SIXTH FRAMEWORK PROGRAMME

PRIORITY 1.6. Sustainable Development, Global Change and Ecosystem

1.6.2: Sustainable Surface Transport

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

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Title:	**Accident Prediction Models and Road safety Impact Assessment: Results of the pilot studies**
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Summary:	The results of four pilots that were conducted in Austria, Portugal, Norway and the Netherlands, are confronted with the results of a preceding state-of-the-art report.
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1. Introduction

In order to manage road safety, policy makers and road authorities need to have a good insight in the variables that explain the accident levels on their roads and networks. To this end many models are and have been built that (try to) predict the accident frequency, the so-called Accident Prediction Models (APM) or Road safety Impact Assessments (RIA). In this study an APM is restricted to road types or categories and a RIA is a model that aggregates, usually quite simple, APM-models to the level of a network or area.

There is, however, another type of RIA which is comparable to the Environmental Impact Assessment, EIA. This is used to assess the safety impact of major road changes or new roads, on the road itself and (usually) including the adjacent road network [1]. In some countries specific guidelines for RIA's have been developed [2]. This is normally restricted to the major roads and therefore these RIA's are performed by or under the responsibility of the national road authority. Research on this type of RIA was not included in the original WP2 plans and is therefore only briefly dealt with in the state-of-the-art report.

Within workpackage 2 of the Ripcord-Iserest project, task 2.2 consists of the performance of (4) pilots. The choice of these pilots is based on the outcomes of a state-of-the-art study (task 2.1) that was reported in June 2005 [3]. In task 2.3 the results of the pilots are confronted with the findings of the state-of-the-art study. This report reflects the comparison.

In chapter 2 the conclusions of the state-of-the-art study are given. They regard the preferred methodology for APMs (2.2), APMs for urban and rural roads (2.3) and RIA (2.4). The results of the pilots are summarised in chapter 3, an APM for Austria (3.1), a RIA for Norway (3.2), and APMs for Portugal (3.3) and the Netherlands (3.4). Conclusions are drawn in 3.5. The comparison of both studies is reported in chapter 4, dealing with the coverage of pilots (4.1), the way in which the preferred methodology is handled (4.2) and how pilot results are related to what is known in literature (4.3). At the end the usefulness for practitioners is discussed (chapter 5) followed by references and appendices.

2. Conclusions of the state-of-the-art study

2.1 Introduction

The aim of the study was to give an overview of the state-of-the art of Accident Prediction Models (APM) and Road safety Impact Assessments (RIA). An APM is usually a (set of) function(s) that describes how safety depends on explanatory variables like the amount of traffic, length of the road, road width, number of crossings etc. A RIA does the same for a network but adds to this the possibility to calculate quantitatively the effects of different scenarios on mobility, (road safety) measures etc. In a way a RIA is an aggregate of (quite simple) APMs.

The concept of an APM is widely known and many references could be found. It is therefore the main topic of the study. A RIA is an interesting new development that has only been applied a few times because it needs so many good quality data (chapter 5).

2.2 Methodology for Accident Prediction Models

The basic form of nearly all modern accident prediction models for road sections and intersections is this:

$$\mathrm{E}(\lambda) = \alpha Q_{\mathrm{MA}}^{\beta} Q_{\mathrm{MI}}^{\beta} e^{\sum \gamma_i x_i}.$$

The estimated expected number of accidents, E(λ), is a function of traffic volume, *Q* (for road sections only one Q), and a set of risk factors, x_i ($i = 1, 2, 3, \ldots, n$). The effect of traffic volume on accidents is modelled in terms of an elasticity, that is a power, β, to which traffic volume is raised. Intersections volumes for the major and minor roads are included. The effects of various risk factors that influence the probability of accidents, given exposure, is generally modelled as an exponential function, that is as *e* (the base of natural logarithms) raised to a sum of the product of coefficients, γ_i, and values of the variables, x_i, denoting risk factors.

The volume and risk factors are the explanatory variables of the model and, ideally speaking, the choice of explanatory variables to be included in an accident prediction model ought to be based on theory. However, the usual basis for choosing explanatory variables appears to be simply data availability. They should include variables that:

- have been found in previous studies to exert a major influence on the number of accidents;
- can be measured in a valid and reliable way;
- are not very highly correlated with other explanatory variables included.

Observed variation in the number of accidents is nearly always a mixture of systematic and random variation. It is only the systematic part of the variation that can be explained by means of accident prediction models. There is systematic variation in number of accidents whenever the variance exceeds the mean. This is referred to as overdispersion. The amount of overdispersion found in a data set, can be described in terms of the overdispersion parameter:

$$\mu = \frac{\frac{\mathrm{Var}(x)}{\lambda} - 1}{\lambda}$$

Where λ is the expected value of *x*, the measured variable.

The success of a model in explaining accidents can be evaluated by comparing the overdispersion parameter of a fitted model to the overdispersion parameter in the original data set.

The following criteria have been proposed to help assess if a statistical relationship is causal:

- internal consistency of the relationship, with respect to, for example, subsets of data in a study or different specifications of multivariate models;
- invariance with respect to potentially confounding factors, meaning that a relationship does not vanish when potentially confounding factors are controlled for;
- plausibility in terms of a known causal mechanism or well-established scientific law;
- support for counterfactual statements, meaning that the relationship has a genuine predictive capacity.

Testing predictive performance is essential if one wants to support a causal interpretation of model estimates. One way of doing so is to use the model to predict accident counts in future years. Another is to use only half the data set to fit a model and use the other half of the data set to test its predictive performance.

There are many sources of error in accident prediction models. The most frequently discussed sources of error include:

- omitted variable bias: possibly the most common form of omitted variable bias in current accident prediction models is the incompleteness of exposure data;
- bias due to co-linearity among explanatory variables: explanatory variables in accident prediction models tend to be correlated, sometimes to such a high degree that inclusion of both or all the correlated variables may lead to unstable estimates of the coefficients;
- wrong functional form for relationships between variables: two typical problems are related to the use of average values when estimating the relationship between traffic volume and accidents. The first occurs when traffic volume is represented by an average value, like AADT (average annual daily traffic) rather than the actual traffic volume at the time of each accident. The second occurs when a single function is used when there is reason to believe that this relationship varies, depending on circumstances like daytime and darkness.

Development in the field of accident modelling has been so rapid, that some models that were considered as state-of-the-art only ten years ago look somewhat primitive today. There is today a danger of moving too far in the direction of mathematical sophistication and perfect fitting of models. A good model however is rather the simplest possible model that adequately fits the data, and that contains relationships that may be presumed to hold in general. Based on the discussion in this section, the following criteria are proposed for assessing the quality of accident prediction models:

- The probability distribution of accidents in the original data set should be tested.
- The structure of residuals should always be tested.
- Separate models should be developed for accidents at different levels of severity.
- Separate models should be developed for different types of roadway elements.
- Data on exposure should be decomposed to the maximum extent possible.
- The functional form used to describe the relationship between each independent variable and accidents should be explicitly chosen.
- Explanatory variables should be entered stepwise into the model.
- The correlations between explanatory variables should be examined.
- The overall goodness-of-fit of the final model should be reported.
- The structure of any systematic variation not explained by a model should be examined.
- Any model should explicitly identify those variables for which a causal interpretation is sought.
- Explicit operational criteria for causality should be stated in models seeking causal interpretation of their findings.
- The possible presence of omitted variable bias should always be discussed.
- The predictive performance of an accident prediction model should be tested.
- Accident prediction model should permit results to be synthesised.

These criteria can be further developed into a quality scoring system for accident prediction models, designed to assign a numerical quality score to each model. This quality score will be an important piece of information when synthesising the findings of several accident prediction models.

2.3 Urban and Rural road segments and intersections

Several forms were used for the accident prediction models for *rural road sections*:

$$\mathrm{E}(\mu) = a x_1^{b_1} \cdot \ldots \cdot x_n^{b_n} \cdot e^{\sum b_{n+1} x_{n+1}},$$

$$R = a + b_1 x_1 + \ldots + b_n x_n,$$

$$\mathrm{E}(\mu) = e^{a + \sum b_i x_i + \sum c_{ij} x_i x_j},$$

where $E(\mu)$ is the expected number of accidents, R is the number of accidents per 1000 vehicles and x_i are the explanatory variables. Not surprisingly, the Average Annual Daily Traffic (AADT) and section lengths are used as explanatory variables in almost all models. Also the minor access density, the carriageway width and the shoulder width are used in various models. So it is desirable that accident prediction models to be developed include these explanatory variables. In general the model coefficients were estimated using generalised linear modelling.

In several papers, models are developed for different accident types and/or for different road types. In general the disaggregated models are better (and simpler) than the aggregated models, i.e., they have a better fit. So if data is available for accident types and road characteristics it is better to develop disaggregated models instead of aggregated models. At least the accident severity (PDO, injury, fatal) should be modelled separately.

All the models for *rural intersections* are of the following form:

$$\mathrm{E}(\mu) = aQ_{\mathrm{min}}^{b_1} Q_{\mathrm{maj}}^{b_2} e^{\sum \beta_i x_i},$$

which coincides with the general model given in Chapter 2 of the state-of-the-art report [3]. Therefore it can be concluded that models for intersections should be of this form. As expected the AADT on the major and minor road are used as explanatory variables in all models. Also the “presence of left and right-turn lanes on the major road” is used in several models. Therefore it is desirable that accident prediction models for rural intersections include these explanatory variables

The models for *urban road sections* are generally of the form

$$\mathrm{E}(\mu) = \alpha Q^{\beta} e^{\sum \gamma_i x_i},$$

as described in the methodology section. Any accident prediction model should include next to the AADT and section length, the public street approach (and driveway) density as explanatory variables.

The model forms for *urban intersections* are quite similar, namely

$$\mathrm{E}(\mu) = \alpha Q_{\mathrm{MA}}^{\beta_1} Q_{\mathrm{MI}}^{\beta_2} e^{\sum \gamma_i x_i}.$$

In most papers separate models were developed for intersections with three arms and intersections with four arms and/or for different types of control (STOP, signalised, major/minor priority, roundabouts). This is desirable, because separate models for different intersection types give a better description of the data then one model for all intersections together, which includes the intersection type as an explanatory variable.

The methodology that is used by the majority of studies to estimate the coefficients of the accident prediction models is generalised linear modelling (GLM).

2.4 Road safety Impact Assessment

In order to make an APM many data of good quality are required. For a RIA the level of detail per road may be lower but because a network contains much more roads the total need for good data is much higher, usually too high. There are (at least) two ways to overcome this problem. The first is an extra incentive to gather data, for instance by introducing a subsidy scheme for it or demanding a RIA as a prerequisite for funding road safety plans. Another possibility is to link the RIA to a GIS-system that is already in use by road authorities for other purposes. The VIB of Diepens & Okkema (see RipCord-Iserest WP 11 and 12) is a good example of such an instrument. The VIB will be tested in different situations and countries to see if it can handle different inputs.

There are of course many other ways for road authorities to get an insight in the safety situation of their networks and suggestions for improvement. For instance in WP 6 of RipCord-Iserest the safety analysis of networks and black spot management are dealt with. Another example is the DUMAS project where a framework for the design and evaluation of cost-effective and successful urban safety initiatives was developed and tested. However, the advantage of a RIA is that it enables us to see quantitative effects of different scenarios (mobility, measures, costs). This gives a better opportunity to improve the cost-effectiveness of road safety programmes.

3. Pilots

3.1 Austria

The Austrian pilot of an APM deals with accidents on Austrian motorways [4]. It turned out to be possible to divide them into 4 classes: injury accidents, fatalities, severely injured and slightly injured, instead of the previously reported APM just for fatalities. One of the important advantages of this is the possibility to compare this APM to the Portuguese and Dutch where APMs are made for (injury) accidents.

Data have been gathered regarding the following variables:

- average annual daily traffic (AADT);
- number of lanes per road sections;
- speed limit;
- amount of heavy goods vehicles (HGV);
- section length.

In the analysis the standard Generalised Linear Model (GLM see [3]) using a Negative Binomial Distribution was calculated. The coefficients for speed limits and number of lanes, however, were not significantly different from zero, and therefore excluded from the model. The result was:

$$ACC = 2.388 \times 10^{-4} \times AADT^{1.048} \times Length^{0.889} \times 0.986^{PHGV}$$

ACC = expected number of injury accidents in 5 years
AADT = Annual Average Daily Traffic [vehicles per day]
Length = length of the road section [km]
PHGV = Proportion of Heavy Goods Vehicles [%]

3.2 Norway

This pilot [9] is a road safety impact assessment for Norway, designed to assess the prospects for improving road safety. The report is to a large extent based on work done as part of the development of the National Transport Plan for the 2010-2019 planning term.

A broad survey of potentially effective road safety measures has been performed. A total of 139 road safety measures were surveyed; 45 of these were included in a formal impact assessment, which also included cost-benefit analyses. The other 94 road safety measures were for various reasons not included in the impact assessment. Reasons for exclusion include: (1) Effects of the measure are unknown or too poorly known to support a formal impact assessment; (2) The measure does not improve road safety; (3) The measure has been fully implemented in Norway; (4) The measure overlaps another measure; to prevent double counting, only one measure was included; (5) The measure is analytically intractable.

For the 45 road safety measures included in the impact assessment, use of these measures during the period until 2020 was considered. Analyses indicate that 39 of the 45 measures are cost-effective, i.e. their benefits are greater than the costs according to cost-benefit analyses. Six of these measures were not cost-effective. A preliminary target of halving the number of road accident fatalities and the number of road users seriously injured has been set in the National Transport Plan for the term 2010-2019. This plan is as yet not finally developed and the road safety target proposed has not been officially adopted or given political support. It is nevertheless of interest to examine if such a target can be realised, as previous road safety impact assessments in Norway have indicated that it is possible to drastically reduce the number of fatalities and injuries. The preliminary targets in the National Transport Plan call for a reduction of fatalities from 250 (annual mean 2003-2006) to 125 in 2020. The number of seriously injured road users is to be reduced from 980 (mean 2003-2006) to 490.

The range of options for improving road safety has been described in terms of four main policy options, all of which apply to the period from 2007 to 2020:
1. Optimal use of road safety measures: All road safety measures are used up to the point at which marginal benefits equal marginal costs. The surplus of benefits over costs will then be maximised.
2. “National” optimal use of road safety measures: Not all road safety measures are under the control of the Norwegian government; in particular new motor vehicle safety standards are adopted by international bodies. A version of optimal use of road safety measures confined to those that can be controlled domestically was therefore developed.
3. Continuing present policies. This option essentially means that road safety measures continue to be applied as they currently are. There will not be any increase in police enforcement, nor will new law be introduced (e.g. a law requiring bicycle helmets to be worn).
4. Strengthening present policies. In this option, those road safety measures that it is cost-effective to step up, are stepped up. In particular, this implies a drastic increase of police enforcement.

Estimates show that all these policy options can be expected to improve road safety in Norway. The largest reduction of the number of killed or injured road users is obtained by implementing policy option 1, optimal use of road safety measures. Full implementation of this policy option results in a predicted number of fatalities of 138 in 2020. The predicted number of seriously injured road users is 656. These numbers clearly exceed the targets of, respectively, 125 and 490. It is, however, not realistic to expect road safety measures to be used optimally. In the first place, some of the road safety measures that may improve road safety if used optimally, are outside the power of the Norwegian government. This applies to new motor vehicle safety standards. In the second place, for some road safety measures, optimal use implies a drastic increase of efforts. This applies to police enforcement. It is, however, unlikely that the police will increase traffic law enforcement to the optimal extent. In the third place, optimal use of road related road safety measures requires a maximally efficient selection of sites for treatment. Current selection of sites for treatment is not maximally efficient. It would become so, if sites were selected for treatment according to traffic volume, but this is not easily accomplished in Norway due to resource allocation mechanisms favouring regional balancing, rather than economic efficiency. A more realistic policy is therefore that road safety measures continue to be used along roughly the same lines as they are today. Such a policy will not bring about large improvements of road safety in Norway. A conservative estimate for the number of road accident fatalities in 2020 is about 200. A corresponding estimate for seriously injured road users is about 850. While both these numbers are lower than the current numbers, they are a long way from realising the targets set for 2020 (125 road users killed, 490 seriously injured).

It should be stressed that the estimates presented in this report are highly uncertain. It would therefore not be surprising if actual development turns out to be different from the one estimated.

3.3 Portugal

Accident prediction models for the national road network links are developed, using as tentative explanatory variables: carriageway width, AADT, number of lanes, and shoulder type and width. The network is divided in 7 road classes, ranging from motorway to minor national roads.

The analysis for motorways is reported in *Accident Prediction Models for Portuguese Motorways* [5]. According to the state-of-the-art report [1] GLMs were developed as simple models and extended models. As an example for comparison the outcome for the simple model and the preferred (see [3]) Negative Binomial distribution is:

$$ACC = 8 \times 10^{-4} \times AADT^{0.917} \times Length^{0.932}$$

ACC = expected number of injury accidents in 6 years
AADT = Annual Average Daily Traffic [vehicles per day]
Length = length of the road section [km]

An analysis for rural two-lane roads is reported in *Accident Prediction Models for Portuguese Single Carriageway Roads* [10].

3.4 The Netherlands

The pilot in the Netherlands was conducted in Haaglanden, which is a mainly urban area around the city of The Hague [4]. To make comparisons possible again the GLM outcomes for the simple model and the Negative Binomial distribution are given:

Urban road segments:

$$ACC = 3.3 \times 10^{-4} \times AADT^{0.318} \times Length^{0.999}$$

Rural road segments:

$$ACC = 3.740 \times 10^{-5} \times AADT^{0.497} \times Length^{0.965}$$

ACC = expected number of injury accidents in 3 years
AADT = Annual Average Daily Traffic [vehicles per day]
Length = length of the road section [m]

3.5 Conclusions

3.5.1 Comparison of 3 road types: motorways, other rural roads, urban roads

For motorways in Austria and Portugal, and for urban and rural roads in the Netherlands, 4 different APMs were found. To compare them they are given as expected values of accidents per km road in 5 years and restricted to max. 3 digits:

Austria Motorways $ACC = 2.4\times10^{-4}\times AADT^{1.05}\times Length^{0.89}\times0.99^{PHGV}$

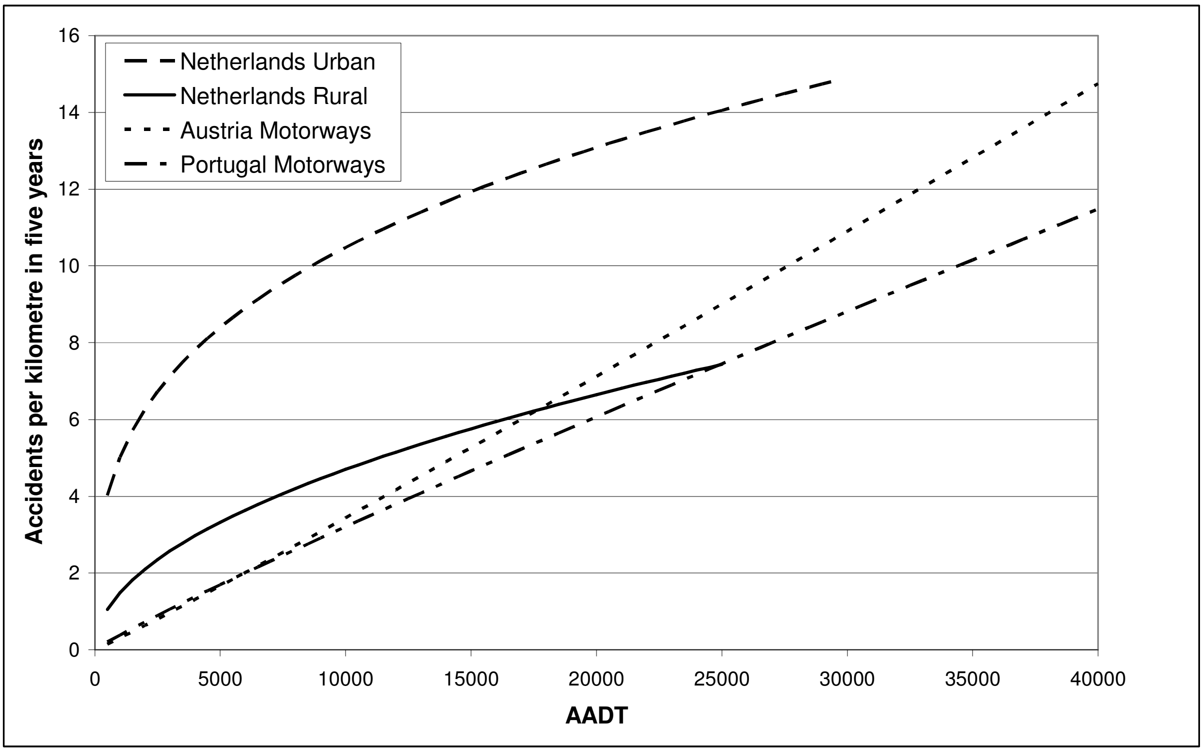
Portugal Motorways $ACC = 6.7\times10^{-4}\times AADT^{0.92}\times Length^{0.93}$

Netherlands Urban $ACC = 0.55\times AADT^{0.32}\times Length^{1.0}$

Netherlands Rural $ACC = 0.047\times AADT^{0.50}\times Length^{0.96}$

At first glance Portuguese motorways seem to have a much greater risk than Austrian motorways because of the much higher intercept (6.7×10^{-4} and 2.4×10^{-4}). The best way to compare them is in a plot of ACC density (ACC per km) against AADT as is done in fig.1. Please note that the range of AADTs is different for different APMs.

Figure 1 Comparison of 3 road types in 3 countries



For a typical AADT of 15,000, segment length of 5 km and PHGV of 10% the outcomes are for Austria ACC= 22.1 (4.4 accidents per km) and for Portugal ACC = 20.8 (4.2). These are quite comparable. With regards to the direction of change it is understandable that a longer road segment is safer per km because you expect more homogeneity in traffic flow. In the Austrian model, however, it seems surprisingly that risk (ACC/(AADT.km)) increases when the AADT increases. In most literature the opposite is reported as indeed is the case in the Portuguese model. In the Austrian model, however, an extra explanatory variable, the percentage of heavy goods vehicles, is included, and this may explain these effects. A brief comparison to the Dutch situation (see [7]) shows that in the Netherlands the accident density is comparable to the Austrian and Portuguese level, but at approximately the double AADT, indicating that risk is much lower at high traffic volumes on motorways.

The AADT for urban (3.000 – 40.000) and rural roads (3.000 – 25.000) in the vicinity of The Hague seems to be rather comparable to motorways in Austria and Portugal. The city of The Hague has almost 500.000 inhabitants and some of the urban roads have 2 or 3 lanes per direction of traffic. The influence of segment length is low and for urban segments negligible. For an AADT of 15000 the accident density (ACC/km) in 5 years is for urban roads: 11.9 and for rural roads 5.4. At low volumes (AADT of 3000) the accident densities are: Austria 0.8, Portugal 0.9, Netherlands urban 7.1, and Netherlands rural 2.4. The corresponding risks (ACC/AADT.km) are therefore much higher for rural and especially urban roads. This is what you would expect, not because traffic in itself is much safer at high volumes at rural and especially urban roads, but because road design is adjusted to (expected) high or low volumes. Of course, one would like to know the effects of different road elements but the data do not allow incorporating many explanatory variables, such as road design elements.

3.5.2 Comparison of rural two-lane roads in Portugal and Netherlands

After the planned pilots were finished some extra pilots were performed in Portugal and the Netherlands. An analysis for rural two-lane roads is reported in Accident Prediction Models for Portuguese Single Carriageway Roads [10]. In the Netherlands a pilot was done in the province of Gelderland [11]. Portugal has approximately 9.5 million inhabitants living on 92,000 km2 (100 inh/km2). For Gelderland these figures are 2 million and 5,000 km2 (400 inh/km2). More details are given in table 1.

Table 1. Pilot results in Portugal and the Netherlands: rural two-lane roads

Comparison Portugal-Gelderland RipCord APM's rural roads

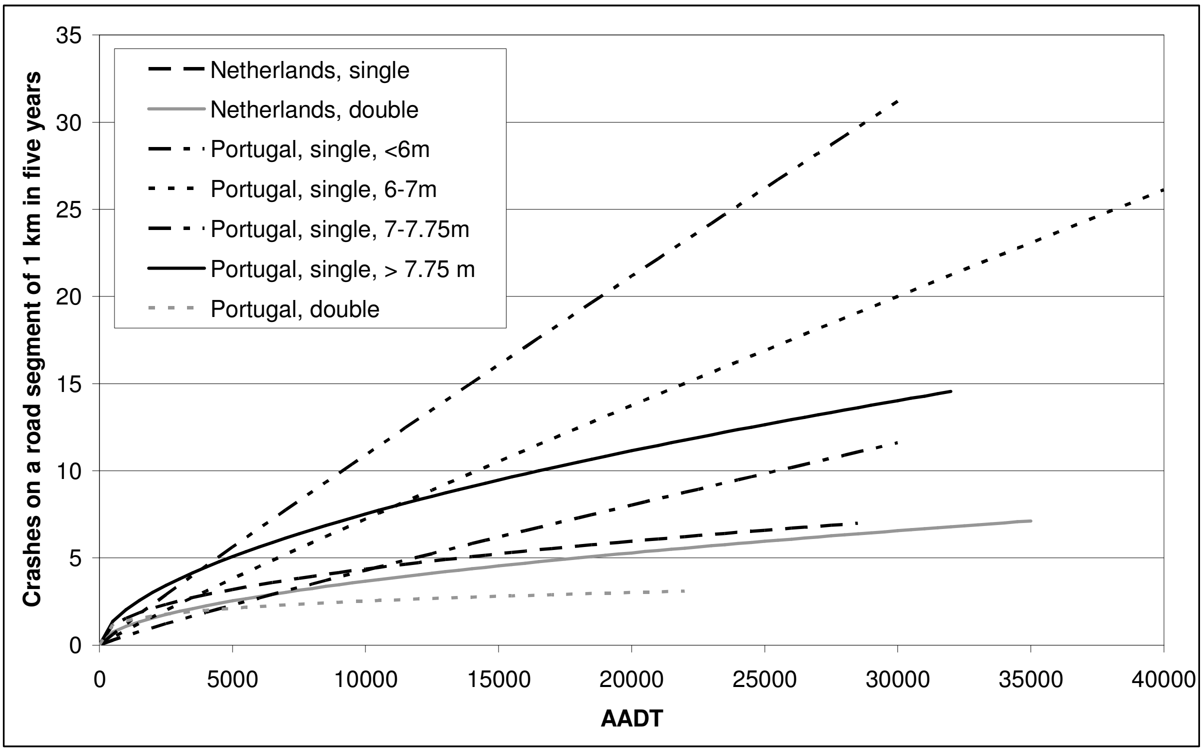
GLM

Portugal

Lane width	no sections	length	volume	accidents	killed	vol/length	av length	acc/length	acc/vol	AADTpar	Lpar
<6	671	7271	49281	18476	950	7	11	2,5	0,37	0,96	0,8
6 à 7	290	3078	34919	14493	897	11	11	4,7	0,42	0,93	1,02
7 à 7,75	76	843	13661	5167	395	16	11	6,1	0,38	0,91	1,22
>7	58	417	9915	2714	232	24	7	6,5	0,27	0,57	0,88
median	35	418	6042	1316	164	14	12	3,1	0,22	0,26	1,13
Gelderland											
single	631	872	12095	2955		14	1,4	3,4	0,24	0,45	0,81
double	133	72	1892	364		26	0,5	5,1	0,19	0,53	0,6
			AADT	vol5years							
single	631	872	7600	12094,64	intersection	44%					
double	133	72	14400	1892,16	intersection	57%					

To get a better insight the comparison of models is shown in figure 2.

Figure 2 Comparison of two-lane roads in Portugal and the Netherlands



In most countries rural two-lane roads are the most dangerous, that is, they have the highest risk (accidents per traffic volume) and highest share of the road safety problem. It is also the main interest of the RipCord-Iserest project. The road safety situation is rather different in Portugal and the Netherlands. In 2004 (ERSO-website, September 2007) the amount of road fatalities per 1 million inhabitants was 125, whereas in the Netherlands it was 50 (ratio: 2 ½). Therefore one would expect the risk on rural two-lane roads to be much lower in the Netherlands than in Portugal.

From table 1 it is clear that most accidents in Portugal take place on roads without a median and a road width <7 m: the black and pink lines in figure 1. In Gelderland these are the ‘enkel’ (single) roads, the dark blue line. For a typical AADT of 15000 Gelderland has about 5 crashes per km in 5 years, for Portugal this is somewhere between 10 and 15 (ratio 2-3). The situation is therefore what was expected.

The density of inhabitants is rather different between Geldeland (400 inh/km2) and Portugal (100 inh/km2; ratio 4). The average length of road section is indeed rather different between Gelderland (single: 1.4 km) and Portugal (< 7m: 11 km). Crashes on intersections are accounted for in the road section models; this means there are no separate models for intersections. In the models this is probably the main reason why ‘length’ is an important explanatory variable with a parameter (Lpar in table 1) different from “1”. Because the road section is on average much longer in Portugal, one would expect the Lpar closer to “1”. In fact it is for road widths <7 m somewhere between 0.8 and 1.02, say 0.9 on average. In Gelderland Lpar is 0.81, indeed what was expected. For this road type the share of intersection crashes is 44%.

Another remarkable difference is the influence of traffic volume (or intensity AADT; table 1: vol/length). This influence is expressed by AADTpar (table 1); if this is (far) below 1 then the influence is high. For Gelderland this is the case (AADTpar = 0.45), suggesting that traffic behaviour is different at high intensities (p.e. platooning) and/or road design is different for high volume roads. For Portugal, AADTpar is 0.93-0.96 for a road width <7m; that means that the influence of intensity (volume) is rather low in Portugal. If traffic behaviour would explain this difference, there are at least two possibilities:

- intensity/volume is less varied in Portugal because this is linked to road width. Indeed the intensity (table 1 vol/length) on <6m wide roads is 7, for 6-7m it is 11, for 7-7.75 m it is 16 and for >7m it is 24. It would be interesting to see the effect of neglecting road width as an explanatory variable on AADTpar;
- for instance, overtaking behaviour is different in Portugal, that is people accept smaller gaps to overtake.

If road design is the main explanation it would mean that in Gelderland (Netherlands) road authorities adjust their roads to volume and expected number of accidents more than Portuguese road authorities.

4. Comparison of state-of-the-art study and pilots

4.1 Coverage

From the state-of-the-art report is was clear that much more (scientific) research is performed on Accident Prediction Models than on Road safety Impact Assessments. An important reason is that conducting a RIA is time-consuming and expensive. Improvements are therefore (also) directed towards simplifications and making use of already existing data, for instance via GIS (geographical information systems or digital networks). Via the merger of Ripcord and Iserest this type of RIA is tested in WP11 and demonstrated in WP12 on a regional scale.

These considerations have lead to the following pilots:

- an APM for motorways (Au);
- APMs for distributor roads with a focus on rural roads (as is the Ripcord-Iserest project focus)(Nl);
- APMs for road links on all road categories of a national network (P);
- a national RIA (N).

The conclusion is that this choice of pilots nicely covers the spectrum of APM/RIA that was found in literature.

In addition to these (original) pilots, two extra pilots were performed in 2007, both on rural (non motorway) roads in Portugal and The Netherlands, therefore addressing the main topic of Ripcord-Iserest.

4.2 Methodology

In Section 2.2 criteria are given for assessing the quality of APMs (for results: see appendices).

1. *The probability distribution of accidents in the original data set should be tested.*
   In all 3 pilots the distribution of the data was not tested a priori. However, after the models were fitted the data were checked for overdispersion. This resulted in the conclusion that the data were not Poisson distributed and that the negative binomial distribution described the data better.
2. *The structure of the residuals should always be tested.*
   This was done in all pilots, but in different ways.
3. *Separate models should be developed for accidents at different levels of severity.*
   In Austria this was done for injuries, slightly injured, severely injured and fatalities. In Portugal for collisions, injuries and casualties and in the Netherlands only for accidents with fatalities or severely injured.
4. *Separate models should be developed for different types of roadway elements.*
   In neither of the pilots the data allowed for this.
5. *Data on exposure should be decomposed to the maximum extent possible.*
   Only in Austria a decomposition of passenger cars and heavy goods vehicles was performed.

6. *The functional form used to describe the relationship between each independent variable and accidents should be explicitly chosen.*
   The general model (see [3]) was used.
7. *Explanatory variables should be entered stepwise in the model.*
   This was dealt with differently: Austria: no, Portugal: yes, Netherlands: not relevant
8. *The correlations between explanatory variables should be examined.*
   This was done in all cases and no correlation was found.
9. *The overall goodness-of-fit of the final model should be reported.*
   This was discussed extensively in all pilot reports
10. *The structure of any systematic variation not explained by the model should be examined.*
    In one pilot this is not done, in the others still under discussion.
11. *Any model should explicitly identify those variables for which a causal interpretation is sought.*
    Does not apply to all pilots.
12. *Explicit operational criteria for causality should be stated in models seeking causal interpretation of their findings.*
    See 11.
13. *The possible presence of omitted variable bias should always be discussed.*
    In neither of the pilots enough data are available to allow for such an approach.
14. *The predictive performance of an accident prediction model should be tested.*
    This is done in the Austrian and Portuguese pilot.
15. *Accident prediction models should permit results to be synthesised.*
    The standard errors of all coefficients are reported in all pilots, z-values also in the Austrian pilot

4.3 Pilot results

In all pilots the general form of APM that was found in the state-of-the-art study was used. Unfortunately not enough good quality data were available for applying many explanatory variables and this was an important reason why not all criteria (see 2.2) could be met and not all preferred variables could be incorporated in the APMs. Nevertheless, the analyses are considered to be of good quality, albeit a judgement by the researchers and their international colleagues themselves. A more independent check is advisable.

The literature study showed that the APM outcomes were rather different in different regions or countries. In our case, the APMs for motorways in Austria and Portugal are rather comparable. The APMs for rural two-lane roads in Portugal and the Netherlands show remarkable, but explainable differences. Within the consortium there is a common understanding and consensus on how to perform an APM-study so a clear advice to practitioners and their research consultants in the WP2 tasks to come, is rather likely. This may well lead to a better comparison of APM and a better exchange of experiences and knowledge, e.g. allowing for a meta-analysis.

The RIA for Norway shows the possible effects of 4 policy scenarios for road safety programmes. One of these is considered most likely to occur, that is the continuation of present policies. It is stressed that many uncertainties exist in the assessment.

Nevertheless, the conclusion is that this scenario will (probably) not result in the desired improvements of road safety: the expected number of road fatalities is estimated at 200, while the target is 125.

5. Discussion of practical use

As stated in the work description of RipCord-Iserest [5] the goal of WP2 is to deliver an advice to users (road authorities) on the best tool for planning and designing. In September (21st, 22nd) the 1st RipCord-Iserest Conference (Road Infrastructure Safety in Europe – moving towards a harmonised approach?) was held and some preliminary ideas on the usefulness for practitioners of an APM was discussed. They were:
- developing an APM is not an easy task, probably not suited for road authorities with the exception of the national level;
- a good and detailed APM requires much data of good quality and detail that is usually not available;
- as a result only a few explanatory variables are included;
- APM could be used to benchmark one's roads. If the expected amount of accidents is significantly lower than what is measured in reality, it is likely that there are some flaws in design. A RSA or RSI could be advisable and of course, if more explanatory variables are included they might give a hint to what is the problem. To this end a standard, and preferably simple, tool for testing the significance of the difference between expected and real accident values should be made available;
- the APM approach is especially of added value when the black spot treatment suffers from 'regression to the mean' effects.

The results of the RIA in Norway where not yet available at the 1st Ripcord-Iserest conference. It is expected, however, that these results are useful for practitioners, in this case, national policy makers. Different scenarios are treated and the likeliness of these to be implemented is discussed as well. This method gives a clear insight in what extra measures are needed to meet the road safety targets that were set.

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Appendix 1 Quality of methodology used

Methodology: Austrian pilot

Criteria	Description	Yes/No	Remarks
1	Testing the probability distribution of accidents in the original data set	Left out intentionally	According to the State-of the Art report and published literature on Generalized Linear Models, accident numbers are assumed to be Poisson or Negative Binomial distributed. It is important to realize that the distributional form of an APM is determined by the random component of the dependent variable. A fundamental aspect of any regression analysis is that the researcher assumes that the model pulls out the systematic part of the Y's, i.e. the dependent variable. What is left over (termed errors or residuals) is assumed to have a particular probability distribution. It is this distribution that determines the link function
2	The structure of residuals should always be tested	Yes	Poisson and Negative Binomial models were used to test the optimal model fit
3	Separate models should be developed for accidents at different levels of severity	Yes	In the Austrian pilot, models were developed for: • Injury accidents • Fatalities • Severely injured • Slightly injured In Austria, data on property damage only accidents are not collected in a systematic way and therefore could not be incorporated into the models.

4	Separate models should be developed for different types of roadway elements	No	Due to missing data on specific roadway elements such as bridges, tunnels, slip roads, etc. models in this pilot are restricted to road sections as the only element analysed.
5	Data on exposure should be decomposed to the maximum extent possible	Yes	Traffic volume on motorways primarily consists of passenger cars and lorries. Pedestrians and cyclists are not allowed to use motorways. Since the pilot uses the proportion of Heavy Goods Vehicles (PHGV) and Annual Average Daily Traffic as explanatory variables, decomposition of exposure is conducted to the highest possible extent.
6	The functional form used to describe the relationship should be explicitly chosen and reasons given for the choice	Yes	The functional form of the pilot matches the model choice of the State-of-the Art report which can be regarded as best practice guideline for modelling accident data.
7	Explanatory variables should be entered stepwise in the model	Yes	9 different model forms were used to examine the stability of the coefficients with respect to the variables included. The unconstrained model (containing all explanatory variables) yielded the smallest overdispersion parameter and therefore was considered best for fitting the data. z-values were computed to answer the question of whether there is a statistically significant relationship between an independent and the dependent variable.
8	The correlations between explanatory variables should be examined	Yes	Correlation analysis is part of the modelling procedure of the software package GLIM. The correlation between the explanatory variables was found to be of no concern.
9	The overall goodness-of-fit of the final model should be reported	(Yes)	A measure of goodness-of-fit of the model (the closeness of the observed to the fitted values) is the deviance. This summary measure is always positive and will be small if the fit is good. For a well-fitting model for Poisson-distributed data, the deviance should be close to the residual degrees of freedom (df); equivalently, the mean deviance the deviance divided by the df) should be close to 1. In the pilot study, the mean deviance was calculated to distinguish the goodness-of-fit of the 9 models used during the modelling process. The model with the lowest mean deviance was chosen for further calculations

			(see chapter 2.3).
10	The structure of any systematic variation not explained by a model should be examined	No	
11	Any model should explicitly identify those variables for which a causal interpretation is sought	No	
12	Explicit operational criteria for causality should be stated in models seeking causal interpretation of their findings	No	The choice of variables in the model is above all based on data availability
13	The possible presence of omitted variable bias should always be discussed	No	
14	The predictive performance of an accident prediction model should be tested	Yes	Considering injury accidents, the pilot overestimates the observed values in most cases. Similar results apply to fatal and slightly injured, respectively
15	Accident prediction models should permit results to be synthesised	Yes	Standard errors and z-values are reported

Methodology: Portuguese pilot

1. *The probability distribution of accidents in the original data set should be tested.*
   The distribution of accidents was not formally tested. This was because the number of accidents consists of count data and the benchmark model for count data is the Poisson distribution.
   Once the model was fitted to the data it was observed that the variance was larger than the mean, meaning that overdispersion occurred. A standard generalisation of the Poisson distribution is then the Negative Binomial distribution which allows a dispersion parameter.

2. *The structure of the residuals should always be tested.*
   The residuals obtained by the fitted models were used for diagnostic checks, namely in visual analysis.

3. *Separate models should be developed for accidents at different levels of severity.*
   The dependent variable consisted on the number of accidents for all the fitted models considered.

4. *Separate models should be developed for different types of roadway elements.*
   The available data at the time of the first draft of WP2 report consisted only on sections of the Portuguese motorway network. In the mean time more data has been made available consisting on road sections with one and two lanes each as well as intersections. These are presently being analysed.

5. *Data on exposure should be decomposed to the maximum extent possible.*
   The data available on the Portuguese road network does not specify the type of vehicles contributing to the traffic.

6. *The functional form used to describe the relationship between each independent variable and accidents should be explicitly chosen and reasons given for the choice.*
   The functional forms used were based on the state-of-the-art report which concluded that there is a basic form for nearly all modern accident prediction models.

7. *Explanatory variables should be entered stepwise in the model.*
   The explanatory variables for the Portuguese motorway network consisted of AADT, Length and Number of Lanes. They were entered stepwise in the model.

8. *The correlations between explanatory variables should be examined.*
   The AADT and Length were not correlated.

9. *The overall goodness-of-fit of the final model should be reported.*

The goodness-of-fit of the models was calculated using the Freeman-Tukey R^2 and the Elvik index.

10. *The structure of any systematic variation not explained by the model should be examined.*
    The systematic variation in the number of accidents was not calculated. It is now under investigation.

11. *Any model should explicitly identify those variables for which a causal interpretation is sought.*
    Not applicable in the Portuguese case.

12. *Explicit operational criteria for causality should be stated in models seeking causal interpretation of their findings.*
    Not applicable in the Portuguese case.

13. *The possible presence of omitted variable bias should always be discussed.*
    It is hoped that with the new available data (by having more explanatory variables) this issue would be better tackled.

14. *The predictive performance of an accident prediction model should be tested.*
    It was tested in some models which include the explanatory variable Lanes. The model was applied on simulated data.

15. *Accident prediction models should permit results to be synthesised.*
    The coefficient estimates and their corresponding standard errors were reported for all the accident prediction models considered.

Methodology: Netherlands pilot

In Section 2.12 of the state-of-the-art report about accident prediction models en road safety impact assessments a total of 15 criteria are given for assessing the quality of APMs. Each of these criteria will be discussed for the pilot study carried out in the Netherlands.

1. *The probability distribution of accidents in the original data set should be tested.* The distribution of the data was not tested a priori. However, after the models were fitted the data were checked for overdispersion. This resulted in the conclusion that the data were not Poisson distributed and that the negative binomial distribution described the data better.
2. *The structure of the residuals should always be tested.* For each of the fitted models the residuals were tested with the help of several plots. The tests were used to determine if there was heteroscedasticity and whether or not the residuals were normally distributed. Especially for the models based on the negative binomial distribution there was no reason to believe that the residuals were not normally distributed or not homoscedastic.
3. *Separate models should be developed for accidents at different levels of severity.* In the Dutch pilots only KSI accidents were considered.
4. *Separate models should be developed for different types of roadway elements.* It was only possible to develop models for road segments and not for intersections. For intersections information is needed about the minor and major traffic flows and this was not available. It was also not known if the considered road sections were tunnels or bridges.
5. *Data on exposure should be decomposed to the maximum extent possible.* Only the AADT for motor vehicles was available.
6. *The functional form used to describe the relationship between each independent variable and accidents should be explicitly chosen.* The length and AADT are the only explanatory variables and the way they are included in the model in the same way as in the literature. Only the so called extended model was slightly different. The model form was indeed checked with the data.
7. *Explanatory variables should be entered stepwise in the model.* Does not apply to the Dutch pilots.
8. *The correlations between explanatory variables should be examined.* The length and AADT were not correlated.
9. *The overall goodness-of-fit of the final model should be reported.* The goodness-of-fit of the models was discussed very extensively. However, in the SotA it is proposed that the variation has to be decomposed in (not) explained systematic variation and random variation.
10. *The structure of any systematic variation not explained by the model should be examined.* See 9.
11. *Any model should explicitly identify those variables for which a causal interpretation is sought.* Does not apply to the Dutch pilots.
12. *Explicit operational criteria for causality should be stated in models seeking causal interpretation of their findings.* Does not apply to the Dutch pilots.
13. *The possible presence of omitted variable bias should always be discussed.* In the Dutch pilots there is a small discussion about the model form. It is explained that this form does not indicate that roads with high AADT are saver,

but that roads with high AADT are designed to handle this high AADT in a save manner. It is preferred to develop separate models for different road types, because then this problem should be eliminated.

14. *The predictive performance of an accident prediction model should be tested.* This is not done.
15. *Accident prediction models should permit results to be synthesised.* The standard errors of all coefficients are reported.

There are some criteria which do not apply to the Dutch pilots. These are in particular the criteria involving explanatory variables. We wanted to developed separate models for different road types instead of entering a lot of explanatory variables into the model. Due to the limited data that was available this was not yet possible. At the moment we are working on APMs for a few provinces in the Netherlands and it seems that we can divide the data into different categories.