Automatic speed management in The Netherlands

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Inhoud

Summary

Speed warning and enforcement can be applied locally, on a road-stretch and on a road-network.
Local automatic speed warning at an urban intersection reduced the mean speed by 5 km/h. Theoretically a reduction in accidents of 25-65% can be achieved. At a rural intersection, the speed limit was reduced from 100 to 70 km/h. An automatic sign warns speeding cars; this resulted in a lowering of the mean speed from around 80 to 63 km/h.
An automatic speed warning and enforcement system on 2-lane rural *road stretches* - speed limit 80 km/h - resulted in a reduction of the mean speed from 78 to 73 km/h, the percentage of speeders went down from 40 to 10%. The total number of accidents was reduced by 35%. This effect was almost the same, 3 years after concluding the experiment. Vandalism was a problem. This could be diminished by mounting the camera on a high pole, mechanically preventing climbing the pole, automatic detection of vandalism and wireless communication to a near-by police station.
Enforcement of speed on a provincial *road network* using radar and camera exclusively, from a parked unmarked car, was conducted in three provinces. A sign, downstream of the enforcement site, shows 'Your speed has been checked. Police'. Periodical information campaigns were conducted to increase the subjective risk of being caught. The result was a reduction of average speed by 4-5 km/h, though the percentage of speeders is still high: reduction from 40 to 30%. This type of enforcement is accepted by 75% of the drivers.
Greater priority for speed enforcement is needed, also automating the enforcement and processing to increase the efficiency.

1. Introduction

In Western societies speed in general is regarded as a positive quality, e.g. speedy telecommunications and computers, speed in thinking and decision making. Time is money! See adverts praising speedy, powerful, aggressive vehicles. Improvements in sound isolation, tires, braking systems, and road surfaces make fast, comfortable, smooth driving in silence possible. In contradiction to this general attitude and developments, drivers on the road are expected to drive slowly and carefully!

1.1. Government Policy on Road Safety and Speed

A 'Multi-Year Road Safety Program' was first introduced by the government for the period 1987-1991. This program is revised periodically (*1*). The overall objective is to reduce the number of traffic victims by 25% in the year 2000 in comparison with 1985.
Speeding of motor vehicles, specifically on 80 km/h two-lane rural roads and on 50 km/h main urban roads, is one of the Spearheads concerned. The national target is to reduce the average speed by five to ten percent by the year 2000, and to have the percentage of speeders below ten percent. A reduction of at least 150 fatalities and 2,000 injured persons is expected.

1.2. Speed Limits in the Netherlands

The general speed limit for cars on motorways is 120 km/h. For motorways of lesser quality or with intense traffic flow the limit is 100 km/h. The general speed limit for all motor vehicles on other rural roads is 80 km/h and on urban roads 50 km/h. The general speed limit for lorries and buses in rural areas is 80 km/h. The rule is that general speed limits are not shown along the road side.

1.3. Actual Speeds

Recent speed measurements on 80 km/h two-lane rural roads show that 40-70% of the cars are speeding (*2*). For lorries and buses the percentage is between 30 and 50%. The percentage of speeders on main urban roads in cities is even higher: 60-80% is not unusual (*3*). So a lot has to be done to achieve the objective on speed reduction.

1.4. Speed and Accidents

A road accident can be described as a process, a chain of consecutive links of causal events. In most cases driving speed will be one of the links. An accident can be prevented by breaking the chain at any one or more of the links. So by influencing the driving speed an accident can be prevented. Empirical studies in the U.S. (*4*), (*5*), Sweden (*6*) and Finland (*7*) have shown that the change of speed limit(s) on rural and urban road networks resulted in a change of the average speed and a considerable change of the accident rate and more so of the injury rate. A reduction/increase in average speed resulted in a disproportionate reduction/increase in accidents or accident rates. A relation between reduction of the standard deviation of the speed distribution and reduction in accident rate was also found. From these empirical findings, a reduction between 20-50% in accident rate may be expected when the national goal on speed is achieved. Koornstra (1989) (*8*) though, contends that the effect of speed limit changes on accident rates are temporary, to be explained by risk adaptation.

1.5. Speed Management Systems

Methods to control speed are - apart from infrastructural reconstructions - warning systems, police enforcement, and information campaigns. Speed warning systems can be static, such as fixed signs showing permanently 'Lower your speed' or dynamic, such as switchable signs, e.g. 'You are speeding' being triggered by speeders. These signs can have limited effect, if not combined with enforcement.

Traditional police surveillance and control, where offenders are stopped, are labour intensive, and often have a temporary effect. The crime problem in industrialized countries prevents road offences getting a high priority by the police.

Figure 1 shows a theoretical relation between level of enforcement and level of compliance to the speed limit. At zero enforcement level a certain percentage of drivers comply to the speed limit. Increase of the enforcement has no noticeable effect at first, then the curve start to rise to end levelling off. If the enforcement level is decreased again, the curve will not follow the original curve, because of a time lag.

Police enforcement can be done stationary or mobile, non-automatic or automatic, with stopping the speeder, or just making a photo of the number plate, and fining him some weeks after detection of the offence. In the Netherlands often a large part of the police endeavour on speed enforcement is done by stopping speeders at the spot. This requires a very large input of manpower. As an example, results of speed enforcement on the Dutch motorways in 1992 is given in *Table* 1 (*9*). The length of motorway to be enforced is 2,200 km (x2 carriageways = 4,400 km).

Notwithstanding this large input of manpower, the percentage of speeders on the Dutch motorways is still high. The Dutch government has concluded that endeavours for managing speed should be sought by increasing the efficiency of the methods used.

The effect of enforcement in time and space is usually very limited. The old speeds are back within a few kilometres from the enforcement spot and within a short time after the enforcement campaign is ended. The level of police enforcement in many countries is so low that even doubling the input of manpower have no noticeable effect on speed behavior.

If enforcement is to be effective, it requires a regular and minimum enforcement frequency. The efficiency of the enforcement can be enlarged by using automatic warning and enforcement techniques. Information campaigns are a necessary part of the enforcement measure, to increase the subjective probability of being detected, to increase the knowledge regarding speed and accidents, and hopefully to change the attitude of the driver.

1.6. The Extent of Speed Enforcement

The extent of speed enforcement can be distinguished spatially:

- At specific dangerous locations, e.g. an intersection, sharp bend, and at road works. The objective is speed adaptation at that specific location, so a warning to road users up-stream on the risk of a speed ticket is desirable.
- On a specific dangerous road stretch. Pre-warning is desirable.

- On a road network. Here it is of importance that the location and time of enforcement be unpredictable for the road user. Warning in general is given by the press or TV and by bill-boards.

This paper deals with three speed management systems in the Netherlands:
- Automatic speed warning system at a *locality*, an urban and a rural intersection.
- Automatic speed warning and enforcement system on a rural *road stretch*.
- Speed enforcement system on a provincial road *network*.

2. Automatic speed management in the Netherlands

2.1. Introduction

Lowering speed of cars will result in:

- More time for perception, judgement, and action; linear relation between speed and time available;
- Shorter braking distance;
- Reduction of accident risk;
- Lowering impact speed;
- Reduction of injury (and fatality) risk;
- Reduction of injury severity.

High objective and subjective detection rate through efficient and effective speed management (warning and enforcement) will result in:

- Increase in attention level of drivers;
- More drivers complying to the rules;
- Speed behavior that conforms to the rules;
- Disproportionate large reduction in the accident rate.

2.2. (Automatic) Speed Signs

It can be learned from literature that static speed signs have little or no (long term) effect on speed behavior (*10*). Dynamic speed signs have the potential of increasing the level of attentiveness of the driver and of lowering driving speed. The objective of automatic speed warning is to give the warning selectively to speeders only. The level of effectiveness of this system is depending on the topicality, the relevance, and the credibility of the information. Also of influence is the level of specificity of behavior instruction given. A better response may be expected when the information is given on specific risky locations, periods, or conditions. Information regarding the reason for the dynamic speed sign will increase the effect.

2.3. (Automatic) Enforcement

(Automatic) enforcement will enhance the effect on speed behavior considerably (*11*), (*12*). Automatic enforcement implies that police manpower is only needed for processing the photos made of speeders; new technology using digital processing of photo or video images have recently been developed enabling automated processing. A possible disadvantage might be that the court is inundated by large numbers of speeders not willing to pay the fine. Violaters not exceeding the speed limit by 30 km/h will be fined according to administrative law in The Netherlands. Those exceeding the limit by more than 30 km/h fall under criminal law and may have to appear in court.
The most effective speed management system is the combination of:

- Information campaign conveying the message to all *potential* road users;
- Fixed signs giving the information to all *passing* road users;
- Dynamic signs warning all *violating* road users;
- (Automatic) enforcement 'catching' all *persisting* violaters;

The philosophy of the whole system is: *first warn then enforce*.
Several experiments were conducted in cooperation with road authorities and the police and were evaluated by the SWOV. The research was commissioned by the Ministry of Transport or provincial road authority.

2.4. A Local Speed Warning System

2.4.1. *Urban Intersection in The Hague*

Three types of speed signs at the approach of an intersection - where a school complex is generating crossing school children periodically - were evaluated consecutively (*13*):
- Permanent fixed '50 km/h' sign.
- Glass fibre sign showing '50' continuously only during school hours.
- Glass fibre sign flashing '50' when an approaching vehicle is speeding during school hours.

Just before the start of the experiment an information campaign was conducted. Speed was measured before the installation of the signs and about three weeks after the start of the operation of the system. The strongest effect was found with the flashing sign: the average speed was lowered by 5 km/h. A theoretical calculation regarding the effect of this system on accidents shows a potential reduction in accidents between 24 and 65%, depending on the approach speed.

2.4.2. *Rural Intersection in the Province of Friesland*

The problem was high speed of cars and as a result accidents occurring at a rural intersection - two-lane rural priority road, speed limit 100 km/h, and a road with a low traffic function.
The following measures were applied:
- An information campaign followed by;
- Permanent sign showing the lowered speed limit of 70 km/h at the approach of the intersection;
- Permanent sign advising to lower the speed;
- Flashing sign warning of speeding.

In the beginning a police car was surveying that intersection periodically. Measurements conducted by the provincial road authority show that speed was reduced in both directions since the start of the operation in summer 1991 until last year. The mean speed went down from around 80 km/h to 63 km/h, the 85 percentile speed was reduced from 96 km/h to around 70 km/h, and the percentage of speeders remained at about the same level (lowered speed limit!). The number of accidents was statistically seen very small: a yearly reduction from seven to two (*14*).

2.5. Four Provincial Road Stretches

Experiments were conducted on four two-lane rural roads with a speed limit of 80 km/h (*15*). Two types of speed measurements were conducted with the following objectives:
A. Reduce high *and* low speeds of motor vehicles on two roads closed for slow vehicle types in the provinces of Noord-Brabant and Overijssel, see *Figure* 2. The lengths of these roads are about 15km.

B. Reduce high speeds only on two roads also open for tractors in the provinces of Gelderland and Utrecht, see *Figure* 3. The lengths of the roads are respectively 13km and 8km.

The experiment consisted of the following steps:
- *Information campaign*
At a press conference before the start of the experiment information was given regarding the experiment. This was published in national and regional newspapers and on national television regarding the danger of unadapted speed, the aim of the systems applied, and the desired speed behavior. Before the start of the automatic enforcement again information was given to the press regarding the high detection risk.

- *Automatic warning signs in phase I* (30 November 1990 - 14 March 1991: 3.5 months)
A. Fixed signs showing (translated in English) 'Safe speed 60-80 km/h' (repeated at important intersections) and an automatic switchable sign '60-80' lighting up when vehicles drive slower than 60 or faster than 80 km/h.
B. Installation of fixed signs showing 'Max. speed 80 km/h' at the beginning of the road stretch (repeated at important intersections) and an automatic switchable sign 'You are driving too fast' lighting up when vehicles driving faster than 80 km/h. On this type of road where slow driving tractors are allowed, it is not meaningful give information for slow drivers to speed-up.

- *Automatic enforcement in phase II* (15 March 1991 - 30 Juin 1991: 3.5 months)
Installation of three to four posts along each of the four road stretches in which a radar, camera, and flash can be mounted alternately. The system is operating at speeds above 90 km/h, from early morning until midnight (after consultation with the police and public prosecutor). Vandalism - breaking the reinforced glass protecting the camera, shooting with a gun at the double cased posts, spraying the glass with paint, and burning the post with gasoline-soaked cotton and forcibly opening the door of the post and removing the camera - necessitated the stopping of the operation during several weeks on two road stretches. Through analysis of the photos in two cases the culprits could be arrested. These interruptions in the operation of the speed cameras had no influence on the evaluation program.

2.5.1. *A cost-benefit calculation*

Costs of the system per annum (interest, writing off, damage by vandals)	: US $40,000
Average benefit per saved injured victim	: US $14,000
Average benefit per saved material damage only accident	: US $ 4,500

The break-even point is reached at a savings of three injured victims or nine material damage only vehicles per annum. Costs of police manpower are not included in the calculation.

2.5.2. *Evaluation*

The evaluation consisted of:
- Speed in the phases 0, I and II;
- A long term evaluation (phase I-II-III) in the autumn of 1994 on the road in Noord-Brabant;

- Accidents during the phases 0 and I+II;
- Automatic enforcement.

2.5.3. *Speed evaluation*

Speed was measured on the four experimental roads in phase 0 - two months preceding the start of the experiment - and in phase I and II, starting about four weeks after instalment of the warning respectively enforcement system. This was conducted by radar, at four locations in each direction on each road. The location of the speed measurements were chosen at some distance from the speed signs and the radar posts. The speed measurements in the phases 0, I and II (and III in Noord Brabant, see further) were conducted at the same locations, time of day and during dry weather. The problems with vandalism (see further) did not influence the speed measurement programme.
A consistent reduction of the characteristics of the speed distribution was found on almost all locations of the experiment roads.
Aggregation of the data of the four roads (compared to phase 0) shows a *reduction* of (*Table* 2):
- Average speed: 3 km/h in phase I and 5 km/h in phase II.
- 85 percentile speed: 3 km/h in phase I and 8 km/h in phase II.
- Standard deviation: 1 km/h in phase I and 2 km/h in phase II.
- Percentage of speeders: reduced from 38% to 28% in phase I, and further to 11% in phase II.
- Percentage of cars driving slower than 60 km/h was small, though it showed an *increase*: from 3% in phase 0 to 4% in phase II.

On the four *control roads* no consistent decrease in speed could be found: average and 85 percentile speeds fluctuate in the phases 0, I and II, partly increasing, decreasing, or unchanged. Also the percentage of speeders - fluctuates and is greater than 40%. Aggregated data are shown in *Table* 2. During the experiment it was observed that drivers tend to brake at the approach of the radar posts and after passing this to increase their speed again, etc., a 'kangaroo' effect. This phenomenon is familiar on roads having radar posts alongside the road.

2.5 4. *Long term speed evaluation*

On the road in Noord-Brabant a speed evaluation phase III was conducted in October 1994, three years after the experiment was concluded in 1991 (*16*). The results are given in *Table* 3. The duration of phase III - concerning the speed evaluation - was one month.
No control road could be found, because of measures being taken in the period between phase II and III that are expected to be of influence on the speed behavior.
The reduction in speed achieved in phase II has slightly increased in phase III: the increase of V-85 speed was 1.5 km/h and of the percentage of speeders 5 percentage points.

2.5.5. *Accident evaluation*

As the total experimental period was only seven months, accidents of different types in phases I and II were totalized for statistical reasons, and this number was compared with the number of accidents in the same seven months of three past years. For the accident evaluation more control roads were used - again for statistical reasons - than for the speed evaluation. *Table* 4 shows the results:

The total number of accidents (lethal, injury, and material damage only) on the experiment roads has been reduced from 150 to 81, a reduction of about 46%. The total number of accidents on the four control roads was reduced from 284 to 237, i.e. a reduction of 17%. Taking this last reduction into account, the effect of the system on accidents yields a *35% decrease*.
A cost-benefit calculation showed that the benefits were almost three times the costs (costs of police not taken into account, no information available).
A *long term* accident evaluation shows that the achieved reduction in accidents remained after the end of the experiment in 1991 up to 1993 (*Figure 4*).

2.5.6. *Evaluation of the automatic enforcement system*

The fear that the automatic enforcement system will overload the police and the court with work, did not materialize. The number of photos made was much less than expected by police and justice authorities, so continuation of the radar and camera system was allowed. At the end of the experiment period the level was lowered to 50% level, because of lack of manpower during the holidays.
After the experiment was concluded in 1991 the system was out of operation for more than a year on the road in Noord-Brabant. In 1994 until October - when phase III speed measurements were conducted - the average operation of the camera was one day a month. The fixed and flashing signs though were operational since the start of the experiment. Yet the speed level remained almost at the same level as in phase II, the concluding period of the experiment.

2.6. Enforcement on a Road Network

Speeders can be distinguished as structural and incidental speeders. Structural speeders - i.e. drivers who are speeding most of the time - will be detected at any location on a road stretch. So when a road network consists of a certain number of road stretches, it will be sufficient to enforce periodically each road stretch. The enforcement site on such a road stretch has to be changed every time for reasons of unpredictability for the road user.
Speed enforcement was conducted on rural provincial roads having a speed limit of 80 km/h in the provinces of Friesland (*17*), Overijssel, and Flevoland. In each province a working group was formed in which the police, public prosecutor, road authority, regional organisation for road safety, and the SWOV were represented. The design of the speed campaign and of the evaluation of this campaign were conceived by the SWOV and this was discussed within the working group. Decisions on strategy, tactics and operations are made in the working group, who also supervised the whole project.
A selection was made of roads that have a great potential in accident reduction (high speeds and relatively many accidents). The total number of road stretches in the three provinces is around 120 with a total length of 800 km. Information regarding the speed campaign was distributed before the start and also during the campaign through the media, regional papers, and regional TV and radio.
Speed enforcement was conducted 100% by radar+camera from an unmarked car stationed on the road side, so no cars are stopped on the site by the police. Down-stream from the enforcement site, feedback is given to all passing road users through the movable sign 'Your speed has been checked. Police' (*Figure 5*). This will enhance the subjective probability of detection. The enforcement at a location was conducted on working days,

during daytime (lack of police capacity during the night), lasting 1.5 - 2 hours, then the radar car proceeded to the next location. A road stretch of the network is enforced on average every five to ten days.
The project consisted of two phases, three months before and three months after the summer holidays. The enforcement level differs in each of the provinces, depending on the capacity of the police. An important objective of the three projects is to determine the optimal enforcement level.
The main results of a *survey* among car drivers in Friesland: a sample of automobile drivers (505) was taken from an existing national data-base (postal address, vehicle use). A card was then sent asking these drivers whether they would cooperate in a survey. Those who responded positively were sent a survey form and a small token of appreciation. The response rate was high: 76% (= 382 respondents). This type of speed enforcement was accepted by 75% of the respondents. About 50% of the respondents claim to follow the speed limits, 70% will adhere to the speed limit when their speed is enforced a couple of times per year, and almost all respondents will stick to the speed limit when their speed is enforced every week.
The effect on *speed* was: the V-85 was reduced by 4-5 km/h, and the percentage of speeders went from 42 to 31%. The absolute level of the speed though is still high.
An *accident* evaluation will be conducted of the three provinces together.
The *police* experienced difficulties in setting up the campaign because of a recent national reorganisation of the police force, resulting in abolishing specialized enforcement teams.
The reports of the experiments in the three provinces will be integrated in an overall report.

3. Conclusions

The national objective on speed is 10% of speeders maximally in the year 2000. The present level of speeds are still far from the mentioned objective. The traditional way to manage speed has not resulted in a satisfying speed behavior.
Traditional police surveillance and control are labor intensive and can be conducted only sparsely, so this often have a temporary effect. Through automating warning and enforcement of speeders the efficiency can be enhanced considerably.
Experiments were conducted in the Netherlands with these systems:
An automatic speed warning system at the approach of an urban and rural intersection resulted in a significant drop in speed.
Experiments on two-lane rural roads with automatic warning and enforcement also resulted in a drop in speed, percentage of speeders from 40% to 10%, and a reduction in accidents by 35%. Problems experienced were: vandalism, a 'kangaroo' effect, labor intensive manual reading of the number plates on photos. Possibilities to prevent vandalism are higher poles for the camera-boxes, measures that prevent climbing the poles, automatic wireless warning to a nearby police station when the poles are vandalized. The 'kangaroo' effect can be prevented when the boxes are visually concealed. Automating the reading of number plates will increase the efficiency of the processing enormously.
Experiments on speed enforcement on a road network using exclusively radar and camera in three provinces have resulted in a drop in 85 percentile speed by 4 to 5 km/h, though the percentage of speeders is still high. In Friesland this percentage was reduced from around 40% to 30%. A survey in Friesland showed that this type of enforcement is accepted by around 75% of the drivers. Around half of the respondents contend that they comply to the speed limit also without enforcement. Around 70% of the respondents will comply to the speed limit when their speed is enforced every month. This percentage is 100 when the enforcement frequency is once a week.

The results show that we still have not reached the optimum level on the curve relating enforcement level with compliance level.
In order to be able to reach the formulated goals, speed enforcement should get high priority. Automating the enforcement and also the further administrative processing will increase the efficiency a great deal, enabling higher enforcement levels, and so a higher probability of getting caught, and higher compliance levels.
It is necessary that the enforcement project be supported by the road authority, the police and the prosecution office. Fear for overloading of the judicial system, can be circumvented by arrangements to limit the operation of the camera depending on the number of photos made in a week or month. Developments in automatic digital reading of number plates show promising results. This could further increase the efficiency of the whole system.

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Enforcement method	Man-hours	Number of speed fines
Radar + camera	4,300	210,000
Radar & surveillance & speeder stopping	81,700	90,000
Total	86,000	300,000

Table 1. *Enforcement method, man-hours on speed enforcement, and number of speed fines.*

Experiment roads				*Control Roads*		
V-charact.	Phase 0	Phase I	Phase II	*Phase 0*	*Phase I*	*Phase II*
N	19,478	11,872	13,417	*5,580*	*5,172*	*5,378*
Average	78.2	75.2	72.9	78.5	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
Std. 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

Table 2. *Aggregated speed on four experiment roads and control roads, phase 0, I and II.*

N-Brabant	**Phase 0**	**Phase I**	**Phase II**	**Phase III**
N	8,225	4,961	5,635	5,370
Average speed	78.6	75.6	73.5	75.1
V-15	70.9	68.9	66.9	68.3
V-85	86.3	83.1	78.9	80 4
%< 60 km/h	1.4	1.9	3.1	2.0
%> 80 km/h	39.2	25.3	106	15.8

Table 3. *Long term speed characteristics in Noord-Brabant.*

Experiment Roads							***Control Roads***	
Injury type	Lethal+ injured		Material damage		**Total**		***Total***	
Phase	0	I+II	0	I+II	**0**	**I+II**	**0**	**I+II**
Accidents	22	14	128	67	**150**	**81**	284	237

Table 4. *Number of accidents in phase 0 and [I+II] on the experiment and control roads.*

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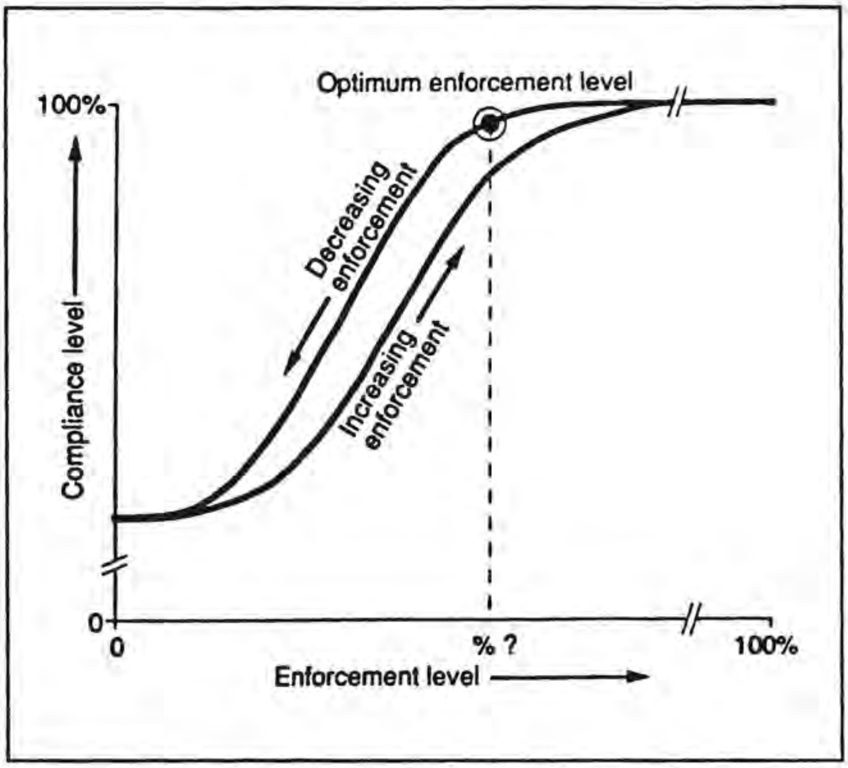

Figure 1. *Hypothetical relation between enforcement level and enforcement compliance.*

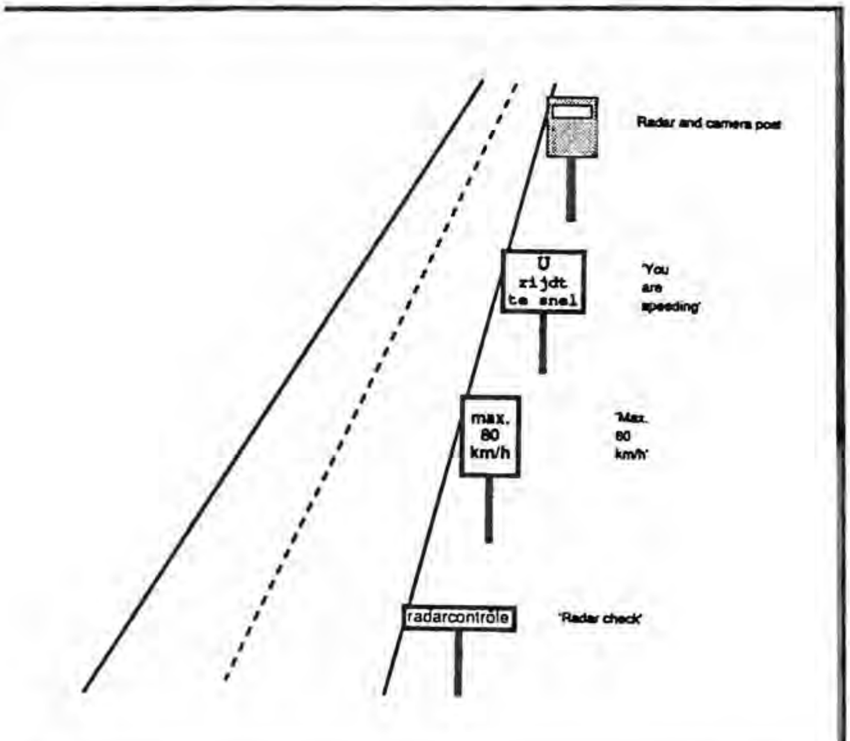

Figure 2. *Set-up of the automatic speed warning and enforcement system on a two-lane rural road closed for slow moving vehicle types.*

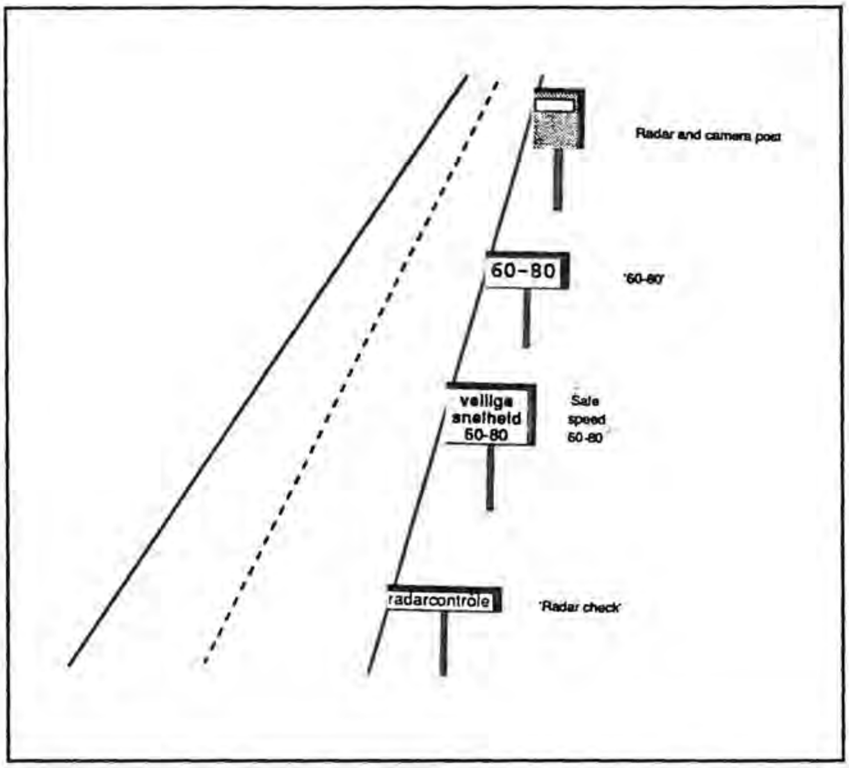

Figure 3. *Set-up of the automatic speed warning and enforcement system on a two-lane rural road closed for bicycles and mopeds (open for motorized vehicles and tractors).*

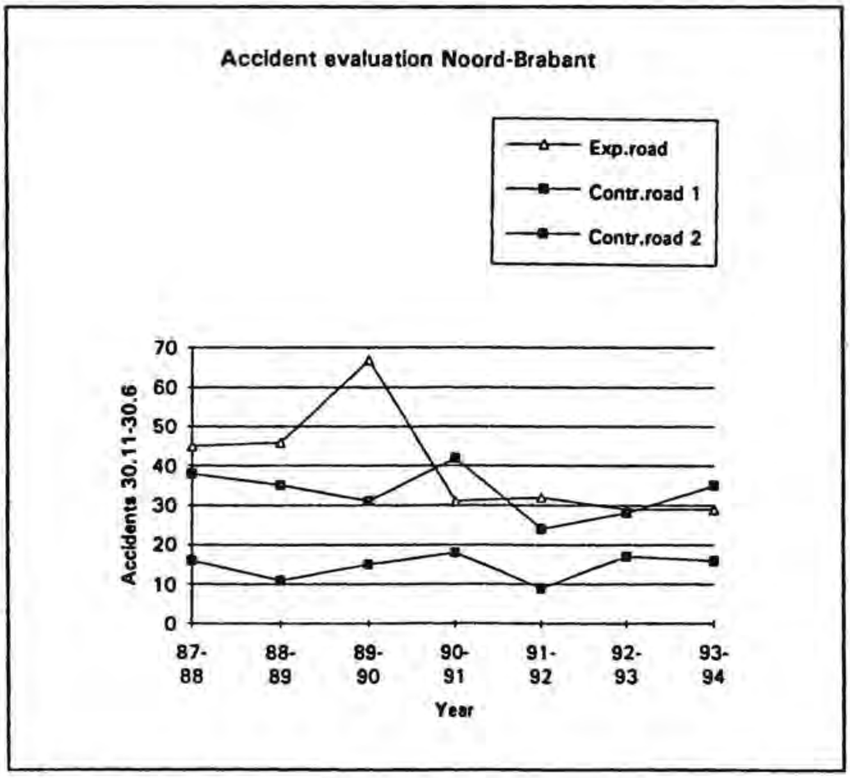

Figure 4. *The number of accidents in phase I, II and III on the equipped road stretch and on control roads in Noord Brabant before, during and after the experiment.*

**'Your
speed has been
checked
Police'**

Figure 5. *The feed-back sign downstream of an enforcement site.*