The effect of enforcement on speed behaviour

A literature study

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The effect of enforcement on speed behaviour: A literature study

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Executive Summary

The objective of the literature study is to give an overview of research on speed enforcement and its effects on speed behaviour and safety. This study will be used to find (new) strategies and tactics to enhance the efficiency and effectiveness of speed enforcement by the police in terms of behaviour (and safety).

In the past 10-15 years many reports and articles have been written on this subject. For correct understanding and interpretation though, often relevant information is lacking, such as government policy on speed, law on speed limits and speed, jurisprudence, system of fines, point demerit system, organisation and practice of police enforcement, enforcement frequency, etc. Also sometimes changes in speed enforcement are related to changes in behaviour, without giving the absolute enforcement level. This is of importance for the resulting behaviour.

The study does not have the ambition to be complete. Examples of experiments at locations, road stretches and road networks are given. Most of the literature deals with enforcement at a locality or on a road stretch, few reports on area wide enforcement. Research reports from the Netherlands, the United Kingdom, Australia, some Scandinavian countries, and the USA are reviewed. In the Netherlands, several experiments were conducted by the SWOV - on behalf of the Dutch Ministry of Transport - regarding automatic warning and enforcement.

Local speed management

An experiment with automatic speed warning to speeding drivers was conducted near a school complex in the Hague, where speeding traffic poses a threat for school children crossing the road. The average speed was reduced significantly with 5 km/h at the urban location. An example calculation showed that this speed reduction will result in a 25% reduction of cars that could not stop in time at the intersection in case of an emergency.

This automatic warning system was then applied at a rural intersection in a province, where the speed limit was reduced locally from 100 to 70 km/h. The average speed at the approach of the rural intersection went down with 20 km/h. The number of accidents at this site (though statistically seen very small) was more than halved.

Speed management on routes

In the Netherlands experiments with automatic warning and enforcement were held on four two-lane rural roads, having relatively many accidents and speeders. Automatic speed warning is given to speeders and automatic enforcement was conducted using radar+camera from a road side box. The average speed went down with 5 km/h and the number of accidents was reduced with 35%. In Finland speed enforcement using a camera from road side boxes resulted in a reduction of the mean speed with 1-2 km/h and of the number of injury accidents with 9%. In metropolitan London a speed camera project resulted in 5 mph reduction in average speed and a 14% decrease in serious injury accidents.

Speed management on road networks

Area wide experiments on rural and urban road networks in the Netherlands resulted in speed reductions. On rural roads the mean speed was reduced with 2-3 km/h, but no accident reduction was found. No clear cut explanations could be found for this. An area wide experiment in the city of Eindhoven resulted in a reduction of the average speed of 2-4 km/h. An accident reduction of 14% was found, partly to be attributed to the enforcement, and partly due to a downward trend of accidents.

In Victoria, Australia, an intensive enforcement campaign - alcohol and speed - was launched in 1989 and was continued the years there after. The publicity was very intensive, showing on TV simulated crashes with the resulting misery for victims, its family, and the drivers who caused them. There were 2,500 camera sites, 54 radar and camera systems, 4,000 camera hours operated every month, on average each car is checked nine times a year, 66% of the car fleet checked every month, the processing is being highly automated. There is a point demerit system and for persistent speeders even stricter sanctions are applicable. The car owner is primarily held responsible for offences committed and the driving license can be withheld or for company cars, the car license. The average speed was not reduced though, but the percentage of excessive speeding was halved. The result after five years of enforcement on speed and alcohol is a 21% reduction in collisions, 38% in major injuries and 49% in fatalities. The effect of the speed enforcement is estimated to be minus 14% road fatalities.

The area wide campaigns in Victoria (alcohol and speed) and in the Netherlands (speed) are compared, the duration in NL was much shorter, 4-6 months, in Victoria it is continued for many years, the enforcement frequency/site/time unit in NL was higher than in Victoria, a big reduction in accidents and victims was found in Victoria in contrast to NL. This can possibly be attributed to the combination of speed and alcohol enforcement in Victoria, the stricter sanctions there, the point demerit system, thus heavier sanctions for recidivists, the withholding of driving license (private car owners), and car license (business cars), the very intensive publicity, and the very high percentage of drivers caught.

Results of experiments in Norway and Finland regarding halo effects in time and space are combined with survey results in the Netherlands regarding contended speed behaviour as a function of enforcement frequency.

The report concludes with recommendations for efficient (optimal enforcement planning given a certain number of policeman hours) and effective (achievement of aimed speed reduction) speed enforcement strategies.

CONTENTS

1 INTRODUCTION

1.1 OBJECTIVE

The objective of the literature study is to give an overview of research on speed enforcement and its effects on speed behaviour and safety. This study will be used, amongst other studies, to find (new) strategies and tactics to enhance the efficiency and effectiveness of speed enforcement by the police in terms of behaviour and safety. Therefore information and recommendations on strategies and tactics, where available will also be given.

The topic of telematics is not being dealt with in this report, as these systems have not been applied as yet in real traffic situations. The intelligent speed adaptor, for example, can pose an effective solution for the problem of speeding related accidents, in future.

1.2 SPEED AND ACCIDENTS

Firstly, why speed enforcement? Empirical studies in Sweden (Andersson & Nilsson, 1997), Finland (Salusjärvi, 1987) and the USA (Godwin, 1992) show that a reduction in speed gives a disproportionate large reduction in accident, injury, and fatality rate. Andersson & Nilsson (1997) states that the empirical results proved to a large extent to be adaptable to the physics law of kinetic energy (= mass x square of the speed) on the basis of two complementary hypothesis: 1) “The probability of a personal injury accident in the road system reported by the police is proportional to the square of the speed - the kinetic energy. 2) The probability of a fatal accident resulting from a personal injury accident is also proportional to the square of the speed, which means that the number of fatal accidents is proportional to the fourth power of the speed.” A very large reduction in injury and fatal accidents may be expected from reaching the national objective on speed. This is expressed in the Swedish Figure 1 (Andersson & Nilsson, 1997): a speed reduction of say five kilometres per hour may result in a reduction in the number of fatal plus severe injury accidents of twenty percent. The purpose of this figure is to give an idea of the potential of accident reduction by reducing speed. To be precise though, it must be stated that the slope of the curves depends on the initial speed, not given by the authors.

Andersson & Nilsson (1997) also give changes in *casualties* of different severity as a result of a change in mean speed; these changes are larger than those for accidents, because of the power law in the relationship between speed and energy in a crash and also because the number of fatalities or injuries per fatal or injury accident is greater than 1. See further (Finch & Kompfner, 1994).

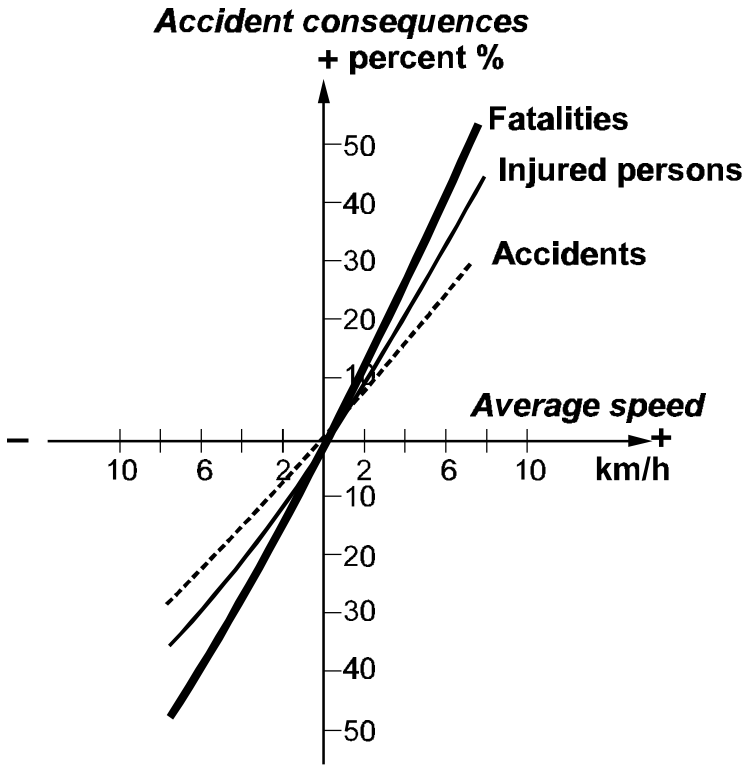

Figure 1. Changes in average speed versus changes in percentage in accidents (Nilsson, 1981)

1.3 ENFORCEMENT LEVEL AND LEVEL OF COMPLIANCE

Figure 2 (Oei, 1994a) gives a theoretical relation between level of enforcement and level of compliance to the speed limit. At zero enforcement level, a certain percentage of drivers will be complying to the speed limit. Increasing the enforcement has no effect in the beginning, as the probability of being caught e.g. once in 5 or 10 years makes no difference in effect. But from a certain enforcement level, an increase of the enforcement will result in an increase of the compliance level. The level of compliance will level off to 100% at a high enforcement level. Then when the enforcement is decreased, at first drivers do not notice this, so the compliance level is still high. The result is a ‘hysteresis’ curve. The question is: what is the enforcement level at which the compliance will be minimally 90% (Dutch target for 2000 AD)?

There are several possibilities to define enforcement endeavour. In literature often ‘probability of being caught’ is used. A practical definition is the number of enforcement hours per road section per time unit.

For example, a probability of being caught once a year seems small, but if a driver drives only once a year on a road stretch where enforcement is operational 24 hours per day, than the probability for that trip is 100%. It may be assumed that, because of this high probability on this one trip, the driver will not speed on that road.

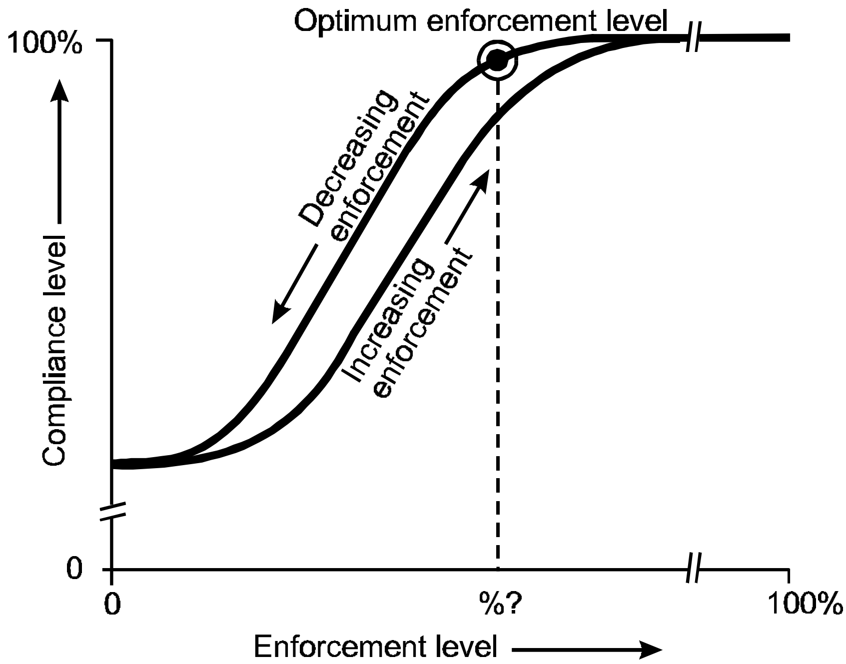

Figure 2. Hypothetical relation between enforcement level and compliance to the speed limit.

1.4 SPEED MANAGEMENT APPROACH

The ultimate aim is to achieve the national safety objectives through lowering the speed level according to the national tasks as already mentioned. It is common knowledge that in industrialized societies speed is in almost every respect regarded positively: speedy thinking and acting, transportation, communication, computers, etc. This might explain why a change of attitude regarding speed on the road - except through strict enforcement - is hard to realize.

As the capacity of the police is not sufficient by far to reach this goal by conventional enforcement methods, other means and methods have to be applied.

Speed management should be directed to those locations and roads, where the problem of accidents and speeding is highest, i.e. having the highest potential reduction in accidents. Selection of roads to be enforced need not be based on accidents where speed was the *main* cause, not only because of unreliable statistical data. (Almost) all accidents occurring on a road can be considered. An accident can be described as a process, a chain of consecutive events, each forming a link of the chain. An accident can be prevented by cutting the chain at any link(s). In most cases speed will form one of the links; being a causal or contributory factor.

Specific and general prevention. In literature the concept of prevention is defined from a *psychological* view point: specific prevention concerns the group of drivers who have received a ticket for speeding, and general prevention concerns the group of drivers who have not received a ticket but did experience a speed check, and/or are informed about the speed checks.

Another definition from *operational* view point is prevention in time and space. Specific prevention concerns drivers passing selected dangerous locations or routes. General prevention concerns drivers on a road network, where at all times all drivers are expected to behave correctly on the whole network.

Both definitions are relevant, so a distinction between these conceptions should be made.

The objective of speed enforcement at dangerous *locations or routes* is *specific* prevention at these selected locations and routes, so drivers should get a warning regarding the strict speed enforcement before approaching the dangerous area.

The aim of speed management on a *road network* is *general* prevention in time and space: drivers are expected to drive carefully everywhere anytime on the whole network. So only general warning is given through the media or posters, but no specific warning is given about the actual locations and times where speed is enforced.

Police enforcement can be conducted by stopping speeders or by sending the fine by post, for which a speed camera is needed, installed in a fixed road side box or in a police vehicle. Stopping speeding vehicles needs a disproportionately large input of manpower, and as this is limited; use of a camera will result in a very much larger output of enforced vehicles. In the future, telematics can impose speed limits through intelligent speed adaptation systems (ITS, 1997).

The Dutch policy a few years ago (abandoned shortly) was to have about half of all traffic offenders enforced by stopping them on the road, the other half without halting the offender (Ministry of Justice, 1993). The motive was to prevent overloading of the judicial system with traffic offences.

Application of new available technologies can enhance the efficiency a great deal, e.g. automatic registering, reading, identification, and processing of number plates of speeding vehicles. For routes speed could be measured at two or three locations on this route and the average speed be calculated and enforced. Through pattern recognition techniques, cars could be recognized at these measuring points, and the whole process be automated.

By improving the communication and feed-back to drivers the subjective probability of being caught can be increased, and thus increasing the compliance level.

The objective of this literature study is to collect knowledge on how efficient and effective enforcement can be. Based on this study, strategies and tactics for speed enforcement could possibly be derived.

1.5 STRUCTURE OF THE LITERATURE STUDY

A literature study on speed enforcement can be classified in many ways, e.g.:

- per country.

- enforcement method: stopping and ticketing the speeding vehicle, automated speed detection and registration of license plates, speed ticket sent to registered address.
- road type and speed limit: motorway, secondary rural road, urban main road.
- size of enforcement area: a spot (e.g. intersection, school), a road stretch or a road network.

The chapters on speed enforcement are ordered as follows:
- Introduction
- Relevant background information
- Speed enforcement at a locality
- Speed enforcement on a road stretch
- Speed enforcement on a road network
- Discussion
- Recommendations

It is found that very often information about relevant back ground conditions are not mentioned in the literature, making correct understanding and interpretation of research results and comparisons between these research difficult or impossible. As this information was available for the Dutch situation, Chapter 2 gives as an example these relevant aspects.

The design of the research conducted is not always clear, and so questions could be put forward regarding the precision of the results of the experiments.

Most literature deals with enforcement on a spot or a road stretch, few deal with road networks.

This study relates speed enforcement to its effects on driver behaviour. The effects on safety will be given, where the information is available. Though it must be stated that accident evaluation often is cumbersome, because of the influence of other - often unknown - factors and of random fluctuations on accidents.

These experiments in the Netherlands were conducted on main roads selected on a consistent history of speeding and accidents. Roads were thus not chosen because of a sudden rise in accidents in one year. Although it is acknowledged that a decrease in accidents on such roads can still be the result of statistical fluctuation, the effect of *regression to the mean* is roughly estimated to explain at most half of the reductions found. The precise effect can not be established because of lack of needed information.

Speed measurements were conducted often comprising thousands of vehicles. Because of the large numbers even small effects are *statistically significant* (Evans, 1991). So the significancy test is regarded superfluous.

The enforcement project in Australia is described more elaborately, because of the availability of the information, the revolutionary intensive way this was conducted during many years, and the resulting large reductions in accidents and road victims.

In this literature study the results regarding *halo effects* will be combined with survey results to come to a desired enforcement frequency.

In the Discussion questions regarding effects on speed behaviour, required and cost-effective enforcement levels, are dealt with.

Notwithstanding above mentioned shortcomings, for the purpose of finding ways to optimize strategies, results of the literature study provide relevant and useful information.

2 RELEVANT INFORMATION RELATED TO SPEED ENFORCEMENT

2.1 INTRODUCTION

The effect of speed enforcement on behaviour and safety is of course not only depending on the input of police manpower and of technical hardware, but also on other aspects and conditions. In the literature most of this information, needed for correct understanding, often is not given.

In this chapter as an *example*, information is given for the Dutch situation, because of the readily availability of these relevant conditions that is of influence on speed behaviour, in relation to speed enforcement: e.g. government policy, the speed limit system, law and jurisprudence on speed and speeding, penalty system, daily practice regarding police enforcement, a point demerit system, publicity, etc.

2.2 NATIONAL AND PROVINCIAL GOVERNMENT POLICY

The national and provincial policy regarding speed is relevant because they influence the police task on speed enforcement. In the Netherlands the first national ' Multi-year Road Safety Programme' was formulated for the period 1987-1991. This programme is adapted periodically (Ministry of Transport, 1991). The overall objective is to reduce the number of road victims with 25% in the year 2000, in comparison with 1985. The number of road victims in 1996 was 50,163, and in 1985 49,993, so there has been no reduction at all.

One of the spearheads was lowering the average speed of motor vehicles on provincial and main urban roads with 5–10%, later a maximum of speeders of 10% was set for the year 2000 (ministry of Transport, 1993). The road and police authorities are autonomous in setting their own goals, and most of the authorities have set as objective a maximum of 10% of vehicles exceeding the enforcement threshold (speed limit + 6 km/h).

Several provinces are conducting demonstration projects to obtain a *sustainable safe road system*, by designing the road in such a way that the provoked driving speed does not exceed the speed limit, and by separating the traffic directions, to prevent head-on collisions (Catshoek, 1995).

2.3 SPEED LIMITS

The speed limit system is of importance because it influences speed behaviour (Nilsson, 1981; Salusjärvi, 1981). In the Netherlands there are four *general* speed limits stipulated by law: 120 km/h for motorways, 100 km/h for rural highways, 80 km/h for other rural roads, and 50 km/h for urban roads. As a rule general speed limits are not shown along the road side. In general, speed limits are coupled to function and road type, but in practice discrepancies exist, e.g. a dual carriageway in a 50 km/h residential area. Exceptions on these general limits are stipulated in guidelines (Ministry of Transport et al, 1991a). For lorries and buses the general speed limit on all road types, except on urban roads, is 80 km/h.

2.4 LAW ON SPEEDING

The law on speeding is relevant because this is the basis for police action in enforcing speeding. In the Netherlands the owner of the car is held responsible for traffic law trespassing, unless he identifies the person who made the trespassing. Speeding with less than 30 km/h falls under administrative law, then the driver is not accountable for old criminal traffic offences (recidivism). From + 30 km/h and up the offence falls under criminal law, and the offender can be called to appear in court, where he is also accountable for old criminal traffic offences (Ministry of Justice, 1996).

The law stipulates which speed measuring techniques are to be used for enforcement purposes. Radar and inductive loops are allowed. Laser is as yet not allowed, except when used as a supporting system for the policeman, who has determined by sight that a car is speeding, driving with a certain speed. The laser system then can corroborate this.

2.5 PENALTY FOR SPEEDING

The penalty system is relevant, because this is assumed to be of influence on speed behaviour. The penalty for speeding depends on the level of speeding: per km speeding between f 5.- (in a built up area, less than 10 km/h speeding), and f 30.- (on a motorway between 35 and 40 km/h speeding). Excess speeds can be punished by (temporary) withdrawal of the driving license. For speeding above 30 km/h recidivists receive heavier penalties.

2.6 POINT DEMERIT SYSTEM

This system is relevant because of its possible influence on behaviour. There is no such a system in the Netherlands (as yet). Most speeders do not speed more than 30 km/h above the speed limit. This category of speeders falls under administrative law as said, ‘Mulder law’. For this category there are no stiffened penalties for repetitive speeding, other than the standard fines. A point demerit system could enhance the effectiveness of intensive speed enforcement. Such a system might not be compatible with the primal responsibility of the car owner - instead of the car driver - for trespassing traffic laws and with the ‘Mulder law’.

2.7 ORGANISATION AND PRACTICE OF SPEED ENFORCEMENT MANAGEMENT

The organisation and practice of speed management is relevant because this determines the enforcement frequency and therefore will also affect driver behaviour. The Dutch police has been reorganised since 1993; the police force has been decentralised and regionalised, and the policeman has to fulfil a broad scope of tasks (generalist). Almost all specialised speed enforcement teams were abolished, knowledge and experience were scattered. As in many industrialised countries, priority is given to combating criminality with the consequence that the allocation of manpower for traffic enforcement is relatively low. So often, speed enforcement is conducted intensively on a few selected rural routes during a couple of weeks, and thereafter discontinued or continued at a very low level. The effect is that speed is lowered during the intensive campaign, but will soon reach old pre-campaign levels.

Although not yet common practice, letters of intent concerning speed management, stipulating the cooperation and division of tasks between the police, provincial, and state road authority, have been signed in several cases (ROF, 1995).

There are many organisations involved in road safety activities, such as national, provincial, and city council road authority, public prosecution office, police, regional road safety organisation, national road safety campaign organisation, SWOV, and other traffic institutes. In order to cope with the problem of speeding and accidents, more and more working parties are formed. These include most or all of the mentioned organisations, to supervise speed projects. The benefit of such an approach is that problems could be tackled speedily in an early phase, as all parties concerned are present in working sessions.

2.8 SPEED MEASURING NETWORK

Such a network is relevant, because this enables monitoring whether the goals are going to be met. A speed measuring network for rural secondary, provincial roads was designed by the SWOV on behalf of the Ministry of Transport (Oei, 1994b). This design was conceived for two purposes: collecting data for national speed policy and for provincial policy purposes, such as speed management, but also to monitor the use of roads related to road function and design. The police can use the data from this network for selection of roads to be enforced. Dysfunctional use of roads, e.g. traffic by-passing a congestion by using residential routes, can be detected. At present six of the twelve provinces have installed a speed measuring network, using inductive loop detectors installed in the road surface, the other provinces are to follow in the coming years.

2.9 PRESENT SPEED LEVELS

Speed measurements on two lane rural roads using radar were conducted in 1994 (Catshoek, et al, 1994), the percentage of speeders was between 40-60%. On main urban roads this percentage can even go as far as 80% (Catshoek, et al, 1994). So the speed levels are still well above the set national objective of 10% speeders.

2.10 PUBLICITY

It is generally considered a must that speed enforcement campaigns be accompanied by publicity for several reasons, though publicity alone will have only a temporary effect. Firstly, the public should be informed of the campaign, the danger of speeding, and the potential of reducing accidents by lowering speed, secondly the number of speeders at the start of and during the campaign should be reduced, and thirdly rules of ‘fair play’ should be followed to gain public acceptance. The MASTER report (Levelt, 1998) recommends to approach the emotion of the driver in publicity campaigns next to a cognitive approach.

3 LOCAL SPEED MANAGEMENT

In this chapter *examples* of this type of speed management are given from Dutch experience in an urban and rural situation, varying from automatic warning, automatic warning with police surveillance, to automatic speed and red light enforcement. Of course there are other location types, such as a sharp bend or cycle crossing, where this type of speed management could be applied.

The aim of speed enforcement at a locality is to reduce speeding at the chosen location. In practice the selection is often based on speeding behaviour and accident history at these locations. The ultimate objective is to reduce the accident risk at these localities. So fore warning of drivers approaching these locations is relevant (special prevention).

Before a number of experiments was started in the Netherlands, a literature study was conducted with the following results (Oei, 1988):

- Fixed information systems are generally less effective than variable signing.
- Flexible signs has more potential to catch the attention of the driver.
- A necessary condition is that the level of the speed limit be compatible to the road characteristics.
- The effectiveness of the sign is related to the topicality, relevancy, credibility, and the specificity of the information given by the sign.
- Restricted application of speed signs to high risk locations and time periods will strengthen the effect on behaviour.
- The effect of warning signs for crossing pedestrians depends also on the visual presence of pedestrian wanting to cross.
- Information regarding the reason for the speed sign will strengthen its effect.
- The measure of its effect depends also on the character of the reason.
- A combination of automatic speed warning and enforcement will have the greatest effect on behaviour.

3.1 SPEED WARNING AT AN URBAN SCHOOL COMPLEX

Experiments were conducted at an *urban* intersection, where a school complex is situated, with periodically many crossing children (Oei & Papendrecht, 1989). Before the experiment, the percentage of speeders on the main artery, 150 m upstream of the intersection, was 80%. An information campaign just before the start of the experiment gave information regarding the experiment, and the danger of speeding over there. Passing drivers were warned, first by a fixed speed sign, then *speeders* were warned by an automatic flashing sign showing the speed limit ‘50'. This sign only operates during periods when the school is open.

The effect of the fixed sign was small. The percentage of speeders with the flashing sign was lowered to 47%, the mean speed went down with 5 km/h. A theoretical calculation example showed a reduction in the percentage of cars not being able to stop before the intersection (in case of an emergency), i.e. a reduction in accidents, of 25%.

3.2 SPEED WARNING AT A RURAL INTERSECTION

At a *rural* intersection, the main two lane road had a speed limit of 100 km/h. At the approach of the intersection the speed limit was lowered to 70 km/h, and a fixed sign upstream shows ‘Lower your speed’. Drivers still speeding were warned automatically with a sign showing ‘You are speeding’. At het start of the experiment a parked police car was surveying periodically at the intersection, this surveillance was reduced, and stopped after a while. The mean speed went down from 80 to 60 km/h, and this speed level remained 2 years after the installation of the system. The number of accidents was statistically too small for analysis, though the average number per year dropped from 6 to 2 accidents (Province of Friesland, 1994).

Table 3.1. Speed and accident evaluation results at an urban and rural intersection

Intersections	**Mean speed km/h**		**% speeders**		**Accidents**	
	Before	After	Before	After	Before	After
Urban	56	51	80%	47%		-25% (calculated)
Rural	80	60			6 (average/year)	2

3.3 RED LIGHT + SPEED ENFORCEMENT AT URBAN INTERSECTIONS

Speed and red light enforcement was conducted in Amsterdam (Oei, 1997). Four intersections were selected by the police based on accident record and speed of the past years. The speed limit on three of the selected intersections spread across the city is 50 km/h (general speed limit in urban areas). On the fourth site the limit is 80 km/h. Traffic is controlled by a camera in one direction only. The system is able to control two traffic lanes. Traffic passing through red light (a one second margin) with a speed greater than 10 km/h or driving through yellow or green light with a speed higher than 60 km/h (90 km/h, respectively) is put on a photo for enforcement purposes. The cameras is triggered by detection loops, making two photos of each trespasser. Two cameras were interchanged between the four sites, each site is enforced during 3-5 days continuously. A fore warning is given through an information campaign, and through a fixed sign showing (English translation) 'Warning! Red Light and *Speed* Enforcement' (white background with black letters). Such a warning sign is appropriate, as this concerns specific prevention at the selected intersections. If in future many more intersections are installed with this type of enforcement system, general prevention might be the objective, and then a fore warning will not be appropriate.

Before- and after-measurements were conducted in 1994 and 1997 respectively, using inductive loops (organizational problems of the authority responsible for the measurements caused this delay in the after measurements). The consequence of this delay is that most of the regular drivers supposedly have knowledge of the system. On the other hand the situation at the sites might have changed in this three year period; no control sites were incorporated in the evaluation, as the after-measurements were planned a couple of months after the before-measurements).

The *result of the evaluation* was that the percentage of red light trespassing was reduced on all four intersections between 4.8 and 1.1 percentage points. The percentage of drivers having a speed higher than the enforcement threshold (speed limit+10 km/h) was reduced at all sites, between 12.1 and 1.0 percentage points (except at one site; supposedly the conditions have changed at this site). The warning sign was rather inconspicuous. The conspicuity of the sign can be improved by installing the sign on both sides of the lane and by enlarging the sign and using other colours.

No accident evaluation was conducted because of the, statistically seen, too small number of accidents.

Table 3.2. Percentage of red-light trespassing and speeding at four intersections

Amsterdam	**% of red-light trespassing**		**% > 50+10 km/h**	
	Before	After	Before	After
Intersection 1	2.9	1.0	16.2	4.1
Intersection 2	2.5	1.3	1.7	0.7
Intersection 3	8.2	3.4	1.8	0.6
Intersection 4	1.6	0.5	0.01 >80 km/h	0.45 >80km/h

3.4 CONCLUSIONS

The examples of local speed management show positive results: the speed in the three cases and the percentage of red-light trespassing in the last case were lowered. A calculation shows a reduction in accidents may be expected at the location next to the school complex.

At the rural intersection the local conditions were adapted to the speed warning system, through lowering the speed limit at the approach of the intersection on the main artery. The effect on speed being lowered, was long during. The number of accidents showed a large reduction (very small numbers).

It is advisable to monitor the speed at such locations periodically, so when the number of speeders rises again, police surveillance or enforcement in combination with publicity can counter this. When enforcement is conducted automatically, the duty cycle of the camera can be optimized based on speed data from the speed monitor.

The combination of speed and red-light enforcement system resulted in reduced red-light trespassing and speeds during green phase. Because this speed measure was applied at a very limited number of locations in Amsterdam, the effect of publicity through national daily papers might have limited effectivity. Therefore local and district papers of the city should also convey the message. It is of importance that the signs at the approach of the intersection be conspicuous, easy to read, and to understand.

Enforcement at locations can be conducted automatically, because of the limited area to be enforced.

When speeding and safety problems occur at consecutive intersections on a route, then the problem should be approached from the context of the route.

4 SPEED MANAGEMENT ON ROUTES

Examples are given from experiences with speed management on motorways and 2-lane rural roads in the Netherlands, London, Norway, Finland, the USA and Canada. There are no examples of urban routes being enforced, possibly because the length of routes to be enforced in cities often being too short. An example of a route (trunk road) in a metropolitan area (London) leading to and from the city is given.

4.1 SPEED ENFORCEMENT ON A MOTORWAY SECTION

The Dutch motorway police KLPD started in December 1993 to enforce speed intensively on part of the A2 from Amsterdam to Utrecht, in both directions, having a length of about 20 km. The speed limit on this road was for a part 120 km/h and for another part 100 km/h.

Photos were made unobtrusively of speeding cars from the side of the road. The speed enforcement campaign was accompanied by intense information given through television, daily papers and bill boards along side the road.

The number of enforcement hours per month for both motorway carriageways increased from 50 hours in November to 700 hours in December 1993, in the following six months this number was lowered to an average of 300 hours per month.

The percentage of speeders on the 100 km/h limit part dropped in December 1993 from 65% to 20% and fluctuates further between 20 and 30% until September 1994.

On the 120 km/h part the percentage of speeders dropped in December 1993 from 30% to 10% and remained at that level during four months, to rise again fluctuating between 10 and 20% until September 1994.

In the fall of 1994 the SWOV was asked for advice by the motorway police KLPD regarding the enforcement level(s) needed for continuation of the speed enforcement on this motorway section. To answer this question, the following was done by the SWOV:

- a preliminary study, based on the before mentioned evaluation results, tactical and operational information from KLPD and the road authority;
- a design for intensified speed enforcement, as the level has been lowered considerably after the start of the campaign;
- a short term evaluation of the intensification of the enforcement level was conducted (half November - half December 1994) on behalf of the Dutch Ministry of Transport (Oei, 1994).

The intensified enforcement comprised among other things of the following:

- around 300 hours of speed enforcement per month, compared to around 100 hours during the months before;
- on the 120 km/h part the enforcement level was reduced as the speed level was below accepted margins;
- on the 100 km/h part the enforcement was intensified;

- during the weekend and dark hours the enforcement was intensified, compared to the months before, as during these periods the speed level was relatively high.

The short term evaluation in general showed no reduction of the percentage of speeders and of the average speed. There was no publicity around the intensification of the enforcement, as advised, and this might explain the lack of an effect.

It was recommended to *modulate* the enforcement level (deducted from the hysteresis curve, see Figure 2) i.e. period of intensified enforcement accompanied by publicity in the media, after a couple of weeks followed by a period of reduced enforcement. It was also recommended to monitor frequently the speed on this road stretch through the loop measuring system of the road authority. So, when needed, the enforcement level could be adapted to the speed level.

4.2 ENFORCEMENT BASED ON AVERAGE SPEED ON A MOTORWAY

The first experiments with this new way of enforcing speed were conducted on a provincial road, where at two locations speed of vehicles driving in one direction is measured from an observation post at the road side (KLPD, 1997). License plate number, and time of passing at the two control points is registered by the operators, operating the speed radar, who communicate by porto-phones. Only cars speeding are so checked. The average speed is calculated using a lap- top computer, and when a speeder is so ascertained, the car is stopped downstream by a policeman, who is informed by mobile phone. The distance between the two locations was rather short, otherwise cars might turn off the main road. It is advised that at least 80% of cars pass both locations. The limitation of this system is that the number of cars that can be checked is limited because of manual input of the data in the lap top.

Recently this system is applied on a part of one carriageway of the motorway A2 as mentioned in 4.1., having a length of 3 km and a speed limit of 120 km/h. At the approach of the enforcement site drivers are warned by a fixed sign. At three locations with an inter-distance of respectively 750 and 2,200 metre, respectively, each lane is equipped with induction loops, and above these lanes video cameras are installed to register the 'signature' of passing cars 24 hours a day. Through pattern recognition, a car can recognized at the three measuring points, and the average speed be calculated. When at the first road section the average speed surpasses the speed limit plus a margin of 6 km/h, the characteristics of the car is measured and registered. If the average speed on the second part is above this speed threshold, then the owner of the car will receive a ticket within three weeks sent by post. Characteristics of other cars will be erased automatically for privacy reasons. 40% of the registered cars can be 'read' automatically, still 60% need personal intervention.

The percentage of cars exceeding the threshold speed (speed limit+6 km/h) is 1%. This system will increase the enforcement efficiency and effectivity enormously. This method has been approved by the court; approval by the High Court is being sought.

4.3 (AUTOMATIC) SPEED WARNING AND ENFORCEMENT ON RURAL ROADS

4.3.1 Experiments in NL on 2-lane rural roads

Experiments have been conducted on four Dutch provincial roads (Ministry of Transport & SWOV, 1993).

A structural speeder, driving on such a route, will have a high probability of being caught, independent of the location of the enforcement site on this route. By varying the site of the enforcement and the enforcement period, the enforcement will be unpredictable for the driver.

These provincial routes, have a length varying between 8 and 20 km; the speed limit was 80 km/h. These routes had no major discontinuations, e.g. change in the number of lanes, in road width, in speed limits, and had no major intersections. The routes were selected by the road authority and the police, based on accident history and speed level of the past years. The experiments were conducted on two types of road, each having their specific objectives, and signs (Figures 3A & 3B):

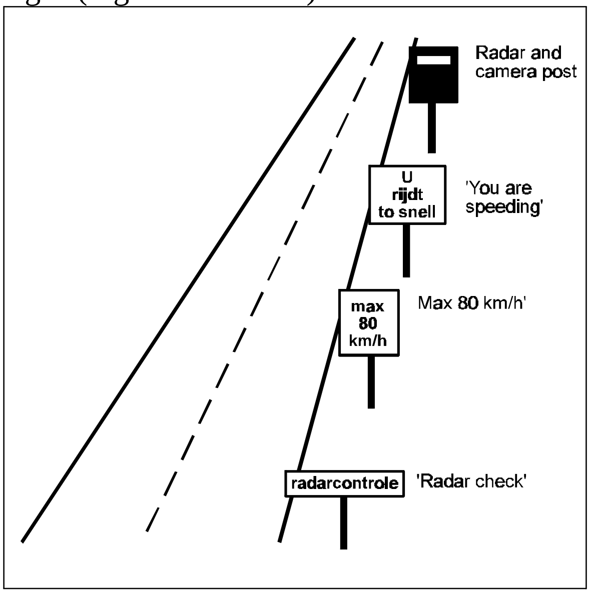

Figure 3a. Design of the automatic speed management system on 2-lane rural roads open for all cars, motorcycles and tractors only.

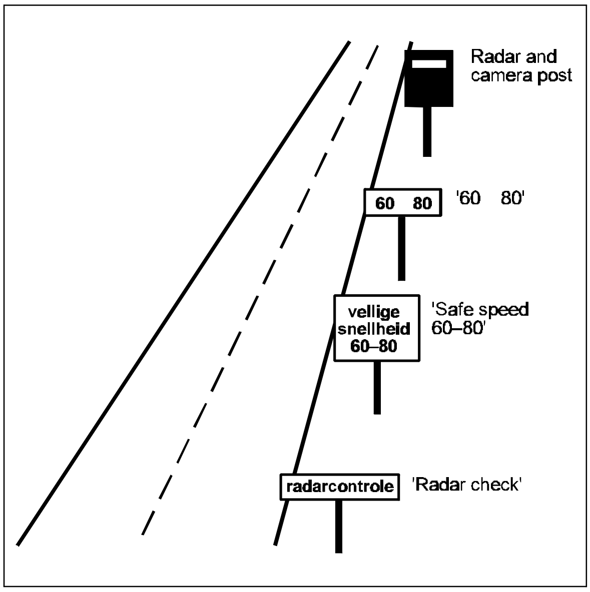

Figure 3b. Design of the automatic speed management system on 2-lane rural roads open for all cars and motorcycles only.

Road type A. On two roads slow moving agricultural vehicles were also allowed on the road. The objective of the experiment on these roads is to lower the number of vehicles speeding.

At the beginning of these routes on both ends, firstly a fixed sign warns all passing drivers of the speed limit: ‘Max 80 km/h’. About 300 m further downstream drivers still speeding are warned by an automatic sign: ‘You are speeding’ (English translation). Further on the road, three to four radar boxes were installed along both sides of the road, in which one set of radar and camera system can be circulated. A photo is made of cars speeding with more than 10 km/h. The camera system enforces speeding cars travelling in both directions.

Road type B. On the two other roads only cars and motorcycles were allowed on the road. The objective is to lower the number of cars speeding *and* also the number of slow driving vehicles. At the beginning of these roads a fixed sign reads: ‘Safe speed 60-80 km/h’ (English translation). About 300 m further downstream drivers speeding or driving slower than 60 km/h are warned by an automatic sign showing ‘60-80'. Further downstream on the route, three to four radar boxes were installed along both sides of the road. One set of a radar and camera system can be circulated in these boxes. Again cars speeding by more than 10 km/h, are photographed (there is no legal basis for fining slow moving vehicles).

Before the start and also during the experiment a *publicity campaign* was conducted to convey information regarding the aim and operation of the project and the four roads being enforced roads, to warn potential users of the danger of speeding, and of the high probability of being caught when speeding. The camera was operated continuously, or in some cases from early morning till midnight, during a period of three months.

The overall result was a reduction of speeders from 38% to 11%. The percentage of drivers driving slower than 60 km/h was small, though this was increased somewhat.

The total number of all types of accidents (fatal, injury and damage only) on the four roads was reduced from 150 to 81, a reduction of 46%. When the 17% reduction on the control roads is accounted for, the reduction is 35%.

A *long term* evaluation of speed and accidents was conducted three years after conclusion of the experiment on one of the four roads (Oei et al, 1995). In this period the camera was out of operation during one year because of vandalism, and after reinstallment, this system was operated only one day per month. The percentage of speeders increased from 11% to 16%.

Table 4.1. Speed and accidents in before- and after-situation on experiment and control roads

Experimentroads	**Mean speed**		**% speeders**		**Total accidents**	
	Before	After	Before	After	Before	After
Short term 4 roads1 road	78 79	73 74	38% 39%	11% 11%	15053 average/year	81 31
Long term1 road		75		16%		30 average/year

Control roads	**Mean speed**		**% speeders**		**Total accidents**	
	Before	After	Before	After	Before	After
Short term 2 roads	79		41%	44%	28449 average/year	237 60
Long term2 roads		75		16%		43 average/year

4.3.2 Automatic speed enforcement on a rural road (Finland)

A two year experiment was conducted on a 50 km section of a two lane 80 and 100 km/h rural road west of Helsinki (Mäkinen, 1994). Only one direction of traffic is enforced. The study was based on an experimental design with before-after measurements and a control road leading east of Helsinki. The other side of the test road was used for measuring the carry-over effect of surveillance in the direction without camera installations.

There were 12 camera poles, with distances between the poles varying between 1.5 to 7 km and one camera+computer. The duration of the surveillance at a site varied from 8 to 36 hours. Signs warn approaching drivers of the camera zone, as the objective is prevention. The threshold for enforcing on speed was 15 km/h above the limit. A frontal photo is made, so drivers can be identified, the photo of the front passenger is overexposed for privacy reasons; the driver is responsible for speeding. When identification of the driver was not possible the case was dismissed.

- Total operation: 8,065 hours in 2 years
- Rate of operation: 46%
- Number of vehicles monitored: 1.46 million
- Speeding vehicles: 24%
- Number of photos made: 3,504 (0.24%)
- Fines issued based on photos: 54%, or 0.13% of all vehicles monitored
- On the control road no comparable speed reductions were measured.

Bad weather conditions were a main reason for the impossibility of identification of the driver.

A great majority of the photographed cars speeded between 10-15 km/h above the posted speed limit. The mean speed was reduced with about 1-2 km/h and the percentage of speeders went down with 5 to 8%.

A halo effect was found extending from -3 km to +2km from the camera poles.

The majority (90%) of the drivers approved the automatic speed enforcement, when warned beforehand by signs.

The evaluation period regarding injury accident rate was extended to March 1995: a reduction of 9% was found (Mäkinen, 1997).

Table 4.3. Effects on speed and accidents

Finland	Before	After
Mean speed		minus 1 to 2 km/h
Percentage of speeders	32%	24%
Percentage >95 km/h		0.13% of monitored vehicles
Injury accident rate		minus 9%

4.3.3 Experiment with manual enforcement in Norway

A 35 km section of road, having speed limit zones of 60 and 80 km/h, was subjected to an increase in police enforcement having a daily average of 9 hours, during an enforcement period of 6 weeks. This enforcement consisted of 5.5 hours stationary enforcement with stopping speeders, 2 hours mobile surveillance, 1.5 hours empty parked police car,(Vaa, 1997).

No publicity was included at all. A survey was conducted before, during, and after the speed enforcement experiment including questions regarding the risk of apprehension as perceived by the drivers.

Average speed was measured from neutral grey boxes along the road side, using radar and loops (not for enforcement purposes). The average speed was reduced between 0.9 - 4.8 km/h in both speed limit zones and for all times of the day. The comparison was made with the before-situation and a road nearby where the enforcement was not being increased.

The percentage of drivers driving faster than 70 km/h in 60 km/h zones was reduced from 11% to 8% in the period 3 to 7 pm, and from 30% to 20% during 0.00 to 6.00 am.

In the 80 km/h zone, the percentage of drivers driving faster than 80 km/h in night time was reduced from 54% to 43% and during daytime from 33% to 29%.

Table 4.4. Effects on speed

Norway	**Before**	**After**
Av. speed; speed limit in ( )		minus 0.9 to 4.8 km/h
%>70 km/h (60) day time	11%	8%
%>70 km/h (60) night time	30%	20%
%>80 km/h (80) day time	33%	29%
%>80 km/h (80) night time	54%	43%

4.4 SPEED MANAGEMENT ON A ROUTE IN A METROPOLITAN AREA

A description of the experience of speed camera operation in London is given here.

The government in the UK has a commitment to reduce the number of accidents by one third by the year 2000 from a baseline corresponding to the average number of accidents in the years 1981-1985 (Swali, 1993). The number of speed related accidents on London trunk roads showed an increase. Trends in killed and seriously injured accidents showed, that compared with England (excluding London), London trunk roads had a smaller rate of reduction. Legislative changes were needed for using new technology (Road Traffic Act in 1991). This entails: requirement for the car owner to identify the driver, admissibility of photographic evidence in court using approved equipment, use of 'conditional offer fixed penalty' procedures. The prosecution system allowed only two weeks to issue a notice of intended prosecution.

Speed camera scheme on links of a route

The London Speed Camera Scheme was initiated by the London Regional Office of the Department of Transport (Swali, 1993; Winnett, 1994). This scheme started in October 1992, and was run by the Metropolitan Police. The red-light and speed camera sites chosen were along the principal road links to London (A4, A40, A316 and A30). So the enforcement is conducted on road links. Criteria for selection of the sites were:
- high incidence of speed related accidents
- high incidence of serious and fatal accidents
- high incidence of single vehicle accidents involving loss of control

It was considered of great importance, that a careful assessment of traffic conditions, speeds and accidents was made before a decision could be taken to install enforcement cameras.

Elements of the strategy

- Inform drivers: warning signs (see Figure 4), use of dummy flash units, high profile launch, media publicity.
- Deter speeding: provide adequate detection to convince drivers it is too risky to speed.
- Make 'non compliance' a painful experience: penalty points and fines.

- Monitor and adjust as necessary: e.g. use of camera in mobile mode.
- If ‘successful -> reward’: thank drivers, inform of casualty savings.

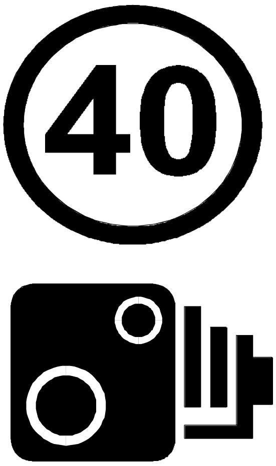

Figure 4. Speed enforcement sign in London.

Driver behaviour

There were logistic difficulties in planning suitable before- and after-studies of this project. Camera housings were installed before measurements could have been made; further the traffic counter loops sometimes failed. At one location (Swindon) the data during periods of weeks were of good quality.

The mean speed was lowered with 3 mph by means of a combination of signs, and a camera installation. The camera had effect on the roads installed, *not on the adjoining roads*. This was also found in West London.

The effect can be very local, 200 m upstream of a camera speed can be significantly higher; drivers brake when approaching a camera.

It is advised to use movable installations to fill in the gaps between the fixed camera sites. As yet, a strategy using a combined fixed/movable system, is lacking

Effect on speed

The following effects were found:
- At a site having a speed limit of 40 mph, the number of drivers driving with a speed higher than 60 mph in 24 hour period dropped from 1,090 to 30 (97% reduction).
- Mean speed have been reduced by 5 mph and V-85 speed by 7 mph.
- Speed cameras have a speed reducing effect even under circumstances when excessive speed is not possible (at high traffic flows).
- It is concluded that the speed cameras on links have no ‘halo’ effect on the surrounding road network.

- The use of a combination of a red-light and speed camera at junctions could be very cost-effective.
- No mention was made of vandalism problems.
- It was deemed necessary to design an effective overall strategy using mobile and fixed cameras, combined with signing, to achieve area wide optimum speed reductions.
- One policeman is needed per eight cameras.
- Maintenance/operational costs are 50% of purchase costs.

Table 4.2. Effect on speed behaviour

Speed limit 40 mph	**Before**	**After**
No. of speeders +20mph	1,090	30
Mean speed		-5 mph
V-85		-7 mph

Experiments in **Devon** showed that signing only, without enforcement, will render no effect. It is stated that enforcement activities need to be seen by drivers, otherwise there will be no effect.

Accident evaluation

The speed and red-light cameras resulted in a significant 14% decrease in fatal and serious accidents on the roads that were installed. Accident reductions were found at link sections between junctions and at junctions themselves.

The before period was: 15.10.91 - 30.09.92 and the after period 15.10.92 - 30.09.93. The roads were differentiated in camera installed roads and all other roads. Fatal, serious, and slight injury accidents were the accident characteristics of the evaluation.

The following was found:

- There is a significant decrease in fatal and serious accidents on the link roads of 36% (from 134 to 77, including junctions), for minor injury accidents the (non-significant) decrease was 8% (from 489 to 461), the total decrease was 14% (from 623 to 538). On the other roads the fatal accidents increased with 7%, slight injury accidents remained on the same level.
- The decrease in accidents was as important on the junctions as on the links between the junctions.
- In the before period as well as in the after-period red-light cameras were in operation. It was thought not unreasonable to attribute, maybe the largest part of the effect, to a general reduction in speed, brought about by the use of the speed cameras on the road sections.

4.5 ENFORCEMENT IN URBAN AREAS IN USA AND CANADA

Blackburn & Gilbert (1995) report in the chapter on effects on compliance and safety:

‘A number of attempts have been made to assess the impact of automated speed enforcement (ASE) on speed limit compliance. The data presented in the literature indicate that use of ASE devices to enforce speed limits will reduce the incidence of speeding to a certain extent. Most of the speed reduction claims are based on observations and not on scientifically formulated experimental designs.’

The information given in the report was not sufficient for correct interpretation. So the results can be considered as indicative.

During the first 3 months of the ASE program in Pasadena, California, about 7.4 percent of the motorists passing the enforcement locations were cited for speeding above the detection setting. Seventeen months after the operation began, the percentage of vehicles cited for speeding dropped to 5 percent.

The percentage of speeders cited before ASE began is not given. The Paradise Valley Police Department estimated that speeds on most roads in the city were reduced by about 8 mph during the first 3 years of operation. The speed reductions claimed in both Pasadena and Paradise Valley are based on enforcement data and not on controlled experiments.

In March 1988, the Victoria, British Columbia Police Department conducted a study of the effectiveness of an ASE device in reducing traffic speeds (Blackburn & Gilbert, 1995). The study design included collecting baseline speed data before the enforcement phase and also two periods of publicity concerning enforcement aspects of the program. The effectiveness of the ASE device was tested under two conditions: when the presence of the ASE device at a particular site was known and when the device was used as a general deterrent whose exact location was unknown. When drivers understood that enforcement was concentrating exclusively at one site, there was a tendency for higher mean speeds at other locations. When people were told that the ASE device would be at any location, mean speeds were between 3 and 13.6 percent lower than during the baseline survey, even when the device was not actually present at the enforcement site. When the ASE device was at a particular site and the public was told it could be operating anywhere, the presence of the ASE device accounted for mean speed reductions of between 9.2 and 19 percent compared to the baseline period.

From September to December 1990, the Ministry of the Solicitor General and the Vancouver, British Columbia Police Department conducted a study on the effectiveness of ASE on traffic speeds (Blackburn & Gilbert, 1995). Approximately 1 week of pre-intervention, 2 months of intervention, and 2 weeks of post-intervention, vehicle speed data were collected on both a test and control section in Vancouver. An auto-regressive, integrated, moving average, model-building procedure was carried out on the time series speed data for vehicles of the ASE travelling on both sections. The analysis indicated that the average daily vehicle speed and the percentages of vehicles exceeding the 50-km/h speed limit consistently and gradually declined at the enforcement location throughout the intervention. By the end of the enforcement period, these reductions became significantly different from the pre-intervention levels. The average daily speed at the end of the intervention was 57.9 km/h, compared to the average daily speed of 59.1 km/h during the pre-intervention period (2 percent reduction). The mean percentage of vehicles exceeding 50 km/h at the end of the intervention was 81.9 percent compared to the mean percentage of 86.6 percent during the pre-intervention period (5.4 percent reduction).

Table 4.5. Effects on speed

Vancouver	**Before**	**After**
Average daily speed	59.1 km/h	57.9 km/h
Mean % > 50 km/h (limit)	86.6%	81.9%

The effects of ASE on speed compliance and safety in the United States are being investigated under a current, multi-year study funded by NHTSA. The study involves field evaluation of the effectiveness of selective ASE programs in up to three US communities. The evaluation will seek to determine the effectiveness of each ASE program in reducing speeds and speed-related crashes, both community-wide, and at specific sites within those communities.

4.6 HALO EFFECTS

Based on the findings from research on the effects of speed enforcement on speed behaviour, i.e. effects in time and space - halo effects - (actually memory and halo effects) the following deduction is made:

A time halo effect was found (referred by Várhelyi, 1996) of 2 weeks (in some cases up to 8 weeks). During morning rush hours from 6-9 am, no speed reduction was found during the experiment period or thereafter (Vaa, 1997).

Ostvik & Elvik (1990), also referred to by Várhelyi (1996), brought together evidence concerning the halo effect of speed enforcement: “A stationary police check usually has a local effect only. The extent of the effect in time and space varies, but is usually very small.”

“A stationary clearly visible, parked police car gave a ‘space’ effect on the speed level up to 1.9-2.5 km from the actual checkpoint.” “In an American study a stationary police car was moved around randomly, giving the impression of a massive concentration of checks. The effect on the speed level could be observed up to 20 km from the car.” “The effects of one single control lasted for three days, and of repeated enforcement up to 6-14 days.” “Automatic speed surveillance in Norway on a 80 km/h road reduced the average speed by up to 10 km/h. Such effects were found two years after the introduction of the countermeasure, even if the cameras were only active during 12 hours per week. The percentage of offences was reduced from 43% to 14%.”

Information regarding the *percentage* of cars showing different levels of halo effects, as it may be assumed that not 100% of the cars show the halo effects, is not given.

4.7 CONCLUSIONS

We can conclude from the different examples that speed enforcement on routes had a reducing effect on speeds and accidents.

It is a necessity that drivers are informed about the speed enforcement campaign. Therefore publicity aimed at the target group should be given.

As the objective is to lower speed on the selected relative dangerous route, forewarning should be given to passing drivers about the speed measure. Application of a dynamic sign to speeding drivers will strengthen the effect.

Two examples show that the enforcement level using automatic cameras from road side posts, can be relatively low, and still have a significant speed reducing effect. It is assumed that this is caused by the unpredictability for the driver of the camera being in operation or not.

The visibility of the camera posts on the road side has a ‘kangaroo’ effect, i.e. braking at the approach of the camera and after that speeding again. This effect can be reduced by concealing the posts behind objects (trees, road signs) and also by using cheap dummy posts (not fit for placing a camera).

For efficiency and effectivity purposes speed needs to be monitored, enabling the police to find the optimum way for camera operation.

On routes enforcement can be conducted on links and at intersections, where a combined red-light and speed camera is installed.

5 SPEED MANAGEMENT ON ROAD NETWORKS

Speed enforcement on a road network needs a different approach than enforcement at locations and on routes. It is practically not possible nor desirable to install in a whole network flexible signing and automatic enforcement posts. The objective in a network is, as said before, general prevention. So the enforcement should be unpredictable for the driver in space and time.

In this chapter experiments on motorways, two lane rural roads and urban roads will be described. The countries involved are Australia, the Netherlands and Norway.

5.1 MOTORWAY

Speed enforcement conducted on motorways in the Netherlands in 1992, showed that of the 86,000 enforcement hours spent, 5% was done using radar + camera, and 95% including stopping the speeder (also with surveillance; Ministry of Transport, 1993). Of the 300,000 speeding tickets issued, 70% was achieved using the camera, and 30% by stopping the speeder.

If 100% of the enforcement hours is spent *exclusively by using radar and camera*, a very high enforcement frequency, and a high compliance level is expected to be the result.

A calculation is made of the enforcement frequency, when enforcement is conducted by using the camera only, without halting speeders.

An example calculation: Length of motorways in NL: 2000 km, i.e. 4000 km of carriageway to be enforced. Average length of a road section is 20 km (between two main interchanges), so there are 200 road sections to be enforced. The average number of enforcement hours per road section per year is (86,000 : 200) 430 hours. On average, speed checks will be conducted once in 10 days, if this is done during day time from 7-19 hours. A structural speeder driving five days a week during day time, has a probability of being checked on speed some 29 times a year. The general prevention effect of the sight of a stopped speeding vehicle on passing drivers, can be compensated by a portable sign showing 'Your speed has been checked. Police' placed down stream of an enforcement site. The motorway police started an experiment on a 20 km road stretch in 1993, based on this approach, using radar plus camera only, combined with publicity (chapter 4.1.).

5.2 PROVINCIAL ROAD NETWORKS IN NL

In three provinces in the Netherlands (Friesland, Overijssel, and Flevoland) a speed enforcement campaign was conducted on in total around 100 selected secondary rural roads having a length of 700 km (Oei & Goldenbeld, 1995a, 1997a). As the total length of rural roads in these provinces is around 13,000 km, a selection of roads to be enforced was a practical necessity. Criterion for the selection of the roads was the potential reduction in accidents when the average speed is reduced with 10%. The enforcement was conducted during a period of 4-6 months, before and after the summer. Information regarding the speed campaign was given through regional TV, radio, and the press, so drivers were forewarned. During the campaign the results of the enforcement is given in the papers periodically. The enforcement was conducted only during working days and during day time (7-19 hours) from an unmarked police car, parked along side the road, using radar + camera. The frequency of speed checks for every road was between 0.75 to 1.3 hours per week, being 55 to 80% of the planned frequency. The police was confronted with capacity problems, due to the national reorganisation of the police force, lack of trained radar personnel, and defective apparatus. Downstream from the radar car a portable sign was placed, showing *'Your speed has been checked. Police'*. The aim of this sign is to increase the subjective enforcement level. This sign though was used only sporadically, because of the size and weight. Posters were spread along the network, showing a speedometer and texts such as 'Do you mind slowing down?' or 'It must be lowered!'. A speed sign (using a radar gun) showing the driving speed was applied periodically on the network (without enforcement) to draw the attention of drivers on their driving speed. Some of the approaching drivers brake at the view of the parked car.

The project was conducted under supervision of a working party, with participation of the road authority, public prosecutor, police, regional road safety organisation, organisation for road safety campaigns, and SWOV.

A survey among drivers showed that this type of enforcement method was condoned by the majority of the drivers. 50% of them contend that they will comply to the speed limit also without enforcement, 85% say they will do this when they are checked once a month, and almost all drivers say they won't speed when checked every week. So if this survey result is correct, *to attain 15% speeders only, in average a monthly speed check from 7-19 hours is needed, meaning the enforcement frequency should be increased substantially.*

The speed evaluation was conducted using *radar* measurements from an unmarked car, parked along the road side. Some of the drivers brake their car seeing the parked car, supposing speed checks being conducted by the police. This effect may be greater during the campaign because of the information given through the press, etc. The result of two 80 km/h road types is shown in the Table: a reduction of the average speed between 2 and 3 km/h, the percentage of speeders was lowered from 37-60% to 29-49%.

Table 5.1. Speed and accidents in before- and after-situation

Network speed management	Average speed Before	After	% speeders Before	After	Accidents Before: '91-'93	After: 1994
Control area					average: 720	761 [+ 6%]
Friesland	80 78	77 75	42 37	32 29	average: 17	33 [+94%]
Overijssel	83 83	81 81	60 56	49 48	average: 112	127 [+ 14%]
Flevoland	80	78	42	38	average: 29	25 [-13%]

In the control area (the remaining nine provinces) there was an increase in accidents of 6%. The number of accidents was not reduced as expected, an increase (corrected for control area) in Friesland of +84%, in Overijssel of +8% was found; and only in Flevoland there was a decrease of -17%, although not significant. There are no explanations for this disappointing result, but it is not considered likely that this was caused by the campaign.

In the south eastern part of the province of Friesland the speed campaign was continued in 1996, with a relatively high enforcement frequency (Oei et al, 1996a).

A Memorandum Of Understanding MOU was signed between the provincial authorities, the provincial police and the Ministry of Transport, in which the police promised to enforce speed on eight 2-lane rural roads for a total of 16 hours per week during three months. This period was extended with another three months because of a national strike of the police during the first period. The enforcement frequency realised was 70% of the planned frequency. The speed evaluation was conducted using *inductive loops*. The percentage of speeders was reduced with 25 percent points and the v-90 with 7-8 km/h.

A comparison between radar and loop measurements was made at five sites: the average speed of the loop measurements was at all sites higher than of the radar measurements: the difference varies between 2-5 km/h.

5.3 AUTOMATIC SPEED ENFORCEMENT ON RURAL ROADS IN NORWAY

Selection criteria of roads: 1) accident rate higher than normal for that road type, 2) at least 0.5 injury accidents/km/year, 3) mean speed higher than the speed limit. Not all roads with automatic enforcement comply with these criteria. There were 64 road sections - total length 336 km - at the end of 1995, that were included in the analysis. The article does not mention whether these road sections form a road network or are a collection of separate road sections.

Speed enforcement was conducted from radar boxes along the road side (Elvik, 1997; 1997a). An information sign 'Automatic traffic enforcement' is required on all road sections, where photo radar units have been installed. A photo is made from the front of the vehicle, so the face of the driver can be identified. A tolerance level of 10 km/h is applied usually. The ticket is sent to the owner of the vehicle. When he denies driving the car that speeded, he is required to identify the driver to the police. Standard fines range from US$ 47 to 470. Speeding more than 30-40 km/h will result in suspension of the driving license and normally in a jail sentence.

No speed data were collected during the before-period. The analysis took into account a bias due to regression to the mean.

There were considerable variations between the road sections regarding the effects of automatic speed enforcement on accidents. For all road sections a decline of 20% in accidents was found. The largest percentage decline of 26% was found for road sections complying to the selection criteria and the smallest of 5% was for the sections not complying to any of the criteria.

There were no data available on:
- speeds in before-period
- frequency and duration of operation of radar-camera unit
- behaviour adaptation because of the radar posts such as kangaroo effect and a possible migration of accidents.

5.4 SPEED ENFORCEMENT IN EINDHOVEN

In the city of Eindhoven a speed enforcement campaign was conducted in 1995 on a selection of main urban roads. The number of traffic victims per capita is second highest of all the cities with a population of more than 100,000. This was the reason for conducting the speed campaign (Oei & Goldenbeld, 1996).

Based on the enforcement hours that the police has planned during a period of six months, a selection of roads was made by the road authority of Eindhoven and the police. This was done in such a manner, that the average enforcement frequency be 10 hours per month per road section.

A survey held in three provinces (see 5.2.) showed that 80-85% of the drivers contend that they will comply to the speed limit when the enforcement frequency is once a month (average).

The campaign started in the last week of March 1995. This was combined with information being spread through the press, local radio/TV, and posters on the road side.

A sign reading 'Your speed has been checked. Police' was planned to be used down stream of the radar car.

The enforcement was done using a radar plus camera from a parked unmarked car.

The campaign was evaluated on speed and accidents. A survey among drivers was conducted, and the police evaluated their experiences.

The average speed, 2 months after the start of the campaign (in May 1995), was reduced by 2-4 km/h, and the percentage of speeders went down by between 5-13 percentage points. The percentage of speeders (except for the 80 km/h type) though is still high: between 27-66%.

The enforcement frequency was only 30% of the planned frequency, in average 0.5 hours per road section per week. This was caused by the necessary training of the radar personnel, so often the radar car was manned by two persons instead of one.

The number of fatal and injury accidents involving at least one motor vehicle in Eindhoven was reduced with 14% in 1995, compared with 1994. The number of accidents in the control area, i.e. urban areas in the Netherlands, remained more or less at the same level. The accident reduction can partly ascribed to a downward trend in accidents, and for another part due to the campaign. It is advised to continue the speed campaign in the same manner, but realizing the enforcement frequency as planned and, using the feed back sign.

Table 5.2. Speed in before- and after-situation

Speed management in Eindhoven	**Average speed** Before	After	**% speeders** Before	After
2x2 70 km/h	66	62	40	27
2x2 50 km/h	59	55	79	66
50 km/h, with cycle path	51	48	55	44
50 km/h, no cycle path	47	45	37	29
1x2 80 km/h	66	63	14	9

Table 5.3. Accidents in Eindhoven and in NL in before- and after-period

Accidents	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Eindhoven	409	369	330	376	399	344
Netherlands	19,922	18,488	18,502	18,028	18,485	18,326

5.5 AMSTERDAM

A speed enforcement campaign was conducted in the autumn of 1993 in Amsterdam (Catshoek, 1994). A selection of 57 main urban roads, spread across the city, was made by the police based on accident history and speeding of motorized traffic. Speed enforcement was conducted from an unmarked police car with radar and a camera, and sometimes by stopping speeders on the spot. Periodically surveillance was conducted using a video camera. An intensive information campaign was conducted before the start of the speed enforcement.

The overall average speed was lowered from 55 to 53 km/h (before versus after situation - six months later). Ten months after the before situation the average speed remained at this level.

Table 5.4. Average speed and percentage speeders in before- and after-situation

Amsterdam	**Average speed**		**% speeders**	
	Before	**After**	**Before**	**After**
All roads	55	53	64	58

The number of injury accidents on the roads enforced in the autumn of 1993 went down with 25% compared with the fall of the previous two years. For road victims the reduction was 36%. It may be assumed that this reduction is due to a combination of a descending trend in accidents and the enforcement campaign. As the selected roads were known to be unsafe through the years, regression to the mean is not a probable explanation for this reduction.

Table 5.5. Number of injury accidents and road victims in before and after situation

Amsterdam	**1991**	**1992**	**1993**
Injury accidents	79	70	49
Road victims	88	85	55

5.6 SPEED (AND ALCOHOL) ENFORCEMENT IN AUSTRALIA

Introduction

As the strategy and intensity of the enforcement on the main road network in the State of Victoria, and the results are unique in the world, they will be described in more detail in this chapter. Often excerpts of Australian reports are quoted literally.

The police in Victoria has started massive speed enforcement combined with education campaign in 1990 to curb the upward trend in accidents (Bodinnar, 1994). The Victoria Police Force, VicRoads (State Road Authority), Insurer responsible for road trauma rehabilitation, Transport Accident Commission (TAC) joined forces to stop the carnage. Representatives of these formed a Senior Officers Joint Consultative Committee. A Ministerial Committee on Road Safety - Minister of Transport, and for Police & Emergency Services would oversee and respond to the recommendations of the first Committee.

Problem statement

It is stated that excessive speed is the primary cause in 20% of all fatal and major injury crashes. Unsafe speed and alcohol impairment were estimated to be a primary causative factor in 50% of all road crashes in Australia (and Victoria). In Victoria in 1989: 51,000 collisions reported, with 777 deaths, 10,000 major injuries, and 25,000 other injuries. Every 11.2 hours a road fatality.

Cost per road death: $ 450,000 and major injury $ 92,000. Annually loss (including lost productivity): A$ 1.5 billion.

Speed campaigns

A large scale information campaign was conducted on the problem areas of speed (and drunk driving). Speed enforcement was put under a single coordinating strategy. The strategy was focussed on community awareness through advertising and marketing of road safety.

Specially chosen police officers were stationed at primary schools across the State to supplement the *adult education*, and community awareness activity. The long term objective is to make speeding and drunk driving socially unacceptable, and a high level of voluntary compliance.

It is considered of great importance that the campaign be fair and reasonable to be accepted by the community, and that this is applied firmly and consistently.

A *specific deterrent* is achieved when a speeder after being fined does not speed any more. When drivers change their behaviour for the better, without being caught for speeding, but after learning about the strict speed enforcement program (advertising and sighting enforcement activity) a *general* deterrent is achieved. There are no site specific signs indicating the presence of an operational speed camera, as the *objective is general deterrence*.

Publicity

The power of human perception was considered to be the key to achieving immediate change to existing dangerous behaviour. To override undesirable values, attitudes, and perceptions leading to speeding, a perception is created in every Victorian driver ‘If I speed I will be caught by a speed camera and fined!’.

At all state border entry points and on all major highways, and arterial roads a large sign is posted showing ‘SPEED AND RED LIGHT CAMERAS OPERATE THROUGHOUT VICTORIA’.

Speed advertisements on TV show captions as ‘Don't fool yourself. Speed kills’. All the films show different kinds of misbehaviour leading to accidents and the suffering. Shown are the direct victims: the driver, passengers, and also parents, and other family members, surgeon, researcher. Different kind of crashes and consequences such as blindness, loss of hand, revalidation, passengers in burning car, passengers drowning in car in river, bicycle, and child overrun by car, were staged and shown. Further speed camera in car, driver in court and in jail can be seen on TV. Judicial problems with insurance companies that are costly and can take many years, time and fuel costs, environmental effects form no part of the publicity campaign.

Enforcement

In the past the enforcement level was known to be much too low to be effective. The actual *level of enforcement necessary* was difficult to forecast, but decisions were to be made before the start, such as the number of cameras needed, and the processing capacity.
The enforcement activity consisted of the following:

- Statewide, no geographic areas where drivers could develop perceptions of relative immunity.
- Seen by the community solely as a road safety initiative, must focus on areas with a validated speed related crash risk.
- Supplemented by a high impact TV advertising campaign during the lead up and the program.
- Totally unconnected with the by-product of fine revenue.
- Demerit points would apply to speed camera violations.
- Carefully monitored incremental approach to the level of enforcement to establish 1) the behavioural response lag subsequent to each increment, and 2) behaviour effect of each level of enforcement. This information could not be found.
- A *tolerance of 9 km/hour* above the posted speed limit is allowed before recording an infringement.

Police guidelines were formulated to ensure ‘fair play’.

From data collected on the road regarding mean and absolute travel speeds across the State, it was determined that the *appropriate level of enforcement coverage* was resourced by:

- 54 speed cameras spread across the State
- a processing capacity of 100,000 records per month with a system capable of managing
    a) automatic 'on line' look up of vehicle owner and driver license details,
    b) collect fine payments and reconcile records against banking,
    c) general correspondence, including driver nominations, pleas, open court contested hearings, and unpaid ticket follow up.

Processing of infringements

The system automatically links office images and associated infringement records, applies additional fees and charges when appropriate, and refers records for sequential attention in accordance with the law automatically. Images of offending vehicles are available at specified work stations and the public can view their image, and have their case explained by Traffic Camera Office (TCO) staff free of charge. The TCO system is connected with vehicle and driver's license data bases, and with Chase Manhattan Bank, which collects and remits all fines. Images are registered and audited. Film is scanned into digital form; offence details are automatically character recognised by the computer. Images are individually examined by trained offence verification staff. TCO system identifies vehicle owner from VicRoads vehicle data base. Infringements are issued and written to magnetic computer tape for printing and posting to the owner. The registered owner of a vehicle is initially liable for the offence.

Corporate owners of motor vehicles must in every case *nominate the actual driver* of the vehicle at the time of the offence. Failure to comply results in the corporation being fined

A$ 600,- plus the original offence fine, and the vehicle registration is suspended for three months. Owners have to pay the *penalty* and gets *demerit points* on his account when they cannot or will not identify the driver. TCO automatically matches the offending driver with the license record at VicRoads, and assigns the appropriate demerit points against the driver.

Infringement notice administration

Owner driver pays within 28 days or nominates actual driver within 28 days. Nominated driver pays penalty within 28 days. Additional 28 days to pay permitted with $ 12.50 fee. Demerit points automatically assigned against driver at VicRoads license data base. Unpaid records transferred automatically for court and sheriff warrants to arrest or seize property (incl. costs and fees). Contested cases referred to open court hearing.

Effect on speed behaviour and recidivism

From analysis of a limited number of sites, it can be inferred that the speed camera programme has *not resulted in a measurable decrease in mean speeds* in Victoria. The percentage of vehicles exceeding the speed limit by more than 15 km/h, however, did decrease and remained at a much lower level in both speed zones of 60 and 75 km/h. As the mean speed did not change much and the high percentiles being reduced, the low percentiles must have increased. However the percentage of vehicles exceeding the speed limit by more than 15 km/h decreased from November 1989 and has remained at a much lower level in both 60 km/h and 75 km/h speed zones. Measurements were conducted with double loops.

In 1993 the rate of second infringements (*recidivism*) was 29% less, for third infringements the reduction was 45%; a marked reduction in multiple infringements was found.

Safety effects

The accident evaluation concerns the number of collisions/injuries/fatalities in Victoria from January 1989 to June 1994.

Monash University Accident Research Centre MUARC conducted a study on the effects of the Traffic Camera Program on road accidents (Cameron et al, 1992 & Rogerson et al, 1994). Cameron (1995) published a concluding article regarding the evaluation. The road toll was reduced with 49%: from 777 in 1989 to 396 deaths in 1992 (i.e. 0.95 deaths per 100 million kilometres travelled).

The introduction of the speed camera program and supporting publicity in Victoria has been associated with decreases in the frequency of reported casualty crashes which occur in low alcohol times of the week, and also in their injury severity. The program appears to have had its greatest effects on arterial roads in Metropolitan Melbourne and on 60 km/h roads in rural Victoria, where the majority of the speed camera operations have taken place.

To enable *differentiating speed from alcohol effects*, accidents during low alcohol hours - during daytime - were analysed (Cameron et al, 1992). Most of the speed programme was conducted during the day. Serious casualty crashes during daytime only include 4% where alcohol is a factor.

The reductions in the *frequency of casualty crashes* (in low alcohol hours) - 32% on arterial roads in Melbourne, 23% in country towns, and 14% on rural highways - appear to be linked with speed camera Traffic Infringements issued to detected drivers, and Transport Accident Commission road safety advertising publicity. Reductions in the injury severity - principally in Melbourne - were also found. It is not known whether this was achieved by specific and/or general deterrence.

About 15% of the total reduction of 49% can be attributed to increased unemployment and 12% to reduced alcohol sales (Cameron, 1995). A reduction of 25% (49% minus 15% minus 9%) can be attributed to the campaign.

The effect of *speed enforcement* is estimated to be 14% (18/32x25) and of random breath testing 11% (14/32x25; Rogerson et al, 1994).

5.7 CONCLUSIONS

From the examples given in this chapter we can conclude that speed enforcement on road networks has a speed reducing effect as a whole respectively only for the fast driving group.

As the enforcement endeavour required in a network is high for the police, it is a must that the enforcement is conducted in an efficient way. Organisation, publicity, enforcement, should be coordinated. An integrated approach of enforcement for drunk driving, speeding and other traffic infringements is desired.

From the surveys an enforcement frequency of an average of 12 hours per five working days, may result in almost complete compliance to the speed limit (if the enforcement is conducted on working days during day time only).

It is advised to conduct an experiment to put this to the test.

The enforcement approach in Victoria State is unique in its approach: relevant organisations were directly involved and combined forces, the input of police manpower was very high, combined with a point demerit system, the number of locations was spread over the whole State, the publicity was very intense, and was continued periodically during the campaign, the duration of the campaign continued for many years.

The public relation part to gain public acceptance was carefully done. The enforcement programme is set up to be reasonable, fair, and not ‘driver unfriendly’. It is explicitly not the objective to maximize the number of tickets (= financial income), but to reduce the number of accidents and road victims.

On roads where cars are rarely parked along the road side, such a radar car will raise suspicion and approaching drivers will lower their speed. A speed evaluation conducted at times when no enforcement is conducted will therefore show no effect on speed. A possible improvement is concealed enforcement with a sign downstream reading ‘Your speed has been checked. Police’, as has been applied in the Netherlands.

It is surprising that although there is a point demerit system in Victoria, Australia, the intensive enforcement in combination with massive publicity, the effect on average and v-85 speed was absent. Only the percentage of speeders driving faster than 15 or 30 km/h above the limit was halved. This implies that the group of slow driving cars is driving faster. So the accident reduction seemed to be the result of the reduction in the group of fast speeders. On Victoria roads having 100 km/h limit there was no effect on speed at all.

The effect of speed enforcement only in Victoria, on accidents (excluding effect of random breath testing) is approached by looking at the accidents during low alcohol hours (daytime).

A calculation of the average enforcement frequency in Victoria: 2500 camera sites, on average 30 cameras in operation daily, per camera 80 sites to be enforced, 4000 camera-hours per month, each camera in average daily operation during 4.4 hours, i.e. 244 minutes for 80 sites, or 1,5 hours per site per month.

A design for an efficient and effective integral approach of enforcement of drunk driving, speed, aggressive behaviour, etc. is needed.

6 DISCUSSION

As the effects of enforcement in the areas local, route and network show great similarities, the following general questions will be dealt with here (where relevant the different areas will be treated too):

- how does enforcement in its various approaches influence driving speed behaviour
- what effects can be expected
- what minimum level is needed
- what level seems most cost-effective

Mainly findings from the literature treated in this report are used here, and logical considerations.

6.1 INFLUENCE OF ENFORCEMENT ON BEHAVIOUR

Influence of speed management through warning, enforcement and publicity on the driving behaviour can be realized through change of attitude, gain in knowledge regarding speed and accidents, and enhanced attentiveness.

Although the described experiments in preceding chapters vary in many respects, most of them resulted in a lowering of the speed and/or the percentage of speeders. This is the case for *local, route and network* enforcement. So it can be concluded that speed enforcement definitely has the potential to lower speed.

Speed enforcement in general does have effect on speed behaviour when it is subjectively perceived by the driver that the probability of enforcement in time and space is high. This subjective perception is related to the objective enforcement level, publicity, signs and own experience. Publicity without realisation of (increased) enforcement will have temporary effect only. The way behaviour is influenced can be distinguished in whether specific or general prevention (in space and/or time) is the objective:

1) Specific prevention is aimed at lowering speed on problem *locations and routes* (selected on problem of speeding and accidents). Most of the described experiments regards speed management on routes. Pre-warning through signs on the selected road or route is given in most of the experiments, this can be considered as a functional requirement.

2) General prevention in space and time is aimed at lowering speed in a whole *network* (Australia and the Netherlands). So no pre-warning upstream of an enforcement site should be given. A sign *downstream* of the enforcement site informing drivers they have been checked on speed, will increase the subjective experience of enforcement. Ideally the speed enforcement is done unobtrusively and automatically, e.g. by registering the electronic number plate and by automatic writing off the fine from the bank account.

6.2 EFFECTS ON BEHAVIOUR

The magnitude of the effect of speed warning and enforcement on speed behaviour in time and space depends on several factors, such as the objective and subjective enforcement frequency in time and space. In general the more specific and relevant the information the greater the effect. The effect on speed is greater, the greater the conceived probability of enforcement and the better the compatibility between infrastructure and speed limit. Other influencing factors are e.g. demerit point system, type of sanctioning system, level of the fines, etc.

A demerit point system, increased penalties for recidivism, possibility of confiscating the car, withdrawal of the driving license, etc. can be assumed to enlarge the effect on speed behaviour. Often no information is given in the literature regarding these aspects. A correct comparison between research results therefore is rather difficult.

A visible enforcement site, e.g. a camera post, may reduce the speed only in the neighbourhood of this site, between the sites drivers may speed again. This may be countered by using dummy camera posts next to posts where a circulating camera can be placed inside.

A further problem is vandalism of the camera and post, as experienced in the Netherlands.

Enforcement from a parked car on the road side can have a limited speed reducing effect, i.e. only at the approach of the visibly parked car (parking on rural roads is seldomly allowed or done), unless unobtrusive parking is possible. Camouflage of the radar and camera by housing them in a movable electricity box, dustbin or a trailer is practised in the Netherlands, no evaluation has been conducted.

Automatic enforcement from road side radar posts has a relatively long lasting effect because of the permanent probability of a camera being operational.

In Victoria State, Australia, through massive enforcement in the whole State on drunk driving and speeding, during several years, accompanied by intensive publicity campaigns (on TV with simulated accidents and victims), the average speed was not reduced, though the percentage of fast driving cars went down. This implies that the speed of slow driving vehicles must have risen.

6.3 EFFECTS ON ROAD SAFETY

Accident evaluation is often cumbersome because of the, statistically seen, relative small number of injury accidents and the great number of years needed to have sufficient accident data and the possibly changed conditions in this period.

In the Netherlands the experiment with automatic speed warning at an urban location resulted in a speed reduction of 5 km/h. A theoretical calculation resulted in a potential reduction of accidents at this location of 25% (Oei, 1989). Experiments on *rural locations* resulted in a marked reduction in accidents, though the number of accidents was statistically seen very small.

Experiments with speed management on rural *routes* in the Netherlands have resulted in an accident reduction of 35%. The injury accident reduction in Finland on a two lane rural road was 9%, the reduction in fatal and serious accidents on a metropolitan route in the UK was 14%.

No reduction in accidents was found in the Netherlands after the experiments on *rural road networks*. No clear cut explanations could be found for this disappointing result. Two experiments on *urban* road networks showed a 14% and 25% reduction in injury accidents respectively.

In Victoria State, Australia, the massive enforcement campaign in this State resulted in a 49% reduction in the number of road fatalities, with an estimated 14% reduction, as result of speed enforcement.

6.4 LEVEL OF ENFORCEMENT

The hypothetical hysteresis curve relating level of enforcement with level of compliance shows an optimum point: least enforcement needed having a maximum effect. An indication of this level can be derived from surveys conducted in the Netherlands and from halo effects as described in Chapter 4.5.

The surveys were conducted in three different provinces: around 85% of the respondents contend they will comply to the speed limit of 80 km/h when confronted with speed enforcement once a month, almost all respondents contend they will do this when the enforcement frequency is once a week.

An average of once a week means that in average each week enforcement is conducted during 12 hours, during daytime, say from 7 to 19 hours. This can be done in different ways, for example every day during 1.45 hours, this can be spread evenly during the day and evening. Another possibility is for example every other day during 3.5 hours. Of course the timing should be unpredictable for the drivers. If enforcement is conducted also in the evening hours then the average number of enforcement hours will be say 18 hours per week.

From experiences regarding halo effects the optimal enforcement frequency can also be derived: 12 hour operation of the camera resulted in long term speed reducing effect in Norway (see Chapter 4.3.3.). This result corresponds with the above mentioned derived result from the surveys.

This enforcement frequency can be realised at a *locality* using radar and camera from fixed posts, using a time clock.

The same applies for enforcement on *routes*. We may assume that drivers who structurally drive too fast will be caught at any point on the route where enforcement is conducted. So a circulating camera at the posts on the route should be operated during an average of 12 (or 18 including the evening) hours in a week. The results from the long term evaluation study (see Chapter 4.3.1.) lie in the same line and do not contradict this finding.

This level could not be reached at the experiments on *road networks* in the Netherlands, because of insufficient personnel to enable reaching this level of enforcement.

Although not quite comparable, in Victoria State the average level of speed enforcement was lower than in the Netherlands. The average speed was not lowered in Victoria State, the percentage of fast driving cars was lowered, the percentage of slow drivers increased.

6.5 COST-EFFECTIVE SPEED ENFORCEMENT AND SPEED ADAPTATION

Speed enforcement and processing need to be automated, so manual labour can be minimized. The most efficient way will be automatic unobtrusive automatic enforcement, e.g. by measuring speed through inductive loops and registering the electronic number plate of speeders. A vehicle can be identified automatically by electronic means. This needs social acceptance and a political decision.

Automatic enforcement by averaging speed from measurements of two sites on a route can increase the efficiency, the distance between the two points should not be made too short.

Another development is intelligent speed adaptation, where no enforcement will be needed anymore, as speeding will be made impossible. This can be done using transponders at points on the road side where there is a change in speed limit. A signal is transmitted to the car and a speed limiter will prevent speeding. Another possibility consists of an autonomous system in the car. Information of the whole road network including the speed limit of each road section is registered on a CD ROM. The road section where the vehicle is located is determined using GPS. A speed limiter will prevent speeding.

6.6 NEW ELEMENTS

The question can be posed whether there are elements in this study, that can be considered as ‘new’ and can improve the efficiency and/or effectivity of speed enforcement. The following elements can be considered as such:

- The hysteresis curve representing a hypothetical relation between enforcement and compliance.
- Modulation of the enforcement deduced from this curve for increased efficiency.
- Categorizing enforcement according to spatial extensiveness: local, route, network.
- Criterion for selection of locations or routes: potential reduction in accidents.
- Specific and general prevention in space/time.
- Coupled to this prevention category, fore-warning at selected locations or routes and post-signing downstream of an enforcement site in a road network.

- Survey question regarding enforcement frequency related to compliance to deduce optimum enforcement frequency.
- Deduction of optimum enforcement frequency based on halo-effects and survey results.
- Automatic enforcement by measuring average speed.
- Massive integrated enforcement and publicity in Australia.

7 RECOMMENDATIONS

7.1 GENERAL

Based on the literature findings, acquired experience from the experiments and logical considerations, the following recommendations are given.

For speed enforcement strategies and tactics to be effective, certain conditions need to be fulfilled:

- Synergy, a strategic alliance between relevant ministerial departments, road authorities, and other parties should be formed, e.g. Department of Transport, Justice, Interior, Finance, Health, state, provincial and municipal road authorities (Bodinnar, 1994).
- Explicitly and quantitatively formulated government policy regarding accident reduction through speed enforcement is needed (Dutch Ministry of Transport, 1991).
- A possibility to arrange the tasks of the road authority and of the police regarding speed management; an agreement (MOU) can be made between the road authority, the police, and prosecution office, in which the road authority promises to adapt the road infrastructure - within a certain number of years - in such a way that speeding will be reduced. Until then the police promise from their side to enforce speed (ROF, 1995).
- Speed enforcement is regarded to be a permanent and sustained task and not just a temporary action, though the enforcement endeavour could be varied in time.
- The law should be adapted so the car owner is primarily responsible for offences committed with his car (Dutch law).
- Next to withdrawal of a driving license, a withdrawal of the car license of business cars is another possibility (Bodinnar, 1994).
- The law should enable completely automating the enforcement process without involving a police officer for efficiency reasons.
- A point demerit system might enhance the efficiency and effectiveness of intensive enforcement, so the enforcement frequency could possibly be lower than without such a system (chapter 6.2.).
- A loop speed measuring network will facilitate the selection of roads for enforcement and the continuous monitoring of speed (Oei, 1994a).
- Selection of sites and roads should be based on accidents and speed (potential reduction in accidents/road victims by speed enforcement; Oei, 1995a).

- It is of great importance that the strategy be primarily prevention and not punishment and be reasonable for the public (Bodinnar, 1994).
- Use of new electronic technologies that will increase the efficiency and effectiveness of the enforcement process is recommended, such as automatic registering, reading and identification of number plates of speeding cars. A high objective and subjective frequency of speed checks can thus be reached.
- A working party supervising a continued speed campaign increases the efficiency because it enables direct communication and feed back between parties involved (Oei et al, 1995a).
- The start of a speed enforcement campaign should always be combined with publicity, to lower the number of speeders and also for reasons of open and fair play. Also an intensification, after a period of reduced enforcement endeavour, should be accompanied by publicity.
- The public must be informed about the dangers of speeding, to change the attitude of drivers by approaching the emotion, next to a cognitive approach, and to warn drivers of the strict speed enforcement (Levelt, 1997, a MASTER report).
- Though the impact of publicity will dissipate over time, weekly publication of the number of cars checked and speeders caught can enhance the subjective probability of being caught.
- Communication with the driver, using new techniques and technologies, can possibly increase the subjective enforcement level. The target groups - young drivers and business car drivers - should be approached separately.
- Enforcement in regions needs an information campaign that extends the boundaries of the region, as part of the traffic has its origin outside this region.
- Ministers and other VIP's need to give a good example; they can commit themselves publicly that they will obey the speed limits strictly.
- Inform drivers of positive effects and thank them for their cooperation (OECD, 1991).

7.2 SPEED ENFORCEMENT AT SPECIFIC LOCATIONS OR ROUTES

- Signs at the road side giving forewarning regarding speed enforcement are functional where the enforced location or road is selected based on a safety (and speed) problem. The objective is to manage speed at these selected sites.
- Speed enforcement can readily be conducted from road side boxes, one camera circulating between several boxes.
- On two lane rural roads it is advisable to enforce speed in both directions at the same time for efficiency reasons.

- If on a road section the main safety problem is the intersections, it might be advisable to install the cameras at the approach of the intersection, enforcing red light trespassing and speeders.
- Flash units can be installed in boxes without a camera to increase the subjective probability of being caught. However, in publicity campaigns drivers should be informed about this (fair play).
- From the hysteresis curve it can be deduced that to increase the efficiency, the enforcement frequency be modulated, starting with intensive enforcement, then decreasing this level, to increase this again after a while.
- By continuous monitoring the speed by inductive loops, the moment for a decrease and increase of the enforcement levels can be deduced.
- It is advised to conduct an experiment with road side camera boxes having different enforcement frequencies such as an average frequency starting from 24 hours (or 18 hours for enforcement during day plus evening) per week to six hours per week.
- To prevent a ‘kangaroo effect’ the radar+camera box can be made inconspicuous by camouflage enlarging the unpredictability of the enforcement.
- At dangerous sites such as intersection or school exit, the camera box should be made conspicuous.
- The camera boxes should be made vandal-proof.

7.3 ENFORCEMENT ON A ROAD NETWORK

- Prevention on a whole network needs randomized (unpredictable in space and time for the car driver) speed enforcement from unmarked cars. No pre-warning, but warning after the speed check should be given, i.e. a sign, downstream of the radar car, that speed has been checked.
- Random selection of enforcement sites on a road section will enlarge the time and distance halo effect because of the unpredictability of the enforcement for the driver in time and space.
- For area wide enforcement the road network shall be subdivided in road sections, bordered by two main discontinuities. The enforcement site should be varied in space on the road sections. A structural speeder will anyway be ticketed on such a section. Variation in the time of enforcement is also needed.
- For enforcement using cameras from unmarked cars it is advised to have an experiment with average enforcement frequencies per road section ranging from 12 hours (during day time) per week to 12 hours per month.

- It is advised to have a one hour speed check at a stretch, then to move to another location. Further it is advised to split the enforcement in as many units as possible, so one hour per day check repeated during six days, instead of six hours at a stretch per week. This for unpredictability reasons.
- Frontal photos of the driver (and car number) are preferred for identification reasons.
- Speed checks using a camera should - if possible - be conducted in both traffic directions at the same time, doubling the efficiency.
- On road sections being installed with road side boxes in which a camera is circulated, use of dummy flashes in the boxes that are empty can enhance the effect on speed behaviour. The public should also be informed about this, where openness and fairness are aimed at.
- Design for an integral approach for efficient and effective enforcement on drunk driving, speed, aggressive behaviour, etc. should be developed. This design will differ for each country, because of differing problem areas and conditions as described in Chapter 2.

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