AUTOMATIC ENFORCEMENT OF SPEED AND RED LIGHT VIOLATIONS

Applications, experiences and developments

R-92-58
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Leidschendam, 1992
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CONTENTS

1. WHAT IS AUTOMATIC ENFORCEMENT?

Strictly speaking there is no automatic enforcement applied in any country at the moment if we understand the term referring to the whole enforcement 'chain' including the process of treating the consequences of detection as well.

The term 'automatic enforcement' refers rather to automatic detection and recording the licence plate number of a vehicle involved in a traffic offence and in some countries such as the Netherlands also the identification of the owner of the vehicle. Procedures from that moment onwards are in present systems far from automatic – often even time consuming. So in this article 'automatic enforcement' is used in this latter meaning even accepting that automatic detection of offences may require one officer to supervise the equipment in operation (e.g. speed cameras).

2. THE NEED FOR AUTOMATIC ENFORCEMENT

Automatic enforcement is mainly applied to detect speed limit and red-light transgressions, the last type is closely related to speed.

There is a kind of contradiction in the problem of speed on the road: in Western society speed in a general sense is regarded as a positive quality, also active, powerful, dynamic and fast. Time is money! Slow, passive, static, and weakness are considered to be negative aspects in our culture, the 'softies'.

In accordance herewith car sales promotion has been stressing the performance – power, acceleration and top speed – of cars very actively in the 1980's (Mäki, 1989). It has been shown that the top speed of passenger cars increased between 1955 and 1985 more than 50% and the acceleration considerably more (Auto Motor und Sport, 1985) and the development in the performance of cars is still continuing. Furthermore improvements of isolation materials, tires, braking systems, and road surfaces makes fast, comfortable driving in silence possible.

In contradiction to this general attitude regarding speed in our society, drivers on the road are expected to drive slowly and carefully!

It is not surprising that it took an energy crisis to make policy makers and the motoring public speed conscious, although motivated by fuel economy and not road safety. Since 1973 speed limits were introduced in many industrialized countries and as a result of this evaluation on speed and safety were conducted. Until ten years ago or so the general opinion regarding the effect of measures that lower the speed of motor vehicles was 'a couple of kilometres per hour less, so what?', implying that such measures will hardly have any effect on road safety. Not so nowadays. Empirical studies in the U.S. and in Sweden and Finland have shown that the introduction respectively the lowering of speed limit(s) on rural and urban roads resulted in a reduction of the mean speed and a considerable reduction of the accident rate and more so of the injury rate. A relation between reduction of the standard deviation of the speed distribution and reduction in accident rate was also found.

Recent speed measurements on two-lane rural roads in the Netherlands show that a great percentage of cars are trespassing the speed limit of 80 km/h. A calculation of the potential safety improvement of lowering the 85 percentile speed to the speed limit shows that a benefit between 25–50% in accident rate (from damage only to lethal accidents) can be expected, assuming that the formula of Nilsson (1984) can be applied for the Dutch situation (Oei, 1991).

Traffic volumes have also been increasing almost continuously all over the industrialized world and the absolute number of vehicles speeding has been increasing too. This has accordingly increased turbulence in the traffic stream like accelerations and decelerations which are basic factors in accident causation. Also excessive speed creates overtakings and many violations are connected in one way or another to overtakings especially on two lane rural roads (Mäkinen & al., 1987).

So police enforcement on traffic rules, especially speed limits is a necessity. 'We need police because we can't police ourselves.'

Police resources have not been able to cope with this development. In fact the risk of being ticketed from speeding is very low, e.g. once in every 10.5 years on an average in Finland (Mäkinen, 1990).

Speed today is an important subject for policy makers, road authorities, research institutes, police authorities and speed enforcement industries. In the Netherlands a 'Multi-year Road Safety Programme' was introduced for the period 1987–1991. The programme is adapted periodically. The overall objective is to reduce the number of traffic victims with 25% in the year 2000 related to the number of victims in 1985. One of the main areas concerned is speed of motor vehicles on two-lane rural roads and on main urban roads because of the high level of speeds and the great number of victims on these roads. So the safety potential of speed management on these roads is expected to be very high. The objective regarding speed is to reduce the average speed by 5 to 10 percent and the 85 percentile speed not to exceed the speed limit in the year 2000, resulting in a reduction of 150 fatalities and 2000 injured persons at least.

A speed management project on four rural roads in the Netherlands has been set up and evaluated by the SWOV, of which a description is given in this paper.

3. PROBLEM ANALYSIS REGARDING SPEED

Often the approach to prevent accidents is to seek for 'the' cause of an accident and then try to remove this cause. Another approach is to describe an accident on the road as a process, a consecutive chain of events. Driving speed, not necessarily being the main causal factor, in most cases is forming one of the links in the chain. An accident can be prevented by braking the chain at any of the links. So through speed management an accident can be prevented.

Speed selection is part of the driving task and the driving task can be structured hierarchically into:

- Trip preparation: selection of destination, mode of transport, arrival and starting time and the route under way. This phase of the driving task has a big influence on driving speed en-route. A late departure or selection of a wrong route will result in time-pressure and to compensate this in speeding. Further a well prepared trip will alleviate navigational problems on the road.
- Navigation en-route: to identify the location and direction of the vehicle on the road and the route to be followed. The quality of the route that is chosen has direct influence on speed selection. Real-time information regarding road conditions will help the driver in selecting the appropriate route.
- Manoeuvring the vehicle: the most important manoeuvres are following the track, intersection-approach, car-following, and overtaking. Speed selection is part of these manoeuvres. Law stipulates that at any time a driver has to be able to halt his vehicle within the distance inwhich the road is free and can be overlooked. A collision can be considered as a result of the fact that the driver could not stop his vehicle in time, that is the selected speed was not appropriate considering the prevailing conditions.

An analysis of 1991 accident data in the Netherlands on roads having 80 km/h speed limit shows that the main accident types are (Table 1).

Accident type	Percentage
Single vehicle accident	32%
Collision between crossing vehicles at or near intersections/exits	24%
Collision between vehicles driving in opposing direction	19%
Collision between vehicles driving in the same direction	20%
Other types	5%
Total fatal and injury accidents 8,388	100%

Table 1. Fatal and injury accidents according to accident type on 80 km/h roads in the Netherlands in 1991.

These accidents can (partly) be ascribed as being a result of failure in the execution of the following specific manoeuvre/speed tasks (Table 2).

Driving task	Accident type	Location
Following the track	Single vehicle	Bends & straight road sections
Crossing	Side impact	Intersections & exits
Car-following	Rear-end	Straight roads, at intersections
Overtaking	Head-on	Straight roads & bends

Table 2. Correspondence between driving task, accident type and accident location.

Summarizing: A great dispersion of speeds on the road generates dangerous overtaking manoeuvres, so it is not only the vehicles driving too fast but also those driving too slow that behave dangerously, resulting in among other things head-on accidents. Further speed as part of car-following behaviour is connected with rear-end accidents. Intersection accidents between crossing vehicles can be ascribed to failure in selection of the right speed of one or both of the approaching vehicles. Speeding is also connected to off-the-road accidents a result of problems in following the track of the road. Too fast driving gives less manoeuvring space/time to correct steering failures.

So a self-evident approach to counter these specific accidents is by speed management at each of the specific driving tasks. This approach is suitable in case specific accidents being limited on specific locations only. On the other hand when several types of accidents occur on a road stretch, this approach will lead to speed management systems that interact with each other. A much simpler approach then is to manage speed on the whole stretch of road, i.e. lower the high speeds (and raise the low speeds). The idea is that through lowering high speeds in general, the speed in executing the above mentioned specific tasks will also be lowered and through influencing speed selection the accident rate and the impact speed will be reduced resulting in a reduction of the injury rate and injury severity.

Traditional measures to reduce speed of motoring traffic are infrastructural reconstruction of the road, information campaigns in which the dangers of speeding is explained and police enforcement. The costs of road reconstruction works often are prohibitively high, further the possibilities of these kind of measures (narrowing the road width and incorporating curves) are restricted because of the function these roads fulfil. The effect on speed is limited as main two-lane rural roads are designed for buses and lorries as well and small passenger cars can easily travel with high speed.

Enforcement to be effective requires a high level and regular input of police manpower. Campaigns have a temporary and often limited effect. The level of police enforcement is at such a low level that even doubling the input of manpower may have no noticeable effect on speeds in the long run.

Some behavioural critics allege that measures aimed to improve road safety have no positive safety effect because of 'behaviour compensation' on part of the road user. However measures resulting in a reduced speed give few possibilities for drivers to compensate their behaviour in a negative way, except possibly on other roads where no speed measures are applied to catch up for time lost.

It is known that police enforcement has a considerable effect on the number of speeders, but this effect will be gone after a relatively short period (a couple of days) after the enforcement is lifted. Further this kind of enforcement needs relatively intensive manpower of the police force. Automation of the detection of speeding cars reduces considerably the need of police to do this.

4. APPLICATION OF AUTOMATIC ENFORCEMENT

Automatic enforcement was applied first in Switzerland in 1972 and in Germany in the early 1970's. The first efforts in Sweden took place in 1972–1978 when five intersections in Stockholm were chosen for the automatic detection of red light violations. First trials of this technique in Norway are 10 years old. Since then automatic enforcement has been tested at least in Australia, Great Britain, The Netherlands, Japan, Singapore and The USA. In all, the use of automatic enforcement supporting conventional traffic enforcement has been scant.

Scientific and experimental studies dealing with the effects of automatic traffic enforcement are even rarer than the number of countries testing it. The effects of red light cameras on red light violations have been studied in Sweden in (TFD, 1979), Australia (Lau, 1986; South & al., 1988) and in Singapore (Chin, 1989). The effects of automatic enforcement on speed has been experimented in Germany (Lamm & Kloeckner, 1988) and in the Netherlands (Papendrecht & De Vries, 1989; Oei Hway-liem, 1992). In both experiments dealing with automatic speed enforcement automatic detection equipment was not the only measure aimed at suppressing speeding; a feed-back warning sign was incorporated in the Dutch experiments.

Moreover, the results of experiments on automatic detection of speed violations in Norway and Sweden are being evaluated. At the moment Finland and the USA are conducting scientific experimentation of automatic enforcement on speeds.

5. EFFECTS OF AUTOMATIC ENFORCEMENT ON RED LIGHT VIOLATIONS AND ACCIDENTS

5.1. Sweden

Probably the first study aimed at reducing red light violations was conducted in Sweden (TFD, 1979). In Stockholm a detector loop operated camera was installed at five intersections from 1972 to 1978. At these crossings the share of violators was 0.3%–0.7%. The threshold for punishments was the distance of at least 10 meters from the light pole when the light turned to red. The results of the experiment are as follows:

- The camera was operated at each intersection 240 days a year at the most.
- 71% of ticketed drivers paid their fine.
- The share of drivers passing through red light didn't decrease practically at all at any of the intersections.
- Handling one violation (including the maintenance of a camera + the identification of a driver) took 3.3 manhours. It took 4.3 manhours for conventional enforcement (a patrol of 4–5 men) to handle one case.

The experiment in Sweden was carried out without posted signs telling about the red light camera or without public information campaign. It is possible that most drivers were not aware of the automatic enforcement system. Moreover, the baseline level of red runnings was close to zero. So there was no reason to expect great changes in the share of violations. On the other hand the experiment took five years, so if there were an effect it could have been established. The design was 'before-after' without control intersections, so it is not known what happened at intersections in general.

5.2. Great Britain

On the northern ring road A 406 near London red running was general. In february 1990 red light cameras were installed at some intersections. Within a month after the equipment having been taken in use violations went down considerably, on some sites even 80% (The Sunday Times, 1989).

5.3. Australia

The first experiment about automatic red light enforcement was conducted in Australia in the years 1979–1981 (Maisey, 1981). The results of one intersection gave the indication that right angle accidents decreased but rear end accidents increased. The total number of accidents was minor and no statistical inferences were drawn.

At another busy intersection there was also a red running detection equipment installed (Maisey, 1981). Before – no publicity was given regarding automatic enforcement – some 300 violations were recorded per week. After automatic enforcement was made known to drivers the number of weekly violations went down to about 20.

A thorough and carefully conducted experiment was realized in Australia during the years 1983–1986 (South & al., 1988). 92 intersections were chosen for the experiment.

Every other intersection received a red light camera. Accident data from the years 1981--1986 was used as a basis of evaluation. A sign telling 'RED LIGHT CAMERA AHEAD' was installed at each intersection equipped with a camera. Also public information was connected to the experiment. It received a lot of publicity, especially in the beginning. The effects were measured through the number of casualties. The number of accidents decreased statistically significantly only in the class 'right angle' (these are accidents in which vehicles coming from adjacent arms of an intersection collide). On the other hand this is a very general accident type (see Table 3). Of the ticketed drivers 83% paid their fines on time.

Accident type at an intersection	Accident reduction	N %	Significance level
Right angle	-32	123	p <.05
Right angle (turning)	-25	17	n.s.
Right-against	+ 2	224	n.s.
Rear-end	-31	68	n.s.
Rear-end (turning)	+28	37	n.s.
Other accidents	- 2	127	n.s.
Totally	- 7	596	n.s.

Table 3. The effects of automatic enforcement on casualty accidents by accident type in Australia.

The next study comes from Australia too (Lau, 1986). A camera was installed at a pedestrian crossing the cycle of which may be changed by pedestrians. A sign was erected on both sides of the pedestrian crossing with a message 'RED LIGHT CAMERA AHEAD'. Results are as follows (Table 4).

Vehicle type	Before	4 week after	7 weeks after
N	244	298	235
Lorries	6	5	1
Other cars	9	4	1
Totally	15	9	2

Table 4. The number of red runnings per 100 cycles in a pedestrian crossing.

Red light runnings decreased some 40% during the first four weeks and during the following three weeks the number of violations decreased to the level of 15% compared to the before-period.

5.4. Singapore

Automatic enforcement at intersections was started in 1986 (Chin, 1989). The object of an experiment was to install a camera at 120 intersections. The first part of the experiment consisted of 16 intersections of which 11 received a camera and 5 served as control group. Cameras reduced red runnings by 40% on an average (Table 5). This level was reached after some five weeks. The effect was greatest on lorries and busses. The number of violations was decreased also at the arms of intersections with no camera installed.

Intersections with	Red runnings/cycle			
a camera	Before	After	Coefficient	t-stat.
An arm with a camera	0.344	0.201	0.586	-4.52
Totally	0.335	0.219	0.587	-6.36
Control intersections	0.283	0.331	1.057	0.42

Table 5. Analysis of regression of the effects of red light cameras on red runnings.

6. EFFECTS OF AUTOMATIC ENFORCEMENT ON SPEED AND ACCIDENTS

6.1. Introduction

Automatic enforcement has been applied about 20 years until now. Despite this time period the number of scientifically carefully conducted evaluation studies dealing with the effect of automatic enforcement is *very scant.*

Most studies have been either conducted or reported in a deficient way. The following shortcomings can be identified in most of these 'experiments':

- A design is a before-after type, no control roads or intersections were chosen.
- Roads with high accidents rates have been chosen as test areas or sometimes an area with very few {red light} violations (Stockholm) and no regressive effects have been controlled.
- Automatic enforcement has been a part of other measures and the effects of automatic enforcement could not have been differentiated from other effects.
- In several studies no information about automatic enforcement has been given to drivers which made the process of learning very slow.
- Part of the experiments have been very short in duration.
- Experimental areas (especially road sections) have been very restricted in length, only a few kilometres at best. Then reductions of other driving errors connected to speeding could not have been expected.

Despite the shortcomings put forth above, the results of most studies are in agreement. It seems that automatic enforcement has reduced the number of offenses and possibly also increased safety.

The changes in many studies have been so strong that it is reasonable to ascribe at least a part of the effect to the increased objective and subjective risk of apprehension caused by automatic enforcement.

It is not certain, however, that automatic enforcement may decrease violations and accidents by 50% as it has been reported in some studies. It has been calculated about 10% reduction in the number accidents in the swedish experiment, but these results have not yet been officially confirmed (Hassel, 1992).

6.2. Evaluation research

6.2.1. Germany

A most profound study dealing with the effects of automatic speed enforcement (among other things) was conducted in Germany (Lamm & Kloeckner, 1984). Accident rates were high on an autobahn section between Köln and Frankfurt compared to other comparable sections. The motorway had three lanes in the test area. In 1971 85% speed was about 150 km/h for passenger cars on the left lane, on the middle lane 135 km/h and on the right lane for trucks about 80 km/h. In 1972 two left lanes had 100 km/h speed limit and the right lane had speed limit of 40 km/h. The speed limit decreased 85% speeds a lot, 25–30 km/h for passenger cars but even after this, of those driving on the left lane 60% and of those on the middle lane 30% were speeding. Also 10% of the trucks were still speeding. In May 1973 above each lane an automatic device for measuring and detecting speeders was installed. The effects of automatic speed enforcement were measured in 1974, one year after they were taken in use. In addition to the effects of speed limits the speeds were decreased on the left lane about 20 km/h and on the middle lane 5 km/h. Among trucks the share of speeders decreased down to 7%. The number of traffic fatalities decreased from an annual 7–8 to only one fatality. The duration of the experiment was very long, 10 years. It is possible that not all of the savings in fatalities can be ascribed to the automatic enforcement system. Still it is obvious that automatic speed enforcement had a major impact on safety through increasing considerably the objective and subjective risk of apprehension on speeding. In addition to this the experiment received a lot publicity and also conventional enforcement was resorted to, especially during holidays.

6.2.2. Norway

Another automatic speed enforcement experiment is being conducted in Norway (Östvik, 1989). First data about speeds are already available. In Telemark, Norway speed measurement equipment was installed on 80 km/h road. Drivers were informed about automatic speed measurement through signs erected in the area. After the experiment had started speeds were reduced really dramatically. Mean speed decreased from about 100 km/h to 75 km/h. The share of speeding drivers decreased from 80–90% to 15–25%. Also the standard deviation of speeds decreased as might be expected. Later, it turned out, speeds started gradually to increase when drivers learned that cameras are rather seldom in operation.

6.2.3. U.S.A

Some limited tests on automatic speed and red light violation enforcement has been conducted in several states of U.S.A since 1976 (Fitzpatrick, 1992). Often drivers' reactions have been found hostile, especially towards automated speed enforcement.

It has been shown in several cases that automatic enforcement reduced the number of violations considerably and resulted in a relatively small decrease in the mean speed of vehicles.

Driver interviews showed a need for educating them on the advantages of speed adaptation reached through automated enforcement.

So called ORBIS-system stored speed data through detectors installed under a street surface. Before The ORBIS was installed some 800 vehicles a day were speeding at least 16 km/h. Within a week after the system was installed the share of speeders was cut down to a half. Then the ORBIS was not even active yet. After the system was activated the share of speeding cars gradually decreased to 15–20 speeders a day on which level the share remained (Shinar & McKnight, 1985).

6.2.4. Switzerland

Automatic speed enforcement was initiated in Switzerland probably the first country in the world (beginning of the 70's). Then automatic registration of speed offenses was started on 11 sites. In the course of ten years the number of automatic enforcement sites was increased to 105. Data about the effects of automatic enforcement is available only from one road (from Wetzikon to Hinwil). An intersection on this road had a high accident toll. In 1971 a speed limit of 80 km/h was imposed at this intersection. This measure had no effect on safety. So an automatic speed enforcement device was installed at the intersection during the fall of 1972. After this measure was taken the number of accidents went down by 50% and no traffic deaths were registered at this site (Indigo Electronics, 1983).

6.2.5. The Netherlands

Two-lane rural roads passing through small city centres has become somewhat of a problem. Speeds are often excessively high among those drivers. To eliminate speeding an experiment was launched in which an electronic feed-back speed sign showing 'You are speeding' and an automatic speed camera was used (Papendrecht & De Vries, 1989). The route was installed in both directions with a detection, automatic warning and enforcement system. Speed is measured by the detectors and this information is sent tot the speed sign box. When the speed exceeds the speed limit the speed sign will light up. A speed camera was erected between these feed-back indicators. No information campaign was connected to the experiment. Speed started to decrease gradually when drivers became aware of the enforcement. The effect on speed of the feed-back indicators was evaluated to be smaller than that of the speed camera. The results of the study are given in Table 6.

Speed characteristics	Before	After
N	59	94
Mean speed	56.2	48.1
85-percentille speed	64.7	54.3
Standard deviation	7.5	5.8
% Speeders	83	36
Maximum speed	78.9	63.9

Table 6. The combined effect of electronic speed feed-back signs and speed camera on speeds.

Automatic speed enforcement is applied elsewhere in the Netherlands too. There has been erected automatic speed measurement posts on a busy four lane road between Wassenaar and The Hague. A small barrier separates the opposite lanes. The section of road under automatic speed enforcement is 5.5 kilometres long. The road has 50 km/h speed limit near the border of both cities, elsewhere the limit is 70 km/h. The number of enforcement posts on each side of the road is altogether 5. One camera is rotated at random order from one post to another. There is no experiment connected to these activities. One special enforcement campaign has been devoted to the automatic enforcement. Local radio has given publicity twice regarding the system. According to the Wassenaar police (Oei, 1990) enforcement equipment has decreased speeding but no data about the effects were available. Moreover, the police told that the share of speeders is great especially during the night. A sample of speeds was taken to have an idea of the speed level in the area (Oei & Mäkinen, 1990). The sample was taken between 12.00–15.00 hours in busy traffic (Table 7).

Direction	Speed limit	Mean speed	St. dev.	85-% speed	Speeding (%) >10 km/h	N
Leyden	50	55.8	8.4	64.0	26.0	288
The Hague	50	57.5	10.0	67.0	34.2	304
Leyden	70	64.7	5.5	69.0	1.5	270
The Hague	70	66.1	8.4	73.0	7.8	295

Table 7. A sample of speeds on the Wassenaar road.

Measurements on the Wassenaar road revealed that the share of speeding drivers is great on 50 km/h stretches of the road in spite of automatic enforcement. Cars with speeds 15 km/h or more above the limit were fined. A letter (imposing) declaring the fine was received within 7–10 days after the detection of the offence. About 80% of the ticketed drivers paid the fine.

Experiments in four provinces

Two kind of speed experiments were recently reported on four two-lane rural road stretches, 10–17 km in length. Four control roads were included in the experimental design.

A. The first type of speed experiment is aimed to reduce the number of speeding and of slow driving vehicles (faster than 80 km/h and slower than 60 km/h). On this road type only motoring traffic is allowed on the main carriage-way, so it is forbidden for bicycles, mopeds and tractors. The experiment consisted of two phases: in the first phase fixed signs showing 'Safe speed 60–80 km/h' and a speed sign lighting up '60–80' when vehicles travel faster than 80 km/h or slower than 60 km/h, are installed. In the second phase boxes alternately posted along both sides of the road periodically housing one set of speed radar and camera. Both phases are preceded by an information campaign explaining the danger of too fast and too slow driving and of the aim of the experiment.

B. <u>The second type</u> of experiment is aimed to reduce the number of speeding vehicles, i.e. having a speed greater than 80 km/h. On this road type tractors are allowed on the carriage-way. In the first phase of the experiment fixed signs showing 'Max. 80 km/h' and speed signs lighting up 'You are speeding' when speed exceeds 80 km/h. The second phase is similar tot the above experiment.
A speed and accident evaluation was conducted at the end of phase one and phase two for both experiment types.
The hypotheses is that through the mix of information campaign, fixed signs, warning matrix signs and automatic enforcement a positive effect on speed behaviour will be achieved and that this will be of long duration and that the number of accidents will decrease considerably.
The results on speed are shown in the Tables 8 and 9; the results of the experiments on the number of accidents are shown in Table 9.

Speed distribution characteristics	Experimental roads			Control roads		
	Phase			Phase		
	0	I	II	0	I	II
N	19478	11872	13417	5580	5172	5378
Average	78.2	75.2	72.9	78.7	80.2	78.9
15-%	70.2	68.7	66.4	68.8	71.4	71.9
85-%	86.7	83.8	78.9	88.3	90.4	88.6
Stand. dev.	10.0	9.2	8.0	11.7	10.9	11.7
% < 60 km/h	2.8	3.0	4.4	3.9	2.3	3.6
% > 80 km/h	38.2	28.0	11.4	40.9	50.2	44.4

<u>Table 8</u>. Speed distribution characteristics in phases 0, I and II on experimental and control roads.

Province	Accidents				Experimental roads		Control roads	
	Injury		Damage		Total		Total	
	bfr.	aft.	bfr.	aft.	bfr.	aft.	bfr.	aft.
Overijssel	5	3	27	10	32	13	82	53
Noord-Brabant	5	3	48	28	53	31	44	27
Gelderland	7	5	35	17	42	22	24	30
Utrecht	6	3	18	12	24	15	134	127
Total	22	14	128	67	150	81	284	237

<u>Table 9</u>. Accidents in before and after period (phase I + II) on experimental and control roads on the four provincial roads.

Formula: reduction in accidents as result of the speed measures·

$$1 - \frac{N after : N before[experimental\ road]}{N after : N before[control\ road]}$$

Province	Total
Overijssel	37%
Noord-Brabant	5%
Gelderland	42%
Utrecht	66%
Total	35%

Table 10. Percentage reduction in accidents as a result of the speed measures.

This reduction in the number of accidents may be ascribed to the decline in speed and possibly also by a greater attentiveness on the part of the car driver as result of the information campaign and of the flashing signs.

Other effects

• The number of photo's made was within the constraints stipulated by the public prosecutor. Apparently the high objective and subjective detection risk had a deterrent effect.
• The number of photo's of approaching cars was larger than of receding cars. Car drivers apparently assuming that only speed of receding traffic being controlled. The law is to be changed this year in The Netherlands so that the owner of a car will be responsible for offenses made with the car unless he provides the police with information regarding identity and address of the driver.
• Vandalism occurred on all four roads: breaking the enforced glass before the camera, pouring petrol and burning the radar post, spraying with paint and even shooting the double cased radar posts. Special surveillance teams were operated. Through analysis of the photo's some vandals could be identified and brought to court.

A cost-benefit calculation is made on the speed management system: the costs of the speed management were Dfl. 360 000 and the benefit caused by the reduction in accidents Dfl. 924.000.

6.2.6. Finland

Automatic speed enforcement project was started in Finland in 1991 when before measurements and technical tests were initiated in test and control roads. The experimental

area is a fairly busy two-lane road on the southern cost of Finland. About 55 km long surveillance stretch is covered with 12 loop detector based camera poles. The distance of surveillance sites from each other varies from about 1 to 7.5 km and covers speed limits of 60, 80 and 100 km/h. Four signs informing the drivers of automatic speed enforcement were erected in the experimental area. Before the operation of the system an information campaign was launched and the opinions of the road users towards automatic speed enforcement were recorded. Automatic speed enforcement was put in operation on the 1st of April in 1992.
The attitude of drivers towards automatic speed enforcement with fixed warning signs was very positive: 88% of the respondents found automatic surveillance either 'acceptable' or 'very acceptable'. So far no vandalism to the surveillance equipment occurred (July 1992).
The share of speeding drivers started to reduce already after the installation of the surveillance equipment and information campaign in November and December 1991. Two months after operation of the automatic enforcement system the mean speed in the test area decreased by about 2 km/h and the share of speeding drivers was cut down to a half. No such changes took place on the control road, i.e. the opposite direction not being installed with the enforcement system.
Table 11 below is based on observations of one of fifteen different measuring sites covering about 80 km of the experimental road. Speed limit is 100 km/h and the distance of this site from the nearest surveillance sites are respectively 2.4 km and 1.5 km.

	April		May	
	1991	1992	1991	1992
Mean speed	90.0	87.7	90.2	88.4
Standard deviation	10.1	9.0	10.4	9.2
All speeding	12.7	6.6	13.5	7.9
Speeding > 10 km/h	2.4	0.9	2.8	1.1
Speeding > 20 km/h	0.4	0.1	0.5	0.1
Maximum speed	178	143	179	152
N (x 1000)	41	28	64	27

Table 11. Speed distribution characteristics in before and after periods.

7. SOME PRACTICAL APPLICATION CONSIDERATIONS

It seems to be important when realizing automatic enforcement experiments that drivers are made aware of the increased risk of apprehension which has been created by automatic enforcement. Otherwise it will take a unnecessarily long time for the system to have its effect, as the general deterrent effect will be absent then. Especially automatic enforcement needs the support of information campaigns to be really effective. Moreover the effect of the enforcement system will be enhanced by application of a mix of measures, i.e. next to information campaign to be given periodically, fixed and speed dependent warning signs and then automatic speed camera's.
Another important point when applying automatic ('red light') enforcement (for evaluation purposes) at intersections is that a sufficiently large number of intersections be selected to allow statistical evaluation of the effects. Five intersections or so is far too low a number for accident evaluation purposes.
As a good example of a design for measuring the effects of automatic enforcement at intersections serves the study of South & al. (1988).

When applying automatic enforcement on speeds on two lane rural roads the main thing is that the area for surveillance is long enough. This is important especially for eliminating many speeding violations which are followed by errors connected to overtaking.

The technical and tactical solution of automatic enforcement is a matter of concern for reasons as follows:

- Photographs should be used to identify a vehicle only, not a driver.
- A ticket should be sent to the possessor of a vehicle; it is a lengthy process finding the driver. In most cases the possessor and the driver are the same person or belonging to the same family. Commercial, leased and rental cars cause problems. Moreover, police is reluctant to search for a driver (in Finland) in case it gives unnecessary lot of work considering the seriousness of the violation. In the Netherlands the law was changed recently: the vehicle owner is responsible for traffic violations unless provides the police with identity and address of the driver who was in possession of the vehicle during the time the violation was committed.
- Heavy snow fall can reflect the flash light such that the number plate of the speeding car may remain undetected. On the other hand the effect of an automatic enforcement system is based on general deterrence, not 100% special deterrence or an objective risk of a magnitude of 1.
A red filter in front of the flash light is recommended to prevent blinding and startling drivers. One way mirroring reinforced glass in the front of the camera will prevent drivers from seeing the presence or absence of the camera.
- The system is vulnerable to vandalism. Vandal-proof construction is needed.
- Drivers learn to anticipate the enforcement sites and adjust their speed accordingly. Removable camera posts is a partial solution. Also areas of not very many commuters are recommendable, because it makes anticipation of surveillance poles more difficult.
- A problem in automatic enforcement is also the treatment of registered offenses, because the number of apprehended drivers will increase (at least in the beginning) and consequently the work load of prosecutors will increase (e.g. Wassenaar). A campaign

through local and regional papers, radio and television will increase the subjective risk of detection and so decrease the number of speeders and photo's.

• It is possible that other offences like driving while intoxicated will increase in areas of automatic speed enforcement, as drivers do not expect to be checked on alcohol use. Speeding after passing an enforcement area to catch up time lost may also be possible. It should be stressed that automatic enforcement is an additional means for police traffic safety work, not a substitute for it. This applies especially to areas on which automatic enforcement is in operation.

• To be really effective in traffic safety work, automatic enforcement ought to be applied extensively. This causes a kind of ethical problem: should driver behaviour be controlled so intensively just for the sake of safety. Automatic enforcement ought to be seen (applied extensively) as a 'last means', other means for improving safety should be tried first (like improving the environment).

• Automatic enforcement may be best realized combined with other measures like public information, local speed limits (e.g. Lamm & Kloeckner, 1984) and environmental changes (e.g. barriers, see Wassenaar Road).

• The optimal point in the curve enforcement versus compliance level should be determined (see Figure 1).

• A design for an integral speed management system for a road *network* using a mix of speed measures should be developed.

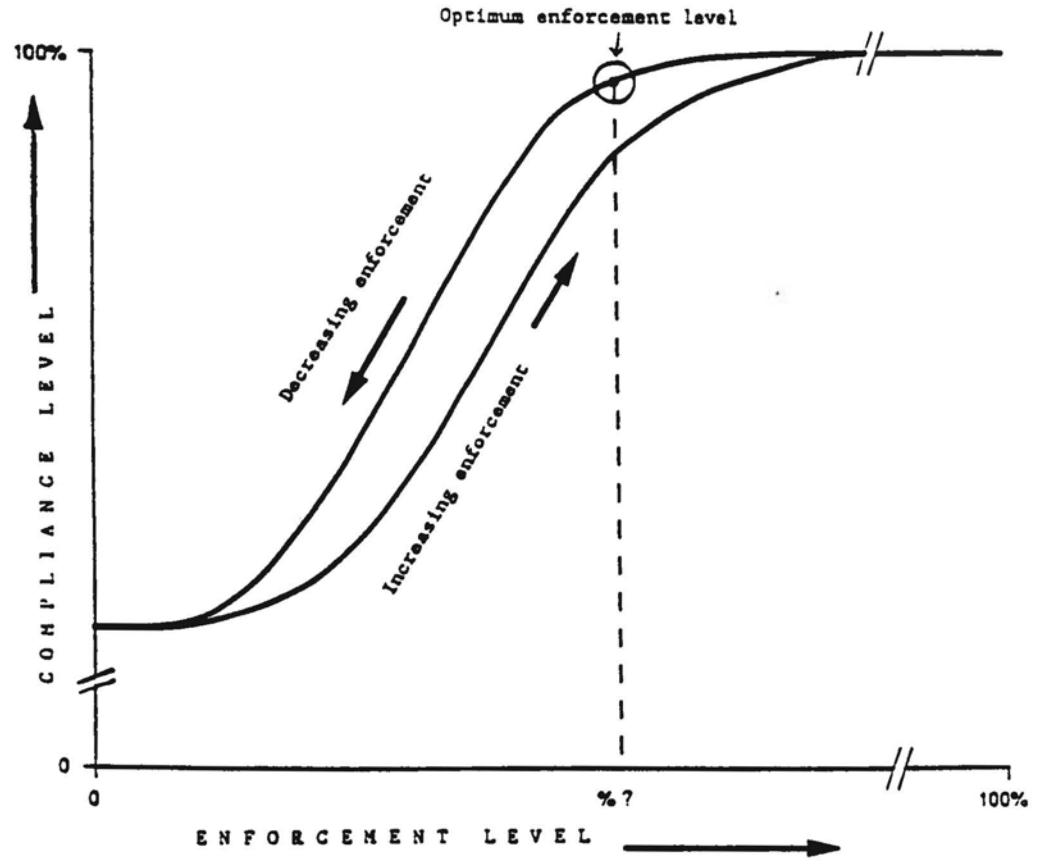

Figure 1. Compliance versus enforcement level.

8. FUTURE DEVELOPMENTS

A last remark must be made on future developments regarding *technological* measures, such as electronic detection and processing of vehicle-identification data. European concerted efforts (Prometheus, Drive) will result in the application of electronics for road traffic management in the near and far future. Warnings regarding driving behaviour such as speeding will be given to individual drivers by in-car information systems.

In a next step where fines are 'fiscalized' the bank account of the trespasser can be debited automatically. For infringements of speed limits the amount of the fine can also be made dependent on road type (e.g. motorway, 2-lane rural road, urban road), road characteristics (e.g. intersection, bend, bridge), period of day and weather conditions. Electronic vehicle identification tags will simplify the detection and identification of the vehicle, no number plate reading is needed any more. The whole chain of the enforcement process can so be automated easily.

The only problem rests in the judicial process as this cannot be (as yet) automated. This problem arises when a trespasser does not acknowledge the infringement of the rule he is accused of and wants the court to pass it's judgement on the case.

Electronic speed control systems being imposed from the road side on the vehicle can make speed enforcement superfluous as speeding will no longer be possible. Moreover, electronic drivers' licences which store parameters related to driving may also be a possibility to suppress reckless driving. Proper technique for controlling driver behaviour is no more a problem. A problem may be the wide application of modern technology in behaviour control without breaking the subtle boundaries of human dignity. Even a traffic death has got its price.

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