Deliverable 3 (WP2)

The impact of enforcement on accidents

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ABSTRACT

The present document is deliverable 3 (D3) 'The impact of enforcement on accidents', prepared for ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement). It summarizes evidence concerning the safety benefits resulting from traffic policing. The report begins with the reasons why enforcement should be expected to influence safety. It goes on to estimates the potential impact of enforcement and then deals with evidence on the actual impact enforcement has had on accidents.

Theoretical estimates of the potential accident reduction impact of policing, based on enforcement inducing full compliance are fairly high, up to 50% reduction. Estimates based on statistical analysis of empirical studies suggest much lower estimates, with 10% being on the high end. Some well-implemented and sustained enforcement efforts have documented large safety gains, in the range of 25%. Typically these programs involved both speed and drink-driving control.

Much of the evidence comes from increased enforcement efforts in projects and experiments restricted to either selected roads, to few behaviours or to a limited periods. In practice this means that in most projects there was temporary increase in local resources or shifting of resources to concentrate policing efforts in the selected area.

A large and permanent increase in policing resources is not an attractive or feasible option in most countries. However, enforcement programs in Australia and New Zealand demonstrated substantial safety gains by policing with random deployment management of low intensity traffic surveillance. This was combined with automated photo-radar for speed detection and random breath tests.

All these elements exist in routine enforcements programs in several European countries, many of which have as good or better safety record than the countries above. Therefore, such approach merits a more detailed examination and perhaps a more systematic application.

EXECUTIVE SUMMARY

The present document is deliverable 3 (D3) ‘The impact of enforcement on accidents’, prepared for ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement).

The document summarizes evidence concerning the safety benefits resulting from traffic policing. The report begins with the reasons why enforcement should be expected to influence safety. It goes on to estimates the potential impact enforcement may have on accidents and then deals with evidence on the actual impact enforcement has had on accidents.

Estimates are primarily based on three sources of data. The first is the extent of involvement of a non-compliant behaviour in accidents as a causal factor. The second source of data is involvements of driver, vehicle or environmental conditions in accidents and engineering or medical assessments of crash mechanisms and severity. The third source of data is evaluations studies of the actual benefits of introducing new legal requirements (such as wearing helmets) or enforcing existing laws, (such as speeding).

Theoretical estimates of the potential accident reduction impact of policing, based on enforcement inducing full compliance are fairly high. A recent policy review estimated that about 50% of traffic accidents in Europe could have been prevented if road users were completely dissuaded from committing traffic violations (ETSC, 1999). The Norwegian Traffic Safety Handbook estimates that full compliance with speed regulations, avoiding drink-driving and always using protective devices could save up to 38 % of fatalities and up to 17% of other traffic injuries.

The actual safety benefits of specific enforcement methods have been assessed in many empirical studies. A recent meta-analysis of such studies was prepared by Elvik, Mysen, and Vaa (1997) for their Handbook of Traffic Safety, and adapted for this report. This review was extended to more recent studies, especially those involving area-wide and routine enforcement operations.

Manual speed enforcement reduced the number of accidents by 2%. The reduction in fatal and injury accidents is higher, -14% and –6%. Automated speed enforcement shows a reduction of 19% to 35% of accidents. Speed cameras have a larger effect in urban areas. Early studies of Red light Cameras (RLC) at signalised intersections showed an 11% reduction of accidents, but later studies cast some doubts on the size of impact.

Drink-driving, more than any other non-compliance issue, was always considered a social behaviour issue, therefore, enforcement of drink-driving is usually considered a package of measures, with direct policing on the road being one component, albeit an important one. The overall effect of controlling drink-driving by direct policing and all other accompanying measures is a reduction of 3.7%, 9%, and 7%, of all, fatal, and injury accidents, respectively. Some specific measures have a larger impact; for example, revocation of driving licence has reduced the number of drink-driving accidents by 18%.

Safety belts enforcement has had a 5% to 14% impact. In assessing the separate effects of various sanctions-, warning letters and license revocation stand out as having had 15% impact on accident reduction compared to 5% influence by demerit-points-systems.

Several careful evaluation studies of community-wide and state-wide long terms speed and drink-driving enforcement program in Canada, USA, Australia and New Zealand reported 10%, 25% and even 33% reductions in relevant accident categories. Studies in Israel suggested much smaller reductions. The positive impact is larger with fatalities and serious injuries, pointing to the importance of speed control and possibly also of improved emergency response with improved or increased police deployment.

Much of the evidence, in earlier studies, for the impact of policing comes from projects with increased enforcement efforts restricted to either selected roads, to few behaviours or to a limited periods. In practice this means that in most projects there was temporary increase in local resources or shifting of resources to concentrate policing efforts in the selected area.

A large and permanent increase in policing resources is not an attractive or feasible option in most countries. However, the more recent programs in Australia and New Zealand demonstrated substantial safety gains by policing without large increases in manpower resources. The programs employ random deployment management of low intensity traffic surveillance. This is combined with automated photo-radar for speed detection and random breath tests.

All these elements exist in routine enforcements programs in several European countries, many of which have as good or better safety record than the countries above. Therefore, such approach merits a more detailed examination and perhaps a more systematic application.

A point of caution is that many of the studies reviewed here and elsewhere, have been carried out in various states and communities in North America and Australia rather than in European countries, and many of the studies are from past decades with different social, legal, roadway, and traffic context. The validity of conclusions derived from that past experience needs to be examined in the framework of present day EU countries.

Traffic policing includes general surveillance and more targeted activities aimed at controlling specific non-compliance behaviour such as speeding, drink-driving or not using protective devices. Only in special projects there is a focus on doing or evaluating one activity. In the real practice all are carried out simultaneously. In addition, other factors in society or the economy are at work, which may influence changes in traffic safety.

Therefore, it is of interest to assess the relative impact on safety of major policing actions and other factors. Newstead, Cameron & Narayan (1998) did such analysis for 1990-1996 data in Victoria, Australia. They estimates that speed and drink-driving control together contributed at least 22-25% reductions in serious crashes, more that any other influencing factor at the same time. Elvik (2000), in a working paper for ESCAPE, arrived at a similar conclusion with Norwegian data.

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1 INTRODUCTION

The present document is deliverable 3 (D3) 'The impact of enforcement on accidents', prepared for ESCAPE WP2.

The document summarizes evidence concerning the safety benefits resulting from traffic policing. Traffic policing is generally restrictive and some of the justification for its application rests on the belief that policing saves accidents. By looking in more detail at the benefits associated with various policing operations, it may be possible to identify non-compliance areas where enforcement has been more effective in reducing accidents. Additionally, looking at various methods of enforcement and their impact on safety may suggest which methods appear to be more effective. A more direct analysis of this issue was carried out by Elvik (2000) in Wp1: 'Cost-Benefit Analysis of Police Enforcement'.

The report begins with the reasons why enforcement should be expected to influence safety. It goes on to estimates the potential impact enforcement may have on accidents given the incidence of non-compliance and assuming enforcement would eliminate it. The bulk of the report, however, deals with evidence on the actual impact enforcement has had on accidents. Part of the evidence was previously analysed by Elvik, Mysen and Vaa (1997) as part of a larger study estimating the safety impact of several types of counter-measures. That study has relied on meta-analysis methods to generate statistical 'best estimates' based on as many relevant studies as possible in each counter-measure category. For the present review only enforcement related counter-measures were re-considered. More recent studies, especially those dealing with general and wider application of policing, rather than small local experiments, are described in more detail and not in a meta-analysis context.

Going over the references and studies, one cannot miss the impression that the majority of the studies have not been carried out in EU countries. There are many from North America and Australia. This is not very satisfactory situation, as traffic enforcement takes place in a specific geographic, social, and transport context. The reason for the relative shortage of European studies is not obvious. Is it failure of the authors to access European publications, especially in non-English languages? Is it failure of transport databases to include more European publications? Is it lack of studies and reports originating from EU countries? We do not know the answer, but hope that the implications of the review are valid, nonetheless.

2 HOW DOES TRAFFIC LAW ENFORCEMENT INFLUENCE SAFETY

The direct objective of Traffic Law Enforcement (TLE) is to assure compliance with traffic law. However, the social justification for investing in TLE and imposing restrictions and sanctions on people rests on the belief that TLE is contributing to efficient traffic and to safety. Demands for more, or more effective TLE are, almost always, linked to bad safety situation or promises to improve it.

There are basically two mechanisms through which TLE could prevent accidents or reduce their severity. One is transparent and tangible and the other is somewhat more speculative in nature. The system management aspect of TLE helps maintain traffic and roadway conditions that pose fewer hazards to road users and, therefore, generate fewer risks, fewer errors, fewer conflicts and, ultimately, fewer accidents. Traffic regulations, police re-directing traffic, police removing defective vehicles off the roads, are clear examples of system management functions.

The second mechanism is based on a chain of logic that begins with the assumption that a substantial share of traffic accidents are caused, directly or indirectly, by road users failing to comply with traffic regulations. There is, indeed, sufficient evidence to support an association between non-compliance and accidents (see Zaidel, 2001). Road systems with a high rate of non-compliance experience high accident rates and, similarly, drivers who do not comply with traffic regulations are also over-involved in accidents.

The next step is to assume that TLE can substantially reduce non-compliance in the traffic system. While there is little doubt that TLE <u>can</u> influences traffic and driver behaviour, it is also clear that non-compliance remains very common on all European roads (see Zaidel, 2001). The hypothesised mechanisms of fear-based deterrence (specific and general) and probability of detection cannot be expected to fully account for TLE success or failure, nor can they exclusively direct its policy (Harrison, 1998; Zaidel, 2000).

The last step in the chain of logic for the non-compliance / deterrence based mechanism for improving safety, is that TLE can decrease non-compliance where it matters; that is, with respect to behaviours, locations, times, drivers and situations that matter for safety. This is not a trivial assumption, since <u>almost all</u> non-compliance events <u>do not</u> lead to accidents. It is possible for policing efforts to change non-compliance incidence or distribution yet not affect accidents. There have also been cases were TLE had had no impact on non-compliance yet there was a change in accidents. The theoretical and practical implications of these situations are not well understood (Zaidel, 2001).

It is most likely that both influencing mechanisms are at work when TLE is applied, but traditionally most attention was given to the 2nd mechanism, which focuses on individual drivers and legal sanctions. For example, discussions of automated speed enforcement often describe how each element in the process is designed to enhance the presumed mechanism of high cost (punishment), high subjective probability of being detected, specific deterrence and wide general deterrence-all leading to higher compliance (e.g. Oei, 1996; Zaidel and Makinen, 1999).

Oei reported impressive reductions in mean speeds and in speeding rates as a result of operating automated photo-radar and warning systems. Based on this record he estimates that reduction in accidents of 25 to 65% can be achieved.

Because of the chain of assumptions involved in the deterrence mechanism, failure to achieve safety gains with TLE is difficult to interpret and correct. It could be poor planning or performance by traffic police, but it could also be a logical flaw in one or more of the assumptions in the chain of logic.

3 POTENTIAL IMPACT OF TLE ON ACCIDENTS

The impact of enforcement can be estimated as the potential accident savings resulting from having all drivers comply with all traffic laws and regulations all the time. It is evident that much of the compliance is voluntary or a result of successful socialization mechanisms not depending on active policing. Therefore, such estimates are the maximum value estimates for TLE impact.

Estimates are primarily based on three sources of data. The first is the extent of involvement of a non-compliant behaviour in accidents as a causal factor. Examples are speeding, drink-driving, talking on a cellular phone (where it is illegal). The second source of data is involvements of driver, vehicle or environmental conditions in accidents and engineering or medical assessments of crash mechanisms and severity. For example, the involvement of visibility conditions in accidents gave rise to daylight running lights requirement and to estimates of the number of accidents saved as a result of it. Similarly, understanding of crash dynamics prompted various vehicle safety requirement and safety belt laws, whose impact was estimated.

The third source of data for estimating the potential savings of full compliance are evaluations studies of the actual benefits of introducing new legal requirements (such as wearing helmets) or enforcing existing laws, (such as speeding). When accident savings are associated with concurrent compliance levels, extrapolation to the impact of full compliance can be made. This estimate is confounded, of course, with the effectiveness of enforcement to begin with.

A recent policy review estimated that about 50% of traffic accidents in Europe could have been prevented if road users were completely dissuaded from committing traffic violations (ETSC, 1999). An earlier report (ETSC, 1996) proposes that if every car occupant in EU countries had used safety belts during 1996 (at that time 75-80 % of front seat occupants reported using them), about 10,000 out of the 25,000 fatalities who were car occupants would have been saved.

The Norwegian Traffic Safety Handbook gives the following estimates (based on meta-analysis of studies in many countries) of the potential safety impact of full compliance with traffic regulations (Table 1, adapted from Elvik, Mysen and Vaa, 1997).

Table 1: Potential of reduction in personal injuries and fatalities assuming full compliance (Adapted from Elvik, Mysen and Vaa, 1997)

	Per cent change in number of injuries and fatalities (95% confidence interval)	
Main groups of traffic laws	**Injured persons**	**Fatalities**
Speed limits	-9 (±5)	-15 (±8)
Use of protective equipment	-5 (±3)	-14 (±8)
Alcohol Laws	-3 (±2)	-10 (±7)
Other behavior rules in traffic	-8 (±6)	-7 (±5)
Vehicle technical requirements	-1 (±1)	-1 (±1)
Requirements of drivers	-1 (±1)	-1 (±1)

No single category of non-compliance accounts for a overwhelming majority of accidents but, clearly, full compliance with speed regulations, avoiding drink-driving and always using protective devices could save up to 38 % of fatalities and up to 17% of other traffic injuries. The same handbook estimates the collective safety impact of all forms of driver punishment to be 10%, for all injury accidents.

A more specific estimate for Norway suggests that if 16 of the most frequent traffic law violations were eliminated, the number of fatalities could be reduced by 48% and the number of casualties could be reduced by 27% (Elvik, 1997). Preliminary similar estimates for Sweden (Elvik, 1999) suggests that by eliminating traffic violations, the number of fatalities in Sweden could be reduced by 76% and the number of casualties by 48%.

Provided such estimates are valid for Norway or Sweden it is likely that similar gains could be made in most other motorised countries. Evans (1991), for example, has estimated that the number of traffic fatalities in the United States could be reduced by about 40% if just drink-driving was eliminated. Lowering the legal BAC limit from 80 mg% to 50 mg% was estimated to have the potential of reducing total fatalities in Canada by 6% to 18% (Mann et al 1998).

It should be noted that all these estimates are not very accurate. The record shows that they often tend to overestimate the impact of safety regulations and thus also the impact of their enforcement. The overestimates are about the contribution of violations to accidents and about the possibility of eliminating the violations by conventional enforcement. Depending on the length of the list of regulations (and other safety measures) it is quite possible to accumulate estimates of accidents savings that surpass the count of actual accidents.

One methodological reason for inaccuracies or discrepancies in estimates is the fact that they are based on different samples of "relevant accidents", a fact often lost in subsequent generalizations. Another problem stems from the fact that TLE consists of legislation, police surveillance, non-compliance detection, punishment and other legal or administrative consequences.

It is difficult to separate the effects of each step in the process, as they are inter-dependent. For example, recent lowering of the legal BAC level in Austria has had a strong effect on alcohol related accidents (Bartle and Esberger, 2000). The authors stress the role of the public legal step, media support, mandatory psychological driver improvement courses <u>and</u> persistent police enforcement for drunk drivers in bringing about the less drink-driving and fewer accidents.

4 SAFETY IMPACT ASSESSMENT OF POLICE ENFORCEMENT

The impact that enforcement has had on the number of accidents and their severity was evaluated in many studies varying in scope, methodology and, one must assume, also in reliability. Zaal (1994) has reviewed much of the research up to that time. Few years later, Elvik, Mysen, and Vaa (1997) published, in their Handbook of Traffic Safety, the results of a meta-analysis that estimated the safety benefits of police enforcement. In the analysis they included many of the studied reviewed by Zaal, when they conformed to the methodological requirements of the analysis. The present chapter is based in part on that meta-analysis but also on more recent evaluations. The structure of this chapter follows the contribution by Vaa (1999) with additional material interspersed where appropriate.

4.1 MANUAL SPEED ENFORCEMENT

The literature on the effects of police enforcement on speeding behaviour, accidents and injuries has often failed to give precise descriptions of the enforcement methods used (ETSC 1999). In addition, many experiments involve the use of more than one method, which makes it difficult to attribute the effects to any specific enforcement method. However, one useful way to sort studies is to make a distinction between manual and automated methods of speed enforcement.

A manual (and stationary) method generally involves a configuration that includes an observation unit, typically an unmarked police car more or less hidden at the roadside, and an apprehension unit comprising one or more marked police cars, clearly visible. The observation unit will have a measurement device such as radar or a laser device and possibly a documentation device, such as a still or video camera. Speeding vehicles are detected at the first station, their description is relayed to the apprehension unit downstream, which flags them to stop and issues citations to drivers.

Earlier literature on enforcement distinguishes between stationary and mobile speed enforcement methods. The distinction mainly referred to surveillance by moving patrol cars versus surveillance by clearly visible parked patrol cars. The method of speeding detection at the time was mainly manual (and only manual in the US), and often the detecting police unit also gave chase to the speeding vehicle, rather than working in tandem with an apprehension unit.

Speeding detection methods were varied as well, and included car following and speedometer matching, timing passage through a marked distance on a road section, speed-guns, photo-radar and other methods. In general, the US and Australia came relatively late, compared to EU countries, into using high yield and evidential equipment and methods. These facts need to be considered when evaluating together studies from different countries and periods.

The following 17 reports have evaluated the effects of manual (mostly stationary) speed enforcement on the number of accidents. In some studies, the method used have been pure stationary, in other reports the enforcement activity has been a composite, i.e. stationary speed enforcement was one of the elements among other methods used.

Novak and Shumate (1961, Wisconsin - USA)
Ekström, Kritz og Strömgren (1966 - Sweden)
Andersson (1991 - Sweden):
Brackett and Beecher (1980 - Texas USA)
California Highway Patrol (1966 - USA)
Campbell and Ross (1968 - Connecticut, USA)
Carlsen and Svendsen (1990 - Norway)
Carr, Schnelle and Kirchner (1980 – USA)
Kearns and Webster (1988 - Australia).
Legget (Australia, Tasmania – 1988)
McCartt and Rood (1989 - New York USA)
Munden (1966 - England)
Roop and Brackett (1980 - Texas USA)
Sali (1983 - Idaho USA)
Salusjärvi and Mäkinen (1988 - Finland)
Saunders (1977 - Australia)
Statens vegvesen Buskerud/Utrykningspolitiet (1996 - Norway)

A meta-analysis of the results from the above studies is presented in Table 2.

Table 2: Best estimates of the effects of manual / stationary speed enforcement
Best estimates and confidence intervals (CI = 95%) of the effects of manual / stationary speed enforcement on accidents. Percentage change of the number of accidents (from Elvik et al, 1997).

	Percentage change of the number of accidents		
Injury level	**Accident types affected**	**Best estimate**	**CI (95%)**
All	All	-2	(-4; - 1)
Fatal accidents	All	-14	(-20; - 8)
Injury accidents	All	-6	(-9; - 4)
Property-damage-only	All	+ 1	(-1; + 3)

The overall effect of manual speed enforcement on accidents is a reduction of the number of accidents by 2%. However, the reduction in fatal and injury accidents is much higher, –14% and –6%, both statistically significant. The 1% increase in damage-only accidents was not significant.

An Australian study reported results of eleven months of aerial speed enforcement in New South Wales (Kearns and Webster, 1988). The method is essentially manual, as it involves a coordinated stopping, by a patrol car, of single vehicles spotted by aerial surveillance. The program resulted in a vehicle crash reduction of 22%. However, this program was not continued.

4.2 AUTOMATED SPEED ENFORCEMENT WITH CAMERAS

Automated speed enforcement refers to various departures from the conventional procedure where a police officer stops a speeding vehicle and hands the driver a speeding citation. One truly automated system operates on a major highway in The Netherlands (Malenstein and van Loosbroek, 1997).

Briefly, permanent video cameras spaced along the road, digitally record every passing vehicle at a number of locations. A computer program identifies licence plate numbers and vehicle features and tags all vehicles that were speeding between two camera posts. The list of violating vehicles is automatically matched against a database of vehicle owners, citations are automatically issued and letters are automatically generated with a bank code for paying the fine and mailed to owners. When the fine is paid, the event is closed.

In practice, most so called automated systems, especially in the past, are only partially automated, at one or more steps of the process. A common semi-automatic mode of operation is one where the detection unit at the roadside, usually within a parked police car (clearly visible, hidden, or unmarked) equipped with photo-radar or similar device, records speeders but instead of stopping them the photo evidence is processed in the office and citations are sent to vehicle owners. In some countries, the processing of automatically detected speed violations was, or still is, a largely manual and labour intensive process. See Zaidel and Mäkinen (1999) for more details on the various methods of automated speed enforcement.

The following nine studies were included in the meta-analysis. They represent different degrees of automation and various legal settings regarding issues of owner responsibility and driver identification. For example, some studies cover unattended cameras fixed to poles while others refer to visible, hidden, or unmarked patrol car units with photo-radar equipment. In some countries citations were sent to vehicle owners who had little choice but to pay, in others police had to prove the identity of the offending driver.
Blackburn and Gilbert (USA 1995)
Cameron, Cavallo and Gilbert (Australia 1992)
Hook, Kirkwood and Evans (England 1995)
Krohn (Norway 1996)
Lamm and Kloeckner (Germany 1984)
Nilsson (Sweden 1992)
Oei (the Netherlands 1994)
Swali (England 1993)
Winnet (England 1994)

Based on the results from these nine studies, the best estimates of the effect of automated speed enforcement on accidents are presented in the Table 3.

Table 3. Best estimates of the effects of automatic speed enforcement on accidents
Best estimates and confidence intervals (CI = 95%) of the effects of automatic speed enforcement on accidents. Percentage change of the number of accidents (from Elvik et al, 1997).

	Percentage change of the number of accidents		
Injury level	**Accident types affected**	**Best estimate**	**CI (95%)**
All	All	-19	(-20; - 18)
Casualties	All	-17	(-19; - 16)
All	Accidents in urban areas	-28	(-31; -26)
All	Accidents in rural areas	-4	(-6; - 2)

When all levels of injury are combined, the effect of automated speed enforcement on the number of accidents shows a reduction of 19%. Considering casualties only, the accident reduction is 17%. Speed cameras have a larger effect in urban areas (28% reduction) than in rural areas (4% reduction). All reductions presented in Table 3 are statistically significant. The accident data do not allow a separate estimation of the effect on fatalities.

The Netherlands has pioneered the testing and implementation of several speed control schemes based on fixed and mobile photo-radar cameras, video cameras, automatic warnings and automated office citation processing. Oei (1996) presented data on safety impacts found in several of the studied there. Automatic speed warnings coupled to photo-radar camera system operating from either an unmarked parked vehicle or from fixed poles have been evaluated. Two-lane rural road stretches experienced a 35% reduction in the total number of accidents. The effect remained at the same level three years after concluding the experiment.

4.3 AUTOMATIC ENFORCEMENT OF RED LIGHT VIOLATIONS

Red light cameras (RLC) at signalised intersections have been in use for many years in EU countries. Yet, at the time of the meta-analysis the number of studies evaluating the effects of RLC on accidents were rather few. The meta-analysis was based on just three reports.
Hillier et al (Australia 1993)
South et al (Australia, 1988)
Statens vegvesen (Norway, 1996)

The Australian studies are by far the most comprehensive ones as they are based on nearly 1,000 accidents in the before-periods. A common feature in all of the studies is that a posted warning sign in advance of the RLC site has informed drivers of the automatic surveillance of red light violations. The best estimates of the effect of RLC on accidents are presented in Table 4.

Table 4: Best estimates of the effects of Red Light cameras on accidents
Best estimates and confidence intervals (CI = 95%) of the effects of automatic surveillance of red light violations on accidents. Percent change of the number of accidents. (From Elvik et al, 1997).

	Percent change of the number of accidents		
Injury level	**Accident types affected**	**Best estimate**	**CI (95%)**
All levels	Accidents at junctions regulated by traffic signals	-11	(-18; -3)
Fatal accidents	Accidents at junctions regulated by traffic signals	-45	(-17; + 260)
Injury accidents	Accidents at junctions regulated by traffic signals	-12	(-20; -2)
Property-damage-only acc.	Accidents at junctions regulated by traffic signals	-9	(-22; + 7)
Injury accidents	Right-angle accidents	-31	(-53; + 2)
Injury accidents	Rear-end collisions	-15	(-42; + 24)

The best estimate of the effect of red light cameras on all accidents is a reduction of 11%, which is statistically significant. The reduction of all injury accidents is by 12% and also significant. The reduction in the sub-categories of fatal accidents, property-damage-only accidents, right-angle accidents and rear-end collisions were not statistically significant. Other studies have also found decreases in accidents following installation of RLC at high-accident intersections (Chin, 1989; Ng, Wong, and Lum, 1997; Retting et al., 1999).

The South et al (1988) study linked violation rates to changes in the number of accidents. They report that the 6.6% overall decrease in the number of accidents at 41 urban and sub-urban intersections in Melbourne was associated with a large decrease in red light violations. From a frequency of 300 violations per week at the sites to 20 per week, more than 90% reduction.

However, subsequent re-analysis of the data cast doubt on the very positive earlier results (Andreassen, 1995). This new report points out several methodological difficulties in the original selection of sites and in the analyses of the earlier evaluation. For example, that prior study did not clean the accidents database sufficiently. The new conclusion is that the installation of the RLC at the 41sites did not provide any reduction in accidents, compared to "before period" and to other signalised intersections. Specifically, it identifies an increase in rear end accidents and accidents on the approach legs without cameras.

Another analysis (Kent et al, 1995) of a sample of signalised intersections in the same metropolitan area (Melbourne, Australia), which by then boasted 120 RLC installations, found no significant relationship between the frequency of crashes at RLC and non-RLC sites and differences in red light running behaviour. This study also found that camera and non-camera sites did not differ in the rate of RL encroachments (red light running) and it suggests to reduce the small incidence of encroachments with improved engineering design.

Unlike speeding, RL violations often reflect poor design at specific intersections or even at one leg of an intersection. Before rushing in to install RLC, authorities should examine the role of proper engineering design of signalised intersections in reducing the incidence of both non-compliance and accidents. There is certainly sufficient evidence for safety benefits of proper RL design (e.g. Retting, Williams and Greene 1998; Retting et al, 2001; Datta, Schattler and Datta 2001; and see Zaidel, 2001, sec. 2.1.1).

It is very likely that the positive impact of RLC found in most early implementation trials and evaluations was a real effect (even after discounting biased selection of sites and regression to a mean). However, as design standards and operation of signals improved, and as old sites were upgraded (sometimes as a result of data provided by RLC), the marginal contribution of RLC cameras to safety can be expected to declined, even to the point of negative contribution (e.g. front-rear collisions).

4.4 DRINK-DRIVING ENFORCEMENT

Drink-driving, more than any other non-compliance issue, was always considered a social behaviour issue, even a medical issue, and not just an issue of individuals not obeying the law. Therefore, enforcement of drink-driving is usually considered a package of measures, with direct policing on the road being one component, albeit an important one. The list below describes the characteristics of major drink-driving programs, in terms of the activities undertaken by police and other participants in the program.

The list of studies included in the meta-analysis gives further information on TLE measures included in each specific study.

"ASAP": "Alcohol Safety Action Projects" - consists of drunken driving enforcement, judicial investigations concerning the identification of individuals with an alcohol problem, rehabilitation of problem drinkers, information and education.

"STEP": "Selective Traffic Enforcement Project": A strategy especially applied in the USA and Canada. STEP comprise three main components: Education/information, enforcement and sanctions, and evaluation.

"RBT": "Random Breath Testing": Drink-driving enforcement performed in a random manner, i.e. there is no requirement of suspected drunken driving in advance of stropping a driver and applying a breath test. RBT are common in EU, Australia and NZ, and are only recently being introduced to some jurisdictions in the US.

The following 36 studies were included in the meta-analysis:

Amick and Marshall (1983 - USA) Drunken driving enforcement, sentences, paroles and rehabilitation

Bailey (1995 - New Zealand): Enforcement of drunken driving ("CPT": "Compulsory Breath Testing")

Broughton and Stark (1986 - England): Enforcement of drunken driving and stricter punishment

Cameron and Strang (1982 - Melbourne, Australia): Intensified enforcement of drunken driving (RBT)

Cameron, Strang and Vulcan (1981 - Victoria, Australia): Enforcement of drunken driving (RBT)

Derby and Hurst (1987 - New Zealand): Enforcement of drunken driving (RBT)

Deshapriya and Iwase (1996 - Japan): Licence revocation

Engdahl and Nilsson (1986 - Sweden): Intensified enforcement of drunken driving (RBT)

Foley (1986 - USA): Enforcement of drunken driving accompanied by a media campaign

Hagen (1978 - California, USA): Licence revocation

Hingson et al (1987 - Massachusetts, USA): Stricter punishment, fine, licence revocation and prison/treatment

Homel (1988 - New South Wales, Australia): Enforcement of drunken driving (RBT)

Hurst and Wright (1981 - New Zealand): Intensified enforcement of drunken driving, media campaigns before and after enforcement

Johnson et al (USA - 1976): Drunken driving enforcement ("ASAP")

King (1988 - Australia): Enforcement of drunken driving (RBT)

L'Hoste, Duvall and Lassarre (1985 - France): Enforcement of drunken driving (RBT)

Mann et al (1995 - Canada): Treatment of alcohol and drug addicts

Neustrom and Norton (1993 - Louisiana, USA): Stricter sanctions: Fines, licence revocation, community service and workshops

Nilsson, Engdahl and Nilsson (1986 - Sweden): Enforcement of drunken driving (RBT)

Preusser, Blomberg and Ulmer (1988 - Wisconsin, USA): Licence revocation

Preusser, Ulmer and Adams (1976 - USA): Rehabilitation and licence revocation

Ross (1977 - Cheshire, England): Drunken driving enforcement ("ASAP") and campaign

Ross (1982 - England) Enforcement of drunken driving

Ross and Klette (1995 - Norway, Sweden): Change of sanction/punishment: From imprisonment to fines

Sadler, Perrine and Peck (1991 - California, USA): Treatment and licence revocation

Sali (1983 - USA): Intensified enforcement of drunken driving ("STEP")

Smith, Maisey and McLaughlin (1990 - Western Australia): Enforcement of drunken driving (RBT)

Thomson and Mavrolefterou (1984 - Australia): Enforcement of drunken driving (RBT)

Törnros (1995 - Sweden): Intensified enforcement of drunken driving accompanied by campaign

Vaas and Elvik (1992 - Norway): Change of sanction/punishment: From imprisonment to fines

Vingilis and Salutin (1980 - Canada): Enforcement of drunken driving and information

Vingilis et al (1990 - Canada): Fines and licence revocation compared to imprisonment and licence revocation (the same results also published in Mann et al (1991))

Voas and Hause (1987 - California, USA): Intensified mobile patrolling/enforcement of drunken driving at night-times in weekends

Wells, Preusser and Williams (1992 - New York, USA): Enforcement of drunken driving

Wolfe (1985 - USA): Enforcement of drunken driving accompanied by a media campaign

Zador (USA - 1976): Drunken driving enforcement ("ASAP")

A majority (26) of these studies have evaluated the impact of drink-driving policing alone or in combination with another measure --usually an accompanying media campaign. Seven of the studies evaluated licence revocation, as the only measure, or compared it with other types of sanctions such as fines, imprisonment or community work. Six of the studies have evaluated some type of driver treatment, mostly as an alternative to other measures such as licence revocation. Seven of the studies evaluate effects of changes in sanctions. The reason why the number of measures exceeds the number of studies is because a study may evaluate more than one measure or the joint effect of two or more measures.

In cases where it was not possible to separate in the analysis the effects of different measures, the study was categorised according to the measure that has been considered, in the original study, as the most predominant. Usually it was the police enforcement component.

Table 5 presents the effects on accidents of different measures, or groups of measures.

Table 5: Effects of drink-driving enforcement, licence revocations, sanctions / punishment and treatment / rehabilitation, on accidents.
Best estimates and confidence intervals (CI = 95%) of the effects on accidents of drunken driving enforcement, licence revocations, changes in sanctions/punishment and treatment/rehabilitation. Percent change of the number of accidents. (From Elvik et al, 1997).

	Percent change of the number of accidents		
Injury level	**Accident types affected**	**Best estimate**	**CI (95%)**
Enforcement of drunken driving			
All	All	-3,7	(-4,2; - 3,2)
Fatal accidents	All	-9	(-11; - 6)
Injury accidents	All	-7,1	(-7,6; - 6,6)
Fatal and injury accidents	Night-time/single accidents	-7	(-9; - 5)
Fatal and injury accidents	Daytime accidents	-12	(-15; - 9)
All	Accidents in urban areas	-3	(-4; -2)
All	Accidents in rural areas	-2,6	(-4,5; - 0,6)
All	Pedestrian accidents	0	(-3; + 2)
Licence revocation alone			
All	All	-18	(-19; - 16)
Treatment/rehabilitation as alternative to licence revocation:			
All	All	+ 28	(+ 21; + 36)
Injury accidents	All	+ 15	(-1; + 35)
Property-damage only	All	+ 41	(+ 18; + 70)
Treatment alone:			
All	Alcohol-related accidents	-27	(-86; + 274)
Fine, licence revocation, imprisonment (all components joined)			
All	All	-4	(-5; - 3)
Change of sanction: From imprisonment to fines			
All	All	-4	(-5; - 3)
Fatal accidents	All	-19	(-24; - 14)
Injury accidents	All	-3	(-4; - 2)

The overall effect of controlling drink-driving by direct policing and all other accompanying measures is a reduction of accidents by 3,7%. A further breakdown shows that reductions of fatal and injury accidents are 9% and 7% respectively. It is somewhat surprising that the effect on daytime accidents seem to be larger than at nighttime as the daytime reduction is 12% compared to 7% at nighttime. All reductions are statistically significant.

Revocation of driving licence alone has reduced the number of accidents by 18% and is thus the most effective measure in reducing the number of alcohol-related accidents. Using treatment and rehabilitation as alternatives to licence revocation seem, however, to increase the number of accidents by as much as 28%. Both estimates are statistically significant.

A differentiated application of fines, licence revocation and imprisonment has been used alongside the introduction of drink-driving laws in several American states and in Canada. The joined effect of all three components is estimated to be a statistically significant 4% reduction in the number of accidents.

A change from straight imprisonment to a differentiated use of fines and conditional / unconditional imprisonment, depending on the level of alcohol in the blood or breath, has reduced the number of accidents by 4%. The effect on fatal accidents is larger than on injury accidents with reductions of 19% and 3% respectively. These estimates are based on the changes of drinking-driving laws in Norway (1988) and Sweden (1990).

The state of Victoria in Australia has had RBT program for many years. Patrolling officers as well as special bus teams participate in the testing. In 1993 a decision was made to increase the scope of the program, especially on rural roads. Policing effort was accompanied with substantial media coverage. Nearly 800,000 tests were conducted annually. Even by EU Nordic countries standards this is a sizable amount of tests in relation to Victoria's four million population.

One-year accident evaluation found an overall 9% reduction in serious crashes during the typical drinking hours ("high alcohol hour"), compared to expected number of crashes (Cameron et al, 1997). One unexpected finding was that in regions of intensive media and enforcement activities, the major rural roads experienced a decline in drink-driving serious crashes, but there was an increase in crashes on minor rural roads in the same area. This has led to a recommendation to extend the RBT also to minor roads.

Random breath tests were introduced late to the US compared to many European countries, Australia or NZ. On the road drink-driving enforcement was, and still is, mainly based on stopping vehicles suspected to be driven by a drunk driver. One of the first evaluations of RBT (or sobriety checkpoint) is significant for the very careful experimental methodology used in the implementation of the program and its evaluation (Stuster and Blowers, 1995).

Six comparable but far apart California communities were selected to participate in the study. In four of the communities police conducted variants of sobriety checkpoints. A 2x2 implementation configuration was tested: staffing level (three to five officers vs.

eight to twelve) and mobility of the checkpoints (remaining in one location for the evening vs. three sequential locations within the city).

In the fifth community police implemented a conventional program of aggressive roving patrols that focused on DWI enforcement. The level of effort devoted to the roving patrols was equal to the officer hours required to operate the high-staffing level checkpoints. The police in the sixth community refrained from implementing any special DWI enforcement effort for the duration of the project and served as another control site.

The project lasted nine months and checkpoints were set twice a month on the average. Public information and education programs supported the special enforcement efforts. Crash, arrest, and BAC data were obtained from the participating police departments and a state reporting system. State-wide data provided additional comparisons.

The checkpoint communities experienced declines in the proportions of alcohol-involved crashes of 43%, 32%, 19%, and 16%, while the state-wide decline for other communities was only 8%. In the control communities there was a 5% decline in alcohol related accidents. Logistic regression analysis indicated alcohol involved crashes declined significantly in the checkpoint sites, and did not change significantly at the comparison sites. Comparing with state-wide data, the reduction of accidents at checkpoint communities was more than 3 times greater.

There were no significant differences among the four configurations of checkpoints tested in this study. Thus, decisions regarding an optimum checkpoint configuration can be made on the basis of other factors.

A recent review of the Austrian experience with controlling drink-driving demonstrated the potential and limitations of setting lower legal BAC limits (Bartl and Esberger, 2000). In 1992 the legal BAC limit for novice drivers was lowered from .08% to .01%. Five-year accident data showed a 30.9% reduction in injury accidents in contrast to a reduction of only 5.9% in the group of experienced drivers. Later, in 1998, the legal BAC limit for all drivers was lowered from .08% to .05%. In the first year the drink-driving injury accidents fell by 10%, but the gain declined over time, and in the second year there was even an increase in drink-driving accidents.

4.5 ENFORCEMENT OF SEAT BELT USE

For many years the issue of safety belt enforcement was first making the use of safety belts mandatory. Even after it has become mandatory, in most EU countries, for all vehicle occupants to wear safety belts, many jurisdictions do not target non-compliance with this regulation for primary enforcement and the violation is considered a minor one (Zaidel, 2000b). In some countries no record is kept of safety belt enforcement.

Evaluation studies have dealt mainly with the impact of mandatory use law on wearing rates or with the possibilities to raise wearing rates through various programs, including enhanced enforcement. The separate effect of direct policing of safety belt use on accidents or injuries was difficult or impractical to evaluate. Two USA studies from New York and North Carolina reported small (4% to 8%) but not statistically significant accident reduction as a direct consequence of police safety belt enforcement (Wells, Preusser and Williams, 1992; Williams, Reinfurt and Wells, 1996).

4.6 WARNING LETTERS, PENALTY POINT SYSTEMS AND LICENCE REVOCATION

Eleven reports about the effects of warning letters, penalty point systems and licence revocation on accidents were considered in the meta-analysis (some of the studies addressing revocation of driving licence, were also considered in the section on drink-driving).

Deshapriya and Iwase (1996 - Japan): Revocation of driving licence
Drummond and Torpey (1985 – Australia/Victoria): Penalty point system and driver improvement course
Epperson and Harano (California, USA - 1975): Warning letter and leaflet
Hagen (1978 - California, USA): Revocation of driving licence
Jones (Oregon, USA - 1987): Revocation of driving licence
Jones (Oregon, USA - 1997): Two different types of warning letters
Kadell (California, USA - 1987): Two penalty point systems and a driver improvement course
Kaestner, Warmoth and Syring (Oregon, USA 1967): Three different types of warning letters
McBride and Peck (California, USA 1970): Comparison of three different types of warning letters
Preusser, Blomberg and Ulmer (1988 - Wisconsin, USA): Revocation of driving licence
Utzelmann and Haas (Germany -1985): Penalty point system

Table 6 presents the results from the meta-analyses.

Table 6: Effects of warning letters, penalty point systems and licence revocation, on accidents.

Best estimates and confidence intervals (CI = 95%) of the effects on accidents of warning letters, penalty point systems and revocation of driving licence. Percent change of the number of accidents. (From Elvik et al, 1997).

	Percent change of the number of accidents		
Injury level/Measure	**Accident types affected**	**Best estimate**	**CI (95%)**
All	All	-12	(-14; - 9)
Fatal and injury accidents	All	-17	(-18; - 15)
Property-damage-only acc.	All	-9	(-15; - 3)
All/Warning letters	All	-15	(-18; -13)
All/Penalty point systems	All	-5	(-11; 0)
All/Revocation of licence	All	-17	(-19; - 16)

All effects shown are statistically significant. The overall effect of the measures, i.e. the joined effects of all three components, is a reduction of the number of accidents by 12%. The joined reduction of fatal and injury accidents is about twice as high as the effect on property-damage-only accidents, 17% reduction versus 9% reduction. The effects of warning letters and revocation of driving licence are of about the same magnitude and also about three times as high as the effect of penalty point systems.

The interpretation of the results is not simple. Each of the measures is a type of a sanction, which is a possible consequence of police enforcement but its application depends on criteria and decisions by other agencies. Each study evaluated a measure in a given context of TLE and the nature of the measures is such that comparison across contexts is uncertain at best.

5 ACCIDENT REDUCTION GAINS BY AREA-WIDE, ROUTINE ENFORCEMENT OPERATIONS

5.1 COMMUNITY LEVEL SPEED ENFORCEMENT

Numerous local safety projects that include an improved or intensified enforcing program take place in many countries. Many are considered a success by their initiators and participants; relatively few such projects underwent independent evaluation.

Stuster (1995) reported the evaluation of a municipal speed enforcement program in California. Three comparable and separated communities participated in the project that was planned according to an experimental design and lasted for six months. In two of the communities (A, B) police implemented special speed enforcement programs, in six zones within each community. The third community (C) served as a control, police there doing their regular work.

Officers in experimental communities spent, on average, eight hours each week conducting manual (radar and laser-assisted) speed enforcement in each of the special enforcement zones. Police also participated in public information and education activities related to the project. An external contractor collected, from all three communities, unobtrusive speed data and accident data.

Communities A and B experienced 19% and 10% reduction in number of vehicles exceeding the legal speed limit. In the control community C there was a reduction of 3%. In community A speed related accidents declined by 10.3%, in B by 1.1% and in C they increased by 3.4%. Times series analysis found that only the effect in community A was significant. The gain in safety was estimated to be 112 fewer crashes than expected.

As described in section 4.4 of this review, Stuster and Blowers (1995) demonstrated a substantial accident reduction as a result of a community level enforcement application of RBT (sobriety checkpoints). The methodology of the evaluation study was similar to the one on speed enforcement.

5.2 STATEWIDE SPEED ENFORCEMENT PROGRAM IN BRITISH COLUMBIA

Chen et al, (2000) evaluated a provincial enforcement program in British Columbia, which targeted speeding as a major cause of accidents. Automated Photo Radar for speeding control, based on mobile units, was introduced in British Columbia on a province (statewide) basis in 1996. The stated goal of the enforcement program was to reduce mean speeds by 3% on roads throughout the province, hopefully leading to a reduction in the number of speed related traffic injuries, which reached 8000 in 1995.

The program is based on special speed enforcement police teams operating 30 vans equipped with photo radar linked to laptop computer. Vehicles are usually not stopped. Tolerance threshold is usually 11 km/h. The photo is printed on the ticket, along with the all details of the violation. Fine is $100.00–150.00, depending on amount of speeding. The teams usually operate in daytime at sites of high accident history and at locations where there is a perceived speeding problem.

The program started on 1 March 1996. From March to July, the owners of the speeding vehicles were issued warning letters. Starting 2 August 1996 the owners of speeding vehicles began to receive violation citation tickets. A major education and media campaign accompanied the program.

In the first year of operation, the photo radar units were deployed for a total of approximately 30,000 hours, and issued 250,000 citations. This utilization level and citation output level are not particularly intensive but are similar to levels reported in Australia, NZ, Israel, and in EU countries using mobile, semi-automated photo-radar.

The program evaluation study considered the accident data, radar-based speed data collected at the time of enforcement, and independent speed data monitored continuously at a sample of 19 locations not near enforcement sites.

The program has had clear influence on speeding behaviour in the province. The percentage of vehicles driving over the posted speed limits dropped from 66% in May 1996 to 33% at the end of the year. The proportion of speeding vehicles at the deployment sites has remained since at below 40%. The percentage of vehicles exceeding the speed limit by 16 km/h or more dropped from 10.5% in May 1996 to 2.6% at the end of the year.

At the independent speed monitoring sites across the province the percentage of vehicles driving over the posted speed limits dropped from 69% before the start of the program to 61% after the start of the ticketing phase of the general, photo-radar based, speed enforcement program.

The impact on safety was analyzed using simple 'before and after' comparison, time-series cross-sectional analysis, and interrupted time series analysis on speed related accident and injuries counts. Speed related collisions are those where the investigating police officer assigned 'unsafe speed' as a contributing factor to the collision.

To estimate the program effect, interrupted time series models were fitted to the series of monthly totals of daytime speed related collisions. Since the enforcement was mainly during the day formal evaluation was for daytime collisions although there appeared to be also night-time positive effects. Figure 1 shows monthly series of injuries from speed related collisions, during the day and during the night.

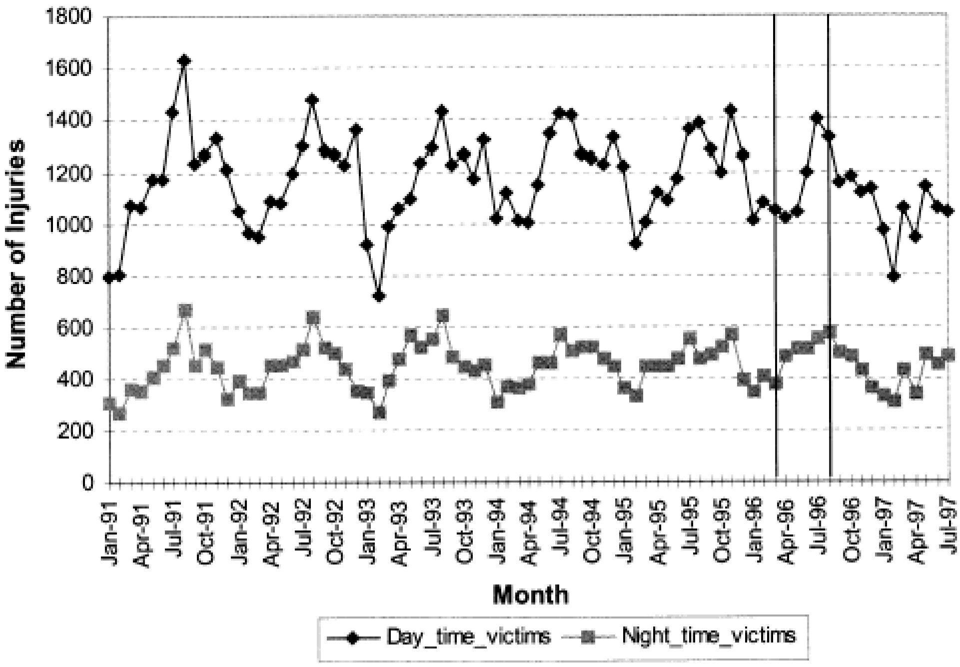

Fig. 1: Monthly traffic collision injuries in BC, by day and night (from Chen et al, 2000)

After August 1996, the start of the violation ticket phase, a substantial drop in the reported collisions occurred, compared with the forecasted numbers. The province wide reduction was about 150 daytime speed related collisions per month, which represents an approximate 25% reduction over the expected number (in BC police may be called to investigate damage-only accidents). In terms of injuries, similar analysis showed that the photo radar speed enforcement program saved 139 daytime traffic collision injuries per month, which represents approximately an 11% reduction in injuries and 17% reduction in fatalities over the expected number.

The authors are aware that the evaluation presented does not address the long-term effectiveness of the program and the possibility that its initial impact could wane over time. Nevertheless, as was shown in several states in Australia and in New Zealand, this program, too, demonstrates that a sustained speed control program covering a large part of the network, can deliver immediate safety benefits, which are substantial because of the accumulated small gains over a large area.

5.2.1 Corridor enforcement experiment for spill-over effect

A subsidiary study in British Columbia's evaluation of mobile photo radar tested more specifically the question whether the effects of speed enforcement are limited to the site of police operation or do they spill over" to adjoining road sections or areas (Chen, Meckle, and Wilson, 2002). One could ask the question in a negative implication-is there speeding or accident "migration" from locations with speed control to other roads sections.

One highway corridor, 22-km long, was selected for more detailed study. The corridor is a four-lane divided highway with concrete barrier median and speed limits of either 80 or 90 km/h. It runs through primarily rural or light residential land. Nine locations for parking the enforcement van and operating the radar were identified. One km on each side of the location was considered a photo-radar zone of influence (PRP); Road sections between the PRP zones were considered non-PRP zones.

The 2 km was selected on the basis of older "hallo effect" studies. The length of non-PRP locations varied from 0.4 km to 5.9 km. Non-PRP segments serve as control for the enforcement effect on the PRP segments. Another reference group of roads was selected from similar highways in BC (also subjected to the general, less intensive, photo-radar enforcement as all roads in BC were at the time). This reference group was needed for calculations of "Expected number of accidents" in the model building for statistical analysis.

Traffic speed and volume data at the PRP locations were collected with the radar units while they were operating at the site. All passing vehicles were recorded, not only speed violators. Traffic speed and volumes at non-PRP locations were measured continuously with unobtrusive detection loops at a monitoring site far from PRP location. Police-reported collision data were obtained for two years before and two years after the March 1996 milestone date, when the warning letter phase of the program started. Similar, more aggregated data from all four-lane divided highway segments in BC were used as the reference group to construct the collision model for statistical analysis. The total length of highway sections in the reference group is approximately 650 km.

Analysis included before– after comparisons and monthly trends analysis as descriptive statistics. Observational before– after method with comparison groups was used to estimate the safety effect. To control for regression to the mean and time effect, Empirical Bayes (EB) method was used. The steps in this analysis are described by the authors in clear detail worth repeating:

1) Fitting a traffic collision model for the reference groups to empirically estimate the prior distribution of the hypo-parameters for the before period;

2) Integrating the Expectation of prior collision with the observed collision counts, to arrive at the posterior Expected collisions for the before period;

3) Predicting the Expected collisions in the after period adjusting for time effect through comparison groups;

4) Comparing the predicted mean collisions calculated through the previous steps with the Expected collisions as measured by observed collisions at each location; and

5) Combining the estimates to derive aggregated program effects at PRP and non-PP locations, and for the study corridor as a whole.

Local police determined photo-radar deployment at each PRP section on the 22 km (x 2 directions) corridor. Their records show that the amount of enforcement varied from section to sections and from time to time. The total time of deployment over the year was 1313 hours, or averaging about 3.5 hours a day at some point on the corridor.

The mean and variance of speeds at the monitoring site (away from any enforcement site), averaged over the before and the after periods, are presented in Figure 2. The speed distribution clearly shifted to the left. Mean speed decreased by approximately 2.8 km/h, and the standard deviation declined by 0.5 km/h. The posted speed limit at the sites is 80 km/h.

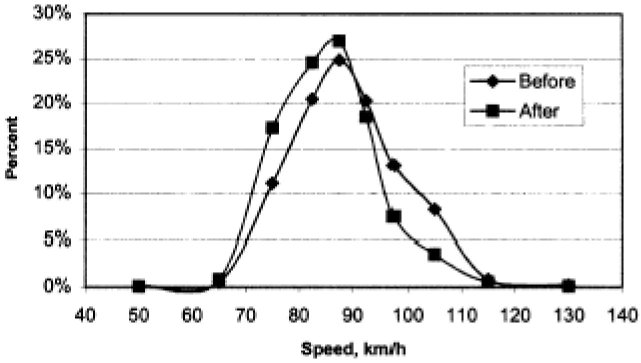

Fig. 2: Speed distribution near enforcement sites, before and after start of photo-radar experiment (from Chen, Meckle, and Wilson, 2002)

Table 7, adapted from Table 3 of the original article, shows the accident counts for the PRP and non-PRP segments, two years before and two years after the start of the photo radar enforcement program. The total counts dropped at both types of segments, even more so at the non-PRP segments. What happened on the other roads? The three police jurisdictions adjacent to the road corridor provided accident data for the same periods. Overall, the total number of collisions in the area declined from 609 two years before to 554 in the two years after, a 9 % reduction.

Table 7: Collision counts at Photo-Radar and non-PR locations (adapted from Chen, Meckle, and Wilson, 2002)

Segment type	**Apr 94–Mar 96 Before period No. of collisions**	**Apr 96–Mar 98 After period No. of collisions**
Enforcement segments-PRP	163	141
Near segments-non-PRP	161	116
	324	257

Following the Empirical Bayes method, outlined above, with the larger reference data, the adjusted estimates show that the enforcement program has led to a 14% (±11%) reduction in collisions at the PRP, "enforced", locations and a 19% (±10%) reduction on the non-PRP segments, more than 1 km away from the enforcement locations. The operation of the photo-radar vans at the corridor had a positive safety effect on all its segments regardless were exactly the vans were operating from.

Overall, the expected number of collisions on the treated corridor as a whole decreased by 16% (±7%). This was slightly more than the savings experienced on the whole network of the province at the same time, as reported by (Chen et al., 2000). The authors suggest that the calculated impact might be an underestimate of the effect of the specific enforcement program on the highway corridor because using "other roads" in the province as reference group may have suppressed the estimated impact.

The authors interpreted the finding of a similar enforcement effect throughout the whole corridor as support for a "spillover" effect. However, as the enforcement impact was actually stronger on non-PRP segments, the original notion of "spillover" effect does not seem appropriate here. From the point of view of traffic and drivers, the corridor had a somewhat more intense enforcement activity compared to other roads in the area, and the enforcement appeared to be random in time and location, conditions that helped maintain its influence.

5.3 SPEED ENFORCEMENT BY MOVING MODE PHOTO-RADAR IN VICTORIA, AUSTRALIA

In 1994 the state of Victoria in Australia embarked on an intensive program of speed enforcement using mobile photo-radar units operated from patrol vehicles. Over the next three years 73 such units were acquired. Victoria police prefers to use the units in a moving mode, automatically recording an on-coming, and speeding vehicle. They are used primarily on 100 km/h rural, undivided roads. Closely co-ordinated and specific media campaign accompanied the program.

At full capacity, the units had put about 900 hours of enforcement a week. This amounts to about 12 hours per unit per week, which is not very intensive. Interestingly, the same total amount of activity was carried out during the first year, with only 48 units available at the time. The operational effectiveness of the activity was measured as the number of offences detected per hour of operation. During July 1995-June 1996, the monthly rate on average was 0.68 offences per hour. However, during the following 12-month period, the monthly rate had increased to 0.83 offences per hour. The measure is confounding, however, the operational efficiency of detection with the true prevalence of non-compliance, which might have been going down, perhaps, after few years of enforcement?

A safety evaluation study of the impact of the mobile radar program was reported by Diamantopoulou, Cameron and Shtifelman (1998). The evaluation covered two years of operation. It was based on analysis of accident frequencies for the period in which the new units were operational (July 1995-June 1997) with the corresponding two-year period before their introduction (July 1992-June 1994).

Preliminary findings gave no evidence of crash reductions in the outer metropolitan regions where mobile radar was used. This was because there was little or no effect on accidents beyond four days after the enforcement was present. Therefore, subsequent analysis refers to roads in rural areas only, were there was a longer term, up to seven days effect.

The impact on accidents was apparently not clear-cut. Certain combinations of time slices used in analysis (4 days after enforcement in an area) and nature of publicity that accompanied the enforcement, produced higher accident reductions in specific rural roads, compared to "before" period. However, even the highest estimates (8% to 28%) were not significant. It is not obvious why the authors conclude, "the findings suggest that, in rural areas of Victoria, mobile radar enforcement is an effective tool for reducing casualty crashes on undivided highways."

5.4 STATEWIDE ENFORCEMENT PROGRAM IN ISRAEL

5.4.1 Short term evaluation of the enforcement program

A study in Israel (Hakkert et al, 2001) accompanied a one year concentrated effort by the National Traffic Police in Israel to increase general enforcement on 700 km of interurban roads (Project-700). The selected roads are the backbone of the interurban network. They accounted for 60% of all rural accidents and about half of the severe accidents. The enforcement project began in April 1997 and lasted for 1 year, aiming at a 10% reduction of severe accidents on those roads.

The evaluation included three components: (a) monitoring of everyday police operations (b) monitoring changes in drivers' attitudes and behavior and (c) evaluation of the impact of the enforcement program on accidents. The behavioural changes found in this study were examined in working paper 3 of ESCAPE, (Zaidel, 2001). Overall, during the campaign of Project-700 there was a general reduction in violation rates of most behaviours. The actual intensity of police enforcement activities varied over time and in different geographic areas corresponding to different police districts. These differences were taken in account in accident analyses.

Two periods (first four start-up months and next seven months with more intense enforcement), three geographic zones, two levels of enforcement within each zone, and a set of inter-urban 'Control road's were considered in the analysis of accident trends on Project-700 roads. A statistical model combining the odds ratio and time series methods was developed and applied to counts of all injury accidents, severe accident or counts of serious injuries.

Table 8, taken from Hakkert et al (2001), shows the summary results of the analyses on severe accidents.

Each value in the first two columns of Table 8 is the ratio of the number of serious accidents in a given "after" period (I or II) to the number of accidents in the corresponding "before" period in the previous year. The confidence intervals are shown in parentheses. Data were lost for roads in the south zone with lower intensity enforcement.

Table 8: Impact of general enforcement increase on severe accidents on inter-urban roads in Israel (from Hakkert et al, 2001).

Table 4
Odds ratios and estimated 'gains' for severe accidents on the project road groups

Evaluation period[a]	After/before ratio (odds) for the project roads	After/before ratio (odds) for comparison- group roads	Odds ratio	Estimated 'gain'[b]	Observed accident count[c]
Road group: north, higher police presence					
I	1.75	1.29	1.35	−7.74	29
	(0.93; 3.27)	(0.90; 1.86)	(0.66; 2.79)	(−19.09; 15.67)	
II	1.37	1.41	0.97	1.02	36
	(0.75; 2.50)	(0.99; 2.00)	(0.49; 1.95)	(−18.18; 39.48)	
Whole year	1.50	1.37	1.10	−5.92	65
	(0.88; 2.54)	(1.00;1.86)	(0.60; 2.02)	(−33.88; 45.61)	
Road group: center, higher police presence					
I	0.95	1.42	0.67	28.58	58
	(0.70; 1.29)	(0.94; 2.15)	(0.40; 1.12)	(−6.07; 86.64)	
II	0.76	1.32	0.57	58.02	76
	(0.57; 1.02)	(0.89; 1.96)	(0.35; 0.93)	(5.52; 143.62)	
Whole year	0.82	1.36	0.61	88.06	134
	(0.64; 1.06)	(0.96; 1.92)	(0.39; 0.93)	(9.85; 208.44)	
Road group: south, higher police presence					
I	0.85	1.06	0.80	4.18	16
	(0.47; 1.53)	(0.69; 1.64)	(0.38; 1.66)	(−6.53; 26.50)	
II	0.95	1.23	0.77	6.48	22
	(0.54; 1.70)	(0.80; 1.89)	(0.38; 1.59)	(−8.24; 36.67)	
Whole year	0.91	1.17	0.78	10.74	38
	(0.55;1.51)	(0.80;1.70)	(0.42; 1.46)	(−12.24; 53.72)	
Road group: north, lower police presence					
I	0.97	1.29	0.75	14.16	41
	(0.63; 1.48)	(0.90; 1.86)	(0.43; 1.31)	(−9.91; 56.26)	
II	1.25	1.41	0.89	11.58	90
	(0.86; 1.81)	(0.99; 2.00)	(0.53; 1.47)	(−29.21; 79.39)	
Whole year	1.14	1.37	0.83	26.51	131
	(0.82;1.59)	(1.00; 1.86)	(0.53; 1.31)	(−31.67; 118.13)	
Road group: center, lower police presence					
I	0.79	1.42	0.56	10.56	13
	(0.31; 2.00)	(0.94; 2.15)	(0.20; 1.54)	(−4.66; 52.51)	
II	0.65	1.32	0.49	19.58	19
	(0.27;1.60)	(0.89; 1.96)	(0.19; 1.31)	(−4.57; 83.76)	
Whole year	0.70	1.36	0.52	30.38	32
	(0.32; 1.55)	(0.96; 1.92)	(0.22; 1.22)	(−5.94; 116.43)	

[a] The project periods: I (first) 5/97–8/97; II (second) 9/97–3/98.
[b] 'Gain' corresponds to loss in the accident number due to the project.
[c] The observed accident counts for the before period and for the comparison group roads are given in Appendix A.

The odds ratios in the third column are between the ratios of Project roads to Control roads. An odds ratio smaller than 1 indicates fewer than expected accidents relative to the comparison category.

During the project’s life there was a general increase in accidents on most interurban roads. However, as Table 8 shows, in four out of five road groups, the mean values of the odds ratios were less than 1. This suggests that the special enforcement effort may have restrained the increase in comparison to control roads. Though consistent, the magnitude of the effects was small and only few of the specific comparisons (including an increase in accidents in the north group of roads with intensive enforcement) were statistically significant.

The original goal of reducing the absolute number of severe accidents by 10% has not been achieved. The authors seem to conclude that intensifying traffic enforcement over a large area, over a long time, using essentially the same police force instructed to re-deploy and put more effort while using the same routine methods-has its limitations.

An earlier evaluation of the safety impact that the National Traffic Police (NTP) in Israel might have had was carried out in 1993, as part of an organization and performance evaluation of the newly formed NTP (Hocherman, Zaidel and Hakkert, 1994). Similar analysis methodology (odds ratio and time series) was used with three “before” years as control period. Urban areas and inter-urban roads not patrolled by the new force served as control groups. Two level of enforcement intensity were included.

The results were not consistent. There was no dramatic drop in accident numbers or severity. The odds ratios method suggested improved safety (10 %) compared to the urban areas, but not compared to inter-urban control-roads. The time series analysis, which predicts the expected number of accidents if NTP had not been operating (and given the changes in traffic activity), suggested an average 12 % reduction in all injury accidents. This trend was apparent only in the second period of operation.

5.4.2 Longer term evaluation of the enforcement program

Few years later, a longer time series was available and the issue of the safety impact of the National Traffic Police, NTP, in Israel was re-examined by Beenstock, Gafni and Goldin (2001). They have analyzed 31 months (1993-1995) of accident data for road sections under the control of NTP. Number of citations issued on each road section was a proxy measure of enforcement intensity, allowing a dose-response type analysis. No comparison with roads not under NTP control was attempted.

The authors, two economists and a statistician, applied sophisticated multivariate regression techniques to explore both cross-section and time-series models. Problems in merging accident data and citation data resulted in a database covering 135 out of 170 road sections controlled by the NTP. The merged data of 10,500 accidents and 471,530 citations covered 60% of the citations and 75% of the accidents registered on all NTP roads.

An "observation" was a road section in a given month-135x31 = 4185 observations. Each observation could have citations and accidents associated with it. About 50% of the 4185 observations had had no accidents during a given month. The maximum number of accidents was 28 and the distribution declined monotonically. Monthly traffic volumes were estimated from annual counts. The intricacies of building the various models, which were tested against the data, can't be summarized here. The models tested the relationships between enforcement intensity and accident frequency, as well as temporal and spillover effects.

The results of the analyses were fairly clear and revealing. While there was an overall statistically significant policing effect on accidents, its size was very small. This was shown in the small elasticity of the models. For example, if policing is increased by 1% the expected number of accidents falls by only 0.00358% in the short-run, and slightly more than this in the long-run. However, the models also show that elasticity is greater on road sections with high concentrations of policing. The same applied to a model with spillover effects; it was only large scale policing that has had beneficial spillover effects. The effect of policing does not last; once policing is withdrawn from a heavily policed road section, the accident rate rises rapidly.

The authors suggest that small concentrations of policing are ineffective, and that it is better to concentrate available police resources on a small number of road sections, where they will have an effect, than to spread them too thinly over a larger number of road sections, where their effect will be very small. This conclusion contrasts with the assessment, in Australia, of the impact of low intensity random surveillance (in the next section).

The results of this evaluation agree, in general, with the previous evaluations, mentioned above, of NTP's impact on accidents. The small positive effects, which have been detected in all these studies, were mainly due to those road sections that had experienced considerably higher enforcement levels. As was described in WP3 (Zaidel, 2001), the establishing of the Israeli NTP force roughly doubled police effort indicators on inter-urban roads, an increase well below what is deemed necessary to achieve substantial or lasting influence (see Bjørnskau and Elvik, 1992).

Therefore, somewhat paradoxically, the local and temporal effects identified in the large-scale evaluation studies may have reflected the shifting of policing resources among sites rather than some more general influence. In that, the studies' results replicated those of numerous experiments with localized and time-limited enforcement projects.

5.5 LOW INTENSITY, RANDOM, EXTENSIVE SURVEILLANCE IN AUSTRALIA AND NZ

Most attempts to increase the impact of police enforcement involved increasing police presence or increasing the yield of citations. This usually means more resources. In the short term, many such programs have been successful (e.g. Zaal 1994; earlier sections of this document). However, increases in resources or in intensity of police activity are difficult to sustain both economically and for psychological-operational reasons (Bjornskau and Elvik, 1992).

Edwards and Brackett (1978) hypothesized that an approach based on randomized scheduling methods could enable low levels of police presence to achieve both long-term and widespread accident reductions. They suggested that the random presence of traffic police, in time and place, would increase substantially their deterrent effect on non-compliance. With a given level of resources police could cover a larger geographic area thus having an overall larger impact of safety. Low intensity enforcement (at a specific location) has the added benefit of not being too intrusive or give an impression of an oppressing police force.

Edwards and Brackett tested their approach with stationary patrol cars on one roadway and demonstrated speed reduction with a halo effect of 22 km, much greater than what was assumed possible.

Such an approach goes against the grain of most traffic police agencies, which plan their deployment according to a 'black spot approach". More, and more frequent, enforcement resources are sent to locations, sites, roads, etc. where the need is perceived to be greater-either where accidents had occurred in the past or where non-compliance is believed to be high.

In fact, many safety researchers or other 'experts' advise police to do just that. This approach is responsive to public concerns and can have, sometimes, immediate benefits at the special locations. However, it is not necessarily a good guide for routine and sustained traffic enforcement aimed to raise compliance all over the network, at all times.

The random, low frequency approach was taken up seriously in several Australian states and in New Zealand where it was refined and adapted to local needs. Table 9, taken from Newstead, Cameron and Leggett (2001), shows the extent of its implementation in

Australian states. In every state, some part of the network (expressed in terms of proportion of state accidents accounted by the covered area) is enforced with this deployment planning method.

Table 9: Implementation of low intensity wide coverage surveillance in Australia and NZ
(From Newstead, Cameron and Leggett, 2001)

Jurisdiction and date of implementation	Implementation sites	Measured crash effects (and evaluation reference)
Tasmania, Australia December 1984 to December 1986	Three rural highway sections, each 12–16 km in length. Each road length was divided into 1 km sections, with the section to be enforced and the 2-hour time block for enforcement assigned randomly. Enforced times between 15:00 and 23:00 h	Sixty percent reduction in crash rates Significant reductions in mean travel speeds Leggett (1988, 1992)
New Zealand December 1988 to March 1990	Three 20 km stretches of rural roads designated as accident black spots Enforcement carried for 1 and 2-h periods two or three times a week on each highway	Twenty-five percent decrease in fatal and injury crashes Reduction in both mean and 85th percentile speeds Significant variation in program performance between the three sites used Graham et al. (1992)
New South Wales, Australia June 1990 to May 1991	Three hundred and eighty-five kilometres section of the Pacific Highway Six program sectors for enforcement, 2-h segments chosen for enforcement between 08:00 and 20:00 h once or twice a week	Decrease in total reported crashes of 7% Forty percent decrease in serious injury crashes AGB (1991), Leggett (1992)

In the Australian state of Queensland the program is called Random Road Watch (RRW). Newstead, Cameron and Leggett (2001) describe the results of safety evaluation of the RRW program, as used in Queensland.

RRW is resource management technique used for randomly scheduling low levels of routine and conventional police enforcement in a manner intended to provide long-term, widespread surveillance coverage of a road network. The technique involves dividing each police jurisdiction into a number of sectors, and the week into a number of time blocks. The hours of 06:00 h to midnight were divided into 2 hours blocks for enforcement. The sector to be visited and the time at which it is to be visited are assigned randomly. Enforcement involves conspicuous stationing of a marked police vehicle in the chosen sector (road) for the allocated time block and doing routine enforcement, which may include operating a speeding detection device. (As patrol vehicles have to travel to each sector, they are seen along the way, as well).

From 1992 to 1997 RRW was progressively introduced into all eight police regions across Queensland. Each of the 279 participating police station has selected a number of road segments within it (typically 40) for enforcement. Each station operates an individual program that covers as many routes as possible in the station's territory. In all the regions combined, the number of accidents in the year before the program started was 15,154. In aggregate, the routs selected to be in the program accounted for 8278 (54.6%) of the accidents. The range (within regions) was from 34% to 94%.

The program evaluation design was based on comparing accident data for periods under enforcement plan (06:00 to 24:00) to the period remaining; the roads enforced under the RRW plan to the remaining roads. Enforcement deployment records, citations data and monthly accident data for each jurisdiction over the period January 1986 to June 1997 were analyzed using log-linear regression models.

The starting point of the program in each region was different, a fact taken in account in the time-series and before-after analysis. The authors discuss at some length why they had not addressed explicitly in the analysis the potential problem of regression to the mean and why this should not be a significant issue in this particular analysis.

Table 10 summarizes the estimates, derived from the regression models, of the average net effect of the RRW program in Queensland on crash frequency. The roads were stratified according to urban / rural area (defined by speed limit). The Metropolitan south region was fitted with a different model.

Table 10: Estimated average percentage crash reductions as a result of Queensland RRW program: November 1991–June 1996
(From Newstead, Cameron and Leggett, 2001)

	Fatal	Hospitalisation	Medical/first aid treated	Property damage	All crashes
Non metropolitan regions					
Rural areas	34.3[b]	4.1	4.9	1.3	4.78
Urban areas	25.7	20.6[b]	14.7[b]	13.1[b]	15.0[b]
All areas	31.0[b]	13.2[b]	11.5[b]	8.9[b]	11.2[b]
Metropolitan south region					
Rural areas	−133.5	7.8	31.8	−33.9	−5.1
Urban areas	62.0	4.1	4.2	32.3[b]	20.8[b]
All areas	14.3	5.3	12.2	24.8[b]	17.4[a]

[a] Statistically significant at the 5% level.
[b] Statistically significant at the 1% level. NB: Negative values indicate an estimated crash increase.

The estimated reductions of 31% in fatal accidents, 13% in serious injury accidents, 9% in property-damage-only crashes, and an overall 11 % reduction of all accidents were all significant. The program was effective in all police regions except in the Metropolitan area of Brisbane, where reductions were not statistically significant.

Regions varied considerably in the size of area covered by the RRW program and in the various input and output indicators of policing. Analyses linking these variables to the safety performance of regions revealed positive correlations but program coverage was the only factor showing statistically significant association with total crashes saved. The factors of total hours enforced and number of offences detected had positive, but no significant coefficients in the regression model, which accounted for 64% of the variation in total crashes.

Crash reductions attributable to the program increased with time. It was estimated that the program saved 1266 crashes in the first year of program implementation, and 2749 crashes in its third year. Compared to the overall 3-year average, the reductions in the third year of the program, in fatal, serious injury and property damage only crashes were estimated at 33%, 25% and 22%, respectively.

Increasing effect size with time could indicate a cumulative effect of the program amongst the public-for example, more awareness, more acceptance of compliance demands, better driving habits. It could also mean more efficient enforcement work by the police.

Since 55% of the accident generating road network is covered by the RRW program, the state-wide savings in the third year of program operation translate into 12% of the state's crashes of all severities and some 15% of the state's fatal road crashes. The opportunity-cost benefit: cost ratio for the program was estimated to be 55:1.

The safety impact of the program is indeed impressive, especially in light of very thinly spread enforcement. From enforcement inputs / outputs measures in the different regions, presented by the authors, it can be calculated that total RRW deployments per year in Queensland equal 40, 000 hours. This provides for about 4 hours, or two deployments, per site per year. A site can be 0.5 to 10 km.

How do these low doses translate into substantial crash reductions? One possibility is that quite small changes in speeding behaviour (assuming that most of the influence of policing was on speed behaviour) can be expected to generate larger crash reductions. Driving distances in Australia are long. Even if drivers are not likely to come across a police car at the same location twice, they are likely to sight a patrol car in a large variety of locations, perhaps even strange places they would not have expected police to operate there. This might convey a more convincing message to the driving public that the police, and society, are serious about the issues of compliance, especially speed and drink-driving compliance. If one prefers, this can be conceptualised as having a better deterrent effect.

The statistical analysis of the links between resources, coverage, and accidents reductions also supported the notion that it is better operationally to have widespread coverage even if the intensity of visits per kilometre of route is reduced. This view is contrary to the approach of many advocates of automated enforcement technology who see it as a means for high yield citations output to compensate for smaller number of police units. Indeed, Queensland police do have many units of advanced speed enforcement devices, but they are not using them very intensively, nor do they issue many citations.

5.6 THE JOINT IMPACT OF ENFOREMENT AND OTHER FACTORS ON ACCIDENTS

Traffic policing usually includes general surveillance and more targeted activities aimed at controlling specific non-compliance behaviour such as speeding, drink-driving or not using protective devices. Only in special projects there is a focus on doing or evaluating one activity. In the real practice all are carried out simultaneously. In addition, other factors in society or the economy are at work, which may influence changes in traffic safety. These may be independent of or interact with policing. Therefore, it is of great interest to assess the relative impact on safety of major policing actions and other factors. Elvik (2000) has done it for Norway, in a working paper for ESCAPE. He demonstrated that police traffic enforcement was one of the more cost effective methods of accident reduction.

Newstead, Cameron & Narayan (1998) analysed 1990-1996 data in Victoria, Australia, in order to estimated the contribution of several factors to reducing traffic injuries in Victoria over the period 1990-1996. The major factors considered in the study were those that have been found over the years to contribute to the substantial reduction in accidents in Victoria since 1989: RBT, speed cameras, mass media, black spot treatment and other factors. The dependent measure was the number of serious injury accidents for each month over the period 1990-1996.

Models linking variations in crashes to various factors were computed using the monthly crash data. Subsequently, the contributions of random breath testing, speed camera tickets issued, levels of road safety television publicity, unemployment rates and alcohol sales to the reduction in the number of injury crashes were estimated. The effect of accident black spot treatments was estimated and desegregated from the monthly trend.

"The major contributors and the apparent percentage reduction in serious injury accidents due to each measure/factor were estimated as:

- Speed camera operations (principally speeding tickets issued): 10-11% each year
- "Speeding" and "concentration" television advertising: 5-7% each year
- Drink-driving program (bus-based RBT together with "drink-driving" publicity campaigns) 9-10% each year
- Reduced alcohol sales: 3% in 1990; 6% in 1991; 7% in 1992; 9% in 1993; 8% in 1994; 9% in 1995; 10% in 1996
- Reduced economic activity (measured by unemployment rates): 2% in 1990; 12% in 1991; 15% in 1992; 16% in 1993; 14% in 1994; 1 0% in 1995; 10% in 1996
- Accident Black Spot treatments 1.6% in 1990; 2.5% in 1991; 3.2% in 1992; 5.3% in 1993; 6.2% in 1994; 6.2% in 1995; 5.6% in 1996

The anti-speeding and drink-driving programs together are estimated to have contributed reductions in serious casualty crashes of at least 22-25% during these seven years. Including the accident black spot treatments, the overall contribution of road safety initiatives is estimated to have risen from 23% reduction in 1990 to nearly 30% reduction in 1993-1996."

There is little to add to the authors' succinct summary.

6 CONCLUSIONS

Theoretical estimates of the potential accident reduction impact of policing, based on enforcement inducing full compliance (and the role of non-compliance in accidents) are fairly high, up to 50% reduction. Estimates based on statistical analysis of empirical studies dealing with specific enforcement elements generally suggest much lower estimates, with 10% being on the high end.

However, some well-implemented and sustained enforcement efforts have documented large safety gains, in the range of 25%. Typically these programs involved both speed and drink-driving control. The positive impact is larger with fatalities and serious injuries, pointing to the importance of speed control and possibly also of improved emergency response with improved or increased police deployment.

Much of the evidence for the positive impact of increased police enforcement (as separate from new legislation) on safety comes from enforcement projects and experiments restricted to either selected roads, to few behaviours or to a limited period. In practice this means that in most projects there was temporary increase in local resources or shifting of resources to concentrate policing efforts in the selected area. Even after discounting the overestimate of safety gains due to methodological limitations of many of the studies, the safety benefits of police enforcement are often substantial.

One suspects that not all local projects of intensified enforcement result in success, but they are more likely to be quietly dispensed with and not widely reported. One of the few exceptions was reported by Weiss and Freels (1996) regarding the null safety effect of Dayton's experiment in community-wide aggressive traffic policing.

Most assessments of policing effects on safety follow introduction of new traffic related regulations, increases in policing resources or change in enforcement practices. Some quantitative studies measure intensity of enforcement, which may include no enforcement at some locations or times, but this refers to the <u>specific</u> enforcement activities under study and it does not rule out other expressions of policing.

There have been, however, few evaluations of the safety impact of cases where police have not been doing any traffic enforcement. Carr et al. (1980) report the results from a natural experiment when the Nashville traffic police force first intensified enforcement for two months but, subsequently, went on a slow-down strike as part of a contract dispute. There were large differences between the three periods in surveillance and citation levels but there were no corresponding changes in the amount or distribution of accidents recorded in the three periods. Temporary withholding of policing activities, at least for short duration, need not result in safety costs.

In another case, the Finnish police forces went on strike, which lasted for two weeks, during 1979. Traffic enforcement, among other things, was completely stopped. A small-scale observation study was undertaken immediately (Summala & Roine, 1980). Speeding increased considerably both in urban and rural areas. Drivers did also not slow down when passing a parked car at a rural roadside (formally signifying a police car controlling speed). Such general increase in speeding must have had a negative impact on accidents but, unfortunately, it could not be assesses by the authors.

A large and permanent increase in policing resources is not an attractive or feasible option in most countries, and the evidence on the effectiveness of this approach is somewhat equivocal. The 'common wisdom' is that increases need to be at least 3-5 times over 'current levels' before substantial safety gains could be maintained. However, what is already being done with 'current level' of traffic policing, what is the 'current' incidence of non-compliance, and what safety level is enjoyed in a jurisdiction must also be important in determining thresholds for police impact, base-level and ceiling effects.

Enforcement programs in Australia and New Zealand demonstrated safety gains by policing with random deployment management of low intensity traffic surveillance. It is combined with automated photo-radar for speed detection and random breath tests. All these elements exist in routine enforcements programs in several European countries, many of which have as good or better safety record than the countries above.

Nevertheless, the approach merits a more detailed examination and perhaps a more systematic application. It is possible, for example, that the safety efficacy of some general enforcement programs is achieved not only, or not primarily, through the mechanism of deterrence but through mechanisms of better system management.

Another point of caution is that many of the studies reviewed here and elsewhere, have been carried out in various states and communities in North America and Australia rather than in European countries, and many of the studies are from past decades with different social, legal, roadway, and traffic context. The validity of conclusions derived from that past experience needs to be examined in the framework of present day EU countries. For example, the acceptance of drink-driving, owner responsibility and safety belt legislation; the use of RBT, photo-radar and automated speed and RL cameras; the extent of belt use and drink-driving all have been different in Europe and are different now compared to 20 years ago.

REFERENCES

Amick, D. R. (1983) Marshall P. B: Evaluation of the Bonneville, Idaho, DUI Accident Prevention Program. Transportation Research Record, 910, pp. 81-92.

Andersson, G. (1991) Effekter på hastigheter av intensifierad övervakning med radar. Transportforskningberedningen (TFB) og Statens väg-och trafikinstitut (VTI) forskning/research nr 6.

Andreassen, D. (1995) A long term study of red light cameras and accidents. ARRB Transport Research Ltd. Research Report No. 261.

Bailey, J.P.M. (1995) An evaluation of compulsory breath testing in New Zealand. I Kloeden, C.N og McLean, A.J. (Eds) “Alcohol, Drugs and Traffic Safety T’95: Proceedings of the 13th International Conference on Alcohol, Drugs and Traffic Safety, Adelaide, 13 - 18 August” (Volume 1).

Bartle, G. and Esberger, R. (2000) Effects of lowering the legal BAC limit in Austria. Proceedings of T2000 - 15TH conference on alcohol, drugs and traffic safety, 22-26 May, Stockholm, Sweden..

Beenstock, M., Gafni, D. and Goldin E. (2001) The effect of traffic policing on road safety in Israel. Accident Analysis and Prevention (33), pp. 73–80.

Bjørnskau, T. and Elvik, R. (1992) Can road traffic law enforcement permanently reduce the number of accidents? Accident Analysis and Prevention (24), pp. 507–520.

Blackburn, R.R; Gilbert, D.T (1995) Photographic enforcement of traffic laws. National Cooperative Highway Research Program, Synthesis of Highway Practice 219. Washington D.C, National Academy Press.

Brackett, R.Q. and Beecher, G.P. (1980) Longitudinal Evaluation of Speed Control Strategies. College Station, Human Factors Division, Texas Transportation Institute, Texas A&M University, Final Report - Volume 1 - Executive Summary. Volume II. TSS 80-06-02-D-1-AA.

Broughton, J. and Stark, D. C. (1986) The effect of the 1983 changes to the law relating to drink /driving. Research Report 89. Crowthorne, Berkshire, Transport and Road Research Laboratory.

California Highway Patrol (1966) Operation A, Phase 1: Background and accident analysis. Final report. Sacramento, California.

Cameron, M., Diamantopoulou, K., Mullan, N., Dyte, D. and Gantzer, S. (1997) Evaluation of the country random breath testing and publicity program in Victoria, 1993-1994. Monash University Accident Research Centre - Report #126.

Cameron, M.H. and Strang, P.M. (1982) Effect of intensified random breath testing in Melbourne during 1978 and 1979. ARRB Proceedings Volume 11, part 5, pp 1-12.

Cameron, M.H., Cavallo, A. and Gilbert, A. (1992) Crash-based evaluation of the speed camera program in Victoria 1990-1991. Phase 1: General effects. Phase 2: Effect of program mechanisms. Monash University Accident Research Centre, Victoria, Australia, Report No. 42.

Cameron, M.H., Strang, P.M. and Vulcan, A.P. (1981) Evaluation of random breath testing in Victoria, Australia. In GOLDBERG, L. (ED): Alcohol, Drugs and Traffic Safety, Vol III, 1364-1381. Stockholm, Almqvist & Wiksell International.

Campbell, D.T. and Ross, H.L. (1968) The Connecticut crackdown on speeding. Time-series data in quasi-experimental research. Law and Society Review, pp 32-53.

Carlsen, E. and Svendsen, S. (1990) Rapport fra forsøk med økt trafikktjeneste i Tønsberg politidistrikt sommeren 1990. Tønsberg, Tønsberg Politikammer / Utrykningspolitiet, rapport datert 30.

Carr, A.F., Schnelle, J.F. and Kirchner, R.E. (1980) Police crackdowns and slowdowns: a naturalistic evaluation of changes in police traffic. Behavioral Assessment (2), pp. 33–41.

Chen, G., Meckle, W. and Wilson, J. (2002) Speed and safety effect of photo radar enforcement on a highway corridor in British Columbia. Accident Analysis and Prevention (34), pp. 129–138.

Chen, G., Wilson, J., Meckle, W. and Cooper, P. (2000) Evaluation of photo radar program in British Columbia. Accident Analysis and Prevention, (32), pp. 517–526.

Chin, H.C. (1989). Effect of automatic red-light cameras on red-running. Traffic Engineering and Control, *30,* pp. 175-179.

Datta, T.K., Schattler, K. and Datta, S. (2000) Red light violations and crashes at urban intersections. Transportation Research Record 1734, pp. 52-58.

Derby, N.M and Hurst, P.M (1987) The effects of random stopping in New Zealand. In Nordzij, P.C and Roszbach, R. (Eds): Alcohol, Drugs and Traffic Safety, Amsterdam, Excerpta Medica, T86, 421-427.

Deshapriya, E.B.R. and Iwase, N. (1996) Are lower legal blood alcohol limits and a combination of sanctions desirable in reducing drunken drover-involved traffic fatalities and traffic accidents? Accident Analysis & Prevention, Vol. 28, No 6, pp 721-731.

Diamantopoulou K., Cameron, M. and Shtifelman, M. (1998) Evaluation of Moving Mode Radar for Speed Enforcement in Victoria, 1995-1997. Monash University Accident Research Centre - Report #141.

Drummond, A.E and Torpey, S.E. (1985) Driver improvement program evaluation. Victoria Road Traffic Authority, Report No 11/85.

Edwards, M.L. and Brackett, R.Q. (1978) The management of speed. Traffic Safety, October 1978, pp. 18–30.

Ekström. B., Kritz L.B. and Strömgren, L. (1966) Försök med förstärkt trafikövervakning på europavägarna 3 och 18 sommaren 1965. Stockholm, Statens Trafiksäkerhetsråd.

Elvik, R. (1997). Vegtrafikklovgivning, kontroll og sanksjoner. Potensialet for å bedre trafikksikkerheten og nytte-kostnadsvurdering av ulike tiltak. TØI notat 1073. Oslo, Transportøkonomisk institutt.

Elvik, R. (1999) Improving road safety in Sweden. Draft report in preparation. Oslo, Institute of Transport Economics.

Elvik, R. (2000). Cost-Benefit Analysis of Police Enforcement. Working paper WP1 for ESCAPE.

Elvik, R., Mysen, A.B and Vaa, T. (1997) Trafikksikkerhetshåndbok (Traffic Safety Handbook). Institute of Transport Economics, Oslo, Norway.

Elvik, R., Mysen, A.B. and Vaa, T. (1997) Trafikksikkerhetshåndbok, Tredje utgave (Handbook of Traffic Safety, Third edition) Oslo, Transportøkonomisk institutt.

Engdahl, S. and Nilsson, E. (1986) Intensifierad övervakning med utandningsprov. Del B. Effekt av intensifierad övervakning med utandningsprov. TFB-rapport 1986:12. Stockholm, Transportforskningsberedningen,.

Epperson, W.V. and Harano, R.M. (1975) An evaluation of some additional factors influencing the effectiveness of warning letters. Accident Analysis & Prevention, Vol. 7, pp 239-247.

ETSC (1996) Seat belts and child restraints - Increasing use and optimising performance. European Transport Safety Council (ETSC). Brussels, 48 pp.

ETSC (1999) Police enforcement strategies to reduce traffic casualties in Europe. European Transport Safety Council (ETSC), Brussels, 53 pp.

Evans, L. (1991). Traffic safety and the driver. New York, NY, VanNostrand Reinhold.

Foley, D. (1986) Case Study in DWI Countermeasures. IN Foley, D. (Ed): Stop DWI, Lexington, Mass, Lexington Books, pp. 33-54.

Hagen, R E. (1978) The efficacy of licensing controls as a countermeasure for multiple DUI offenders. Journal of Safety Research, Vol. 10, pp. 115-122.

Hakkert, A.S., Gitelman, V., Cohen, A., Doveh, E. and Umansky, T. (2001) The evaluation of effects on driver behavior and accidents of concentrated general enforcement on interurban roads in Israel. Accident Analysis and Prevention, (33), pp. 43–63.

Harrison, W.A. (1998) Deterrence may not result from "deterrence": challenges to a deterrence account of the effect of enforcement on behaviour. Road Safety Research, Policing, Education conference, Wellington, New Zealand, vol. 2, pp. 9-13.

Hillier, W., Ronczka, J. and Schnerring, F. (1993) An evaluation of red light cameras in Sydney. Road Safety Bureau, Roads and Traffic Authority, New South Wales, Research Note 1/93.

Hingson, R., Heeren, T., Kovenock, D., Mangione, T., Meyers, A., Morelock; Lederman, R., and Scotch, N.A. (1987) Effects of Maine's 1981 and Massachusett's 1982 Driving-Under-the-Influence legislation. Am. J. Public Health; 77:593-597.

Hocherman, I., Zaidel, D.M. and Hakkert, A. S., (1995) Monitoring traffic enforcement effectiveness on a national scale. Proceedings of International Conference Road Safety in Europe and Strategic Highway Research Program. Lille, France; VTI konferens 1A, Part 1, pp. 247–268.

Homel, R. (1988) Policing and punishing the drinking driver. A study of general and specific deterrence. New York/Berlin, Springer Verlag.

Hook, D., Kirkwood, A. and Evans, D. (1995) Speed cameras in Oxfordshire. Highways & Transportation, February, pp. 11-13.

Hurst, P.M. and Wright, P.G. (1981) Deterrence at last. The Ministry of Transport's Alcohol Blitzes. In Goldberg, L. (Ed) Alcohol, Drugs and Traffic Safety, VOL III, 1283-1297. Stockholm, Almqvist & Wiksell International.

Johnson, P., Levy, P. and Voas, R. (1976) A critique of the paper "Statistical evaluation of the effectiveness of alcohol safety action". Accident Analysis and Prevention, (8), pp. 67-77.

Jones, B. (1987) Oregon's habitual traffic offender program: An evaluation of the effectiveness of license revocation. Journal of Safety Research, Vol. 18, pp. 19-26.

Jones, B. (1997) Age, gender and the effectiveness of high-threat letters: An analysis of Oregon's driver improvement advisory letters. Accident Analysis & Prevention, Vol. 29, No 2, pp. 225-234.

Kadell, D. (1987) Traffic safety impacts of the Home Instruction/Point Reduction Incentive (HI/PRI) program. Journal of Safety Research, Vol. 18, pp. 149-178.

Kaestner, N., Warmoth, E.J. and Syring, E.M. (1967) Oregon study of advisory letters: The effectiveness of warning letters in driver improvement. Traffic Safety Research Review, Vol. 11, No 3, pp. 67-72.

Kearns, I. B. and Webster, K. A. (1988) The Effect of Aerial Speed Enforcement On Traffic Crashes. Traffic Authority of New South Wales, Research Note RN 4/88.

Kent, S., Corben, B., Fildes, B. and Dyte, D. (1995) Red Light Running Behaviour at Red Light Camera and Control Intersections. Monash University Accident Research Centre - Report #73.

King, M. (1988) Random breath testing operation and effectiveness in 1987. Australian Department of Transport, Road Safety Division, Report 7/88.

Krohn, F. (1996) Automatisk trafikkontroll - oppsummering av effekter. Oslo, Statens vegvesen /Vegdirektoratet, Transport og trafikksikkerhetsavdelingen - Transport-analysekontoret/Via Nova, Rapport nr TTS 7/1996.

Lamm, R. and Kloeckner, J.H. (1984) Increase of Traffic Safety by Surveillance of Speed Limits with Automatic Radar Devices on a Dangerous Section of a German Autobahn: A Long-Term Investigation. Transportation Research Record 974, pp. 8-16.

Legget, L.M.W. (1988) The effect on accident occurrence of long-term, low-intensity police enforcement. Proceedings of the 14th ARRB Conference, Part 4, pp. 92-104.

L'Hoste, J., Duval, H. and Lassarre, S. (1985) Experimental study of the effectiveness of random alcohol testing in France. In Kaye, S. & Meier, G. W. (Eds): Alcohol, Drugs and Traffic Safety, Proceedings of the Ninth International Conference on Alcohol, Drugs and Traffic Safety - San Juan, Puerto Rico, 1983, pp. 831-839.

Malenstein, J. & van Loosbroek, J. (1997) Results of continuous applied enforcement and impact on traffic behaviour. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.

Mann, R.E., Anglin, L., Rahman, S., Blessing, L.A., Vingilis, E.R. and Larkin, E. (1995) Does treatment for substance abuse improve driving safety? A preliminary evaluation. In Kloeden, C.N. and McLean, A.J. (Ed) "Alcohol, Drugs and Traffic Safety T'95: Proceedings of the 13th International Conference on Alcohol, Drugs and Traffic Safety, Adelaide, 13 - 18 August 1995" (Volume 1).

Mann, R.M., Macdonald, S., Stoduto, G., Shaikh, A. and Bondy, S. (1998) Assessing the potential impact of lowering the legal blood alcohol limit to 50 MG% in Canada. Addiction Research Foundation, Canada, Report 1998/11. 69p.

McBride, R.S. and Peck, R.C. (1970) Modifying negligent driving behaviour through warning letters. Accident Analysis & Prevention, Vol. 2, pp. 147-174.

McCartt, A.T. and Rood, D.H. (1989) Evaluation of the New York State Police 55 MPH Speed Enforcement Project. NHTSA, USDOT, Washington DC, Report DOT HS 807 618.

Munden, J.M. (1966) An experiment in enforcing the 30 mile/h speed limit. Road Research Laboratory, RRL Report No 24.

Neustrom, M.W. and Norton, W.M. (1993) The impact of drunk driving legislation in Louisiana. Journal of safety research, Vol. 24, pp. 107-121.

Newstead, S., Cameron, M. and Narayan, S. (1998) Further modelling of some major factors influencing road trauma trends in Victoria: 1990-96. Monash University Accident Research Centre - Report #129

Newstead, S.V., Cameron, M.H. and Leggett L, M.W. (2001) The crash reduction effectiveness of a network-wide traffic police deployment system. Accident Analysis and Prevention (33), pp. 393–406.

Ng, C.H., Wong, Y.D. & Lum, K.M. (1997). The impact of red-light surveillance cameras on road safety in Singapore. Road and transport research, 6 (2) pp. 72-81.

Nilsson, E., Engdahl, S. and Nilsson, K. (1986) Utvärdering av LA-lagen: Effekt på olyckor och dömda trafikonyktra. TFB-stencil 39. Stockholm, Transport-forskningsberedningen.

Nilsson, G (1992) Försök med automatisk hastighetsövervakning 1990-1992. VTI, Linköping, Statens väg-och trafikinstitut, VTI-rapport nr 378-1992.

Novak, J.W. and Shumate, R.P. (1961) The use of "control groups" in highway accident research: A field study. Traffic safety Research Review, (5), pp. 20-24.

Oei, H.l. (1994) Effective speed management through automatic enforcement. Proceedings of PTRC 22nd Summer Annual Seminar, Traffic Management and Road Safety, University of Warwick, England, pp 277-288.

Oei, H.L. (1996) Automatic speed management in The Netherlands. Transportation Research Record, 1560, pp. 57-64

Preusser, D.F., Blomberg, R.D. and Ulmer, R.G (1988) Evaluation of the 1982 Wisconsin drinking and driving law. Journal of Safety Research, Vol. 19, No 1, pp. 29-40.

Preusser, D.F., Ulmer, R.G., and Adams, J.R. (1976) Driver record evaluation of a drinking driver rehabilitation program. Journal of Safety Research, Vol. 8, No 3, pp. 98-105.

Retting R.A., Weinstein, H.B., Williams, A.F. and Preusser, D.F. (2001) Simple method for identifying and correcting crash problems on urban arterial streets. Accident Analysis and Prevention, 33, pp. 723–734.

Retting, R.A., Williams, A.F. and Greene, M.A. (1998). Red Light Running and Sensible countermeasures: Summary of Research Findings. Transportation Research Record 1640, pp. 23-26.

Retting, R.A., Williams, A.F., Farmer, C.M., and Feldman, A.F. (1999). Evaluation of red light camera enforcement in Oxnard, California'. Accident Analysis and Prevention, (31), pp. 169-174.

Roop, S.S. and Brackett, R.Q. (1980) Evaluation of Project Increased Traffic Law Enforcement. Texas A&M University, College Station, Final report 80-05-09-C1-AA.

Ross, H.L. (1977) Deterrence regained: The Cheshire constabulary's "Breathalyzer Blitz". The Journal of Legal Studies, Vol. VI (1), pp. 241-249.

Ross, H.L. (1982) Deterring the Drinking Driver. Legal policy and Social Control. Lexington Books, D.C. Heath and Company, Lexington; Massachusetts.

Ross, H.L. and Klette, H. (1995) Abandonment of mandatory jail for impaired drivers in Norway and Sweden. Accident Analysis & Prevention, Vol. 27, No 2, pp. 151-157.

Sadler, D.D., Perrine, M.W. and Peck, R.C. (1991) The long-term traffic safety impact of a pilot alcohol abuse treatment as an alternative to license suspensions. Accident Analysis & Prevention, Vol. 23, No 4, pp. 203-224.

Sali, G.J. (1983) Evaluation of Boise Selective Traffic Enforcement Project, Transportation Research Record 910, 68-93.

Salusjärvi, M. and Mäkinen, T. (1988) Experiment med hastighetsövervakning i Vanda. Nordisk Kommitté för Transportforskning. (ISBN 87-88453-07 3).

Saunders, C.M. (1977) A study on increased intensity of traffic law enforcement as a means of reducing accidents. Research and Statistics Division, Road Traffic Authority, Australia.

Smith, D.I., Maisey, G.E. and McLaughlin, K. (1990) Evaluation of the first year of random breath testing in Western Australia. Proceedings of the 15th ARRB Conference, Vermont South, Victoria, Australian Road Research Board, pp. 93-106

South D.R., Harrison W.A., Portans I. and King M. (1988) Evaluation of the Red Light Camera Program and the Owner Legislation. Victoria Transport, Road Traffic Authority SR/88/1, Victoria, Australia.

South, D.R., Harrison, W.A., Portans, I., and King, B. (1988) Evaluation of the red light camera program and the owner onus legislation. Road Traffic Authority, Report SR/88/1. Hawthorn, Australia.

Statens vegvesen Buskerud (1996) Utrykrykningspolitiet Distrikt 04, Ringerike politidistrikt: "Aksjon riksveg 7 i Buskerud 1995". Et samarbeidsprosjekt mellom Statens vegvesen, Ringerike poltidistrikt og Utrykningspolitiet".

Statens vegvesen Vestfold (1996) Evaluering av ATK = Rødlys. Brev av 1996-03-06 fra Statens vegvesen Vestfold til Vegdirektoratet v/Transportanalysekontoret.

Stuster, J.W. (1995) Experimental evaluation of municipal speed enforcement programs. Report No. DOT HS 808 325, National Highway Traffic Safety Administration, Washington DC.

Stuster, J.W. and Blowers, P.A. (1995) Experimental evaluation of sobriety checkpoint programs. Anacapa Sciences, P.O. Box 519, Santa Barbara, CA, 93102, USA.

Summala H. & Roine, M. (1980) Exceptional conditions of police enforcement during the police strike. Accident Analysis and Prevention 12 (3), pp. 179–184.

Swali, L.N. (1993): The effect of speed cameras in West London. Proceedings of PTRC 21st Summer Seminar Meeting, University of Manchester, Manchester. Traffic Management and Road Safety, part C, pp. 249-260.

Thomson, J. and Mavrolefterou, K. (1984) Assessing the effectiveness of random breath testing. ARRB Proceedings, Volume 12, Part 7, pp. 72-80,

Törnros, J. (1995) Intensifierad övervakning med utandningsprov. Försök i södra Sverige. Linköping, Väg-och transportforskningsinstitutet, VTI meddelande nr 746.

Utzelmann, H. D. and Haas, R. (1985) Evaluation der Kurse für mehrfach auffällige Kraftfahrer. Shriftenreihe Unfall-und Sicherheitsforschung - Straβenverkehr, Heft 53, Bergisch-Gladbach, Bundesanstalt für Strassenwesen,.

Vaa, T. (1999) Effects of enforcement measures on accidents and severity. Working paper for ESCAPE.

Vaas, K. and Elvik, R. (1992) Føreres kunnskap om og holdning til promillelovgivningen. Oslo, Transportøkonomisk institutt, TØI-rapport nr 104/1992.

Vingilis, E. and Salutin, L. (1980) A prevention programme for drinking driving. Accident Analysis and Prevention, 12, pp. 267-274.

Vingilis, E.R., Mann, R.E., Gavin, G., Adlaf, E. and Anglin, L. (1990) Effects of sentence severity on drinking driving offenders. Alcohol, Drugs and Driving, Volume 6, Numbers 3-4, pp. 189-197.

Voas R.B., and Hause, J.M. (1987) Deterring the drinking driver: The Stockton experience. Accident Analysis and Prevention, Vol. 19, No. 2, pp. 81-90.

Weiss, A. and Freels, S. (1996) The effects of aggressive policing: the Dayton traffic enforcement experiment. American Journal of Police, (15), No. 3.

Wells, J.A.K., Preusser, D.F. and Williams, A.F. (1992) Enforcing Alcohol-Impaired Driving and Seat Belt Use Laws, Binghamton, NY. Journal of Safety Research, 23, pp. 63-71.

Williams, A.F., Reinfurt, D. and Wells, J.K. (1996) Increasing seat belt use in North Carolina. Journal of Safety Research, Vol. 27, No. 1, pp. 33-41.

Winnet, M. (1994) A review of speed camera operations in the UK. Proceedings of 22nd PTRC Summer Annual Meeting, University of Warwick, Traffic Management and Road Safety, Seminar J, pp. 265-276.

Wolfe, A.C. (1985) Evaluation of the special alcohol enforcement/education project in Oakland County, Michigan. In Kaye, S. & Meier, G. W. (Eds): Alcohol, Drugs and Traffic Safety. Proceedings of the Ninth International Conference on Alcohol, Drugs and Traffic Safety - San Juan, Puerto Rico, 1983, US Department of Transportation, Washington DC, pp. 1575-1595.

Zaal, D. (1994) Traffic Law Enforcement: A Review of the Literature. Monash University, Accident Research Centre, Australia. Report No.53.

Zador, P. (1976) Statistical evaluation of the effectiveness of "alcohol safety action projects". Accident Analysis and Prevention, (8), pp. 51-66.

Zaidel D.M. (2000a) Ergonomic versus Psychological perspective on Traffic Law Enforcement. ICTTP-International Conference on Traffic and Transport Psychology, Berne, Switzerland, 4-7 September.

Zaidel, D.M. (2000b). Traffic Law Enforcement Practices in Sixteen European Countries. Working paper for GADGET, WP5 - Legal measures and enforcement. VTT, Technical Research Center of Finland, Communities & Infrastructure.

Zaidel, D.M. (2001) Non-compliance and accidents. Working paper W3 for ESCAPE.

Zaidel, D.M. and Mäkinen, T. (1999) Automation Concepts and Technologies for Improving Traffic Law Enforcement. Technical Research Center of Finland, Communities & Infrastructure, VTT Research Report 482 / 1999.