0.05264	-0.41457	0.36554
1976-1985	LDRL	1	-0.0774	0.1220	0.4032	0.5255	0.07451	-0.17539	0.27129
1976-1986	LDRL	1	-0.1483	0.0880	2.8371	0.0921	0.13782	-0.02456	0.27446
1976-1987	LDRL	1	-0.1702	0.0727	5.4713	0.0193	0.15647	0.02720	0.26856
1976-1988	LDRL	1	-0.1632	0.0631	6.6889	0.0097	0.15055	0.03874	0.24936
1976-1989	LDRL	1	-0.1730	0.0569	9.2352	0.0024	0.15884	0.05957	0.24764
1976-1990	LDRL	1	-0.1662	0.0523	10.0970	0.0015	0.15315	0.06171	0.23567
1976-1991	LDRL	1	-0.1918	0.0552	12.0860	0.0005	0.17456	0.08028	0.25917
1976-1992	LDRL	1	-0.1922	0.0515	13.8979	0.0002	0.17484	0.08711	0.25414
1976-1993	LDRL	1	-0.2021	0.0508	15.8312	0.0001	0.18301	0.09748	0.26044
1976-1994	LDRL	1	-0.2094	0.0494	18.0037	0.0000	0.18895	0.10657	0.26373
1976-1995	LDRL	1	-0.2134	0.0476	20.1346	0.0000	0.19220	0.11326	0.26410

MEST = 1-EXP(EST) is the 'real' effect
LEST = 1-EXP(EST+1.96 * STDERR) its lower limit
UEST = 1-EXP(EST-1.96 * STDERR) its upper limit

Table 16.

Now also 1987 has to be included in order to achieve a significant effect, albeit smaller then the effect found using 1980 as well (about 15%). Increasing to about 20% in 1995.

Both results show that the conclusion on the effectiveness of DRL is not very dependent on the length of the period observed. If any reason emerges that alternative influences may exist in the end of the eighties, for instance the promotion of car-DRL in Austria in 1991, this will not invalidate the conclusions. It will however decrease the estimate of the effectiveness of DRL.

6.4. Summary of the results

Using the following assumptions, most importantly that no alternative explanation exists that influenced the number of victims in multiple daytime motorcycle accidents and the assumption that the use of DRL actually did increase after the introduction of the new law, coupled with some distributional assumptions, the results reported above indicate a clear effect of motorcycle daytime running lights in case the effect of the change in the use of DRL due to the introduction of the new law increased in the first few years after its introduction. Even when only a few years after the introduction are allowed to be considered in the analysis, for instance because an alternative explanation may have emerged after 1987, this conclusion still holds. On top of this leaving out the year 1980, the year that levers the effect of motorcycle daytime running lights up substantially, has no consequences on the question of significance of the DRL-effect except that the level of its effectivity is estimated at a lower level. In the extreme case that the change took place in one year (in the last six months of 1982), a significant effect can only be found when it is assumed that no other external effect influenced the numbers of victims in multiple daytime accidents on motorcycles.

However, if there is (strong) evidence that 1980 is an exceptional year and therefore should be omitted, the answer to the question of whether or not motorcycle daytime running lights is effective will depend on the modelled effect (or the presence of 1983). In the most conservative case, fixing on a start of the effect in 1983 and keeping it at the same level afterwards will make the effectiveness of daytime running lights debatable based on the Austrian data. In practice measures rarely reach their ultimate level of effectivity immediately after their introduction.

An alternative explanation using a linear trend in the loglinear model was also considered. This results in an exponential trend for the relative proportion of daytime multiple accident motorcycle victims. This model is very dependent on the last few years (1991-1995). If those years should not be considered or the DRL is allowed to have changed in this period, the DRL models should be favoured over the linear trend model. If those years are to be considered and the DRL effect is assumed to be constant for the last ten years, the DRL effect still fits better to the data than the linear trend model except that it is no more significant when the linear trend is included. The linear trend contributes even less when the DRL effect is present.

Concluding on the results above, it is believed that the measure on daytime running lights in Austria is effective in reducing the number of victims on motorcycles at daytime in accidents involving other vehicles compared to the number of victims in other accidents. An decrease of multiple daytime accidents involving motorcycles of about 16% compared to the pre-law period may be a reasonable, although rather large, estimate based on the results above. This figure is reached when a few years after period are considered in the increasing model without the year 1980. The same figure is also estimated when the zero one effect is considered using all years and 1980 included.

6.5. Analysis of Danish data

6.5.1. *The Danish situation*

In Denmark a law on running lights of motorcycles was effective since 1977. Starting in 1990, it was also effective for cars.
The analysis of the Danish data was included in order to get an insight in the possible effect of running lights in general on the conspicuity situation of motorcyclist as measured by the relative importance of daytime motorcycle victims in multiple accidents. In advance it has to be realised that the period after 1990 is short and the numbers of victims are limited as well as the fact that an intensified alcohol enforcement was implemented at about the same time. This will seriously hamper investigations because the alcohol enforcement is likely to influence the number of nighttime victims more than the number of daytime victims, as well as for cars as for motorcycles. Still, an effort can be made. Emphasis is put on finding a possible negative effect, not on finding such an effect correcting for most alternatives. This allows for the use of simpler models compared to the Austrian case, in which every reasonable alternative should be considered first.
Inspecting the data using *Figures 2a* and *2b* reveals that the numbers of victims for all motorcycle accident types are decreasing. This phenomenon is less clear for the car accidents. All developments seem to be similar.

The results of the Saturated model as well as the model including the third order effects reveals that the third order terms are not the most important ones compared to the first and second order terms. Therefore a model including only second order terms is used as the prime model.

It has to be admitted that the fit is not very good, some overdispersion is indicated.

Criterion	DF	Value	Value/DF
Deviance	71	183.6556	2.5867
Scaled Deviance	71	183.6556	2.5867
Pearson Chi-Square	71	183.3380	2.5822
Scaled Pearson X2	71	183.3380	2.5822
Log Likelihood	.	448542.6151	.

Table 17.

The effect on the motorcycle multiple day victims is positive, meaning a relative increase in its numbers compared to a reported decrease in the number of victims in cars (now with DRL also). The effect is not significant when correcting for overdispersion. If no correction takes place, the effect 'would be' significant.

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
Drl law	1	0.1347	0.0948	2.0182	0.1554

Table 18.

Compared to the decrease in daytime multiple car victims, this result may indicate a relative increase in number of daytime multiple motorcycle victims or a relatively less decrease in the number of daytime multiple motorcycle victims, as it is possible that the number of victims in multiple accidents on motorcycles decreased, although not as much as the number of daytime multiple car victims. Such an effect may be expected due to the fact that many other vehicles at that time started using DRL in Denmark. The result shown above can be used to indicate a vanishing relative advantage of motorcycle DRL, but it may be sensible to keep in mind that it is well possible to specify a model that indicates a vanishing relative effect for motorcyclists resulting from a general daytime running lights measure without an absolute disadvantage for motorcyclists.

7. Summary and conclusions

In many countries in the European Union the use of daytime running lights (DRL) for motorcyclists is mandatory. In the Nordic countries (including Denmark) DRL is mandatory for all motor vehicles. Other countries, Portugal, Spain, France, Luxemburg, Belgium, Germany and Austria have specific laws for motorcyclists. Most laws were introduced in the seventies except for Belgium and Austria (new law) that introduced laws for motorcycles in the eighties and Denmark that introduced a general law, while a specific law for motorcyclists was introduced in 1977. Most laws are behavioural, in the sense that they prescribe motorcyclists to switch on their lights. Austria introduced a technical law in 1982, meaning the lights are automatically switched on when the engine is started. This law superseded a behavioural law that was in practice not enforced. Although the application of the automatic switch was mandatory for all motorcycles, there is evidence that compliance with the law has at least taken some years. No observations of the use of daytime running lights are available in Austria, neither before the introduction of the law nor after introduction.

Many studies have reported positive effects of the use of DRL for motorcyclists, although others reported inconclusive results. The recent study by Radin Umar et al. (1996) in Malaysia where 60% of all vehicles are motorcycles, shows a positive effect of about 30% when increasing the use from nil up to about 80%.

A new study was performed on data of European countries. A questionnaire was sent out to research institutes in Europe in order to get information on the law and data, disaggregated in an appropriate form. Unfortunately, data was not available for all countries or for all relevant years.

At the time of this writing, only full data is available for Denmark, Austria, Great Britain, France and the Netherlands as well as a subset of the data of Belgium (only after the change of the law), Spain and Ireland.

Some information is available on the actual use of daytime running lights by motorcyclists. Some countries have counts for cars. In fact, only France and the Netherlands have observed counts of motorcyclists using running lights available. Both countries do not seem to differ much in terms of use of daytime running lights, although in France use of running lights is mandatory while in the Netherlands it is only recommended. If done at all, it seems reasonable to use the figures for France and the Netherlands as a yardstick for the use of daytime running lights in the European Union. Some indications are that the use may be lower in Ireland and Great Britain, and probably Greece and Italy. It should be noted that the actual use of motorcycles is likely to differ between countries as well. In some countries the purpose of the use (and type of motorcycle) differs from other countries. It is said that the day to day use of motorcycles is more common in southern countries than in northern countries.

It is assumed that the conspicuity of the motorcycle is improved by the use of daytime running lights of motorcyclists themselves although such improvement maybe less if accompanied by the use of daytime running lights by cars.

An analysis was performed comparing the relative proportion of victims on motorcycles at daytime in multiple accidents for different European countries in a manner similar to the manner used for Austria and Denmark. The results, although encouraging, are not as clear as the results found in Austria and to a lesser extent, in Denmark.

The results reported here are dependent on the assumption that no source has influenced the relative proportion of victims on motorcycles in multiple daytime accidents compared to others, other then an increase in the use of daytime running lights. Other influences, such as the introduction of a previous law in Austria have been neglected. The introduction of the seatbelt-law and crash helmet law in Austria in 1984 have been compensated for in the model.

Secondly, it is assumed (and not known from research) that the use of DRL in Austria increased as a result of the introduction of the law. It is also not known how this increase developed over the years. It could be checked whether the introduction of the law really resulted in an increase to about 100% motorcycle headlight use.

Additionally, it is assumed that all counts are approximately Poisson distributed, with a possible overdispersion, a deviance from the Poisson distribution because victims are analysed instead of accidents. All tests that have been used compensate for this possible overdispersion.

The model used for Austria corrects for all influences that are assumed to be unrelated to motorcycle daytime running lights. All developments over the years that affect cars or motorcycles, daytime or nighttime accidents, multiple accidents or single accidents as well as all simple combinations of those such as the development of multiple car accidents are assumed to be irrelevant. The only development that is not accounted for is the development of multiple daytime motorcycle victims; changes therein are supposed to be related to the daytime use of headlights.

For Austria, three possible types of development of the effectiveness of daytime running lights have been modelled:
- A constant effect starting directly after the introduction of the second law in 1982.
- A gradually increasing effect starting directly after the introduction of the second law in 1982 up to a certain year and remains at the same level after that year, of which the model that ends its increase in the year 1987 seems to fit best.
- A model that assumes a certain level of the effect directly after the start of the introduction of the second law in 1982 up to a certain year and moving to a (possibly) different level after that year. Such a model may indicate a novelty effect when the effect in the latter period is less then the effect in the initial period.

Of these models, the model that assumes a gradual increase in the use of daytime running lights up to the year 1987 seems to fit the data best.

The three models described above have been studied under the following conditions:
- The period of data that was used started at 1976 and the last year that was used was varied from 1984 up to 1995. This should give an insight in the sensitivity of the solutions on the number of years that were analysed.

- The inclusion or exclusion of three particular years has been varied. These were the years 1980, inclusion of which inflates the found effect substantially, inclusion of 1982, the year halfway of which the law was introduced, and 1983, inclusion of which deflates the found effect.

The final model should exclude the year 1982 because it is neither a pre-law year nor a post law year, although the results for the gradual model are hardly sensitive to this decision. The exclusion of the year 1983 should be avoided unless there is very good reason to do so because it may falsely inflate the effect of the measure. Except for the fact that it is an influential observation and the inspection of the data singled out this year, there is no reason to exclude the year. Although there doesn't seem to be a reason to exclude the year 1980, this can be done on the basis that it makes the test more conservative. One wants to avoid denoting the DRL effect as significant due to an irrelevant (and unknown) oddity in one year. For this reason both options have been discussed.

From these results it can be inferred that in the extreme case, the increase of the use in daytime running lights from its unknown starting point (probably 65%) up to its final rate of approximately 100% has reduced the number of (relevant) victims by about 22% (with statistical margins between 14% and 30%). This figure shows the largest possible effectivity given all assumptions. Estimates based on weaker assumptions will give a more conservative figure. An estimate of about 16% based on several analysis regarding restricted datasets seems to be more robust. This estimate is similar to the effect found using a zero/one increase in DRL as the result of the law instead of a gradually increasing DRL use.

In Denmark, a small and not statistically significant relative increase in multiple daytime victims on motorcycles compared to others was found after a general DRL law for all vehicles was introduced, although the total number of victims decreased.

Unfortunately the use of DRL in Austria before 1982 is unknown. Tentatively assuming a conservative estimate of about 65% (the use in France in 1988 was 75% in cities and higher elsewhere) this would resemble the same effectivity as an overall reduction of 35% multiple day time victims on motorcycles in case of an increase from nil to 100% DRL-use, using the computational method from Koornstra (1993, page 6-7).

Very tentatively calculating, an European DRL vehicle standard (an automatic switching on of headlights when the engine starts) for motor-cycles would increase the use of DRL for motorcycles from roughly 65% in roughly one fifth and about 90% in four-fifth of the European Union countries to about 100%, which for the European Union as a whole would reduce the number of multiple daytime motorcycle accidents (damage-only as well as casualties and deaths) by about 7% (using the same computational method from Koornstra (1993, page 6-7)).

Alternatively, a measure that results in a use of DRL of about 90% will produce a reduction of the number of victims in multiple daytime accidents on motorcycles of about 11% in countries that have a use of about 65% now. This would mean an 11% reduction in one fifth of the European Union, so approximately one third of the effect of the technical measure.

Mandatory behavioural requirement is probably insufficient to raise the DRL-use for motorcyclists in the European Union in a substantial way.

Since motorcyclists by far have the highest risk of all road users, a European vehicle standard of DRL for motorcycles is recommended, in order to decrease the approximately 4,000 fatalities and 99,000 injured (as far as available in IRTAD data, 1994) every year, roughly half of which would be affected by such a measure as daytime multiple victims account for approximately half the number of victims.

In summary, a technical measure that would increase the use of daytime running lights by motorcyclists would have several positive effects:

- From the point of view of the individual motorcyclist, there is less chance being involved in an accident and as a result of that, a smaller chance of being injured or killed in traffic.

- From the viewpoint of society, a reduction in the number of accidents involving motorcycles and consequent on that a reduction in the number of victims and substantial socio-economic savings are to be expected. Additionally, those countries that have mandatory use of daytime running lights bear the cost of maintaining their use at a high level. From experience, it is known that police enforcement will be necessary and a vehicle standard is likely to be the best option to minimise such costs.

It is sometimes argued that motorcyclists using daytime running lights may assume other road users to see them and as a result ride less defensively and there is some indication that the speed of motorcycles using daytime running lights is estimated lower than the speed of motorcycles without their lights on. There will also be a slight increase in the fuel consumption and wear of bulbs together with the environmental consideration of the visual effect of headlights moving in the scenery. However, these adverse effects seem to be well compensated by the fact that in many other cases, daytime running lights would have helped and thus that the net result is beneficial, significantly reducing the number of fatalities and serious injuries from accidents involving motorcycles.

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Figure 1 - 5

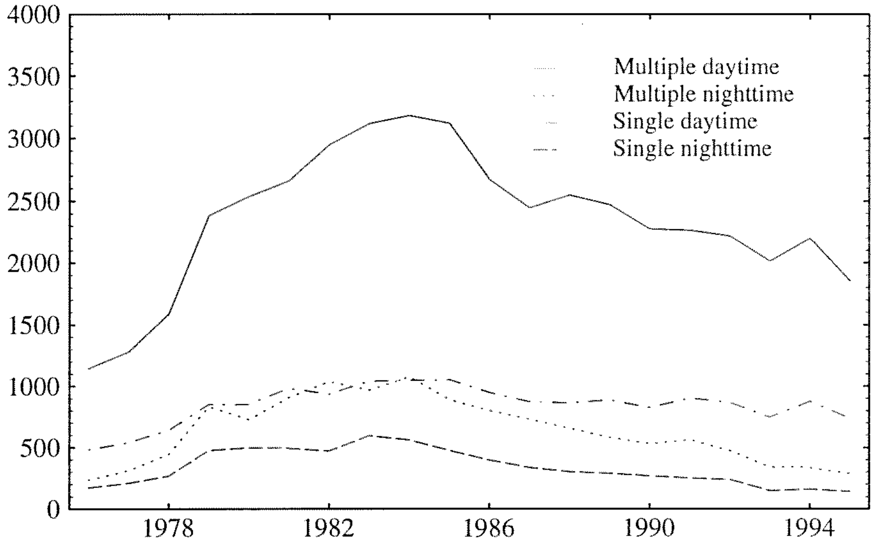

Figure 1a. *Development of the number of victims on motorcycles in Austria.*

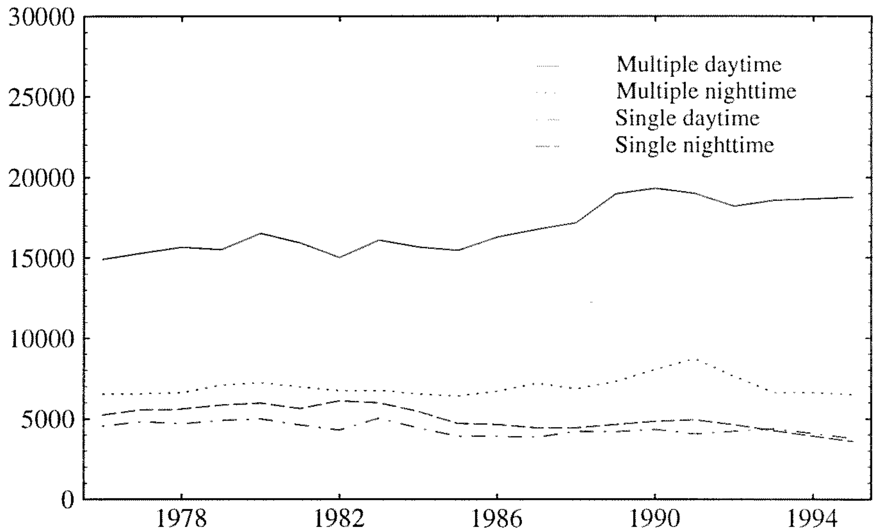

Figure 1b. *Development of the number of victims in cars in Austria.*

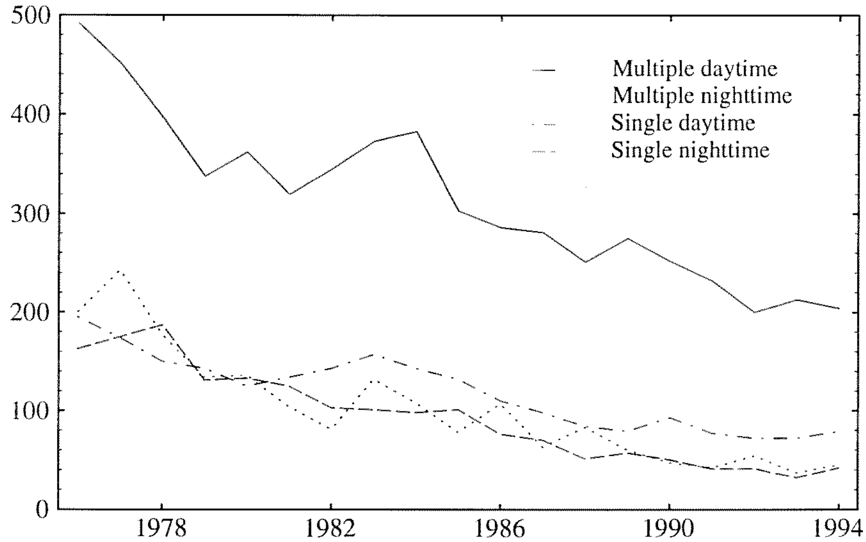

Figure 2a. *Development of the number of victims on motorcycles in Denmark.*

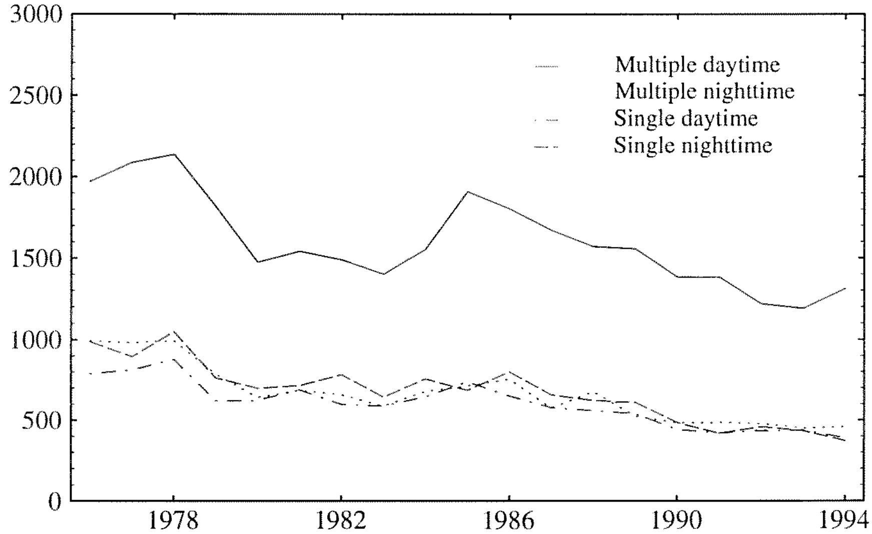

Figure 2b. *Development of the number of victims in cars in Denmark.*

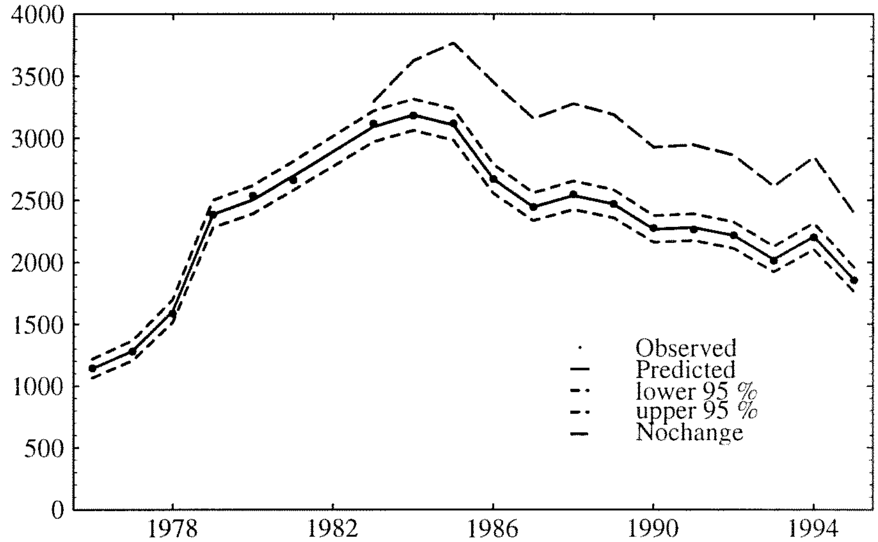

Figure 3a. *Predictions and margins of the number of victims on motorcycles in Austria in multiple daytime accidents, DRL effect included and excluded.*

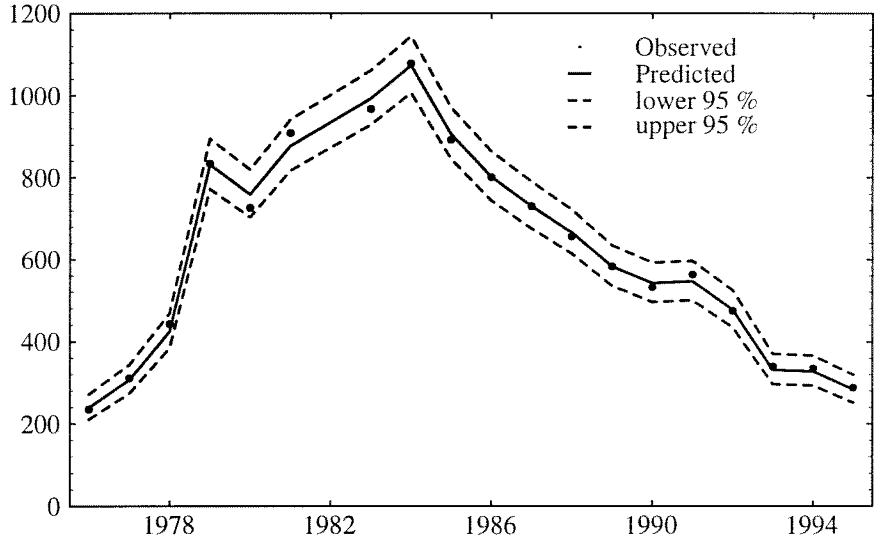

Figure 3b. *Predictions and margins of the number of victims on motorcycles in Austria in multiple nighttime accidents.*

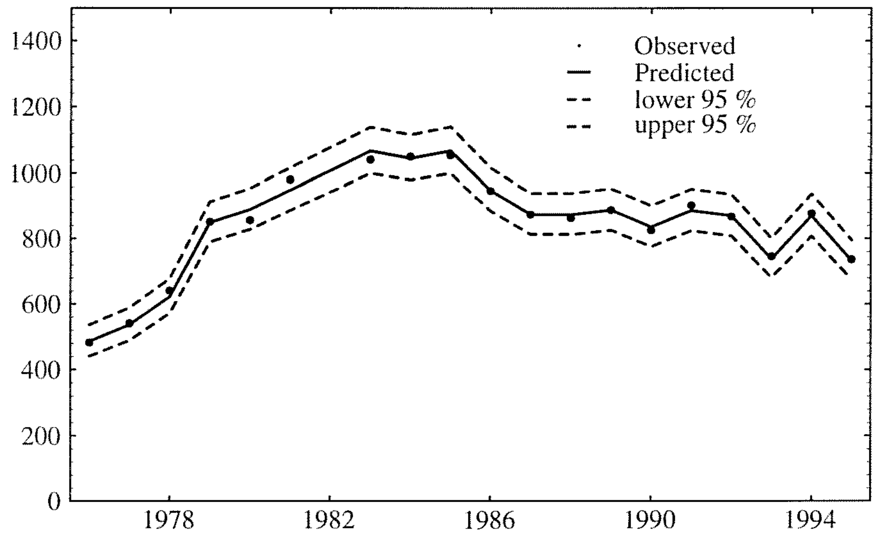

Figure 3c. *Predictions and margins of the number of victims on motorcycles in Austria in single daytime accidents.*

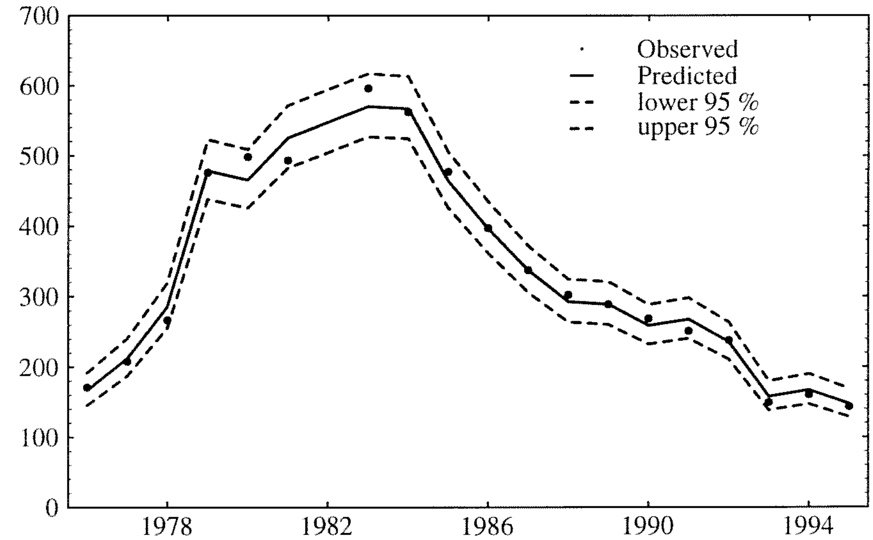

Figure 3d. *Predictions and margins of the number of victims on motorcycles in Austria in single nighttime accidents.*

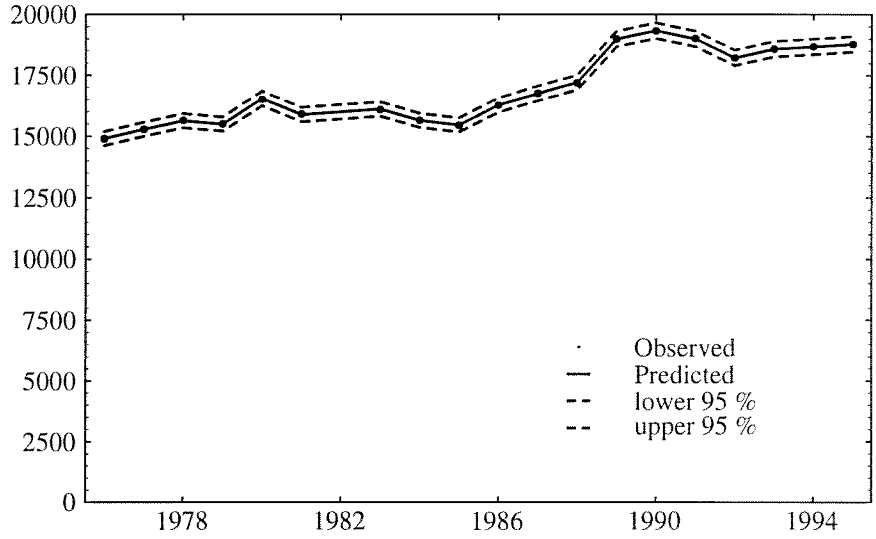

Figure 3e. *Predictions and margins of the number of victims on cars in Austria in multiple daytime accidents.*

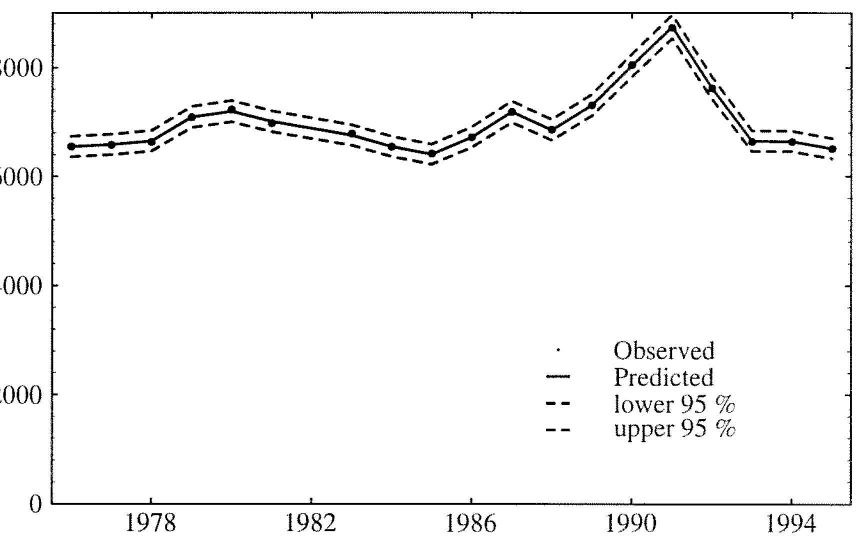

Figure 3f. *Predictions and margins of the number of victims on cars in Austria in multiple nighttime accidents.*

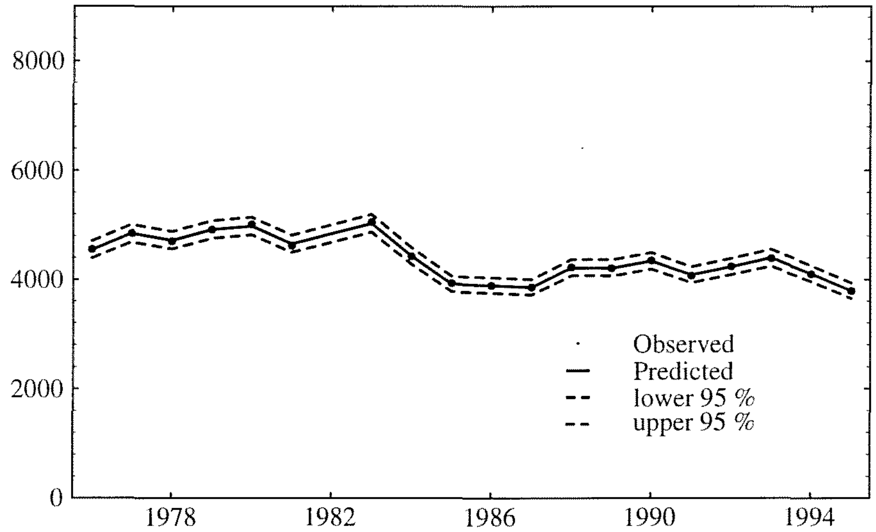

Figure 3g. *Predictions and margins of the number of victims on cars in Austria in single daytime accidents.*

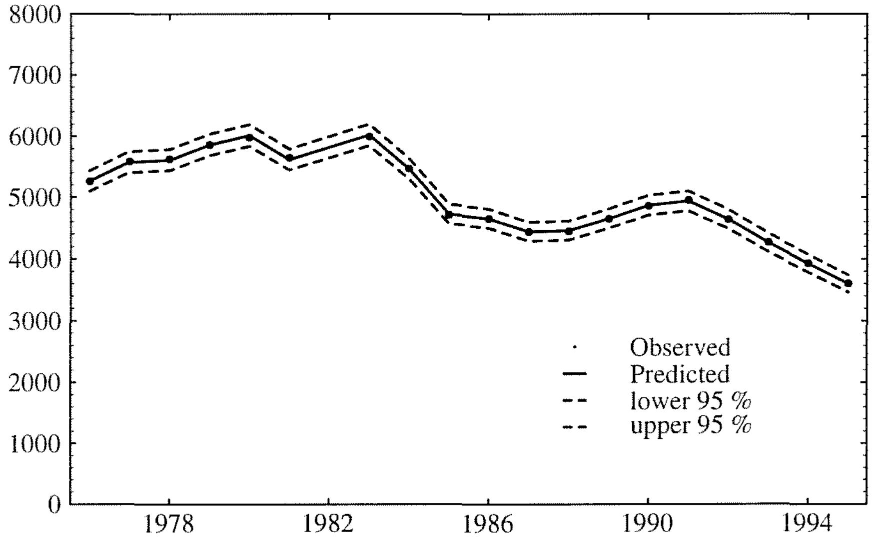

Figure 3h. *Predictions and margins of the number of victims on cars in Austria in single nighttime accidents.*

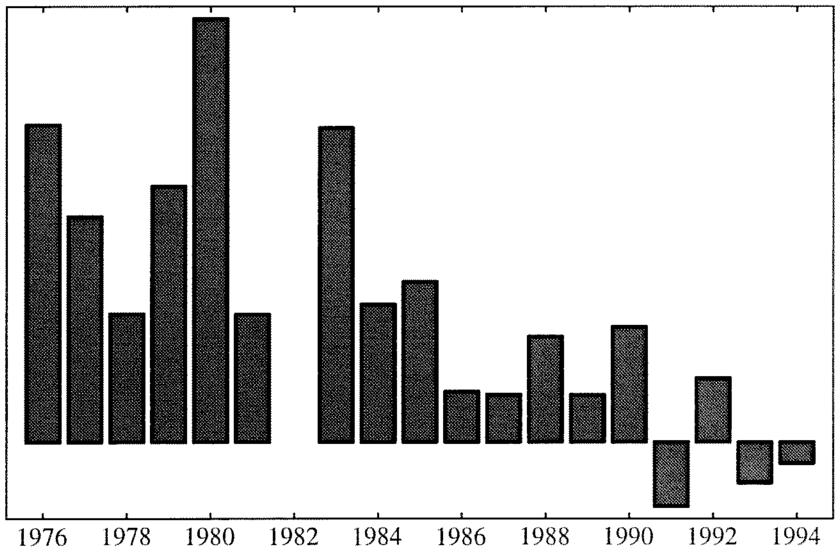

Figure 4. *Estimates for each year of the coefficient for motorcycle multiple daytime victims using the saturated model (1982 excluded).*

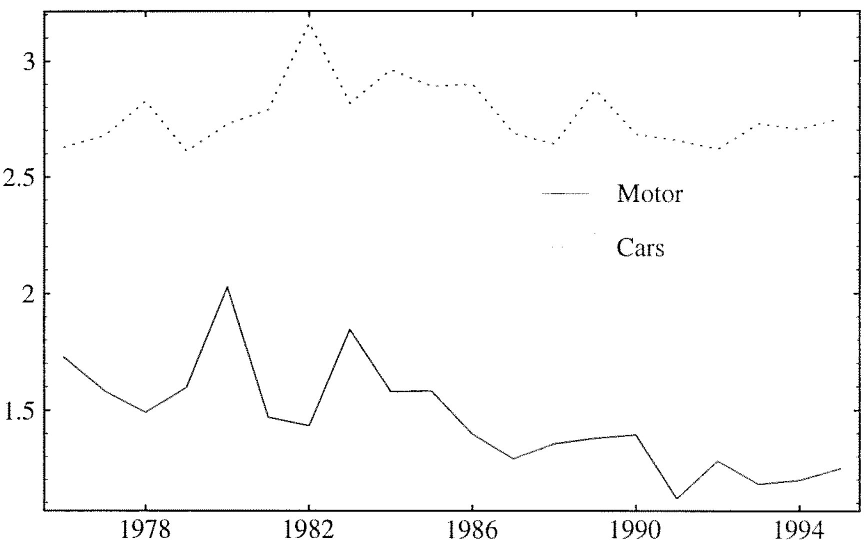

Figure 5. *Odds ratio's ((multiple daytime/multiple nighttime)/(single daytime/single nighttime)) for motorcycle and car victims.*