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1.6.2: Sustainable Surface Transport

Police Enforcement Policy and Programmes on European Roads

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**Working Paper 23**

**Framework for the prediction of the effects of road traffic enforcement measures**

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Abstract

The first development version of a framework for the prediction of the effects on accidents of traffic law enforcement measures is described. It should provide a rough estimate of the expected effects on accidents or injuries. The prediction process involves the following main stages: a) selection of target behaviour, b) definition of enforcement measure, c) definition of the expected effect on road user behaviour, d) definition of the expected percentage change in accidents or injuries resulting from the change in behaviour, e) definition of the baseline number of accidents or injuries, f) calculation of the effect on the number of accidents or injuries, and g) assessment of the uncertainty of the results. The framework is meant to be easy to use by those who make enforcement plans and approve them. It suits best for the prediction of the effects of large scale measures or enforcement campaigns. All data and calculations are presented in a transparent way.
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EXECUTIVE SUMMARY

The main objective of traffic law enforcement (TLE) is to promote road safety by decreasing the number of accidents and reducing their severity. The effects of TLE on accidents result from the changes it causes in road user behaviour.

For efficient use of TLE resources it is important to be able to predict the expected effects of safety. Those who make enforcement plans and decide on their implementation should have at least a rough idea of what is their effect on accidents. The framework described in this paper is meant to provide a simple tool for systematic prediction of the effects of TLE measures before their implementation.

The desired characteristics of the prediction framework include the following:

- applicable to all kinds of TLE measures;
- predictions are given as the number of accidents or injuries that can be prevented;
- easy to use;
- transparent in the sense that all data, calculations and assumptions are made explicit;
- exploits existing accident statistics and previous research results;
- when applicable research results are not available, educated guesses are allowed;
- provides indications of the accuracy of the predictions;
- results are presented on a standard form.

According to the framework the prediction of the effects of TLE measures involves the following stages:

a) selection of target behaviour,
b) definition of enforcement measure,
c) definition of the expected effect on road user behaviour,
d) definition of the expected percentage change in accidents or injuries resulting from the change in behaviour,
e) definition of the baseline number of accidents or injuries,
f) calculation of the effect on the number of accidents or injuries, and
g) assessment of the uncertainty of the results.

A fictional example of the application of this prediction framework is presented in Annex 1 of this report.

This Working Paper is an intermediate report on the development of the prediction framework. The final output from this task will be the PEPPER Deliverable 4b, scheduled for December 2007.
1 INTRODUCTION

1.1 Background

The primary purpose of traffic law enforcement (TLE) is to enhance road safety by decreasing the number of accidents and reducing the severity of their consequences. Therefore, a key measure of the success of TLE is how much it reduces the number of accidents and casualties, especially the number of fatalities and serious injuries.

TLE aims to improve safety by reducing traffic law violations that are associated with accidents. Consequently, one of the key features of successful TLE is that it targets on behaviours for which previous studies have shown to affect the number or severity of accidents, or where there is reasonably strong theoretical ground to expect that the target behaviour affects accidents, even though the effect has not been confirmed by empirical studies.

In order to be able to use resources efficiently we also need to have a reasonably clear understanding of how much the planned enforcement measure reduces accidents or mitigate their consequences. In other words, we need quantitative estimates of the effects on the number or severity of accidents, or both. A logical way to derive such estimate involves two basic steps. First, we need to predict how much the planned enforcement measure will reduce the target violations (e.g. DUI, speeding or non-use of seat belts). Second, we must estimate how much the predicted change in behaviour will affect accidents. However, if research results are available of the effect of enforcement on accidents, the effect on accidents can be predicted directly, without first estimating the effect on behaviour. But even then it is useful to consider also the effect on behaviour because results from previous research may be from studies where the initial degree of compliance was different from the case at hand. In that case also the expected effect on accidents may be different.

The predictions of the effects on safety of enforcement measures are hardly ever very accurate, and it may be difficult assess how uncertain they in fact are. The main reasons for this include deficiencies concerning our knowledge of the link between behaviour and accidents and uncertainties regarding the effects of enforcement on behaviour (and how these depend on road and traffic conditions). Furthermore, because of the random variation of accident numbers, it is usually difficult to estimate with reasonable accuracy the effects of enforcement measures on the observed number of accidents even on the basis of valid before-after studies.

It is clear from the above that accurate prediction of the safety effects of TLE is practically impossible. It is likely, however, that even a rough quantitative estimate of the expected effects could promote the efficient use of enforcement resources by promoting the implementation of effective enforcement measures (instead of more popular but less effective ones).

Those who make enforcement plans and decide on their implementation could benefit from a method and tool, which enables a rough estimation of the effects of enforcement measures before their implementation. Furthermore, the predicted effects can later compared to ob-
served effects, which increase enforcement professionals’ knowledge of the effects of enforcement.

The idea for the development of this framework for the prediction of the effects of enforcement measures was affected by two previous projects; one concerning the assessment of the effects of speed in road traffic in general (Kallberg & Toivanen, 1997) and the other concerning the overall safety potential of enhanced traffic enforcement in Finland (Rathmayer et al., 2004).

1.2 Objectives

The objective of task 4.3b of the PEPPER workpackage 4 (Good practices in traffic enforcement) is to develop a framework for the prediction of the effects of traffic enforcement measures on road accidents and resulting casualties. More specifically, the framework should have the following characteristics:

- applicable above all to measures concerning drink-driving, speeding and seat belt use, but in principle to all kinds of road traffic enforcement measures;
- provides predictions of safety effect as the number (e.g. per year or enforcement operation) of prevented injury accidents of selected severity category (e.g. all, sever, fatal) or respective number of injured persons;
- easy to use with a standard spreadsheet software (MS Excel, for example);
- transparent in the sense that all the calculations and underlying assumptions are made explicit;
- exploits existing accident statistics and previous research results;
- based on scientific research results as far as possible;
- when applicable research results are not available, educated guesses can be used as input, but they need to be explicitly stated and justified;
- provides indications of the credibility of the predictions (e.g. 95% confidence intervals, and if that is not possible, at least a subjective assessment of the accuracy of the prediction);
- provides a clear presentation of the main phases of the prediction process and results on one or two size A4 pages.

An additional objective is to guide potential users of the prediction framework to the sources of relevant information, especially regarding the effects of alcohol, speeding and non-use of seat belts on safety. Provision of the following, however, does not belong to the scope of this task:

- extensive information of the effects of enforcement measures on different kinds of road user behaviour;
extensive information of the effects of changes in different kinds of road-user behaviours on accidents.

This Working Paper is an intermediate report on the development of the prediction framework. The final output from this task will be the PEPPER Deliverable 4b, scheduled for December 2007.
2 BASIC PRINCIPLES OF IMPACT PREDICTION

The basic idea of the prediction of the impacts on safety of enforcement measures is simple: Enforcement affects road user behaviour by reducing traffic law violations, which in turn reduces the number of accidents or mitigates accident severity (Fig. 1).

![Figure 1. Basic impact mechanism of traffic law enforcement.](image)

Consequently, the success of the prediction depends on two things: a) how accurately we can predict the effect of enforcement on behaviour, and b) how well we know the association between behaviour and accidents. Both of these prediction stages involve data collection, utilisation of previous knowledge and usually also expert judgement or educated guesses of the user. We need to know or estimate, for example, what proportion of car drivers don’t use seat belt in the before-situation, how that proportion is likely to change because of increased enforcement, and how increased use of seat belts would affect fatal or severe injuries to car drivers.

It is recognised that the framework usually enables only a rough prediction of the safety effect. One could say that the aim is to differentiate between measures that reduce the expected number of injury accidents by 0, 1, 10 or 50, for example. Because of the approximate nature of the predictions and the fact that the prediction process described in the following sections is rather a series of successive assessments rather than a set of exact mathematical formulas, it was decided to call the process a framework rather than a model.

In addition to providing rough quantitative estimates of the expected outcomes, an essential feature of the framework is that it is transparent in the sense that every step of the prediction process is briefly and clearly described. The data used and the assumptions during the process are visible and open to criticism. The transparency facilitates the assessment of the quality of the prediction process and eases the detection of errors in data or judgement. It also makes it relatively easy to recalculate the impacts on safety if some data or mathematical functions in the process are updated.

The framework also promotes a systematic approach to the evaluation of enforcement measures. Furthermore, the comparability of alternative enforcement measures is improved if they are evaluated consistently by applying the same tool.
3 DESCRIPTION OF PREDICTION FRAMEWORK

3.1 General structure of framework

The structure of the prediction process is presented in Figure 2.

![Diagram of prediction framework]

Figure 2. Structure of the framework for the prediction of the effects of enforcement measures on road safety.

The prediction proceeds in phases from A to H, as shown in the yellow boxes in Figure 1. The pink boxes (from a to e) indicate sources of background information and data. A more detailed step-by-step (from A to H) description of the prediction process is given in section 3.2
3.2 How to use the framework

3.2.1 Scope of the framework

The starting point of the process is a situation where the user has an idea of a potential enforcement measure and he or she would like to derive a quantitative estimate of its effect on road accidents, to be used e.g. in the estimation of the cost-effectiveness of the measure, or in the comparison of alternative ways to use the limited enforcement resources.

The framework is probably most useful for the prediction of the effects of extensive enforcement measures or enforcement campaigns rather small-scale measures. In the latter case the predicted effects on accidents are typically fractions of an accident (e.g. 0.06 injury accidents), which is not always what is expected of traffic safety measures. However, such small predicted reductions can sometimes be informative and useful.

3.2.2 Target behaviour

Enforcement aims to reduce traffic law violations, i.e. different kinds of unlawful road user behaviour. Target behaviour (box A in Fig.2) affects selection of enforcement measure (box B in Figure 2). We may want to reduce certain kinds of violations and choose the measure that fits that purpose. Or we may have some given enforcement measure and want to know how it affects safety. In any case we need to define what kind(s) of unlawful road user behaviour the selected measure is meant to reduce.

Potential target behaviours include, among other things:

- speeding
- drink-driving
- non-use of seat belts and other safety devices (helmets, child restraints)
- close-following and other dangerous driver behaviour
- overtaking
- red light running
- behaviour of pedestrians and cyclists
- technical condition of vehicles
- amount and securing of loads
- driving and resting time violations
- driving licences.

As can be seen behaviour is here defined broadly, and includes things like driving without a valid license or driving a defective vehicle. Enforcement of speeding, drink-driving and seat
belts are generally considered most effective from safety point of view. The list of violations above is not exhaustive, and may also include violations which have not been proven to affect accidents so far.

It may also be that we aim to reduce target violations only or mainly in some specific conditions, e.g. on certain categories of road or in certain time of day. We may also concentrate on some specific group of road users, e.g. young drivers or professional drivers.

Whatever our target behaviour is, we need to define it rather precisely. In addition to the general description (e.g. we aim to reduce speeding), we also need to answer other relevant questions (which may vary) like where, when and by whom.

The selection of target behaviour also depends on the frequency of that behaviour before the implementation of the measure (box c in Figure 2, e.g. 81% of car drivers in urban areas use seat belts). The effect of the measure may depend on the current compliance rate, and high compliance rate often indicates that the effect of enforcement is lower than in the case of low prior compliance level. In the best case prior compliance rate can be estimated on the basis of measured data and valid field observations, but it may have to be estimated from insufficient data. In any case, the basis of the estimate concerning prior compliance level should be described in a way that makes it possible to assess its credibility, at least broadly.

An example of the description of target behaviour could be as follows:

*The target is to reduce drunk driving, especially at weekend nights in the city of Helsinki. On the basis of regular monitoring in recent years [name source] BAC of 3.1% of motor vehicle drivers exceeds 0.5 per mille between 20:00 and 06:00 on Friday and Saturday nights.*

### 3.2.3 Enforcement measure

The enforcement measure (box B in Fig. 2) should be described in qualitative and quantitative terms. Detailed description is not an end in itself, but the description should be detailed enough to allow a reasonable accurate estimation of its effect on target behaviour. As a rule, all aspects of the measure, which affect its effectiveness, should be briefly described. Questions that should usually be answered (at least roughly) include:

- brief description of enforcement method and tools (e.g. random roadside checks of BAC using Alcometer devices by a patrol of four policemen)
- where does the enforcement take place (e.g. city or region, road category, urban or rural)
- when does the enforcement take place (e.g. month(s), weekday(s), time of day; example: for 4 hours each Friday and Saturday night (20:00-04:00) from June 1 to August 31)
- enforcement tolerance (e.g. what is the minimum speed for which sanctions are issued on a 50 km/h speed limit zone)
- supporting measures (e.g. advance information in the media of enhanced alcohol enforcement)
potential obstacles to effective implementation (e.g. during weekend nights police patrols conducting traffic enforcement may be called to attend other, more urgent duties).

This description may include also information that is not necessary for the estimation of effectiveness (e.g. estimated cost and manpower needs of the planned enforcement measure), but could be useful for further purposes, e.g. for the estimation of cost-effectiveness.

The description of enforcement measures for monitoring and evaluation purposes is elaborated further in another PEPPER Working Paper, in the section concerning enforcement performance indicators (Van Schagen et al., 2007).

The description of enforcement measures serves not only the prediction of the safety effects but it also enables later comparison of planned and actual implementation, and provides data for studies of the effects on actual behaviour and accidents.

For practical purposes the framework usually works best when it is applied to large-scale measures, which cover a wide area and last for a long time. In that case the number of target accidents is big enough to result in accident reductions, which are greater than one or two accidents. Therefore, rather than using the framework for the prediction of the effects of each enforcement action separately, it is often better to aggregate them into larger groups or enforcement campaigns.

Example: It was decided to implement speed cameras to 11 road sections, the lengths of which are 7, 13, 18, 19, 22, 23, 25, 26, 30 and 33 km. Rather than predicting the effect on monthly accident number for each road section separately (and then add up the results), it is more practical to calculate the effect on the total 241 kilometres on annual basis (provided that there are no big differences between the road sections in speed distributions).

### 3.2.4 Expected change in road user behaviour

The effects of enforcement measure on road safety can be predicted in two ways:

1. Predict first the effect on road user behaviour and then the effect of the change in behaviour on accidents (involves the arrows from boxes A and B to box C, and from box C to box D in Figure 2).

2. Predict the effect of the measure on accidents directly, without considering the effect on behaviour (involves the dashed arrow from boxes A and B to box D).

Usually the first method is preferred, because the safety effect of enforcement depends on its effect on road user behaviour. If enforcement does not change behaviour it is not likely to affect accidents or injuries either. The second method can be used if there are results from previous research, which make such prediction possible. But then the applicability of previous research results depends also on the difference between the previous and current applications of the measure in the compliance rate concerning the target behaviour before the application of the measure. In other words, the effect of the measure on behaviour and accidents depends of the compliance rate before the measure is applied. Low compliance rate (and frequent traf-
fic rule violations) in the before period indicates bigger effects of increased enforcement than high compliance rate.

When using method 2 it should also be noted that differences in the implementation of the measures between previous and current applications may affect its effects on accidents (and road user behaviour). For example, because of differences between two applications of random breath testing by police patrols in the intensity, locations, timing and selection of drivers for screening, the effect on accidents can be different. Therefore, for example, applying directly the results of a previous study to predict the effect of 50% increase in random breath testing may lead to an over- or underestimation of the true effect.

It is recommended that even in cases where the effect on accidents is predicted directly (method 2), information of relevant road user behaviour (e.g. seat belt wearing rate or mean speed of traffic) before the application of the measure is described, as well as the expected or assumed effect of enforcement on behaviour. Provision of such information is useful in the assessment of the credibility of the predicted effects on accidents.

The two stages in method 1 are supposed to have a multiplicative relationship; therefore this model will be called the Multiplicative Behaviour Model (MBM). Multiplying the expected behaviour change by the effect of that behaviour change on accidents and injuries leads to an estimate of the effect of the enforcement intervention on accidents and injuries. The precision of this multiplicative model is not yet certain and should be subject to validation.

To test the validity of the MBM a simpler model can be used. Here the intermediate variable – behaviour change - is omitted and only the available information on the direct effect of police enforcement on accidents and injuries is being used. Subsequently this model will be called the Direct Multiplicative Model (DMM). Such information is widely available. A literature search in Transport with the search term: ((accident or injury) and enforcement and effectiv*), for example, resulted in 537 hits. Elvik & Vaa (2004) conducted meta-analyses on the enforcement topic. In table 1 a summary of their results on the effectiveness of police enforcement on fatal and injury accidents is presented.
Table 1. Expected percentage change in the number of accidents caused by enforcement measures (Elvik & Vaa, 2004; Erke & Elvik, 2006). (95% confidence intervals in brackets).

<table>
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<tr>
<th>Enforcement</th>
<th>Fatal Accidents</th>
<th>Injury Accidents</th>
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<tr>
<td>Stationary speed enforcement (doubling)</td>
<td>-5</td>
<td>-1 (0; -1)</td>
</tr>
<tr>
<td>Stationary speed enforcement (triplication)</td>
<td>-7</td>
<td>-3 (-4; -2)</td>
</tr>
<tr>
<td>Stationary speed enforcement (six times as much)</td>
<td>-10</td>
<td>-5 (-6; -3)</td>
</tr>
<tr>
<td>Speed cameras</td>
<td>-16</td>
<td>-10 (-12; -7)</td>
</tr>
<tr>
<td>Section control</td>
<td>-38</td>
<td>-25 (-31; -18)</td>
</tr>
<tr>
<td>Patrolling</td>
<td>-4 (n.s.)</td>
<td>-16</td>
</tr>
<tr>
<td>Drink driving enforcement (doubling)</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td>Drink driving enforcement (triplication)</td>
<td>-4</td>
<td>-1</td>
</tr>
<tr>
<td>Drink driving enforcement (six times as much)</td>
<td>-6</td>
<td>-2</td>
</tr>
<tr>
<td>Seat belt enforcement (+80%; urban)</td>
<td>-4 (n.s.)</td>
<td>-3 (n.s.)</td>
</tr>
<tr>
<td>Seat belt enforcement (+80%; rural)</td>
<td>-3</td>
<td>-2</td>
</tr>
<tr>
<td>Seat belt enforcement (+200%; urban)</td>
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<td>Seat belt enforcement (+300%; rural)</td>
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<tr>
<td>Red-light cameras</td>
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<td>-12</td>
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1 All effects refer to accidents on the road sections with enforcement. Seat belt enforcement (effects probably in a larger area than where controls are conducted): fatalities / injuries among drivers and front seat passengers (effects for back seat passengers are a bit lower, but seat belt use is usually enforced only for drivers and front seat passengers, not for back seat passengers (and not for child restraints), at least in Norway.

2 Stationary speed enforcement and drink driving enforcement: Effects are estimated assuming that increased enforcement leads to fewer violations, and that the amount of decrease decreases with increasing enforcement. Unfortunately, effects are dependent on the previous level of enforcement and compliance.

3 Speed enforcement: estimated with power model and (empirical) speed reductions.

In the two-step model we first predict the effect of (the change in) enforcement on road user behaviour and then predict the effect of the change in behaviour on accidents. In the best case there are results from previous research, which help us make these two predictions, but sometimes we may have to rely on less perfect sources of information, e.g. expert opinions. Whenever the two-step MBM is used the behaviours that are changed via enforcement and the behaviours that are estimated to have an influence on accidents and injuries have to be identical.
This issue – as trivial as it might look – is crucial. The information on the effects of police enforcement comes from scientific studies. Either they focus on accidents and injuries (as those studies analysed by Elvik & Vaa (2004) or they report a certain change in behaviour of the road users. In some studies the behaviour will therefore be the outcome, in others it will be the independent variable predicting accidents and injuries. It might not always be easy to find the corresponding behaviours as outcome and as independent variables. It may thus be more promising to choose the DMM instead of the MBM.

Sources of information on the relationship between different road user behaviours and motor vehicle crashes are available. Seat belt use reduces the risk of fatalities by about 45 %, driving under the influence of alcohol and crash risk have been analysed frequently and have been found to double for every 0.02 percent increase in BAC. And for speed the Power Model has been developed that assumes a relation between speed change and fatality risk of about the 4\textsuperscript{th} power (Nilsson, 2004).

Information on the behaviour change due to traffic law enforcement is less widely available and should be based either on scientific publications or observations within the evaluation.

When using the Multiplicative Behaviour Model a choice on the behaviour to be used must be made. For speed enforcement issues this could be the change in speeds driven, i.e. average speed, maximum speed, V50, V85 or variance of speeds measured etc. For drink-driving enforcement or seat-belt enforcement as well as red-light cameras the behaviour to be changed and to have an effect on road safety are also relatively easy to choose: % driving under influence or over the legal DUI limit, % drivers or passengers (front and rear) using the seat belt and % of drivers crossing the red light, respectively.

Patrolling on the other hand might lead to several behaviour changes related to traffic safety – the speeds will probably decrease, the driving behaviour will be less risky and less reckless, seat belts not used will be fastened and drivers under the influence of alcohol might try to choose another route where the patrolling car is not going. For the prediction of the effect of patrolling a whole battery of behaviours will have to be used. The effects of a patrol car, however, are rather limited in time and space, and therefore the effect on accidents may be small (Elvik & Vaa, 2004).

### 3.2.5 Expected effect on accidents

For the most important road safety issues there is information available on how strong the effects of the risk or protective factors are (box D in Fig. 2).

For example for the wearing of seat belts there is a research result from Leonard Evans (1996) available stating that the risk of fatal injuries is reduced by 45 % when wearing a seat-belt – but of course only among those that were not wearing the seat-belt before. The effect on the population depends therefore on the prevalence (the proportion) of seat-belt non-wearing in the population and not only on the efficacy of the measure.
For speed reduction there is a model of Göran Nilsson (2004) stating that the reduction in speed leads to a reduction in the number of accidents and injury severity by an exponent of 4. Elvik et al. (2004) came to the conclusion that this figure is only approximately right. For fatalities they found the exponent to be 4.5, for seriously injured road users it is 3.0. Reducing the speed from 80 km/h to 79 would be expected to lead to a reduction in fatalities by about 5.5%. Since this model holds for the total population and not only for those considered to be at-risk (driving too fast, for example), it can be used for box D directly.

For red light running the issue is different. The effect of Red Light Cameras on the number of motor vehicle collisions or injuries depends on the proportion of red light running crashes among all crashes at the intersection.

The same is true for enforcement on drinking and driving. The percentage of crashes attributable to driving under the influence of alcohol must be known to estimate the effect of the behaviour change on the DUI-crashes. In addition it has to be known what the BAC-levels of the DUI crash drivers were and by how much it is reduced due to police enforcement. The latter is important because a reduction in BAC by 0.1 per mille has different effects depending on the BAC-level. From 0.1 to 0.0 reduces the relative crash risk from 1.03 to 1.00. The same reduction at a BAC from 1.0 to 0.9 reduces the relative crash risk from 4.79 to 3.54 – a much larger reduction in crash risk (Blomberg et al., 2005).

Another issue is how we should measure the effect on accidents. Accidents are a very complex issue. They can happen or not, they can have different physical consequences in the form of more or less severe injuries and the consequences of the injuries may be temporary or permanent. From a societal perspective fatalities and severe injuries are the most costly – especially because of the direct medical costs and the indirect costs of not being able to work. Injuries of minor severity and property damage only crashes are much less important. In most studies the effects measures are the number of prevented fatalities. Sometimes also the number of prevented accidents is counted. The latter is less useful because the economic burden depends very much on the severity of the injuries suffered. And the term “accident” does not specify this. Terms like “injury accident” or “fatal accidents” are not really helpful either because the number of persons injured or killed may vary although only one accident is reported.

The application of the MBM should lead to effect estimates of approximately the same size as Elvik & Vaa (2004) have found them in their meta-analyses. If the estimates differ strongly possible explanations for this will have to be discussed. Reasons for differences could (among other things) be:

- The enforcement measure used is more or less effective than the interventions Elvik & Vaa (2004) included in their analyses. This is very well possible because they analysed several studies with different enforcement interventions of different effectiveness and thus present an average effectiveness. Using the figures from the most effective enforcement measure will probably lead to higher estimates than the results found by Elvik & Vaa (2004).
The behaviour change effect of police enforcement might not be a general effect on all road users but on special types of road users. It could be that high risk drivers are particularly perceptive (or non-perceptive) to police controls.

The postulated relationship between police enforcement and behaviour change might be more than a simple proportional model (more enforcement = less deviant behaviour). For example it could be that police enforcement only works when a certain threshold is overcome. Below that threshold the drivers might not even realize that police enforcement has been intensified. And thus no effect might be found although police enforcement was raised. Such an effect was recently discovered in Switzerland where the drivers did not believe that police enforcement was intensified although the number of persons checked by the police (for DUI) increased from 2.4 to 5% per year (Fink & Vaucher Ducommun, 2006).

There are several confounding variables that have an influence on accidents and injuries. Most of these are not included in the models but can and will have an influence on the precision of the prediction. Among these are properties of the road users (age and gender, mode of transport), properties of the motor vehicle (type of motor vehicle and crash worthiness), properties of the road and roadside (frequency and shape of curves, roadside shape and obstacles).

So in total it can be said that using the MBM includes quite a few uncertainties. It might be more promising to use the DMM and avoid additional sources of possible errors. Having the choice between different prediction models includes the temptation of choosing the model supporting the desired decisions. If more than one model is used all outcomes should be presented to the public as a simple type of sensitivity analysis. Attempts to validate the models and their predictions are useful and most welcome.

### 3.2.6 Baseline number of target accidents

Baseline number of target accidents (or injuries, box E in Fig. 2) is the total number of accidents, which are affected by the enforcement measure. The definition used here should be compatible with the group of accidents for which the expected percentage reduction was estimated above (Box D in Fig. 2). For example, if in box D we use information that the measure reduces accident involving drunken drivers by X%, the baseline accidents should contain those accidents only.

Baseline accidents are typically derived from some accident database. If accident data only from the target area is used it should preferably cover several years to reduce the potential regression-to-the-mean effect. A better estimate of the baseline number of accidents can be produced by the applying the Empirical Bayes methodology (see e.g. Hauer, 1992), where the accident history of the target site is combined with information of the safety of a larger number of similar sites. Nevertheless, it is often sufficient to use only simple accident data from the target site to get a rough idea of the effects of the enforcement measure. It should be taken
into account, however, that if the number of accidents before the application of the measure was exceptionally high, it may cause the overestimation of the safety effect by 20% or more.\textsuperscript{1}

When defining which accidents should be included in the baseline data, at least the following things should be considered:

- Geographical area
- Time period
- Accident type
- Accident severity

For example, the baseline target accidents in the case of area-wide enhanced random breath testing could be the number of (injury) accidents involving drunken drivers in the same area and in at least as long time period as the measure is used.\textsuperscript{2}

Depending on the measure other things worth considering in the definition of baseline accidents include driver age, vehicle type, road type, time of day etc.

It is recognised that the area or duration of the effects of enforcement usually cannot be defined precisely, because the effect typically diminishes gradually when the distance in time and space increases. The best we can do here is to use definitions similar to those used in studies, which were the basis of the effectiveness estimate (box D in Fig. 2).

Accident migration, which means that enforcement in some particular area increases accidents in neighbouring areas (e.g. when speeding drivers change their routes to roads where enforcement is less intensive), is not necessarily considered here. However, when there is reason to suspect that migration could be a significant issue, it should be taken into account when assessing the accuracy of the prediction (box G in Fig. 2). The same concerns the migration of the effects of enforcement, where enforcement in some area affects positively driving behaviour and reduces accidents in neighbouring areas.

### 3.2.7 Expected effect on accidents and casualties

The effect on the number of accidents or casualties is calculated by multiplying of baseline number of accidents (casualties) (Box E in Fig. 2) by the predicted percentage reduction in accidents (casualties) (Box D in Fig. 2). If either or both of these factors are small, then the resulting reduction in accidents is small. It can even be a fraction of one accident. Such small

\textsuperscript{1} For the description of the regression-to-the-mean effect and the Empirical Bayes methodology see e.g. section 6 of Van Schagen et al. (2007).

\textsuperscript{2} The effect of enforcement often extents beyond the actual enforcement area and space. This halo effect, however, can be different for different enforcement measures. E.g. for speed enforcement the effect on speeds has been found to last 8 weeks after the enforcement (Vaa, 1997).
predictions can often be avoided by aggregating measures to larger groups or enforcement campaigns, as suggested in section 3.2.3.

Even if the predicted reduction in the number of accidents (casualties) is small, the reduction should be presented as the absolute number of accidents, rather than a percentage reduction. This is the case, because the objective of enforcement is to reduce the number of accidents and injuries, not percentages. Furthermore, a percentage reduction has little meaning if it is not considered together with the size of the target group. A big percentage reduction (e.g. 30%) concerning a small target group (e.g. 20 accidents) contributes to road safety less than a small percentage reduction (e.g. 4%) concerning a large target group (e.g. 500 accidents).

3.2.8 Assessment of accuracy of predictions

The stages of the prediction process described above all involve inaccuracies, which affect the final result. Moreover, these inaccuracies cannot be easily (if at all) described in exact mathematical terms (e.g. as a 95% confidence interval). When we also take into account that the framework should be easy to use, it is not reasonable to expect that the accuracy of the predictions will be described other than broadly (Box G in Fig. 2). For practical applications of the framework it may well be enough to get a rough idea of the size of the potential error and its sources. Answering the following questions should help in the assessment of the accuracy of the predicted effect on accidents or injuries:

1. Is the expected percentage effect on accidents (box D in Fig. 2) based on research? If yes, did the research indicate confidence intervals of the effect? If yes, recalculate the effect using the upper and lower limits of the confidence interval, and you get the respective confidence interval of the reduction in the number of accidents (casualties).

2. Did the percentage effect (box D) concern the similar group of accidents as was used as target accidents (box E)? If not, is the difference likely to decrease or increase the calculated reduction in the number of accidents (casualties)?

3. Was it possible that the baseline number of accidents (box E) was affected by the regression-to-the-mean effect. In other words, was the enforcement location selected because of its accident record was exceptionally high in the observation period and is it possible that the high accident count was affected by random variation.\footnote{Because of the regression-to-the-mean effect the true effect of enforcement can be considerably (e.g. by 20% or more) lower than calculated.}

4. Is it likely that enforcement affects significantly road user behaviour and accidents outside the enforcement area (area of baseline accidents)?

\footnote{As a rule of thumb the standard deviation of accident counts (s) is equal to the square root of the average (m) and random variation can be \( m \pm 2s \). For example, if the long time average of annual accident counts is 16, counts in different years can vary between 8 and 24 by chance even if there is no real change in safety.}
5. Is it likely that enforcement has significant effects even after the period of implementation?

6. Is it likely that road users who are likely to break the rules change their routes to avoid enforcement (and thus increase accidents in neighbouring areas)?

7. Is it likely that the enforcement measure in fact will be implemented in a smaller scale or otherwise less effectively than planned?

After considering the questions above the user of the prediction framework should have a rough idea of the accuracy of the prediction. At least he or she should have an opinion whether the calculated effect is more likely to underestimate or overestimate the true effect. He or she may even give a subjective estimate of the accuracy of the prediction.

*Example: If the predicted effect was a reduction of 5.4 injury accidents per year, the subjective estimate could be that “the measure reduces the annual number of injury accident most likely by 5 and in any case probably between 3 and 6. It is possible that regression effect (box E) has led to overestimation of the effect, and the percentage effect on accidents (box D) is not precise.”*

### 3.2.9 Presentation of prediction process and results

Finally, the prediction process and the result are described on a standard form, where all data and calculations are presented. A draft of such form is presented in Annex 1.

### 3.2.10 Evaluation aspects

After the decision to implement the measure is made, preparations should be made for the monitoring and evaluation of the effects. Most importantly, the implementation of the measure should be monitored so that the actual implementation can be compared to the planned. The evaluation of the effects on accidents should be based on normal accident recording procedures to avoid situations where reporting procedures before and after implementation are different.
4 NEXT STEPS

The development of the prediction framework continues by critical review of the current version presented in this Working Paper. The framework will be elaborated further on the basis of comments from the PEPPER partners, the project officer and the User Forum. The framework and the guidance to its users will most likely include the following:

- More extensive information of the effects of different enforcement measures on behaviour and accidents, presented in user-friendly format (e.g. tables and charts)
- Examples of the application of the framework to real enforcement actions concerning drink driving, speeding and enforcement of seat belts.
- Preparation of an MS Excel spreadsheet to promote easy application of the framework.
- Development of a form for transparent description of the stages of the prediction process and presentation of the results.
- Discussion and conclusions concerning the theoretic background and practical application of the framework, and an assessment of further needs and conditions for its use by enforcement and road safety professionals and decision makers.

It is emphasised that the resulting prediction framework is a practical tool for rough estimation of the expected safety effects of enforcement measures and actions, rather than a strictly scientific and precise calculation machine. It requires no specific skills from the user, but since part of the input typically requires some sort of expert judgement (concerning especially the expected effects on road user behaviour and the application of existing research results on the effects on accidents) it is probably at its best when used by enforcement and road safety professionals.

The final prediction framework will be described in Deliverable 4b, which is due in December 2007.
5 REFERENCES


6 ANNEX
Annex 1

Fictional example of the application of the prediction framework

The letters on the left refer to the boxes in Figure 2 (page 10).

| A | Target behaviour | Speeding on a 50 km 2-lane rural road with 80 km/h speed limit and means speed of 82.9 km/h |
| B | Enforcement measure | Speed cameras: 24 camera cabinets (12 in each direction) and 2 cameras; operated 12 hours/day; tolerance 10 km/h |
| C | Expected change in behaviour | Reduction of mean speed from 82.9 to 80.4 km/h |
| D | Expected percentage effect on accidents | Effect on injury accidents according to the Swedish power model $= (\frac{80.4}{82.9})^2 - 1 = -6\%$ |
| E | Baseline number of target accidents | Average annual number of injury accidents in the last 3 years was 11.3 |
| F | Expected change in the number of accidents | Expected reduction in the annual number of injury accidents $= 0.06 \times 11.3 = 0.67$ |
| G | Assessment of uncertainty | 1. Effect on speed based on earlier similar applications  
2. Effect of change in mean speed on accidents is based on research  
3. No significant regression effect (3 year accident data)  
4. May decrease or increase speeds on neighbouring roads  
5. Change of driving routes to alternative roads very unlikely  
6. Implementation will take place as planned.  
**Conclusion:** The predicted effect is probably very close to the true effect. |
| H | Predicted total effect on accidents | Predicted total effect on injury accidents is a reduction of 0.67 accidents per year. There is no specific reason to doubt that the predicted effect reflects the true effect. |