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Accident Prediction Models and Road Safety Impact Assessment: recommendations for using these tools
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List of abbreviations

AADT	Average Annual Daily Traffic
ACC	amount of accidents
AMF	Accident modification factor
APM	Accident Prediction Model
DST	Decision support tool
GIS	Geographic information system
PHGV	Percentage of Heavy Goods Vehicles
RIA	Road safety Impact Assessment
RIPCORDER-ISEREST	Road infrastructure safety protection – core-research and development for road safety in Europe; Increasing safety and reliability of secondary roads for a sustainable surface transport
RRSE	Regional road safety explorer
SEROES	Secondary roads expert system

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Executive Summary

In 2001 the European Commission defined the ambitious objective in their Road Safety Policy to halve the number of fatalities in EU15 from over 40,000 to 20,000 in 2010. Road infrastructure related safety measures offer a large potential that could be exploited for a significant reduction of road accidents and their consequences. Considering that most casualties occur on single carriageway rural roads, RIPCORD-ISEREST is focussed on road infrastructure measures for this type of roads. The objective of this project is to collect and to evaluate these approaches in order to make them accessible throughout Europe and to develop tools, which could be used to improve traffic safety.

In order to manage road safety, practitioners such as policy makers and road authorities need to have a good insight in the safety level of their roads, the variables that explain these levels and the expected effects of their road safety plans. In work package 2 (WP 2) of RipCord-Iserest two instruments have been researched, both intended to provide this insight: Accident Prediction Models (APM) and Road safety Impact Assessments (RIA). An Accident Prediction Model is a mathematical formula describing the relation between the safety level of existing roads (i.e. crashes, victims, injured, fatalities etc.) and variables that explain this level (road length, width, traffic volume etc.). A Road safety Impact Assessment is a methodology to assess the impact of plans on safety. This can be major road works, a new bridge etc. that may or may not be intended to raise the safety level. A RIA can also concern a wider scheme i.e. be intended to make plans for the upgrading the safety level of a total network or area. This report gives recommendations for the way in which these instruments can be used by practitioners. It is based on two earlier published reports regarding the state-of-the art on APMs and RIAs, and the results of pilot studies. Both are available at the RipCord-Iserest website (www.ripcord-iserest.com; see section References).

Traffic volumes (vehicles per day) and road lengths (km) are the most important explanatory variables in an APM, both for road sections and intersections. The parameters of the model, however, can vary considerably between road types and countries. The reason is that road characteristics can differ considerably and so can road user behaviour, vehicle types etc. It is therefore recommended to make APMs per country and road type and use these to compare the safety level of a road against the value of the APM for the road type and traffic volume under consideration. APMs can thus also play an important role in identifying black spots.

For a RIA on single (major) road works several methods are available. It is best to use as much scientific evidence as possible, using handbooks, cost-benefit analyses and taking into account network effects. For RIAs on wider schemes or even national levels specific recommendations are given on methodology. In general a RIA is best used in comparing policy options and setting ambitious but realistic road safety targets. Absolute numbers that are predicted are usually not very reliable and in general highly dependant on high quality databases that are usually not available.

1. Introduction

1.1 Ripcord-Iserest

In 2001 the European Commission defined the ambitious objective in their Road Safety Policy to halve the number of fatalities in EU15 from over 40,000 to 20,000 in 2010.

To reach the objective the improvement or implementation of a great variety of safety measures is still urgent. Beside ongoing development processes in the field of car safety (e.g. Human-Machine-Interface, driver assistance) there is also the need to exhaust the reduction potentials of road infrastructure safety measures.

Road infrastructure related safety measures offer a large potential that could be exploited for a significant reduction of road accidents and their consequences. Considering that most casualties occur on single carriageway rural roads, RIPCORD-ISEREST is focussed on road infrastructure measures for this type of roads.

Researchers and practitioners in the member states of the European Union have made great efforts to improve traffic safety. Many of these approaches have already led to a significant reduction in fatalities.

The objective of this project is to collect and to evaluate these approaches in order to make them accessible throughout Europe and to develop tools, which could be used to improve traffic safety.

With these tools RIPCORD-ISEREST intends to give scientific support to practitioners concerned with road design and traffic safety in Europe.

1.2 Workpackage 2: Accident Prediction Models and Road safety Impact Assessment

In order to manage road safety, practitioners such as policy makers and road authorities need to have a good insight in the safety level of their roads, the variables that explain these levels and the expected effects of their road safety plans. In work package 2 (WP 2) of RipCord-Iserest two instruments have been researched, both intended to provide this insight: Accident Prediction Models (APM) and Road safety Impact Assessments (RIA). This report gives recommendations for the way in which these instruments can be used by practitioners. It is based on two earlier published reports regarding the state-of-the art on APMs and RIAs, and the results of pilot studies. Both are available at the RipCord-Iserest website (www.ripcord-iserest.com; see references)

An Accident Prediction Model is a mathematical formula describing the relation between the safety level of existing roads (i.e. crashes, victims, injured, fatalities etc.) and variables that explain this level (road length, width, traffic volume etc.). A Road safety Impact Assessment is a methodology to assess the impact of plans on safety. This can be major road works, a new bridge etc. that may or may not be intended to

raise the safety level. A RIA can also concern a wider scheme i.e. be intended to make plans for the upgrading the safety level of a total network or area. The first type of RIA is not researched in detail in WP2, the second type is, and is also dealt with in WP 11 as a decision support system (DST, [11]) that is demonstrated in WP12 along with the Best practise Safety Information Expert System SEROES (WP 9 [12]). In chapter 2 more information on APMs and RIAs is given.

All partners in WP2 are very experienced regarding the road safety situation in their countries, that is in Austria, Portugal, Norway and the Netherlands. This is also the case for other RipCord-Iserest partners in their countries; therefore a good insight in the needs of practitioners is at hand within the consortium. The ideas on user needs have also been discussed with practitioners at the 1st Ripcord-Iserest Conference in September 2006. User needs are the topic of chapter 3.

In chapter 4 the features of APMs and RIAs are held against the user needs to see what possibilities there are to meet these needs. Recommendations are given on the use of both instruments by practitioners.

2. Accident Prediction Models and Road safety Impact Assessments

2.1 Introduction

In this chapter APMs and RIAs are dealt with in more detail. WP2 started with a state-of-the-art study on both instruments, the results of which can be found in 2.2.1 and 2.3.1. Consequently a choice was made for pilot studies in all participating countries that had to be based on availability of data and –related to that- interest of road authorities. For APMs this resulted in a good coverage of road categories, motorways (Portugal, Austria) and distributor (rural and urban) roads (Netherlands and, partially, Portugal). For RIAs a pilot in Norway was performed on national road safety plans. On a smaller scale an instrument that was originally developed in the Netherlands is tested in WP11. Unfortunately, the sort of RIA that is used in single projects (bridge, major road works, new road etc.) is not tested in a pilot study. However, this type of RIA is well-known in most countries albeit in different forms. Therefore, a discussion on pros and cons of different approaches is considered valuable.

2.2 Accident Prediction Models

2.2.1 Results of the state-of-the-art study

The basic form of nearly all modern accident prediction models is this:

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

The estimated expected number of accidents, $E(\lambda)$, is a function of traffic volume, Q , and a set of risk factors, x_i ($i = 1, 2, 3, \dots, n$). 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. For intersections volumes for the major and minor road 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.

Rural road sections

Not surprisingly, the Annual Average Daily Traffic (AADT) and section length 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.

Rural intersections

As expected, the AADT on the major and minor roads are used as explanatory variables in all models. Also, the presence of left and right-turn lanes on the major roads are used in several models.

Urban road sections

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

Urban intersections

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 it was found that separate models for different intersection types give a better description of the data than one model for all intersections together, which includes the intersection type as an explanatory discrete variable.

2.2.2 Results of the pilots

For motorways in Austria and Portugal and for urban and rural roads in the Netherlands four, 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 decimals:

$$\text{Austria Motorways } ACC = 2.4 \times 10^{-4} \times AADT^{1.05} \times Length^{0.89} \times 0.99^{PHGV}$$

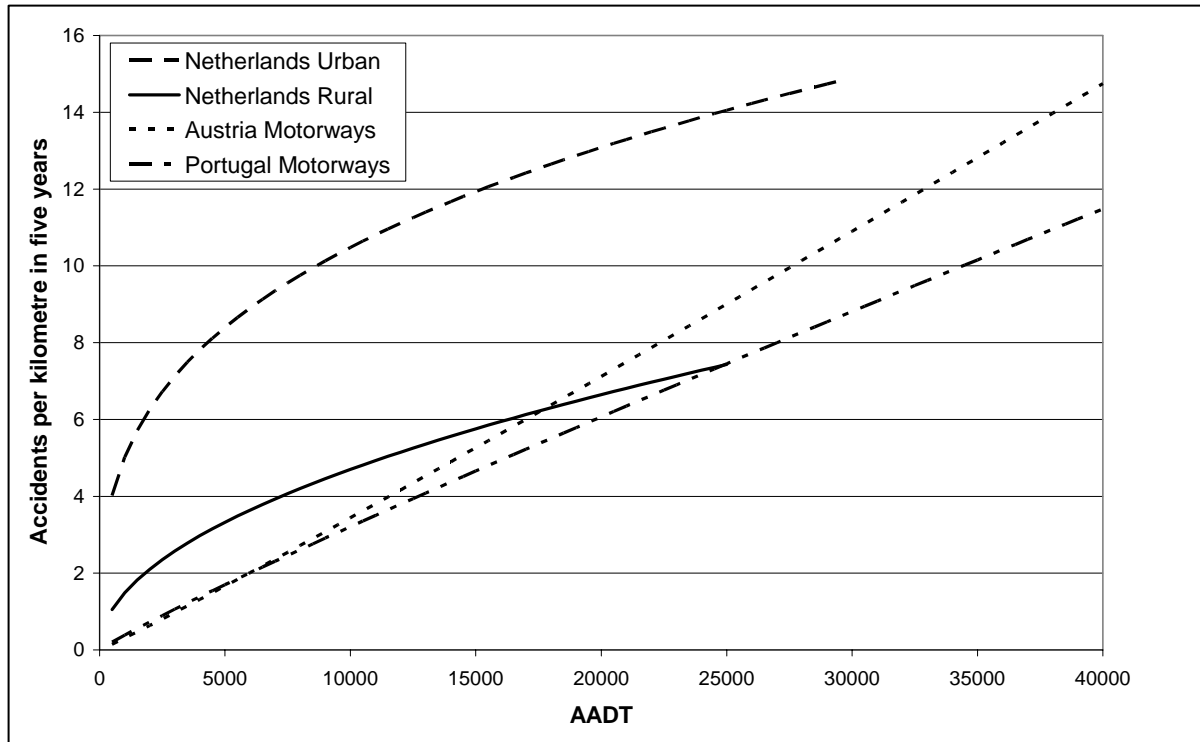
$$\text{Portugal Motorways } ACC = 6.7 \times 10^{-4} \times AADT^{0.92} \times Length^{0.93}$$

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

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

Where ACC = accidents (units)
 AADT = Average Annual Daily Traffic (vehicles per day)
 Length = lengths of the section considered (km)
 PHGV = percentage of heavy goods vehicles

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:



Note that the range of AADT is different for different APMs.

For a typical AADT of 15000, 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 accidents per km). 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 (3000 – 40000) and rural roads (3000 – 25000) in the vicinity of The Hague seems to be rather comparable to motorways in Austria and Portugal. The city of The Hague has almost 500000 inhabitants and some of the urban roads have 2 or 3 lanes per direction. 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.

2.2.2 Comparison of state-of-the-art and pilot studies

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 quality criteria 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 this being a judgement by the researchers and their international colleagues themselves.

The literature study showed that the APM outcomes were rather different in different regions or countries. In our case, the APMs for the same category of roads (motorways) in Austria and Portugal are rather comparable. This could of course be a coincidence, but might also be the result of using comparable ways of working.

2.3 Road safety Impact Assessment

2.3.1 Results of the state-of-the-art study

A first type of RIA is used for (major) road works, a new bridge, tunnel, etc. This is performed in many countries and in many ways. This is not a topic dealt with much detail in the (scientific) literature, the information in WP2 is gathered from RipCord-Iserest partners and a study from BAST (Höhnscheid, 2003).

Four ways of assessing the impact can be identified:

1. Expert opinion

This is a qualitative assessment by experts who can, for instance score each relevant safety aspect negative, neutral or positive. This is easy to apply and will guarantee an outcome but its validity and reliability are questionable.

2. Handbooks

The effects of road safety measures are estimated using (inter)national handbooks. In general these are science based but have large confidence intervals, that means that the expected effects depend highly on the specific situation.

3. Including (local) network

Next to the expected effects from method 2., effects on the adjacent network are considered. Usually this is done by modelling (changes in) traffic volumes and applying (local, national) risk factors per road type. The effects on the adjacent network can be quite relevant and therefore this is a better but more costly method.

4. Cost benefit analysis

This can be part of methods 1-3 or done in a more vigorous way by taking into account the effects on the environment, accessibility, spatial planning, etc. This could be disadvantageous when applied to road safety measures that have an adverse effect on environment or accessibility.

The second type of RIA is used on a network or area level. This is more common in the (scientific) literature, though not as well represented as APMs. In general five steps can be identified:

1. Baseline situation

This describes the current situation (year 0), with respect to traffic volumes and accidents per road type (and from this: risk factors per road type)

2. Future situation without measures

In most plans the function of roads will be changed, for instance by introducing 30 km/h-zones in residential area's, upgrading or downgrading distributor roads etc. This will result in re-directing traffic. This step also includes traffic growth.

3. Applying road safety measures

Per road type and road user group the effects of measures are assessed.

4. Cost-Benefit Analysis

This step consists of a monetary valuation of (safety) impacts which is related to the costs of the measures.

5. Optimisation

In this stage the plans (road function, measures) are changed in order to reach the optimal safety effect or the best cost/benefit ratio.

On a national level sufficient data may be available to use this method (see 2.3.2 for Norway), but on a local or regional level this is unlikely. Therefore a combination of additional data acquisition, modelling and assessments is required, although that can be quite costly, though probably negligible when compared to the costs of the safety plans and the benefit of applying the method. In the Netherlands the Regional Road Safety Explorer (RRSE) was used by 19 regions because a substantial subsidy was foreseen. This resulted in plans that would have delivered the required improvements for the available budgets, according to the RIA in the RRSE. These plans were optimised with the aid of the RRSE, that is, initially they were different. The instrument was modified by Mobycon and is used in WP11 Decision Support Tool, and WP12 Demonstration of RipCord-Iserest. More information can be found in D11 and D12 of RipCord-Iserest.

2.3.2 Results of the pilots

A road safety impact assessment for Norway, designed to assess the prospects for improving road safety, was made. The study 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 out

of the 45 measures are cost-effective, i.e. their benefits are greater than the costs according to cost-benefit analyses. Six of the 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 definite and the road safety targets proposed have not been officially adopted or given political support. It is nevertheless of interest to examine if such targets can be realised. 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 of 2003-2006) to 125 in 2020. The number of seriously injured road users is to be reduced from 980 (mean of 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 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 is 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. 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 in 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. Accident Prediction Models: User needs and recommendations

3.1 Safety level of existing roads

It is safe to say that practitioners (road authorities, policy makers, their consultants) are interested in improving road safety and taking measures that will decrease the number of accidents on (their) roads. Therefore they want to know what the expected numbers of accidents will be in the future. It is also likely that they are interested in measures that can prevent large numbers of accidents at low costs.

With an APM one estimates the expected number of accidents on a road (type) as a function of traffic volume and a set of risk factors. The work in WP2 has given the following insights:

- developing an APM is not an easy task, probably not suited for road authorities with the possible 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 (risk factors) are included;
- APM can be quite different for the same road type in different countries.

It is recommended that on a national level basic APMs are developed for several road types, depending on the national situation. Basic means that no risk factors are included, only the traffic volume is used. In general the accident numbers will be higher at increasing volumes, but the accident rate will drop. If there are more differences in design within the considered road type, then this effect of decreasing accident rate is stronger (see 2.2.2).

These APMs 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 road design. This approach is important in selecting cost effective measures that have apparently been applied on other roads of the same type. It will not necessarily lead to high numbers of prevented accidents because one may select roads with low traffic volumes and, subsequently, low accident numbers, although (much) higher than is usual for this road type. This can easily be overcome by only considering roads with a medium to high traffic volume.

3.2 Explanatory variables

Knowing that a road has a high accident rate is one thing, knowing what the reason is for this and being able to tackle it, is another. To this end explanatory variables or accident modification factors (AMF) should be added. This requires many, good quality data that are usually not available. There are few good examples of APMs including explanatory variables or AMF's. If, however they are (or would be) available, they may give a pretty good hint as to where the safety problem lies.

Though not explicitly researched in WP2 a few recommendations can be given. If there are high numbers of accidents, analyses that are commonly used for Black Spot Management (see WP6) are possible. This may lead to the identification of specific types of accidents or certain accident patterns that could be tackled by

measures that have proven to be effective in preventing these accident types. Another method is comparing the road design to the requirements of current national or international standards that are available for this road type.

3.3 Recommendations

Road authorities

- command or give assignments to research organisations to develop basic APMs for relevant road types;
- implement road databases including at least data on traffic volumes, roadside treatment, median treatment, intersection types;
- select road (types) based on amount of accidents (or traffic volume) and accident risk, using APMs.

Policy makers/Politicians

- allow road authorities to select sites for treatment according to the criteria mentioned above.

Researchers

- make basic APMs for 3-5 road types and preferably also intersections on these road types, using the methods recommended in the state-of-the-art report, that is:

- basic form: $E(\lambda) = \alpha Q_{MA}^{\beta} Q_{MI}^{\beta}$.
- use Generalised Linear Modelling.
- assume a Negative Binomial distribution.

In general: take account of the recommendations in chapter 2 of the state-of-the-art report, and follow the criteria proposed for assessing the quality of fitted APMs.

- if the data allow it: expand the basic APM with AMF's and or add explanatory variables.

4. Road safety Impact Assessment: User needs and recommendations

4.1 Network safety policy

Road safety policy is, by definition, up to politicians, aided by policy makers and road authorities. In many countries road safety targets are set for a period of 5, 10 or 20 years. With regards to what a RIA could possibly do, some user needs or questions seem relevant:

- are these targets ambitious?
- are they realistic?
- are there more (cost-)effective options?
- what is the impact on other issues, such as environment or accessibility?
- do social dilemma's exist?

Road safety is only partly determined by (inter)national, regional or local road safety policy. RIAs show that it is hard to tell which part can be influenced and what external, or autonomous developments will be. Next to this chance plays a vital role, if for instance, the amount of road fatalities drops from 1000 in one year to 970 in another, this is no reason to assume that policy has anything to do with it. The same is true, of course, if it would have gone up to 1030. One should always take an average of a few years (3-5) and look at long(er) term trends. If such a trend would point at a drop of 10% in road fatalities in 10 years, then setting a target of 5% is not very ambitious, and a target of 50% is probably too ambitious. A RIA can give more insight in what is realistic. The Norwegian pilot gives a good example of this. The preliminary national target for 2020 is a maximum of 125, and the RIA indicates that 200 is a realistic target.

An important element of a RIA is the set of expected costs and benefits of (road safety) measures that could or will be realised in the period under consideration. This enables the user to optimise plans given a certain (road safety) budget. A RIA does not (normally) incorporate relevant aspects such as public acceptance of measures, social dilemma's, and effects on other relevant policy issues like the environment or travel times, though especially these last issues are dealt with in state-of-the-art RIAs.

With regards to the RIA on major road works, tunnel etc. the situation is less difficult. The user simply wants to know what the effects are (on safety) and the best way to tackle this is using handbooks or literature for local effect estimates, and using models and risk factors (APMs if available) for effects on the adjacent road network. A cost-effectiveness analysis may be advisable if other policy issues are at stake as well.

4.2 Impact of safety plans

As stated above, the actual road safety situation is not the exclusive outcome of road safety policy. In the Norwegian pilot an attempt has been made to explain past trends by developments in safety issues that are known to have a major influence. This was unsuccessful, partly because safety measures are implemented gradually, 1000 roundabouts are not built overnight, partly because measures or developments have

a major, but unknown impact. A RIA as a tool to compare different safety plan options is of great value. In the Netherlands the application of the Regional Road Safety Explorer led to changes in regional plans that were more cost-effective. What the influence of the Norwegian RIA will be, only time will reveal.

4.3 Recommendations

Road authorities

- for major road works, tunnels etc. always perform a RIA, make use of scientific knowledge (handbooks, etc.) for estimating the safety effects and take into account the adjacent network, rather than using expert opinion;
- use RIAs to optimise safety plans, be aware that:
 - safety measures may influence travel times, environment, etc, especially when roads are downgraded;
 - re-directing traffic to (already) safer roads can be very cost-effective. In the Netherlands a RIA indicated a 4% increase in traffic volumes but 7% less accidents.
- the quality of RIAs is, as in any model, highly dependant on data quality (garbage in, garbage out). Realise good quality databases.

Policy makers/politicians

- it seems wise to set ambitious and realistic road safety targets, a RIA is helpful in doing that but will not give a 'certain' outcome;
- RIAs are best used in comparing different policy options;
- data quality and availability are the most important factors that determine the quality of a RIA. In order to improve RIAs in future data acquisition and quality control is therefore crucial. Promote good quality databases.

Researchers

- use the five steps mentioned in 2.3.1;
- be aware of the limitations and uncertainties of a RIA and communicate this to the end user (chapter 10 in Norwegian pilot);
- promising developments are: GIS-based data (WP11/12) and including effects on environment and accessibility.

Conclusions

The basic form of nearly all modern *accident prediction models* is this:

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

The estimated expected number of accidents, $E(\lambda)$, is a function of traffic volume, Q , and a set of risk factors, x_i ($i = 1, 2, 3, \dots, n$). 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. For intersections volumes for the major and minor road 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.

The work in WP2 has given the following insights:

- developing an APM is not an easy task, probably not suited for road authorities with the possible 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 (risk factors) are included;
- APM can be quite different for the same road type in different countries.

It is recommended that on a national level basic APMs are developed for several road types, depending on the national situation. Basic means that no risk factors are included, only the traffic volume is used. In general the accident numbers will be higher at increasing volumes, but the accident rate will drop. If there are more differences in design within the considered road type, then this effect of decreasing accident rate is stronger.

These APMs 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 road design. This approach is important in selecting cost effective measures that have apparently been applied on other roads of the same type. It will not necessarily lead to high numbers of prevented accidents because one may select roads with low traffic volumes and, subsequently, low accident numbers, although (much) higher than is usual for this road type. This can easily be overcome by only considering roads with a medium to high traffic volume.

A first type of *RIA* is used for (major) road works, a new bridge, tunnel, etc. This is performed in many countries and in many ways. This is not a topic dealt with much detail in the (scientific) literature. Four ways of assessing the impact can be identified:

1. Expert opinion
2. Handbooks
3. Including (local) network
4. Cost benefit analysis

It is best to use as much scientific evidence as possible, using handbooks, cost-benefit analyses and taking into account network effects.

The second type of *RIA* is used on a network or area level. This is more common in the (scientific) literature, though not as well represented as APMs. In general five steps can be identified:

1. Baseline situation
2. Future situation without measures
3. Applying road safety measures
4. Cost-Benefit Analysis
5. Optimisation

On a national level sufficient data may be available to use this method, but on a local or regional level this is unlikely. Therefore a combination of additional data acquisition, modelling and assessments is required, although that can be quite costly, though probably negligible when compared to the costs of the safety plans and the benefit of applying the method. In general a *RIA* is best used in comparing policy options and setting ambitious but realistic road safety targets. Absolute numbers that are predicted are usually not very reliable and in general highly dependant on high quality databases that are usually not available.

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