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THE EFFECT OF ENFORCEMENT ON SPEED BEHAVIOUR; A LITERATURE STUDY

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1 OBJECTIVE

The objective of the literature study (which was conducted within the framework of EU MASTER project) is to give an overview of examples of research results 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. In the past 10-15 years many reports and articles have been published on this subject.

For correct understanding and interpretation of the literature, relevant background information is needed, such as government policy on speed, law and penalty system on speeding, point demerit systems, organisation and practice of speed enforcement, publicity. However, this type of information is often not given in the literature.

2 SPEED AND ACCIDENTS

Empirical evidence regarding the relation between speed and accidents have been found in several countries, such as Sweden, Finland, USA. A reduction in speed appears to give a disproportionate large reduction in accident, injury and fatality rates (see *Figure 1*; see Andersson & Nilsson referred to in Oei, 1998). The purpose of *Figure 1* is to give an idea of the potential of accident reduction by reducing speed. Enforcement can be one way to obtain speed reduction.

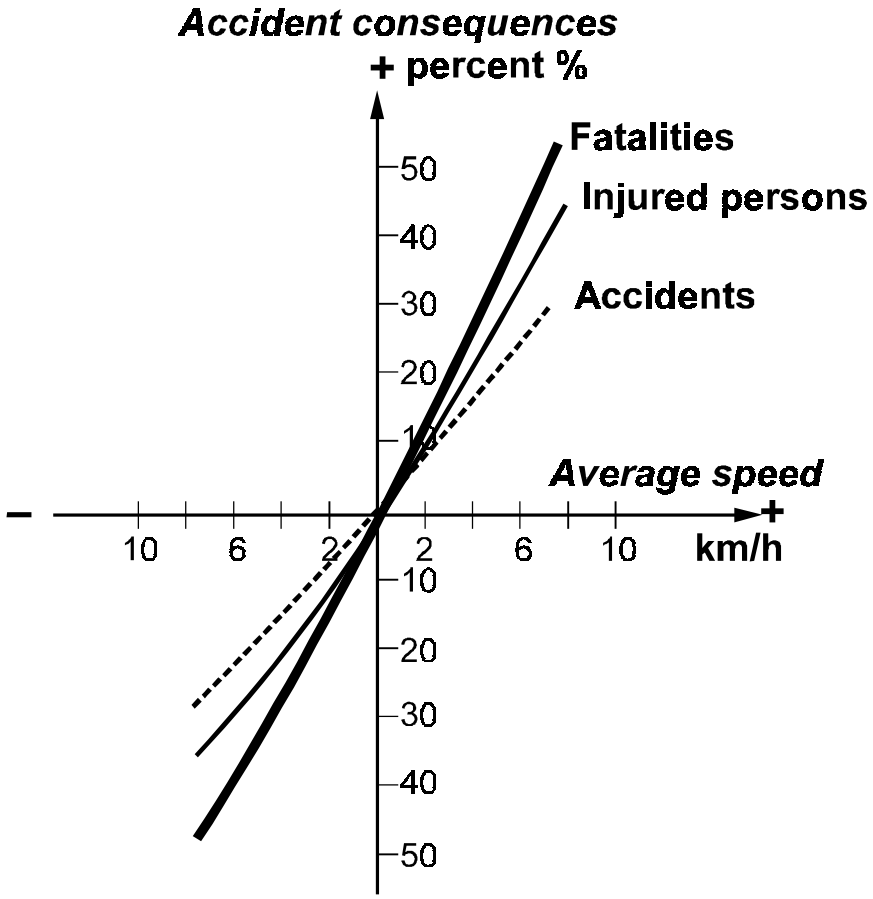

Figure 1. Changes in average speed versus changes in percentage in accidents (Nilsson, 1981)

3 ENFORCEMENT LEVEL AND LEVEL OF COMPLIANCE

A hypothetical relation between enforcement level and level of compliance to the speed limit is given in the hysteresis curve (*Figure 2*). At zero enforcement level, a certain percentage of drivers will comply to the speed limit. This percentage will vary depending on road type and prevailing conditions. A small increase in the enforcement level will have no effect in the beginning, as the probability of being fined e.g. once in 10 years or in 5 years will have no noticeable effect in behaviour. At a certain level of enforcement, however, an increase of enforcement will result in an increase of the compliance level. The compliance level will level off when approaching 100%. Then when the enforcement level is decreased, at the beginning drivers will not notice this, and the compliance level will still remain near 100%. The result is a hysteresis curve. The question is what enforcement level will result in a compliance of say 90% (Dutch target for the year 2000).

The enforcement level can be defined as the enforcement rate per time unit per road section. So 50% means that half of the time a speed check is operational on a road section. A road section is defined as a part of a road between two main discontinuities, such as main intersection, change in road type or in speed limit. The influence of the length of the road section is relative when enforcement is conducted from a radar car and is varied in time and space (to be unpredictable for drivers) and where the aim is to enforce *structural* speeders. This type of speeder will be speeding almost on the whole road section and thus be enforced independent of the location of the radar car and length of the road section. For motorways the average length can be e.g. 20 km and for two lane rural roads 5 to 10 km.

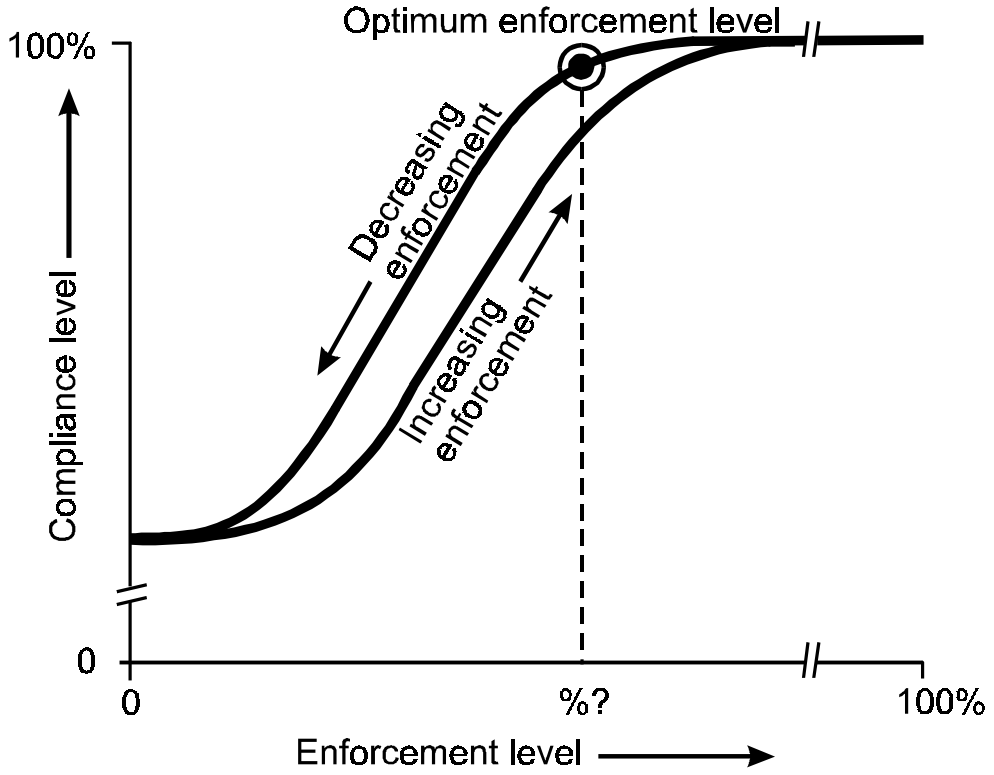

Figure 2. Hypothetical relation between enforcement level and compliance to the speed limit.

The efficiency of enforcement using only a camera is very much higher, compared to enforcement where speeders are stopped and fined on the spot.

4 ENFORCEMENT AT LOCATIONS, ROUTES AND ROAD NETWORKS

Enforcement can be conducted at specific dangerous locations (sharp bend, intersection, school), on dangerous routes (e.g. road works) or on a road network. The objective of enforcement at selected locations and routes is specific prevention at those locations or routes (in space).

The aim of enforcement on a road network is general prevention: the number of speeders has to be lowered at any time on the whole network.

5 GENERAL AND SPECIFIC PREVENTION

In the literature the concept of prevention is usually defined from a psychological/driver point of view. Another possibility is a definition of prevention in time and space. Specific prevention is aimed at lowering speed at selected locations or routes. General prevention is aimed at lowering speed anytime, anywhere (in a network). In the following sections examples are given of various types of enforcement.

6 LOCAL SPEED MANAGEMENT

This type of speed management has been applied in several countries. Some examples of this type of speed management are given from Dutch experiences. In *The Hague* an experiment was conducted at an urban intersection, where a school is located and school children periodically cross the main road. An automatic sign shows the speed limit '50' when a car is speeding, only during periods the school was open. Before the sign was put into operation a publicity campaign was held, informing the public in the neighbourhood of the dangers of speeding the operation of the system, and the expected change in behaviour. Average speed reduced from 56 to 51 km/h (*Table 1*). A theoretical calculation showed a reduction in the percentage of cars that could not stop in time before the intersection (in case of an emergency) of 25%.

Table 1. Speed and accident evaluation results at an urban and rural intersection (NL).

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

In the Dutch province of *Friesland* an automatic sign was installed at a rural intersection with the text 'You are speeding' when a car was speeding. Pre-warning is given through a fixed sign showing 'Speed limit 70 km/h'. The speed limit on the main road was locally lowered from 100 to 70 km/h. Mean speed was reduced from 80 to 60 km/h, the number of accidents decreased from six to two (very small numbers; *Table 1*).

A combination of automatic speed and red light enforcement was applied in *Amsterdam* on four intersections in one direction of the traffic flow. Cars passing through the red light and cars driving faster than 10 km/h above the speed limit, also during green light, were photographed from a road side box. Two camera's were interchangeably used between these sites. A fore warning was given using a fixed sign reading 'Warning! Red Light and *Speed* Enforcement'. Because the aim was specific prevention at these sites (and not general prevention for all intersections), this fore warning was thought to be appropriate. The percentage of red light offenders was reduced with between 1.1 to 4.8 percentage points. The percentage of speeders (limit + 10 km/h) in the before-situation was high only on one intersection: 16.2%. This declined to 4.1% (*Table 2*).

Table 2. Percentage of red-light offenders and speeding at four intersections (NL).

Amsterdam	% of red-light offenders		% > 50+10 km/h	
	Before	After	Before	After
Intersection 1	2.9	1	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 >80 km/h

7 SPEED MANAGEMENT ON ROUTES

7.1 Motorway (NL)

At the end of 1993 the Dutch motorway police started a speed campaign on a 20 km road section, having speed limits of 120 and 100 km/h. The enforcement was conducted using a radar and camera from varying locations along the roadside. Intensive publicity accompanied the introduction of the enforcement. The enforcement endeavour at the start was 700 radar hours during one month, followed by an average of 300 hours per month. The percentage of speeders on the 120 km/h part was reduced from 30% to 10% and on the 100 km/h part from 65% to 20%. The speed campaign has been extended to other parts of the motorway network since then.

Recently experiments were conducted by measuring automatically the *average speed* at three locations with an inter distance of 750 m and 2,200 m respectively. Inductive loops measured the speed, and video cameras determined the 'signature' of passing vehicles (vehicle identification through pattern recognition). When the average speed of a car exceeded the speed limit plus 6 km/h at the first road section, the average speed was checked again at the second road section. When the average speed still exceeded the threshold speed, then the car owner was sent a ticket by post. The system could read the characteristics of the car automatically in 60% of the cases, 40% still needed personal intervention. The percentage of cars exceeding the threshold speed was 1%. This system increases the enforcement efficiency and effectiveness enormously.

7.2 Two lane rural roads (NL, FIN, UK)

Experiments have been conducted on four Dutch provincial roads having a speed limit of 80 km/h. The roads were selected by the road authority and the police based on unfavourable accident and speed history. A publicity campaign accompanied the experiments.

Two of the roads are open for motorized traffic only (type A), the other two roads are also open for slow moving vehicles, such as tractors (type B). The objective of the campaign on the first type of roads was to reduce speeding vehicles. The objective on the second road type was to reduce speeding as well as to increase the speed of slow moving cars.

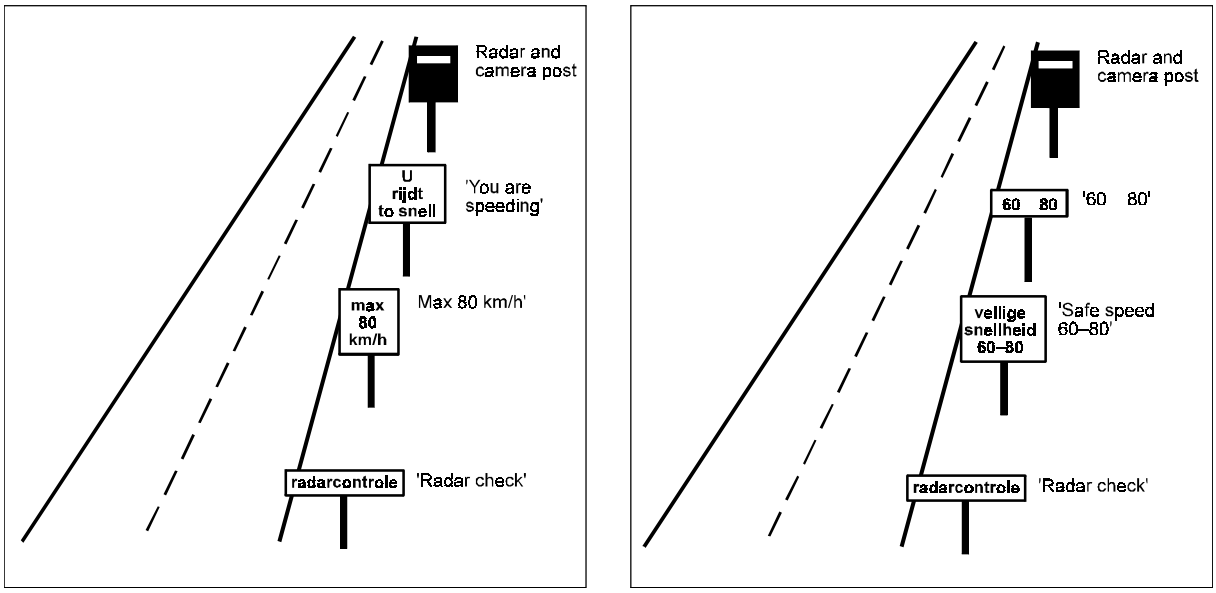

Figure 3. Design of the automatic speed management system on 2-lane rural roads open for a) all cars, motorcycles and tractors only (left), and b) for cars and motorcycles only (right).

At the start of the route a fixed sign informed passing drivers of a) Max. 80 km/h, and b) Safe speed 60-80 km/h.

Drivers speeding get a warning through a sign reading a) 'You are speeding' and b) '60-80'. The law does not allow enforcement of slow moving cars.

Further down the road enforcement was conducted by a circulating radar + camera set for three or four road side boxes during a period of three months. The rate of operation of the radar + camera varied between 50% and 100%.

Cars speeding by more than 10 km/h were fined. The percentage of speeders on all four roads went down from 38% to 11%. The percentage of slow moving cars on road type B was small and showed a small increase. The total number of accidents on the four roads went down with 35% (in comparison to control roads).

Table 3. Speed & accidents in before and after situation on experiment and control roads (NL).

Experiment roads		Mean speed		% Speeders		Total accidents	
		Before	After	Before	After	Before	After
Short term	4 roads	78	73	38%	11%	150	81
	1 road	79	74	39%	11%	53 average/year	31
Long term 1 road			75		16%		30 average/year
Control roads		Mean speed		% Speeders		Total accidents	
		Before	After	Before	After	Before	After
Short term 2 roads		79	79	41%	44%	284 49 average/year	is very much higher. 237 60
Long term 2 roads		75		16%			43 average/year

A long term evaluation on one of the roads of type B, three years after the experiments were concluded, showed that although the camera system was out of operation during one year, and that since reinstallment the rate of operation was one day per month, the percentage of speeders increased somewhat from 11% to 16%, and the number of accidents remained at more or less the same level.

In *Finland* a comparable experiment was conducted on a two-lane rural road with a length of 50 km and speed limits of 80 and 100 km/h. Speed is enforced in one direction. Enforcement was conducted from twelve road side camera poles. Drivers approaching this road were warned through signs. Rate of operation was 8,065 hours in two years, i.e. 46% of the time. Enforcement margin was +15 km/h. The percentage of speeders was reduced from 32% to 24%. On a comparable control road no speed reduction was found. The injury accident rate went down by 9%.

Table 4. Effects on speed and accidents (FIN).

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%

Another example is red light and speed camera operation on a route in a metropolitan area *near London*. The road links were selected, based on high incidence of speed related accidents, serious and fatal accidents, and single vehicle accidents. Drivers were warned beforehand through warning signs, dummy flash units, and publicity. Next to fines, penalty points were imposed.

The mean speed was reduced by 5 mph, no halo effect was found on adjoining roads. The number of fatal and serious accidents decreased with 14% (623 to 538) on the links as well on the junctions.

Table 5. Effect on speed behaviour (GB).

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

8 SPEED MANAGEMENT ON RURAL ROAD NETWORKS

In three rural provincial road networks in the Netherlands - 100 road sections with a total length of 700 km were selected - a speed enforcement campaign was conducted in 1994. The selection criterion was the potential reduction in accidents/victims, i.e. the reduction obtained when the average speed is lowered by 10% (using the Swedish formula). A different approach was needed here, because it was not desirable, nor possible, to install speed signs and camera boxes on all links of the network. For reasons of unpredictability, enforcement should be varied in time and space. Enforcement was conducted using an unmarked radar car. As the aim was general prevention, no fore warning up-stream from a radar car was given. Down stream from the radar car a sign was placed with the text 'Your speed has been checked. Police' to increase the subjective probability of being checked. The enforcement period was between 4 to 6 months, on working days during day time. Publicity just before the start of the campaign gave information about the dangers of speeding, the operation of the system, and the expected behaviour. The enforcement frequency per road section was between 0.75 and 1.3 hours per week.

A survey among car drivers showed that this enforcement method was accepted by a great majority of the drivers. Half of the drivers said they would comply to the speed limit, also when not enforced. 85% said they would do this when speed is checked once a month, and almost all drivers said so when speed is enforced once a week. So if this result is conform reality, an average enforcement frequency of once a week on working

days from 7 to 19 hours will result in almost complete compliance to the speed limit of motoring traffic in these periods.

The average speed was reduced by 2 to 3 km/h, the percentage of speeders with 4 to 11%, although the percentage of speeders during the campaign is still between 29 and 49%.

It should be mentioned, however, that the method of speed evaluation using a radar from a car had its side effects. Some passing drivers slowed down temporarily when sighting the car parked on the road side. According to the radar personnel this phenomenon occurred more frequently during the speed campaign than before.

The number of accidents was compared to a control area. There was no reduction in accidents. In one province there was even a marked increase in accidents. No explanation could be given for this.

The speed enforcement was then continued in a part of the province of Friesland, comprising eight road sections and an average enforcement frequency of 1.4 hours per road section per week. The speed evaluation was done using hardly perceptible loop detectors. The result was a reduction of the percentage of speeders of around 25 percent points.

Table 6. Speed and accidents in before-and-after situation (NL).

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

A comparison was made between radar and loop measurements at five locations. The average speed measured by loops at the five sites was 2 to 5 km/h higher than when measured by radar.

In *Norway* 64 rural road sections with a total length of 336 km were enforced by radar plus camera from road side boxes. The selection criterion was a higher accident rate than normal for the road type, with at least 0.5 accidents per km per year, and a mean speed higher than the speed limit. A fore warning was given by a sign 'Automatic traffic

enforcement'. The tolerance margin was 10 km/h. No before-measurements were available. For all roads together the number of accidents was reduced with 20%.

9 SPEED MANAGEMENT ON URBAN ROAD NETWORKS

In the city of *Eindhoven* the number of traffic victims per capita was second highest of all large cities (>100.000 inhabitants) in the Netherlands. A speed campaign was conducted in 1995 during eight months on a selection of 15 main urban road sections and 5 sites on the ring road. This selection was done by the municipality and the police, based on accident history and speed level. The same method as applied on rural road network was used here. The feed back sign was not used frequently. The enforcement frequency realised was 0.5 hour per road section per week. Publicity was given through daily news paper, local TV and radio and posters on the road side. The percentage of speeders decreased with 5 to 13 percent points. The number of fatal and injury accidents involving at least one motor vehicle was reduced with 14% compared with the preceding year. The accident reduction could partly be ascribed to a downward trend in accidents, and for another part to the campaign.

Table 7. Speed in before-and-after situation (NL).

Eindhoven	Average speed		% speeders	
	Before	After	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 8. Accidents in Eindhoven and in NL in before-and-after period (NL).

Accidents	1990	1991	1992	1993	1994	1995
Eindhoven	409	369	330	376	399	344
Netherlands	19922	18488	18502	18028	18485	18326

In *Victoria State, Australia* a massive speed and alcohol enforcement combined with an education campaign was started in 1990. It was stated that speed was the primary cause in 20% of all fatal and major injury crashes. In Australia unsafe speed and alcohol impairment were regarded to be a causative factor in 50% of all road crashes in Australia. All organisations responsible for road safety joined forces.

The long term objective was to make speeding and drunk driving socially unacceptable and to achieve a high level of voluntary compliance. Specially chosen police officers were stationed at primary schools to supplement the adult education and community awareness activity. The campaign was conducted in such a way that this was considered by the public to be fair and reasonable. The speed limits were respectively 60, 75, and 100 km/h. Signs were installed at all border entry points reading 'Speed and red light cameras operate throughout Victoria'. Speed advertisements on TV showed different kinds of speeding leading to several kinds of (staged) accidents and suffering. Next to fines for speeding, demerit points were also applicable. The tolerance level was 9 km/h. There were 2,500 camera sites spread across the State, on average 30 cameras were in operation daily, per camera 80 sites could be enforced, the camera was operational during 4,000 hours per month. So each camera was in operation daily during an average of 4.4 hours, or 1.5 hours per site per month. The processing was automated and the capacity was 100,000 records per month. Next to a fine to be paid, the car owner could get demerit points (unless he identified the speeding driver). The effect enforcement on behaviour might be enhanced by a point demerit system. The vehicle registration of corporate owners could be suspended above a fine to be paid (unless the driver was identified). The effect on speed behaviour was analysed on a limited number of sites (measured by inductive loops): no measurable decrease in mean speed was found. The percentage of vehicles speeding with more than 15 km/h, however decreased. This implies that the group of slow driving vehicles must have increased their speed. Recidivism - second infringements - was 29% less, for third infringements the reduction was 45%. The total road toll was reduced from 777 in 1989 to 396 in 1992 i.e. 49%. The effect of speed enforcement was estimated to be 14%.

10 CONCLUSIONS

Locations and routes

It can be concluded from the different examples that speed management/enforcement at locations and on routes generally had a reducing effect on speeds and accidents.

It appears to be necessary that drivers are informed about the speed enforcement campaign.

Road side boxes for radar and camera are often visible and so the effect is restricted to the neighbourhood of these boxes. Also a parked radar car is often obvious.

On the other hand, even a relatively small operation rate (e.g. one day/month) of camera boxes, had a speed reducing effect, because of the unpredictability of the presence of the system for the driver.

Camera boxes are liable to vandalism.

Networks

Enforcement on road networks had a speed reducing effect as a whole, respectively on the fast driving group. The extent of the effect depends on the enforcement frequency and duration. In some experiments this level was too low, so the effect was limited.

Speed evaluation using radar had its influence on driver behaviour, as some of the drivers decelerated at the sight of the parked radar car.

Some of the experiments did not result in an accident reduction, in one Dutch province this number even increased strongly. No clear explanations could be given for this phenomenon.

From the results of studies in different countries, it can be concluded that an average enforcement frequency of once a week per road section, i.e. an average of 12 hours during the day per week, will result in almost all drivers not exceeding the speed limit set by the police for fining. This required enforcement endeavour from the police is high, in practice this required level can not be realised easily.

11 RECOMMENDATIONS

The following general recommendations can tentatively be made based on the results of the enforcement studies (see for more detailed information Oei, 1998).

A strategic alliance between relevant departments, road authorities, and other partners is recommended to be formed at a national, provincial and municipal level.

Explicitly and quantitatively formulated government policy objectives regarding speed and accident reduction are needed.

A written agreement allocating the tasks between road authority, the police and prosecution office (MOU) regarding speed management and enforcement for the coming years, is recommended.

Speed enforcement should be regarded as a permanent and sustained task, and not just a temporary action.

Because the efficiency of enforcement using a camera is very much higher than enforcement where speeders are stopped, the first type of enforcement is recommended.

A combination of speed and red light enforcement at intersections will enhance the effectiveness regarding adaption of the driving behaviour.

It is recommended that the car owner is made primarily responsible for offences committed with a car.

Next to withdrawal of a driving license, the withdrawal of the license of business cars is another possibility.

A point demerit system might enhance the efficiency and effectiveness of the enforcement endeavour.

Continuous monitoring of speed by inductive loops will facilitate the selection of problem roads to be enforced and to determine how to modulate the enforcement level depending on the speed level (increase respectively decrease).

For enforcement to be accepted by the public, it is of importance that the objective is primarily prevention and accident reduction, and not punishment or financial gain.

Enforcement should always be preceded and combined with publicity to inform the public about the danger of speeding, the enforcement method, and the effects achieved. This will prevent overloading the processing of speeding tickets at the start of the campaign. Publicity should be aimed at target groups.

Fore warning of speed enforcement is functional where the enforced location or route is selected, based on a safety and speed problem.

On a road network enforcement is recommended to be randomized in space and time (unpredictable). No fore warning should be given except through publicity. A sign informing drivers that their speed has been checked can be given down stream of the speed check.

It is recommended to use camouflage techniques so the enforcement be unpredictable for drivers.

Enforcement systems should be made ‘vandal-proof’.

Use of new electronic technologies will increase the efficiency and effectiveness of the enforcement process. Such as automatic registering, reading, and identification of speeding cars. A high subjective and objective frequency of speed checks can thus be reached.

Development of a design for an integral approach of enforcement on drunk driving, speeding, aggressive behaviour, etc. is recommended.

REFERENCES

Oei, Hway-liem (1998). *The Effect of Enforcement on Speed Behaviour. A literature study.* A MASTER report. Project Funded by the European Commission under the Transport RTD Programme of the 4th Framework Programme.