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Transport

CONTENTS

1 Overview

Traffic law enforcement

Traffic law enforcement is key to the successful implementation of a Safe System approach. It influences driving behaviour through two processes: general deterrence and specific deterrence. General deterrence can be described as the impact of the threat of detection and penalty on the public at large. Specific deterrence can be seen as the impact of actual legal punishment on those who have been apprehended.

Effectiveness and limitations of speed enforcement

Generally, reviews report substantial positive effects of speed enforcement on both speeding behaviour and the number of accidents. The sizes of the reported effects of speed enforcement vary considerably. These differences are most likely to do with the type, intensity and location of the enforcement activities as well as the situation before the enforcement started.

Methods of speed enforcement

Speed enforcement is most effective when it is unpredictable and difficult to avoid, when there is a mix of highly visible and less visible activities, and when it is continued over a long period of time. Furthermore, it is most effective to focus speed enforcement on roads, situations, and times where speeding is having most effect on road safety levels.

Measures to support speed enforcement

Speed enforcement is not a stand-alone measure. To maximise its effect, it is best supported by other measures such as credible speed limits, publicity and efficient technology. It is also important that speed enforcement is embedded in a supportive framework of legislation and sanctions.

Organization of speed enforcement

Ideally, the police work together with partners to prepare, perform and evaluate speed enforcement activities. The main partners for the police are national and local road authorities, court officials, publicity organisations, and researchers. Local road authorities and researchers may assist the police in analysing local road safety problems and in determining priorities. Cooperation with court officials provides clarity about regulations for detecting, prosecuting and sentencing traffic offenders. Publicity organisations can organise supportive publicity programmes, in consultation with the police and the road authorities.

Future possibilities

New vehicle technology can be integrated into enforcement systems. For example, Intelligent Speed Assistance enables speeding control at all times and places (e.g. Lai et al., 2012). It is feasible, in the long term, that police enforcement as we know it may be largely replaced by new technological systems of speed control.

2 General introduction to traffic law enforcement

2.1 Police enforcement as part of the Safe System approach

Countries that have successfully reduced road traffic risk have embraced a systematic approach to road safety intervention which looks at the traffic system as a whole and at the interaction between the road, vehicle, the emergency medical system and the road user in order to identify where there is potential for intervention (Peden et al., 2004). It recognises that human beings make errors and that the road traffic system needs to accommodate these errors. Based on the Haddon Matrix 1980, this intervention strategy seeks to identify and rectify the major sources of error or design weakness that contribute to fatal and severe injury accidents, as well as to mitigate the severity and consequences of injury by:

- reducing exposure to risk
- preventing road traffic accidents from occurring
- reducing the severity of injury in the event of an accident
- reducing the consequences of injury through improved post-impact care

These strategies are embodied in the Safe System approach (e.g. Swedish Vision Zero (Tingvall, 1997) and the Dutch Sustainable Safety vision (Wegman & Aarts, 2006)) which present the latest and most ambitious phase of good practice road safety management. See ERSO web text on Road Safety Management.

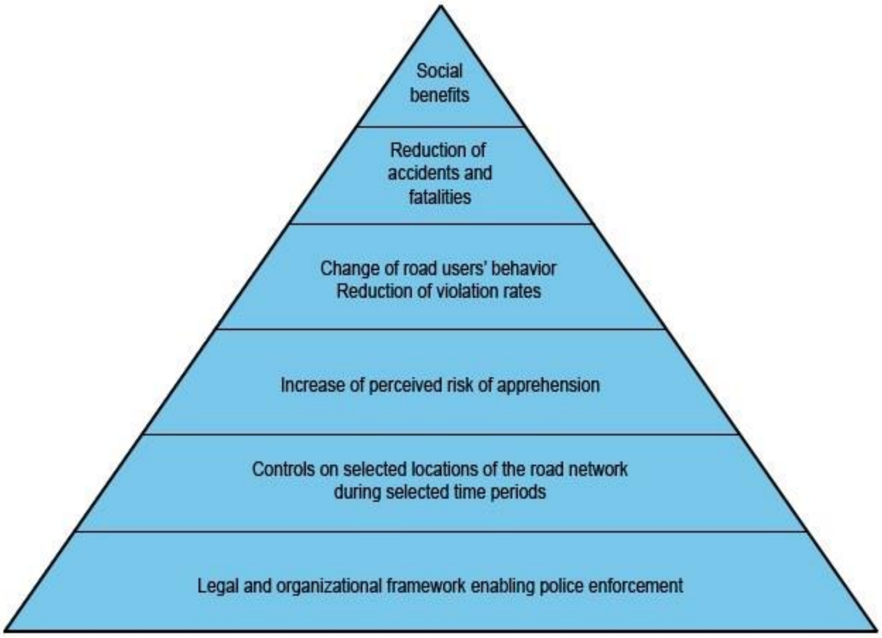
Road traffic law enforcement is one of the instruments to secure or improve compliance with key road safety rules. In the literature, the concepts of 'traffic law enforcement' and 'police enforcement' are often used interchangeably. However, these concepts differ in scope. Traffic law enforcement is broader and covers the entire enforcement chain, from detection of a violation through to the penalty imposed. Police enforcement refers to the actual work of deterring or detecting a traffic law violation, apprehending the offender, and securing the evidence needed for successful prosecution. Police enforcement can only be effective if it operates in a supportive environment of laws, regulations, and a sensitive penal system. Consequently, the effectiveness of police enforcement should not be viewed in isolation.

This web text focuses in particular on speed enforcement. There are two reasons for this. Firstly, the relationship between excess speed and the risk of death and serious injury is well-established and speed management is central to a Safe System approach which is being implemented in many parts of the world. Secondly, speed enforcement merits special attention in view of the variety of policing methods used to prevent speeding violations and continuing technological developments in this area. See also ERSO web text on Speed and Speed Management.

2.2 From laws and policy, to increased enforcement, to social benefits

Yannis et al. (2004) describe the hierarchy of road safety enforcement. The legal and organisational framework enabling police enforcement provides the foundation for actual policing operations. Such a framework creates well-planned, intensified police enforcement on selected locations of the road network or on an area-wide basis, resulting in an increase in the perceived risk of being caught and a decrease in violation rates. Changes in road user behaviour will result in fewer traffic accidents, fewer traffic victims, and in reduced social costs. The figure below describes this ideal scenario.

Figure 1: The hierarchy of road safety enforcement.



Source: Yannis et al. (2004)

Rule 1:
To maximise road safety effects, traffic law enforcement should, first and foremost, prevent violations that are related to the number or severity of serious and fatal accidents.

2.3 General deterrence vs. specific deterrence

It is generally accepted that traffic law enforcement influences driving behaviour through two processes: general deterrence and specific deterrence (Zaal, 1994; Mäkinen et al., 2003). General deterrence can be defined as the impact of the threat of legal punishment on the public at large. Specific deterrence can be seen as the impact of the actual legal punishment on those who are apprehended. Thus, general deterrence results from the public's perception that traffic laws are enforced and that there is a risk of detection and punishment when traffic laws are violated. Specific deterrence results from the actual experience of detection, prosecution, and punishment of offenders.

The general assumption underlying police enforcement is that it should primarily aim at general deterrence, which is first and foremost achieved by increasing drivers and riders' perception of the risk of being caught. The subjective risk of being caught and hence the effectiveness of police enforcement, is larger if police enforcement is (Goldenbeld, 1995):

- accompanied by publicity
- unpredictable and difficult to avoid
- a mixture of highly visible and less visible activities
- primarily focused on times and locations with high violation (maximum feedback to potential offenders)
- continued over a longer period of time

These general principles may need to be tailored to account for regional differences in violation levels, road network status, and, in some cases and for the short term, social norms. Research shows regional differences in the effectiveness of police enforcement (Hakkert et al., 2001; Yannis et al., 2007).

2.4 Targeted enforcement

In major reviews (Delaney et al., 2003; Mäkinen et al., 2003; ETSC, 1999; OECD, 1999) it has been concluded that enforcement targeted at a limited number of high-risk violations is more effective in reducing road accidents than non-targeted general enforcement. This is attributed to the following factors:

Organizational: Given the limited amount of manpower and equipment of police, enforcement managers will always aim to get maximum value from scarce resources. Focusing on a limited number of high risk violations is more efficient than a non-focused general enforcement approach

Road safety: Focusing on one or more well-established high-risk violations such as speeding, drink driving, seat belt use, helmet use and red light running where there is evidence of such problems;

Communication: It is easier to communicate with road users about a limited and specific number of violations than about traffic violations in general.

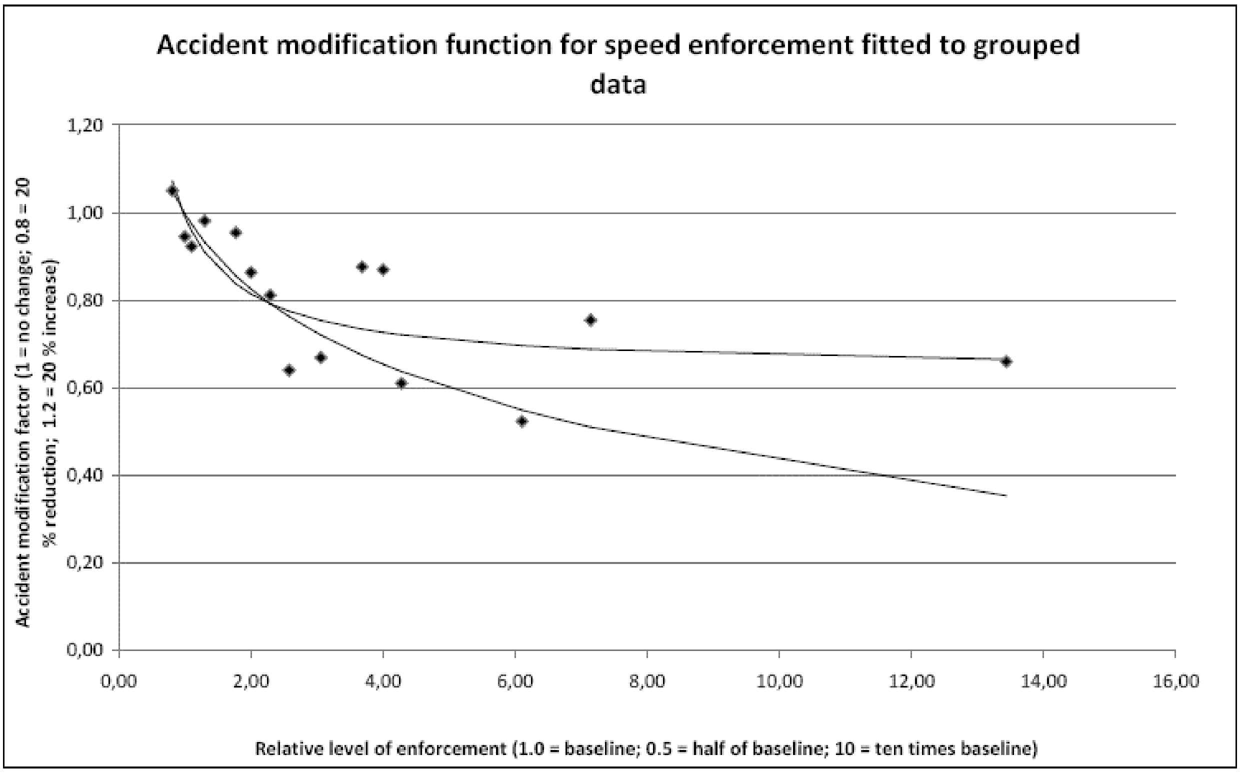
2.5 Enforcement levels and safety improvement

Speed enforcement is a road safety measure that can be applied in different doses. One would, therefore, expect there to be a positive relationship between the amount of enforcement (the size of the dose) and the effect on accidents: the more enforcement, the larger the accident reduction (Elvik, 2011).

On the basis of a range of studies, Elvik (2011) developed a Crash Modification Function (CMF) for speed enforcement, relating the intensity or level of enforcement to the size of the effect on accidents. The function is a dose–response curve for police enforcement, showing how the dose of enforcement is related to the response in terms of changes in the number of accidents.

Figure 1 shows the two nearly equally well fitting functions that best fit the data points taken from 11 'before and after studies' on speed enforcement. In both cases there is a 20% reduction of an injury accident when speed enforcement doubles (i.e. changes from level 1 to level 2)

Figure 1. Crash modification functions for 11 studies of speed enforcement



Source: Elvik (2011).

Further work on dose-response effects in Europe would be useful to inform implementation.

3 Speed enforcement

3.1 Speed enforcement as part of a speed management policy

Speed is at the core of the road safety problem. There is a strong relationship between speed and both the number of accidents and the severity of the consequences of an accident. If the number of speeding violations on European roads can be reduced, many lives will be saved (For more information, see ERSO Speed and Speed Management web text).

There is no single solution to managing excess and inappropriate speed. Excess speed is driving in excess of the speed limit, and inappropriate speed is going too fast for the conditions. A package of countermeasures is necessary, including police enforcement, aimed at increasing the effectiveness of each individual measure (OECD/ECMT, 2006). The most appropriate combination of measures is determined by the circumstances. Wegman and Aarts (2006) propose an integrated, systematic and stepwise approach to speed management:

Step 1: Setting speed limits

A speed limit needs to reflect the safe speed of a particular road, related to road function, traffic composition, and road design characteristics. Furthermore, a speed limit needs to be credible, i.e. it must be logical in the light of the characteristics of the road and the road environment.

Step 2: Information about the speed limit

The driver must know the actual speed limit at all times and in all locations. This can be done by using consistent roadside signing and road markings or by using in-vehicle systems that inform drivers of the speed limit in force.

Step 3: Road engineering measures
At particular locations and in specific areas, low speeds are crucial for safety. Examples are near schools or homes for the elderly, at pedestrian crossings and at intersections. At these locations, physical speed reducing measures such as speed humps, road narrowing markings and roundabouts are appropriate.

Step 4: Police enforcement to control the intentional speeder
If steps 1 to 3 have been applied, unintentional speed violations will become an exception. Drivers who then still exceed the speed limit are doing so intentionally. Police enforcement will therefore remain necessary in this case.

Each of the steps 1 to 4 has to be accompanied by providing information to road users on the problem of speed and speeding, why action has been taken and what outcomes the action is expected to produce.

3.2 Speed enforcement in relation to other road safety measures

A road safety strategy should not only identify specific road safety measures, but also specify how different road safety measures, including road design, setting speed limits, enforcement, etc. are related to one another in a logical and hierarchical manner, and when and where action should be taken. For example, according to the Dutch Sustainable Safety vision, speed enforcement should always be considered in combination with other speed management measures. It should only be carried out when speeding demonstrably contributes to a poor safety record of a road, and when other measures (such as setting safe and credible speed limits, changing the road infrastructure, providing road users with adequate information about limits on road sections) are not possible or insufficient to make road users comply with the speed limits.

Research informs us that different measures can be effective in managing speed. For example, Mountain, Hirst and Maher (2004) compared the speed and safety effects of engineering measures and enforcement by fixed speed cameras. Using a study design that controlled for trends in accidents, regression-to-the mean effects and changes in traffic volume, they found that engineering schemes including vertical deflections (speed humps, cushions, etc.) prevented 44% of personal injury accidents. Further findings include personal injury accident reduction of 29% from engineering schemes with horizontal features and of 22% from fixed camera installation.

The idea behind an integrated speed management approach is to seek for the best possible synergies between the various individual measures. Isolated measures will have an impact but are not the most effective way to achieve a durable reduction in speed (OECD/ECMT, 2006).

Rule 2:
To achieve collective safety benefits by reducing speeds a systematic, integrated speed management policy is necessary. Speed enforcement is one of the elements of an integrated speed management approach.

3.3 General characteristics of effective speed enforcement

The general characteristics of traffic law enforcement, as discussed previously, can easily be transferred to the specific domain of speed enforcement.

The most important requirement for speed enforcement is that it deters drivers from speeding; not only for the future behaviour of those who have been caught but, more importantly, for those who are not. This is called general deterrence. General deterrence is closely related to the driver's perception of the risk of being caught, This perception can be increased by stepping up the intensity of actual speed enforcement and also by making sure that, irrespective of the enforcement method, speed enforcement activities are well-publicised, unpredictable and unavoidable, and sustained over a long period of time.

Furthermore, for maximum effect, it is advisable to focus speed enforcement operations on roads, situations, and times where speeding is having the greatest effect on the level of road safety. Ideally, enforcement operations should be based on a thorough analysis of accidents and their outcomes and the role of speeding therein.

Rule 3:
Speed enforcement gains in effectiveness if it is targeted towards prioritised roads and areas, situations and times.

3.4 Public support for speed enforcement

According to the SARTRE3 survey (2004), public support for traffic enforcement, in general, and for speed enforcement, in particular, is high. The survey interviewed over 23.000 car drivers in 23 European countries to determine opinions and behaviours in traffic. It showed that:

- Three quarters (76%) of all interviewed EU drivers are in favour of increased enforcement of traffic rules
- Two-thirds (66%) of EU drivers are very much or fairly in favour of the use of automated speed cameras
- Three out of five (60%) EU drivers support higher penalties for speeding offences.

In the UK, when residents were invited to rate speeding in traffic against 15 other anti-social behaviours as part of the face to face British Crime Survey (Poulter & McKenna, 2007) results revealed that speeding traffic was considered as the largest problem in local communities, regardless of whether respondents were male or female, young, middle aged, or old. The rating of speeding traffic as the largest problem in the community was replicated in a second, smaller postal survey, in which respondents also provided strong support for enforcement on residential roads and indicated that travelling just above the speed limit on residential roads was unacceptable.

In Israël, survey results from 2010-2013 indicated that about 61% of Israeli drivers predicted a positive impact of speed cameras on road safety (Schechtman et al., 2016).

In 2014, a British survey polled 1.000 drivers of all age groups across Britain, split into 11 regional areas. 79% of respondents agreed that it was acceptable to use speed cameras to identify vehicles involved in speeding offences (IAM, 2014).

Even though public opinion survey results suggest that speed enforcement (particularly about the use of speed cameras) is widely supported, it is also a topic that evokes strong public and political debate, albeit it amongst a vociferous minority. The four general types of dilemmas (credibility, fairness, implementation, and social) that can occur with introducing a new road safety measure (Goldenbeld, 2002), are specifically discussed in view of speed cameras by Delaney et al. (2005). The complaint is that minor offenders are mostly caught, that it is not impartial, and that it is just used to fill the regional or national treasury. In other words, the credibility of camera enforcement requires special attention and is one of the quality aspects of enforcement (Delaney et al., 2005; Soole et al., 2008). Experience shows that speed camera enforcement programmes require clear and transparent rules to ensure public acceptability. The credibility of speed enforcement may be increased by setting credible speed limits, by policy guarantees that exclude profit considerations as a motive for enforcement actions, and by communication about the reasons for enforcement and positive behaviour and safety outcomes.

Rule 4:
The credibility of traffic enforcement should be part of enforcement policy and is to be considered as an important quality aspect of enforcement.

4 Speed enforcement techniques and their effectiveness

There are two main methods of speed enforcement. The first is to check drivers at the roadside and stop offenders. In the literature this is often called stationary enforcement or physical policing. Physical policing makes use of manned (visible or invisible) observation unit and a manned (visible) location where offenders are stopped. This type of physical policing, when randomised in time and location over a large part of the road network, is called random road watch or network-wide random enforcement.

The second method is to detect speed offenders by means of a speed camera and to send them a fine or a notification by mail. Speed cameras can be used full-time at fixed locations (fixed cameras) or can be moved between different locations (mobile cameras). Speed cameras can operate automatically (unmanned) or as part of a manned control (either visibly or hidden in a car or van).

4.1 Physical policing

Physical policing has both advantages and disadvantages. The advantages are related to the fact that violators are immediately stopped by the police:

- The violator is given immediate feedback.
- The police officer has the opportunity to explain why they are enforcing speed limits.

- If violators are stopped at a spot which is clearly visible to other drivers, the subjective perception of being caught is increased.

The disadvantage is that physical policing is far more labour-intensive and so it is virtually impossible to reach the same enforcement level as with speed cameras. Hence the actual as opposed to the perceived risk of being caught is much smaller. This is particularly true for speed enforcement by a police patrol car. A police patrol car follows the traffic stream and therefore has a relatively small chance of detecting a speed violator. It also needs to follow that car for a sufficiently long time to determine the level of speeding reliably.

However, whereas conventional manpower methods of police enforcement of speed have been criticised as being too selective, sporadic, and inconsistent and, in the end, being rather expensive and ineffective (Zaidel, 2000) there is evidence that using conventional manpower intensive methods provides highly-effective speed control over large areas. A specific type of physical policing is the network-wide random enforcement or Random Road Watch (RRW). This is an enforcement resource management technique that randomly schedules levels of police enforcement with the aim of realizing long-term, widespread coverage of a road network. Violators are stopped by the police. A RRW programme in Queensland, Australia, indicated a 31% reduction in fatal accidents on the roads included in the programme (Newstead et al., 2001). The benefit/cost ratio for the programme was estimated to be 55:1.

4.2 Speed cameras

Speed camera enforcement is most appropriate if accidents are clearly concentrated on specific road sections and areas and related to excess speed, and when the volume of traffic makes physical policing a time-consuming and less effective approach.

The best estimates – from meta-analyses - are that automatic camera enforcement results in an accident reduction of 15 to 20% (Elvik & Vaa, 2004; Høye, 2014). Individual evaluation studies differ widely in the reported effects.

Effects of fixed cameras were reviewed by Thomas et al. (Thomas et al., 2008). The authors concluded that injury accidents were reduced by 20 to 25% on road sections where cameras were installed. A second review in 2008 was a meta-analysis of studies on traffic enforcement (Erke, Goldenbeld & Vaa, 2009). In this review, the effects of mobile and fixed cameras were looked at separately. The authors report a 35% reduction in injury accidents for fixed cameras and a 14% reduction in injury accidents for mobile cameras.

Both the British study and the meta-analysis by Erke, Goldenbeld and Vaa (2008) demonstrate greater safety effects for fixed speed cameras than for mobile cameras. A possible explanation for this difference is that fixed cameras are used in locations inside built-up areas with high accident concentrations. If the baseline lack of safety is greater, the effect of the camera can be expected to be greater.

In 2010 a Cochrane review of speed cameras was published (Wilson et al., 2010). The authors looked at 28 studies of varied quality world-wide. In view of the large heterogeneity of results the authors chose not to distinguish effects between fixed and mobile cameras. Wilson et al. concluded that the number of serious injury accidents (fatality or hospitalisation) near camera locations was reduced between 11% and 44% when compared to road sections without cameras. In research into the effects of cameras over larger areas, reductions in injury accidents ranged between 17% and 58%, with most studies reporting a reduction between 30 and 40%. Studies that have looked at safety effects over a longer period of time showed that the safety effects are sustained or even improved. Although the authors are critical about the quality of many studies, they concluded that the consistency in results demonstrates that cameras are beneficial for road safety. Table 1 summarises findings of recent major reviews on the effectiveness of speed cameras.

Table 1: Overview of accident reduction effects of speed enforcement reported by international reviews

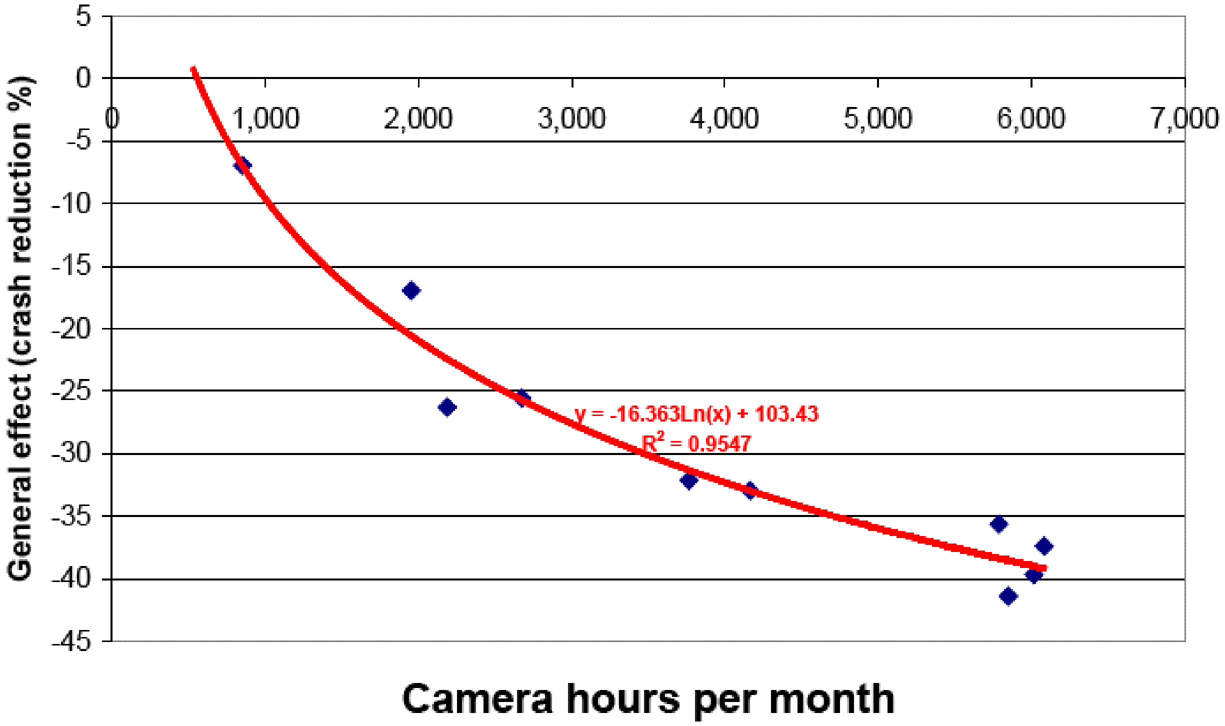
Enforcement Method type	Method	Effect on injury accidents	Source
Fixed speed cameras	Empirical review	Range 20-25%	Thomas et al. 2008
Fixed speed cameras	Meta-analysis	Best estimate 35%	Erke et al. 2008
Mobile speed cameras	Meta-analysis	Best estimate 14%	Erke et al. 2008
Fixed and mobile speed cameras near camera locations	Empirical review	Range 11-44%	Wilson et al. 2010
Fixed and mobile speed cameras larger areas	Empirical review	Mostly 30-40%	Wilson et al. 2010
Fixed speed cameras	Meta-analysis	Best estimate 20%	Høye 2014
Fixed and mobile speed cameras	Time-series	Best estimate 20%	Blais & Carnis 2015

Mobile versus fixed speed cameras

An overview of Australasian enforcement projects indicates that the effects of hidden mobile cameras are spread over larger areas than effects of fixed cameras (Delaney, Diamantopoulou & Cameron, 2003). Whereas fixed cameras have a larger safety effect per location, hidden mobile cameras have a larger area of influence.

In Queensland, overt mobile speed cameras were deployed on urban and rural highways according to a random scheduling program. The Queensland mobile speed camera program started in 1997 and gradually increased its level of monthly camera hours to just over 6,000 during 2003. The program stabilised around that level throughout 2003-2006. An annual average of 300,250 speeding offences was detected by the program and 249,500 infringement notices per year were issued. From an average of 5,934 hours of camera operation per month, 4.2 offences per hour were detected and 3.5 notices per hour were issued during 2003-2006. An analysis of 1997-2006 data indicated the following relationship between monthly camera hours and accident reduction (Cameron, 2008).

Figure 1: Relationship between casualty accidents in Queensland and monthly hours of the overt mobile speed camera program with randomised scheduling, 1997-2006



Source: Cameron, 2008.

Visibility of cameras

A variety of factors influence the decision to use visible or hidden cameras. For example, if it is very important that road users lower their speed on a specific section of the road, e.g. because of an intersection or a nearby school, it is more effective to have a visible speed camera, preferably accompanied by a warning sign. On the other hand, hidden cameras, and, in particular, hidden mobile cameras make speed checks less predictable. Hidden (mobile) speed cameras are often accompanied by a warning sign. This approach may increase the preventative effect, since drivers know that there is a chance of detection but they do not know when and where exactly. Whereas nearly every driver keeps within the speed limit when a camera is clearly visible, a small percentage of drivers may still violate the limit when they drive on a road with hidden cameras. On the other hand, clearly visible speed cameras drivers may tempt drivers to speed up again a few hundred metres after the camera, while they may be less tempted to violate the speed limit when they are aware of the possibility of a hidden camera check.

Using a driving simulator, Marciano et al (2015) tested how drivers reacted to highly visible, overt speed cameras and not visible, covert speed cameras. The researchers compared driving performance under four experimental conditions: 1. overt (clearly visible) cameras with delayed feedback, 2. overt cameras with immediate feedback, 3. covert cameras with delayed feedback, and 4. covert cameras with immediate feedback. They found that both median speed and speed variance were higher with overt than with covert cameras. They also found that a covert camera system along with immediate feedback achieved the best results regarding the aim to let drivers maintain steady speeds at the permitted levels from the very beginning. Finally, in both ‘overt cameras’ conditions "kangaroo effects" were found throughout the entire experiment, i.e. drivers reduced their speed momentarily only near enforcement locations (see also Section 5.3).

Based on the described experiment, the authors conclude that overt cameras are less optimal compared to covert cameras. It should be added that the main function of clearly visible overt cameras is to reduce speeds at specific locations near schools, intersections, pedestrian crossings where there is heightened accident risk. In order to effectively reduce speeds at these locations, the cameras should be very visible from a distance so that drivers have enough time to slowly reduce speed. Basically, overt and covert camera systems serve somewhat different functions, and this should be kept in mind when comparing their value.

4.3 Average speed control

Average speed control (also called 'section control', 'point-to-point control' or 'time over distance control') is a relatively new speed enforcement technique. Average speed control systems measure the average speed over a road section (usually 2 – 5 km). The vehicle is identified when entering the enforcement section, and again when leaving it. The average speed can be calculated based on the time interval between these two points.

Average speed control works 24 hours a day, 7 days a week, which means the chance of being caught is close to 100%. On a stretch of road where average speed control is employed, most drivers obey the speed limit. On sections where speed limits were frequently exceeded in the past, average speed control can reduce the number of offences to a few per cent, or even less than 1%.

In various countries section control systems have undergone evaluation. In Austria, Stefan (2006) evaluated the use of average speed control on an 80 km/h motorway stretch running through a tunnel. In its first year of operation a reduction in average speed by more than 10 km/h was recorded. Stefan estimated that after two years of operation average speed control reduced injury accidents by around 33% and fatal and serious injuries by 49%. Taking into account both effects on road safety and road traffic emissions; Stefan computed a cost-benefit ratio of average speed control of 1:5,3. Positive results with section control were also obtained in the Netherlands. It was found that average speed control reduced the number of speed offenders to less than 1% at an enforced section of motorway (RWS, 2003).

In the United Kingdom, experience with average speed control indicated that a typical number of offences detected above the speed limit is between 50 and 200 per week for a major motorway scheme, representing a tiny proportion of speeders (Collins & McConnel, 2008). The overall result of average speed control is a conveyor belt type flow, with uniform speeds, little braking and larger headways. The key benefit for drivers, other than improved safety, is the reliability of the journey; once on the conveyor belt, the time taken to travel through the control zone is predictable and repeatable (Collins & McConnell, 2008).

Again in UK, Brackstone (2008) compared the performance of average speed control and spot speed camera enforcement at road works. Compared to spot speed camera enforcement, average speed control caused traffic to become more uniform with slightly smaller headways, and reduced the surfing effect where drivers brake on approaching a camera and then accelerate after passing it. Driver glance patterns at roadworks with average speed control showed mixed results; glance patterns differed substantially from the norm with indications of both greater and lesser distraction. The author concluded that average speed control is a potentially safer enforcement system at road works, but that issues concerning capacity effects on throughput, smaller headways, and driver distraction still need to be resolved.

In Victoria, Australia, average speed control started April 2007 on 4 sections of the Hume Freeway, 8, 14, 7 and 25 km in length. The installed system detects about 1.000 offences per day, which suggests an offence detection rate of 1-2% from an estimated 50.000 to 100.000 vehicles per day (Cameron, 2008). In Western Australia 40 road links have been identified where average speed control would have a cost-benefit ratio greater than 10 (Cameron, 2008).

In Belgium, the effects of average speed control on speed was studied on two highway sections (Vanlommel et al., 2015). The results were quite positive. Firstly, the average speed control system reduced the traffic speed over its entire length, effectively enforcing the maximum speed limit. Secondly, traffic speed became more homogenous; the speed difference between the 25th and 85th percentile was reduced to 15Km/h inside the monitored section compared to 30Km/h on similar parts of the highway.

In an Italian study, Montella et al. (2015) investigated longer term effects of average speed control on an urban and a rural motorway. The analysis on speed data over two years after the start of average speed control showed that speed, speed dispersion and non-compliance to speed limits significantly increased over time. According to the researchers, the most likely explanation for this increase is that average speed control were only given to infringements occurring in specific secreted periods previously defined by the police. This should decrease the users' perception of the risk of receiving a fine. Thus, for an optimal effect average speed control relies on a continuous operation of both speed checks and processing of fines.

Two empirical reviews of average speed control report very positive conclusions (Soole et al., 2013; Høye, 2014). Looking at studies from several countries, Soole et al. (2014) report a decreasing trend in KSI (killed or serious injury) accidents after the installation of average speed enforcement in the magnitude of 33% to 85%. However, the authors note that statistical significance testing, the control of confounding factors (including regression-to-the-mean) and the use of appropriate comparison areas were absent from most of these evaluations. Concerning effects on speed, Soole et al. (2013) conclude that average speed enforcement is associated with very high rates of compliance with posted speed limits with offence rates typically falling below 1%. Both average speed and the 85th percentile of speed were usually reduced to just below the speed limit and the proportion driving above the speed limit was reduced to below 1%. Another conclusion is that average speed enforcement is associated with reduced speed variation, due to the fact that the majority of motorists travelling on enforced sections of road travel at speeds close to the posted speed limit. Subsequently, such changes in vehicle speeds typically result in more homogenous traffic flows, improved traffic density, reduced journey travel times, less fuel consumption and reduced vehicle emissions.

In a meta-analysis study, Høye (2014) assessed accident effect of average speed control using five effect estimates from four studies. She reported that the best accident reduction estimate for average speed control was -33% for all accident effect estimates and -56% for Killed-and-Seriously-Injured accidents. Thus average speed control has a greater effect on more serious accidents.

4.4 Laser guns

Increasingly in Europe (e.g. Netherland, United Kingdom), United States and Australia, enforcement of speeding with a hand-held laser gun is used as enforcement method inside built-up areas.

A study conducted in Unley, South Australia (Woolley & Dyson 2003) compared three types of enforcement: hand held laser guns operated by motorcycle police, speed cameras, and Council speed feedback signs (electronic signs that provide information to motorists on their driving speeds). It was concluded that while all three methods succeeded in reducing driving speeds, laser gun enforcement was more efficient than the use of speed cameras by a factor of four and had a significant halo effect that lasted up to ten days after the event.

4.5 Conclusions

Generally, reviews report substantial positive effects of speed enforcement on both speeding behaviour and the number of accidents (ETSC, 1999; Pilkington & Kinra, 2005; Zaal, 1994; Zaidel, 2000). However, the size of the reported effects of speed enforcement vary considerably. For example, Pilkington and Kinra (2005) found that evaluation studies reported that the accident and casualty reduction in the immediate vicinity of speed camera locations varied between 5 and 69% for accidents, between 12 and 65% for injuries and between 17 and 71% for fatalities. These differences will be influenced by the type, intensity and location of the enforcement activities as well as by the situation before the enforcement started.

A TRL study (Elliott & Broughton, 2005) reviewed the literature on police enforcement and found for speed enforcement that:

- speed cameras are more effective than physical policing methods in reducing speeds and accidents;
- speed cameras are more effective in reducing accidents within urban areas than on rural roads;
- fixed speed cameras are more effective in reducing speeds and accidents than mobile speed cameras.

Rule 5:
Speed camera enforcement should be used for a large concentration of traffic crashes at high traffic volume locations, sections and areas. Physical policing can be a good alternative to safety camera enforcement when accidents are scattered provided operations are randomised and applied to a large part of the network.

5 Additional considerations for speed enforcement

This section presents a range of additional considerations which need to be taken into account when identifying and implementing speed enforcement.

5.1 Time and distance halo effects

A common finding in the literature is that automatic speed enforcement effects are limited in terms of both time (Vaa, 1997) and space (Christie et al., 2003; Hess, 2004). 'Time halo' can be defined as the length of time that the effects of enforcement on drivers' speed behaviour continue after the enforcement operations have ended. 'Distance halo' is defined as the distance over which the effects of an enforcement operation continue after a driver has passed the enforcement site.

Physical policing
With regard to time halo, the effects of physical policing methods vary a lot, ranging from effects lasting 1 hour to up to 8 weeks after the police activity has ceased (Elliott & Broughton, 2005). It was also found that less than 6 days of police activity at a given location will have little or no time halo effect after the enforcement effort has been stopped. With regard to distance halo, Elliott and Broughton (2005) conclude that:

- The effects of visible and stationary policing on driving speeds are halved for every 900 metres downstream of the enforcement site.
- The effects of police presence on driving speeds typically last between 2.4 and 8 km.
- Police enforcement can have considerable larger distance halo effects (e.g. up to 22 km), if visible, stationary enforcement is used randomly on a large part of the road network, as such, suggesting a large scale enforcement effort and high unpredictability of checks.

Speed cameras
Only a limited number of studies have examined the speed effects of speed cameras at a greater distance from these cameras. Some studies indicate that 500 metres is about the maximum distance halo of a speed camera. More studies, however, indicate a much larger distance halo effect, even up to 10 km (Elliott & Broughton, 2005).

Overtly deployed mobile speed cameras produce reductions in vehicle speeds, as far downstream as 1,5 kilometre from the camera site, but no reduction at 500 metres upstream from the camera site (Champness, et al., 2005).

Larger distance halo effects seem to be associated with physical policing, especially if the policing method is 'randomised'. The minimum distance halo effect found at speed camera sites (500 m) is almost five times smaller than the minimum distance halo effect of physical policing (2,4 km) (Elliott & Broughton,2005)

When the roads are checked by 24-hour operating speed cameras, the effects on speed and safety are larger in sections within 1 km of the camera site than sections within 2Km (Hess, 2004).

When visible and invisible mobile camera operations are used the effects are more widespread over the road network (Keall et al., 2002).

The effects of visible camera operations along the road side tend to dissipate after 3 days (Diamantopoulou & Cameron, 2002).

A study by De Pauw et al. (2014a) on 2 motorway speed camera locations in Belgium showed a V-profile in the spatial speed distribution: drivers slowed down quite abruptly in the last few hundred metres before the camera and speed up again after passing the camera to regain their original speed after not more than 1 km beyond the camera location. The highest effects were

found at the speed camera, but smaller and even unfavourable speed effects were found at the locations upstream and downstream from the camera.
If speeds are only reduced at close distances to cameras, it can be expected that accident reductions are also limited to distances near cameras. This is indeed confirmed by the meta-analysis of 15 fixed camera studies by Høye (2014). She found that the accident reduction effect of fixed speed cameras decreased with increasing distance from the camera locations. While accidents were found to be reduced by 18% at the camera locations (±250 m), the effect was found to decline to a reduction by 4% at a distance of 1 km or more from the camera location (in both directions) (Høye, 2014).

The main practical road safety implication of these findings is that in order to maximise the impact of speed cameras on reducing speeding, and thus speed related accidents, speed cameras should be installed within a maximum range of about one kilometre from locations that have a history of high-speed related accidents.

5.2 Regression-to-the-mean

Some critics of speed cameras have argued that accident reductions found at speed camera sites are overestimates, since they include regression-to-the-mean effects. The regression-to-the-mean effect is the statistical phenomenon that roads with a high number of accidents in a particular period are likely to have fewer during the following period, even if no measures are taken; this is just because of random fluctuations in accident numbers. Since speed enforcement often takes place at roads with large numbers of accidents, the effects of the intervention may be overestimated if there is no appropriate statistical control.

For example, in a re-analysis of results from a study of Jones et al. (2008), Brenac (2010) found that regression-to-the-mean played a larger part in influencing the results than originally calculated by the authors.

There are several studies that take regression to the mean in account and that again find positive accident reductions as a result of speed cameras. Research by Gorell and Sexton (2004) showed also that, after controlling for regression-to-the-mean, the estimated reduction in all injury collisions due to 77 speed cameras in London was 12%, and the reduction in fatal and serious injury accidents 21%. Similarly, after correction for regression-to-the-mean, Mountain et al. (2004) found that, within a distance of 250 metres of the speed cameras, the overall effect of a sample of 62 speed cameras was a 25% reduction in all injury accidents.

In a study by Allsop (2013), regression to the mean was largely excluded by comparing the years after the cameras were installed with the years of a period more than three years before they were installed. His analysis for 551 fixed speed cameras in 9 areas showed that the number of fatal and serious collisions near camera locations was reduced by more than a quarter (27%) after their installation.

Li et al. (2013) used both an Empirical Bayes (EB) and a Propensity Score Matching (PSM) method on 9-year period data from a total of 771 camera sites and 4787 reference sites to study the safety effects of speed cameras. Both methods are intended to account for regression to the mean. The researchers found significant reductions in Personal Injury Accidents using both methods (EB: 26% reduction; PSM: 23% reduction).

Li et al. (2015) used Empirical Bayes method to take regression to the mean into account and found accident reduction of mobile speed cameras in the range of 14-20%.

Interrupted time-series designs are stronger than a single pre-test/post-test design because of their ability to minimize regression to the mean through collection of repeated measurements. With the use of such a design Blais and Carnis (2015) concluded that the French speed camera enforcement program was associated with a decrease of 19,7% in traffic fatalities and accidents with injuries.

In conclusion, although several camera enforcement studies may not have optimally adjusted for regression to the mean, the studies that have adjusted for this type of bias still show considerable safety benefits from speed cameras.

5.3 Kangaroo effects

In response to speed enforcement, drivers may tend to reduce their speeds momentarily only near enforcement locations, as they seek to avoid a penalty. This type of speed behavior, called the 'kangaroo effect' or Enforcement Avoidance Behaviour (Shim et al., 2015) raises safety concerns because sudden changes in speed may increase the risk of accident occurrence, especially upstream of the enforcement locations.

In a meta-analysis of speed camera enforcement studies, Høye (2014) found that kangaroo driving (braking and accelerating) occurs. But the evidence of studies that have measured speed at a distance of several kilometres downstream of the speed cameras did not find an adverse effect on speed or accidents.

In a large-scale British study, Li et al. (2013) arrive at a similar conclusion. They find that there is no evidence of an increase in accidents upstream and downstream of camera sites. In their method, these researchers controlled for accident migration due to the choice of alternative routes to avoid speed cameras by including annual average daily flow (AADF) as a covariate in the analysis.

However, other study results are not in agreement. De Pauw et al. (2014b) found some indication that a kangaroo effect may negatively influence road safety. Studying the effects of speed camera enforcement on two highway locations in Belgium, the researchers found a limited reduction effect for all injury accidents, and a clear significant reduction effect for all severe accidents at a distance of 250m (upstream or downstream) from the camera. However, at longer distances, 500–1.000m upstream or downstream from the camera, the favorable effect vanished and a (non-significant) tendency of increased accident rates was identified, both for injury accidents and for more severe accidents. The authors posited the kangaroo effect as a possible explanation; drivers compensate the lower driving speed at the speed camera by a higher speed from about 500m after the camera.

Firmer evidence for a negative kangaroo effect comes from a study in Korea (Shim et al, 2015). The researchers found that drivers started to reduce their speeds at about 1.000m upstream of the camera locations. Drivers then returned to their desired speed shortly after passing the camera location. The accident analysis showed that the speed enforcement had a positive effect on overall traffic safety in the sections under study, reducing total accidents by 7,6%. Although the speed enforcement had a positive effect on overall traffic safety, the magnitude of the effect is small and not statistically significant. The reason for the small effect was the 11% increase in accident occurrences in the 1.500m and 500m segments upstream of the enforcement location, where drivers were alerted to the enforcement by either on-board navigation or by road signs and started to decrease their speeds.

In a Brazilian study on speeding in Belo Horizonte, Oliveira et al. (2015) also found evidence for a kangaroo effect. Only 60% of drivers were still complying with the speed limit when observed at a distance of 200m after the speed camera. The observed difference between the average speed at the fixed camera sites and 200m away from them was nearly 10 km/h.

In conclusion, study results on the existence of kangaroo effect and its possible effect on accident numbers differ. Some studies identify no evidence for an increase in accident rates that can be attributed to the kangaroo effect, while other studies do indicate that a kangaroo effect may occur and it may indeed have a negative influence on accidents.

5.4 Intrinsic vs. extrinsic motivation

Psychologists have pointed out that speed enforcement is essentially an extrinsic motivational approach that relies on negative, external factors such as fear of punishment, to change drivers' speed behaviour. It would diminish the intrinsic motivation of drivers to conform to the law, i.e. because they want to. The use of punishment instead of reward could be considered a one-sided psychological approach.

Ideally, traffic enforcement is supported by social norms in a society. Visible police enforcement operations then ‘remind’ road users of the importance of rules and urge them to comply with traffic rules. Whereas, at first, rule compliance may be extrinsically motivated by the aim to avoid punishment, later on drivers may actually change their personal belief about what is the right behaviour and take on board traffic rules.

Over the last four decades, under the combined influences of new laws, police enforcement, and public communication campaigns, many drivers worldwide have come to accept the rule ‘no drinking and driving’ as a strict, personal norm. This positive development towards an intrinsic motivation for a traffic rule is probably more difficult to achieve for speeding behaviour. For many drivers, the relation between personal speeding and accident risk is less evident than the relation between alcohol and accident risk. More information about the effect of speed on accident risk and accident severity may help to increase drivers’ motivation to comply with speed limits.

Experiences with speed enforcement and how others react to speed enforcement may change the motivation to speed. Delhomme et al. (2014) studied how young drivers’ motivation to speed changed under the influence of the automatic speed enforcement program in France. The researchers found that, following speed enforcement, young drivers reported lesser intentions to speed. The decrease in intention to speed was associated with feeling less pressure from the others as well as observing others transgress less often, and also associated with describing themselves as more different from the prototypical deviant driver. Thus, social norms played an important role in explaining the decrease in speeding intention. Moreover, perceived difficulty over speeding, and probability of negative consequences resulting from highly transgressing speed limits played an important role in explaining the decrease in young drivers’ speed behaviour. Thus in order to change speeding motivation of young drivers it may be a good strategy to appeal to norms and to target specific beliefs.

6 Measures to support speed enforcement

Speed enforcement is not a stand-alone measure. To maximize its effect and acceptance, it is best supported by other measures such as credible speed limits and various types of publicity (including on road warning signs). It is also important that speed enforcement is embedded in a supportive framework of legislation and sanctions.

6.1 Safe and credible speed limits

For road users to obey speed limits, it is essential that these limits are safe and credible (Aarts et al., 2009). A credible limit means that it is considered logical by the road user, i.e. the limit corresponds to the expectations that a road's layout and traffic environment evoke. Whereas the idea may not be new, and many countries have such a requirement in their speed limit regulations, there seems to be substantial room for improvement.

Correspondence between speed limits and road layout can be realised by fitting the layout to the limit or the limit to the layout. On some roads the limit may need to be raised, whereas on others it may need to be lowered to achieve a better match between road function, speed limit, layout and design. Another important facet associated with credible limits is that at a place where one speed limit changes to another, road users should always be able to see a clear change in road layout as well. See ERSO Speed and Speed Management web text.

6.2 Publicity

The effect of speed enforcement, and traffic enforcement in general, is substantially increased if it is supported by information targeted at the road user (Williams, 1994; Erke et al., 2009). Communication with road users should:

- Emphasize that safety is the goal of the enforcement activities
- Explain how and why speeding leads to more and more severe accidents
- Explain the enforcement method and procedures
- Preferably illustrate that the revenues from fines are used for the benefit of local road safety.
- Provide feedback on the interim and final results of the enforcement activity, either in terms of traffic behaviour or safety.

6.3 Advance road warning signs

The use of visible symbols, such as signs warning of potential camera presence and marked enforcement vehicles, can help to remind drivers of the possibility of speed enforcement, thus increasing general deterrence (Delaney et al., 2003).

Research supports the use of warning signs in optimizing the results from speed enforcement. In a meta-analysis, Erke et al. (2009) found that accident reductions were larger when speed enforcement was combined with advance warning signs.

Recently, Wilmots et al. (2016) compared the speed effects of stationary police control in an unmarked police car equipped with a mobile radar with and without an advanced (digital) warning sign alongside the road. They found that the speed reduction effect during the speed control with advanced warning sign was larger compared to the speed control only (respectively 4,5Km/h and 2,5Km/h reduction in the V_{85} speed). Furthermore, the continuing effect until one week after the intervention (time halo effect) was stronger when a warning sign was present.

6.4 Facilitating legislation

Legislation is the basis for traffic enforcement. Legislation not only determines the regulations to be enforced, but also how they should be enforced. This is particularly the case for automatic speed enforcement. In some countries the driver is legally responsible for an offence (e.g. Finland, Germany, Norway, Sweden and Switzerland). This means that the automatic camera has to identify the driver in order to prosecute a violation. Generally, this requires a photograph of both the vehicle number plate and the driver. In other countries, the vehicle owner is held responsible for an offence (e.g. Belgium, Italy, France, the Netherlands, and the United Kingdom). In these countries, a photograph of the licence plate from the rear of the vehicle is sufficient. This is technically easier and less expensive. An additional benefit of the vehicle owner being responsible is that speeding motorcyclists can also be fined when detected for excess speed offences.

6.5 Appropriate sanctions

Sanctions are an essential element of effective enforcement to secure compliance with key safety rules. The possibility of a sanction determines the deterrent effect of enforcement. Despite this essential role, the effect of sanctions is not completely clear. It has been argued that in order to be effective, sanctions must be based on certainty and be imposed with minimal delay (Zaal, 1994; Goldenbeld et al., 1999). The argument of immediacy of punishment is deduced from the scientific field of learning theories and animal behaviour experiments. Research into the possible impact of the immediacy of actual sanctions on speeding behavior in real life traffic conditions is lacking.

However, some studies have investigated the immediacy of feedback on offending in combination with special rewards and penalties for study participants. These recent studies show that immediacy of feedback on offending can improve speeding and other driving behavior. Merrikhpour et al. (2014) investigated the effect of a feedback–reward system on speeding and tailgating behaviors. To do this a field trial was conducted with 37 participants with the feedback system installed in participants' own vehicles. Real-time in-vehicle feedback was provided based on speed limit compliance and safe headway maintenance. Participants also accumulated reward points and could view related information on a secured website.

An interesting study by Marciano et al. (2015) indicated that speeding behavior in a simulator showed more improvement under a condition of immediate feedback compared to delayed feedback. In the immediate feedback condition, each time a participant exceeded the speed limit near a speed camera (overt or covert) a sound of a camera shot was activated and the participant knew that she would get lesser monetary bonus. In the 'delayed feedback' condition, an email regarding the performance was sent to the participants about two days after the simulator session. Immediate feedback in combination with covert cameras delivered the best results in terms of steady speed compliance.

Another issue is the size of the fine. An overview of the literature (Mäkinen et al., 2003) did not reveal consistent results on the effects of increasing punishment severity. Elvik and Christensen

(2007) evaluated the effects of increasing fixed speed and seat belt penalties in Norway. They found no effect on speeding, but identified an increase in seat belt wearing rates. The authors suggested that the positive effect of penalties on seat belt use may partly be due to the increase in seat belt enforcement in Norway in the same period. The absence of any effect on speeding was attributed to the fact that the objective risk of apprehension was quite low on most parts of the road network. These findings suggest that increasing penalties may improve compliance with traffic rules, but only when the risk of being caught is high. When it is low, increasing fixed penalties does not make a noticeable difference to the deterrent effect. In a later study in Norway, Elvik (2015) found that increasing fixed speed penalties was associated with a weak, not significant, reduction in speeding.

One way of studying the effect of speed penalty severity is to consider the elasticity of fines, i.e. the relative change in the number of speed fines as a result of a relative change in fine levels. In a Dutch research, before-after violation data was used to assess the elasticity of speed fines at section or average speed control. The study found an elasticity of 0,23, i.e. a 1% raise in fine level was associated with 0,23% reduction in the number of speed offences (Moolenaar et al., 2011).

A few studies have used stated preferences to investigate the effect of the levels of fines and enforcement on self-reported speeding behaviour. Ryeng (2012) reported that the speeds driven by other drivers and enforcement levels were more powerful determinants of self-reported speed behaviour on 80Km/h rural roads than the level of fines. For example, for car drivers who indicated to prefer driving 85Km/h on an 80Km/h road, a doubling of the fine led to an average speed reduction of less than 1Km/h, whereas quadrupling the enforcement hours, or a majority of drivers who reduced speed from 85 to 75Km/h, led to nearly 2,5Km/h average speed reduction. It must be noted, however, that Ryeng only varied the level of fines by a factor of 2, whereas enforcement levels were quadrupled.

In another stated preference study, Hössinger & Berger (2012) found that the levels of enforcement and fines determined frequency of speeding to the same extent when the relative increase factor was kept constant. An increase of enforcement density by a factor of 8,3 was associated with a self-reported reduction in speeding frequency of 61%; an increase in the height of the fine by the same factor (from 36€ to 300€) was associated with a similar reduction (59%).

Watson et al. (2015) studied the effects of changes in speeding sanctions enacted in 2003 in Queensland. Three main changes were made to the speeding penalty regime: (1) the number of offence categories was increased from four to five, resulting in smaller range of speeds covered by a number of the categories; (2) the monetary fines for all offences were increased, with the largest increases applicable to the highest categories; and (3) automatic licence suspension and an eight demerit points penalty was introduced for the highest offence category (>40Km/h over the speed limit). The results were mixed. The researchers found evidence for an absolute specific deterrent effect for some drivers because fewer of them re-offended. Also, on average, fewer speeding offences overall were committed during the time periods elected for the study. On the other hand, the researchers found no indication that there was even a marginal deterrent effect among those drivers who did re-offend. There was no evidence that the changes in speeding penalties reduced the frequency of re-offending or length of time to re-offence.

Although the effectiveness of sanctions can be improved in certain ways, it is likely that drivers will show differences in how they react to sanctions. A survey study in the UK (Campbell & Stradling, 2002) indicated that drivers responded differently to speeding fines. Three separate groups whose size could be estimated were identified:

- Those who subsequently drive more slowly, including both at camera sites and elsewhere: 41 - 56%
- Those who subsequently only slow down at camera sites, but not elsewhere: 30 - 32%
- Those who do neither of these: 14 - 15%

Thus, approximately one half the respondents were more speed sensitive soon after receipt of punishment, one third were more camera sensitive, and one sixth were neither.
Punishment, in the form of a £60 fine and 3 penalty points, had a specific deterrent function for some drivers but not for others.

As a general rule, the use of sanctions is necessary to achieve compliance, but alternatives to traditional sanctions are worthy of further investigation. In a Finnish experiment, it has been shown that stopping drivers and issuing them a speeding ticket was not more effective than a warning letter sent by mail (Mäkinen, 1990). A warning letter together with a fine resulted in decreased speeds among sanctioned drivers of 9 -10Km/h for a period of at least three months.

Rule 6:
To increase its effectiveness, speed enforcement must be supported by setting safe and credible speed limits, by publicity, by legislation facilitating effective enforcement, and by appropriate sanctions.

Rule 7:
Alternatives to negative sanctions (such as warning letters, educational courses, and speed limiters) and their further development merit the serious consideration of authorities, practitioners and researchers.

7 Organisation of speed enforcement

7.1 Targeting results, cooperation and coordination

Enforcement activity works best when it is targeted at dangerous road sections or dangerous road behaviour, accompanied by various publicity and communication activities, and when it results in swift and appropriate penalties for traffic offenders. In order to maximize the potential of traffic law enforcement, the police work together with various authorities and agencies to prepare, target, perform and evaluate (speed) enforcement activities.

The main partners for the police are the local and national road authorities, court officials, publicity organisations, and researchers. Local road authorities and researchers may assist the police in analysing the local road safety problem and setting priorities. Cooperation with court officials or public prosecution officials is necessary in order to have clarity about the guidelines for detection and sentencing of traffic offenders and the capacity to process a larger number of traffic offenders. Publicity organisations can organise special publicity programmes around a new enforcement project, but they need to discuss the choices for the most effective media campaign strategy with police and local road authorities.

Ideally, co-operation between police and partners is grounded on a well-prepared plan that outlines agreements, task division, and shared and separate responsibilities and relates to national targets and strategies. Goldenbeld et al. (1999) put forth the following list of topics to be included in such an enforcement plan:

Box 1: Key elements of a road traffic enforcement plan

- A clear description of the aims and targets to be achieved by the enforcement activities.
- Clear agreements with other parties, e.g. regional and local road safety authorities, municipalities, Department of Justice, fine handling authority, etc.
- Consideration of which groups of road users to be targeted by publicity and enforcement activity.
- The support of enforcement activities by additional measures alongside the road such as adding or placing road signs or road markings or making them more visible.
- A sensible choice of locations and times of enforcement operations.
- Consideration of the best mix between highly visible police checks and more unexpected, less visible controls.
- The set-up and execution of police checks according to time-saving operational guidelines.
- A well-considered build-up and build-down of activities over a longer period of time
- The choice of publicity strategy and message and publicity channels, including the informing the police officers involved in executing the enforcement operations
- Evaluation of the extent to which agreements are fulfilled and the extent to which expected effects of enforcement activities have been realised.

Source: Goldenbeld et al. (1999)

The agreements mentioned above necessitate the availability of good performance, outcome and output measures. The next section discusses this topic.

7.2 Performance, outcome and output measures

Police organisations have their own administrative recording system for policing activities. These days, increasing pressure is put upon police managers to justify the use of policing resources. Ideally, the monitoring system of policing activities provides data and arguments for this. For traffic enforcement and speed enforcement, a monitoring system should aim to show relationships between policing resources (performance), effects on traffic behaviour, speed, (intermediate outcome) and, ultimately, effects on road safety (intermediate and final outcomes). A distinction can be made between performance measures and outcome measures (Swadling & Mclnerney, 1999). Performance measures define what the police actually do on the streets, i.e.: how often, for how long and in which locations is speeding behaviour checked? Outcome measures should reflect the effects of enforcement on behaviour and on the consequences of behaviour, for example, reductions in excess speeds, increases in compliance with seat belt rules, and traffic deaths and serious injuries.

A further distinction can be made between outcome and output measures. Outcome measures refer to intended outcomes, i.e. safer behaviour. 'Output' measures refer to administrative outcomes generated by policing activities such as the number of tickets issued or the number of court cases that result from policing activities, but are not the main aim of these activities. Goldenbeld (1997) argues that some output measures such as the number of speed fines are not a good indicator of the effectiveness or quality of police enforcement. Although there may be good administrative reasons to keep track of these data they do not provide data information about the quality of speed enforcement. At the same time, the number of speed checks have been used in national strategies e.g. New Zealands as an output target to reduce mean speeds (LTSA, 2003). See ERSO web text on Quantitative Road Safety Targets for more discussion on target hierarchies and road safety outputs and outcomes.

Performance measures for speed cameras and non-camera operations proposed by Swadley and McInerney (1999) are presented in Tables 2 and 3.

Table 2: Speed camera performance measures

Non-camera activity	Exposure measure
The number of personnel and hours of general traffic duty (including speed enforcement)	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled Per traffic count data at location
Kilometres travelled by marked police vehicles	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled
Kilometres travelled by unmarked police vehicles engaged in speeding enforcement activity	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled

Source: Swadley and McInerney, 1999

Table 3: Non-speed camera performance measures

Speed camera activity	Exposure measure
Number of vehicles checked	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled Per traffic count data at location
Total hours of enforcement	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled
Percentage of vehicles exceeding the speed limit or the enforcement limit	Against traffic count data at location Against speed monitor data for location
The number of separate speed checks (note: a speed check refers to camera operation for a certain time on a certain location; during one speed check several vehicles are checked)	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled
The number of locations for speed checks	Per 10.000 registered vehicles Per 100.000 population in the area Per 100 million vehicle kilometres travelled
Hours per camera and total hours for all cameras	

Source: Swadley & McInerney, 1999

The most direct form of intermediate outcome measurement is speed itself. Data from speed cameras is of limited use to evaluate effects on speed behaviour since it can be assumed that drivers will become familiar with camera sites and will alter their normal speed behaviour. Covert speed monitoring which is not connected with enforcement activities is necessary to obtain valid data on speed behaviour when enforcement activities are not present.

Depending upon the objectives of public speed management bodies, different speed enforcement indicators are used in different countries. The Queensland automated enforcement programme emphasises the number of operational camera hours, the number of infringements per vehicles passing camera sites, accident reductions, and a stronger emphasis on safety-related uses of programme-generated revenue. In France, the speed management authorities focus on reporting the number of installed and operated devices (fixed radars working permanently) and the number of infringement notices issued (Carnis et al., 2008).

The SafetyNet report entitled "Road Safety Performance Indicators Theory" provides further detail on the method of setting up reliable speed measurement.

Rule 8:
Speed enforcement operations gain in effectiveness if they have specified objectives and success criteria, and are monitored in terms of both process and product.

7.3 Funding

It is important that the public does not falsely perceive that fine revenues are the main aim of enforcement activities. This decreases public and political support for speed enforcement and can, in the long term, lower the effectiveness of speed checks. To avoid the public misperception that speed checks are performed for financial reasons, clear rules are needed stating that speed checks may only be performed at locations with above average numbers of accidents and where speed can be assumed to be a contributory factor to the accidents. A transparent accounting of cost and fines generated by enforcement programmes. The possibility of investing the financial revenues generated, which exceed the costs of the enforcement programme, in traffic safety or traffic mobility measures.

Speed enforcement programmes can, for example, be funded on a 'cost recovery' basis. This means that the police, local road authorities, research and publicity institutes who are involved in the programme are allowed to recover the costs of speed enforcement from the fine revenue. In general this includes equipment costs, enforcement and processing costs as well as communication costs for public information campaigns aimed at changing driver behaviour. Carnis et al. (2008) argue that deployment of funds from automated camera enforcement programs can be used to strengthen public belief in the value of the programmes.

7.4 Different program theories behind speed enforcement

Interventions such as speed camera programs are based on implicit or explicit theories about the way in which the interventions are supposed to work (program or intervention theories). Belin et al. (2010) compared the intervention theories behind the speed camera programs that were introduced in Victoria in 1991 and in Sweden 2006. Table 4 presents the ideas behind camera enforcement in Victoria and in Sweden concerning the problem being addressed, the purpose of the program, the intervention mechanism and its effect.

Table 4: Speed camera systems and intervention theory

Components of the program theory	Victoria 1991	Sweden 2006
What main problem does the speed camera program try to solve?	The problem is that a large proportion of drivers are continuously exceeding the speed limit and thereby creating road safety problems	The main problem is that on a large proportion of the road network speed exceeds the speed level which the roads are designed for from a safety point of view
What is the program trying to achieve?	The main purpose is to create a feeling among drivers that speeding can be detected at any time and in any place across the whole road system	The main purpose is to support and create a new social norm among drivers that it is easier and better to follow the speed limit
What does the intervention mechanism look like?	It aims to catch a large proportion of those drivers who exceed the speed limit so that they experience the consequences and avoid re- offending and, in their turn, discourage other drivers from offending	It informs (through signs and open cameras) drivers that a large proportion of the traffic network (large proportion of the traffic) is covered by cameras
How is the program intended to achieve road safety effects?	A large number of drivers will be deterred from speeding. Excessive speeds and the average speed will decrease and the number of fatalities and injuries will decrease in the whole system	It will prevent most drivers from speeding. The average speed will decrease, as too will the number of fatalities and injuries

Source: Belin et al. (2010)

As explained by Belin et al. (2010), the approach in Victoria is based on the idea that speeding is a deliberate offence in which a rational individual wants to drive as fast as possible and consciously calculates the costs and benefits of this behaviour. The underlying aim of the Victorian intervention is to increase the perceived costs of committing an offence whilst decreasing the perceived benefits, so that the former outweigh the latter. The speed camera system in Victoria is intended to influence driver behaviour through two different processes: specific deterrence and general deterrence. Specific deterrence is a process of encouraging an apprehended offender, through actual experience of detection and its consequences, to avoid re-offending. General deterrence is a process of influencing a potential traffic law offender through fear of detection and its consequences to avoid offending.

The Swedish approach, on the other hand, appears to be based on a belief that road safety is of the utmost priority for road users and that one of the reasons for speeding is lack of information. This approach places less trust in the capabilities of individual road users to make decisions and to calculate the benefits and costs of speeding. It also appears to be based on the idea that other road users, and their choice of speed have a significant influence on the individual's choice of speed.

The speed camera system in Sweden is therefore supposed to increase the level of information in order to support drivers in making a safe speed choice and, through a change in speed behaviour among a large proportion of the traffic (at least the local traffic near cameras), to create a new social norm for appropriate speed (Belin et al. 2010).

Both the Australian and the Swedish approaches appear to produce substantial road safety benefits. However, the approach employed in Victoria seems capable of generating greater road safety benefits at less cost than the Swedish approach (Belin et al., 2010). From a cost– benefit point of view, the Victorian approach seems preferable to the Swedish approach. However, the choice of different policy options is not only guided by value criteria such as effectiveness and efficiency, but also by criteria such as legality, legitimacy, democracy, feasibility, etc. (Belin et al., 2010).

Further comparisons between different speed camera enforcement programs are provided by Cameron (2008).

7.5 Improving organised enforcement in EU Member States

At the ESCAPE workshop on traffic law enforcement (Swadling&Mclerney, 1999) consensus could be found on a list of priorities for better organised police traffic enforcement in the EU Member States:

A strong role for the police as adviser in traffic affairs

The police are the 'ears and eyes' of society and also have a very practical knowledge of how the traffic system actually works. Many traffic and enforcement problems may be avoided in the first place if traffic police are consulted in advance about infrastructural changes, planning of special events etc.

Quantitative targets

Setting targets is necessary to motivate, steer and evaluate police activities.

Solid criteria for planning of enforcement activities

Given the scarce resources of traffic police there should be good criteria on which to base decisions about resource allocation to enforcement activities.

Yearly monitoring of traffic behaviours

Besides accident data, behavioural data provides input for planning of enforcement activities and traffic police targets may be behavioural targets, for example, 85% of the front-seat occupants being required to wear seat belts inside built-up areas.

Accident registration quality

Accident data is the most widely used and often the sole source of data used to plan, steer and evaluate police enforcement activities. Given this importance, the quality of accident data registration should be a continuous concern for police, authorities and research institutes.

Evaluation

Evaluation of police enforcement activities is the only way to find out whether the activities were meaningful, successful, well planned, well-executed etc. Without evaluation, meaningful conclusions cannot be drawn.

European knowledge body
The knowledge gained from enforcement activities in some countries or in some regions should be freely available to every European police force that wants to learn from the experience of others. For this purpose, a European body that collects the practical experience of various European police forces with enforcement activities and that makes this knowledge freely available by modern technological means (internet, electronic helpdesk etc.) would be beneficial.

Enforcement guidelines
Enforcement guidelines for police operations on the roads can play an important part in maintaining the quality of the police work. The organisation TISPOL is investigating whether European guidelines can be established.

Defining clear responsibilities for parties involved in road safety or enforcement activities
The traffic police have a very specific responsibility in road safety and enforcement projects. However, other parties (road authorities, Government, accident-registration agency) are also involved in road safety work. The specific responsibilities of the partners in a project should be clear. In the Czech Republic, for instance, the traffic police are almost solely held responsible for all matters involving road safety when experience elsewhere suggests others need to be involved. Well-defined responsibilities ensure that every partner can be held accountable for a specific performance.

Qualitative targets
Not all qualities can be measured objectively, e.g. road user opinion.

8 Best practice examples

This section presents two examples of best practice in the field of police enforcement, one from the United Kingdom and one from Australia/New Zealand. These two examples have been chosen because the United Kingdom and Australia/New Zealand have demonstrably achieved good results in enforcement. Both are also examples in which success can be attributed to a continuing and close cooperation between police, local government, and researchers, with a consistent focus on improving enforcement practices and learning from the past rather than continuing to follow fixed routines. A number of evaluation and policy reports clearly describe policing practices in United Kingdom and Australia/New Zealand.

Best practice can show us what works well in a given system or context. However, it should be kept in mind that key elements of best practice are rooted in a specific legal, cultural and organisational tradition and context. Individual successful elements of a strategy cannot always be ‘copied’ to another country. Each country should seek its own way of best applying or adapting success factors in other countries to its own traffic system and traffic culture.

Further best practices in the areas of speed and traffic enforcement can be found in Lynam et al. (2005), OECD/ECMT (2006), SUPREME (2007a and 2007b) and Delaney et al. (2003).

8.1 United Kingdom

Organization

In the UK, camera enforcement has been organised by partnerships between police, local authorities and the court (Department for Transport, 2006). These partnerships not only look at speeding but also at running red traffic lights. The cameras are designated as safety cameras and the partnerships as safety camera partnerships. The objectives of Safety Camera Partnerships are to reduce death and serious injury by reducing the level and extent of speeding and running red traffic lights. The aim is to do this by preventing, detecting and enforcing speed and red light offences using, but not limited to, camera technology and driver education programmes. Some partnerships also include road safety engineering as a method of contributing to the aim. The programme was part of the UK government's Road Safety Strategy that sought a 40% reduction in fatalities and serious injuries by 2010 and a 50% reduction in fatalities and serious injuries of children (compared to the average of 1994- 1998). However, the hypothecated funding from speed camera fines to local road safety work was discontinued in 2011 by government.

Effects

Gains et al. (2004) evaluated Safety Camera Partnerships in terms of driving speed and accidents. They included 38 areas where a Safety Camera Partnership had been running for at least one year. The main results were as follows:
<u>Vehicle speeds decreased</u>. Vehicle speeds dropped by around 6% following the introduction of cameras. The number of cars exceeding the speed limit was reduced by 31%. At fixed camera sites this was 70%; at mobile camera sites 18%. The proportion of vehicles speeding excessively (i.e. by more than 15mph (24Km/h)) fell by 91% at fixed sites, and by 36% at mobile sites.
<u>Both casualties and fatalities decreased</u>. After allowing for the long-term trend, but without allowing for selection effects (such as regression to the mean), there was a 22% reduction in personal injury collisions at camera sites. The number of fatalities and severe injuries decreased by 42%.
<u>There was a positive cost-benefit</u> of around 1:2,7. In the fourth year, the benefits to society from the avoided injuries were around £258 million (€ 369 million) compared to enforcement costs of around £96 million (€137 million).

In a later evaluation study, Allsop (2013) focused on eliminating regression-to-the-mean bias by comparing the years after the cameras were installed with the years of a period more than three years before they were installed. His analysis for 551 fixed speed cameras in 9 Safety Camera areas showed that the number of fatal and serious collisions near camera locations fell by more than a quarter (27%) after their installation.

Success factors

Success factors for the Safety Camera Partnerships were (Lynam et al, 2005):

- Evaluation of both the effectiveness of management and financial control, and the effectiveness of accident reduction.
- Extension of trial partnerships programmes to general implementation.
- Sustained debate among researchers to establish conclusive evidence of effectiveness.

Partnerships

The partnerships worked in the following way (Allsop, 2010):

- A detailed operational plan was submitted annually to the national programme board for ministerial approval.
- New camera sites had to comply with national rules.
- All sites were made conspicuous, and their locations were publicised.
- The performance of each site was monitored regularly.
- All existing sites were kept under review.
- A communications plan was developed and implemented to promote understanding and help to change driver behaviour.
- Audited direct costs of operation were refunded to the partnership by the Department for Transport from penalty income.

One of the rules for new camera sites was that there should be no other obvious viable measures to improve road safety along the stretch of road concerned. This had the incidental effect of simplifying evaluation of the programme because it meant that there would be no need to distinguish effects of deploying cameras from effects of concurrent safety engineering interventions at the camera sites.

National guidelines

The Department for Transport issued an annually updated handbook, which contained clear rules and guidelines covering where and how safety cameras should be placed, and measures to be taken to ensure that drivers are aware of them (published on Department for Transport under the Road safety area). The handbook states, for example, that fixed cameras must be located only at sites where there have been at least four accidents per km involving fatalities or seriously injured casualties in the last three years. Additional sites may be considered after all possible sites meeting this criterion have been dealt with. All safety cameras should be bright yellow to ensure maximum visibility.

Funding mechanisms

Safety Camera Partnerships were funded on a 'cost recovery' basis through money raised from fines. This money was reinvested into the road safety camera programme. However, the Partnerships were only reimbursed for programme costs, facilities and equipment costs and public information campaigns. The remaining fine revenues went to the national Treasury. The Partnerships did not make a profit and had been set up as a transparent way of taking the funds from fines and using them to prevent collisions. There was no incentive to install cameras other than to improve road safety.

Public acceptance

Local and national surveys conducted during the Partnership programme showed a generally positive attitude by the public to the use of safety cameras for targeted enforcement. However, there was an indication of some decline in support (Lynam et al., 2005) (Table 5). The Department for Transport responded by providing information on its website clarifying the rules governing the implementation of cameras and their use. The Parliamentary Advisory Council on Transport Safety also published a leaflet to dispel the negative myths about the use and effectiveness of cameras.

Table 5. Percentage of drivers answering yes to statements

Statement about speed cameras	1998	2003	2004-2005
Cameras are intended to encourage drivers to stick to limits, not to punish them	83%	80%	76%
Fewer collisions are likely to happen on road where cameras are installed	67%	72%	68%
Cameras are an easy way of making money out of motorists	45%	45%	52%
Cameras mean that dangerous drivers are more likely to get caught	78%	68%	61%
Use of safety cameras should be supported as a means of reducing casualties	-	-	79%
The primary aim of cameras is to save lives	-	-	68%
There are too many safety cameras in our local area	-	-	22%

Source: Lynam et al., 2005

In the period 2001-2010, the British Automobile Association (AA) asked a sample of its members each year the following question on camera acceptability: 'It is now common for the police to use speed cameras at the side of the road to identify vehicles involved in speeding offences. How acceptable do you think this is? The AA found about 70% of respondents answered 'quite acceptable' or 'very acceptable'. In 2010 this figure increased to 75% (mentioned in Allsop, 2010; also on AA-website).

8.2 Australia and New Zealand

Organisation

In November 2001, the Victorian Government started the "arrive alive!" road safety strategy with the aim of reducing road trauma by 20% by 2007. (http://www.arrivealive.vic.gov.au/). Under this programme speed enforcement efforts were increased with more mobile speed camera hours, new fixed speed camera locations and a reduction in the enforcement threshold. The four government agencies that form the "road safety partnership" are VicRoads, Victoria Police, the Department of Justice and the Transport Accident Commission (TAC). Each agency has specific responsibilities in the area of speed enforcement, but many of these responsibilities are undertaken in consultation or in partnership with the other road safety partners, local government and non-governmental organisations.

In New Zealand, the National Road Safety Committee (NSCR) is the principal inter-agency forum for communicating and agreeing top level strategy between agencies on matters related to road safety (Land Transport New Zealand and New Zealand Police, 2005). The Secretary for Transport, the Commissioner of the Police, the Chief Executives of Land Transport New Zealand, the Local Government New Zealand, the Crashes Compensation Corporation and Transit New Zealand all participate in this committee. The Director General of Health, the Secretary for Justice, and the Secretary for Labour are associate members. The Road Safety to 2010 strategy indicates the direction for road safety in New Zealand and describes the road safety targets for 2010.

Effects

Evaluation of the Victorian road safety strategy by the Auditor General Victoria showed favourable results (Auditor General Victoria, 2006). In the years 2002-2005 there was a reduction in fatalities of around 16%, and approximately 8% in serious injuries. Many factors contributed to these changes but it is likely that reduced travel speeds were a major contributor. The most significant trauma reductions were obtained in metropolitan Melbourne's low speed zones where fatalities decreased by around 40% and serious injuries by 15%. This reduction corresponded with a reduction in free travel speeds in these zones. Travel speeds in both metropolitan Melbourne and country 100 and 110 km/h speed zones remained relatively stable over time and similarly the trauma reductions on these roads were small. Finally, there were large decreases in fatalities and serious injuries for pedestrians, where urban speeds are a major determinant of severity.

Overtly operated mobile speed cameras have been used in New Zealand since late 1993. Their operation has been confined to specific sites (called 'speed camera areas') which aremainly road sections with a record of speed-related accidents. A trial of hidden speed cameras began in mid-1997 in 100Km/h speed limit areas in one of New Zealand's four Police regions. Although motorists could not see the cameras, publicity and warning signs alerted them that they were entering a speed-camera zone. Keall et al. (2002) attributed a 17% reduction in injury accidents (not significant) where inconspicuous mobile cameras were used compared to a 31% reduction in casualties over a 2-year period (significant) for a conspicuous only camera programme running elsewhere in New Zealand. In this study, the generalized effects of the extra hidden camera programme (extending to the whole trial area containing (publicly) open rural roads, including roads with and without conspicuous camera operations) were estimated as an 11% reduction in accidents and a 19% reduction in casualties (both significant).

Success factors

In Australia and New Zealand, speed enforcement activities are performed by partnerships between national, regional and local agencies that all have an interest in road safety.
According to the association of Australian and New Zealand road transport and traffic authorities (Austroads, 2001) the following elements of speed enforcement are important for success:

- Finding a balance between accident-based, intelligence driven targeted operations and managed targeting to wider areas on a random basis. A complete reliance on a targeted approach for a small number of selected sites is not desirable since it leads to predictability and lack of general deterrence.

- Targeting and monitoring performance and outcome measures. Recommended performance measures are the number of vehicles checked, total hours of enforcement, number of separate speed checks and number of locations checked per exposure measure (e.g. number of registered vehicles, population size or vehicle kilometres travelled in an area) as well as the number of hours of traffic enforcement conducted by specialised traffic personnel or general duties police also per exposure measure. Recommended outcome measures are, first, changes in accidents and driving speed, and second, changes in community attitudes and infringement rates. When assessing changes in accident rates, the contribution of other initiatives besides speed enforcement should be recognised although quantification may not be possible. When looking at changes in accident rate changes over time in accident reporting rates between jurisdictions should be taken into account.

- Supporting enforcement operations by public campaigns. Public education campaigns are an effective means of heightening the impact of enforcement and are an essential part of winning support for speed enforcement activity. Campaigns have to be carefully thought out in terms of current community perceptions, the target audience, attitudes and beliefs, the previous history of the issue, and the available time and resources. One single message should be delivered in each campaign. Pretesting can help to ensure that the right message is being delivered in the right format.

- To apply penalties that reflect community views of the seriousness of offences. Demerit points are an effective deterrent for speeding motorists. Loss of licence is an effective deterrent for excessive speeding.

Procedures and guidelines in New Zealand
The Safety Administration Programme (SAP) is the primary planning and funding programme for road safety activity undertaken by the New Zealand Police, Land Transport New Zealand and community groups (Land Transport New Zealand and New Zealand Police, 2005). In their annual programme the SAP details specific projects, their objectives and the performance measures against which they are to be assessed. The SAP is collaborative (built on strong partnerships nationally, regionally and locally), evidence-based (driven by analysis of comprehensive road safety data) and accountable (detailing desired outcomes and quantitative and qualitative performance measures).

The SAP plans and allocates resources for strategic enforcement at the national level, and is directly inspired by a risk targeted road policing model. The annual SAP and the risk targeted road policing model are elaborated locally by way of quarterly/biannual road safety action plans (RSAPs). In general RSAPs:
- are based on data from all key partners;
- are outcome focused, have local targets;
- set out responsibilities and contributions of all parties;
- have evidence based performance measures;
- include community, local and national campaigns.

The RSAPs are implemented through accident books and risk targeted patrol plans. Accident books provide long-term risk profiles of roads and areas and risk target patrol plans (RTPP) allocate strategic enforcement hours by location and time. They are instruments to ensure that enforcement is directed toward higher risk locations, behaviour and times to maximize the effect.

In the area of speed control the SAP outlines the following desired outcomes:
- for rural roads with a speed limit of 100Km/h: a mean speed of 99Km/h and a 85th percentile speed of no more than 107Km/h;
- for urban roads with a speed limit of 50Km/h: a mean speed of 55Km/h and an 85th percentile speed of no more than 61Km/h.

Qualitative performance measures are the extent to which speed control output is in accordance with the RSAPs and RTPPs, the satisfaction of local authorities and regions with police consultation process in the development of the RSAPs and RTPPs, the attention given to targeted issues, and the percentage of road users who believe there is a high probability of detection of speeding.

Public acceptance

In Victoria, telephone surveys in 1999 and 2002 asked licensed drivers to report on their knowledge of and attitudes towards speed enforcement methods, specifically speed cameras (Smith & Senserrick, 2004). On the positive side, from 1999 to 2002, fewer drivers reported that they often drove 5-9Km/h over the speed limit, fewer drivers agreed with the statement 'There's not much chance of being caught speeding' and more drivers reported knowledge of the facts that speed cameras operated from different cars and that speed cameras did not always operate from a fixed location. Better knowledge and better compliance with speed limits did not go hand in hand with more positive attitudes towards speed cameras. On the contrary, there was an increase in agreement with the statement that speeding fines were only for revenue raising purposes. In 2002, 71% of the sample reported that speeding fines were mainly for revenue raising. The researchers attribute this negative development to 'propagation of comments in the media supporting this idea'.

In 2007, 75% of New Zealand adults agreed with the statement 'Enforcing the speed limit helps to lower the road toll' (Ministry of Transport of New Zealand 2007). In 2007, 61% agreed or strongly agreed with the statement 'Using speed cameras helps lower the road toll'. This has fluctuated around 60% in the years after 2001. 64% agreed that 'the way speed cameras are being operated is fair'. Also, 63% said they supported or strongly supported the use of hidden cameras. Support for hidden cameras increased from 56% in 2004, when the question was first asked.

Rule 9:
Cooperation and partnerships between police, local authorities and data experts provides the best guarantee for problem-oriented, outcome-focused and evidence-based speed policing operations.

9 Speed enforcement in the future

9.1 Relationships between speed enforcement and new technologies

Innovation is starting to find its way into speed enforcement operations, such as event data recorder technologies, Intelligent Speed Assistance (ISA) and Electronic Vehicle Identification (EVI, 2004). See ERSO eSafety, Vehicle Safety and Speed and Speed Management web texts.

The question is how these new technologies relate to more conventional ways of speed support and control, such as changes to road environment and police enforcement.
According to Wegman and Goldenbeld (2006) there are three possible, non-exclusive, relationships:

- New technologies co-exist with conventional measures. While cars are increasingly being equipped with new technologies, police checks of speeding may continue or even intensify.
- New technologies are integrated in existing measures and make them more efficient. For example, enforcement is increasingly using information from EVI and thus supports enforcement operations.

- New technologies do something existing measures cannot and will tend to replace conventional methods. For example, when a car is equipped with an event data recorder that monitors driving speed, speed enforcement can be carried out at all times and places.

Zaidel (2000) sketches a utopian view in which speed enforcement by the police is largely replaced by speed enforcement based on technology. According to Zaidel, this could be realised if:

- speed compliance is associated with the vehicle rather than a driver;
- in-vehicle devices and communication technology monitor vehicle speed at all times and keep a record of distance travelled while speeding;
- vehicles owners are given redeemable credits for distance travelled at requested speed and are surcharged for distance travelled while speeding;
- companies and fleet owners are evaluated by authorities with respect to the aggregated speeding performance of their vehicles; and
- a marketing mechanism is created whereby non-speeding generates direct and indirect benefits to vehicle owners as well as to businesses.

The advantages of this system of speed control, as stated by Zaidel, are that it is self- enforcing, fair, self-sustainable, provides immediate feedback and reduces the need for conventional speed control. However, public acceptability would clearly be needed before any such system could be implemented.

9.2 Event data recorders

Event vehicle data recorders, or black boxes, can monitor and store various driving behaviours, including steering movements, accelerating and decelerating and also driving speed. Theoretically and technically it would be possible to compare the information of the speed limit in force and the actual driving speed and use this as a source of information for detecting and enforcing speed limit violations. See also ERSO eSafety and Vehicle Safety web texts.

According to the SARTRE-4 2010 survey – a road user survey in 17 European and 2 non-European countries - 75% of more than 12.000 interviewed drivers were very in favour or fairly in favour of using a black box (Cestac & Delhomme, 2012).

Nowadays the event data recorder or black box has found its way into the world of car insurance. A trend in car insurance is that insurance companies provide “telematics” insurance - sometimes called black box insurance, pay-as-you-drive or pay-how-you-drive insurance. It typically works as follows. An insurer installs a box under the bonnet of your car or on the dashboard, which contains a global positioning system (GPS) and transmits information back to the insurance company via a satellite. This allows the insurers to monitor driving performance, and to calculate the premium based on how driving performance ranks in terms of risk. In a Dutch field experiment with this type of insurance, Bolderdijk et al. (2011) showed that, relative to pre- and post-measurement, as well as a control group, the introduction of a Pay-As-You-Drive insurance fee significantly reduced speed violations of young drivers.

9.3 Electronic Vehicle Identification (EVI)

Electronic Vehicle Identification (EVI) is a system that uniquely identifies a vehicle electronically. More specifically it can be defined as an electronic device that allows the unique, remote and reliable communication of identifying parameters of a vehicle (EVI, 2004). It would typically comprise a secure in-vehicle data storage element, suitable and secure interfaces and a vehicle-to-infrastructure data communication element. EVI can be used for many application such as crime prevention (prevention vehicle theft), vehicle tolling, access control (e.g. overview of cross border traffic). It can also be used for enforcement purpose, not only of speeding, but also running red traffic lights and tailgating.

9.4 Intelligent Speed Adaptation (ISA)

Intelligent Speed Adaptation (ISA) is an in-vehicle system that uses information on the position of the vehicle in a network in relation to the speed limit in force at that particular location. ISA is meant to support drivers and help them to comply with the speed limits everywhere in the network. In that way ISA aims to prevent speeding violations.

If large scale voluntary adoption of ISA reduced the bulk of speed violations, this would not only support speed enforcement but may shift the emphasis of enforcement from general deterrence to specific deterrence. Instead of keeping speeds of the general driving public down - a task then taken over by generally accepted technology - the police can focus more on detecting extreme or repeated speed offenders.

Lai et al. (2012) estimated that ISA could deliver a very healthy benefit-to-cost ratio, ranging from 3,4 (according to a Market Scenario including advisory and voluntary ISA) to 7,4 (according to a Authority Driven Scenario starting with advisory and voluntary ISA and ending up with mandatory ISA). Under both deployment scenarios, ISA would have recovered its implementation costs in less than 15 years. This analysis drew on the data collected in the ISA-UK field trials and then applied that data to the prediction of changes in accident numbers through the application of available speed accident relationships derived from empirical observations.

Rule 10:
To the extent that new technologies facilitate voluntary speed control, police speed enforcement can direct itself more at detecting extreme or repeated speed offenders.

9.5 Smart cameras

Over the past decade, rapid developments in digital technology have paved the way for smarter traffic enforcement systems. The smart camera is a cornerstone in smarter enforcement systems that focus more on traffic violations than speeding.

A smart camera can be defined as a vision system in which the primary function is to produce a high-level understanding of the imaged scene and generate application-specific data to be used in an autonomous and intelligent system (Shi & Lichmann, 2005). The idea of smart cameras is to convert data to knowledge by processing information where it becomes available, and then to transmit only results that are at a higher level of abstraction. In the past, a typical camera was only able to capture images. Now, with the smart camera concept, a camera will have the ability to generate specific information from the images it has captured.

Smart cameras can perform tasks far beyond simply taking photos and recording videos. The built-in intelligent image processing and pattern recognition algorithms allow these cameras to detect motion, measure objects, read vehicle number plates, and recognize human behaviours. In the near future, they will become part of automated control systems for many applications.

In Finland, a multipurpose smart enforcement camera was tested in 2011 as part of the ASSET project (Advanced Safety and Driver Support for Essential Road Transport - http://www.project-asset.com/index1.php?lan=en). The ASSET speed camera can measure driving speeds but it can also determine whether the driver is wearing a seatbelt, determine the distance between cars to ascertain whether a driver is tailgating, and it can automatically detect registration plates so that it can tell if a vehicle is being driven uninsured or untaxed. The ASSET speed camera has been developed by Finnish engineers but is being funded with £7.1m from the European Commission.

Another example of a smart enforcement camera is a camera system designed to detect and record vehicles passing over the railway crossing after the red light had been activated (Sidla & Loibner, 2013). Sparse optical flow in conjunction with motion clustering was used for real-time motion detection in order to capture safety critical events. The cameras were activated by an electrical signal from the railway when the red light turned on. If they detected a vehicle moving over the stopping line, and it was well over this limit, an image sequence was recorded and stored onboard for later evaluation. The system was designed to be operational in all weather conditions, delivering human-readable license plate images even under the worst illumination conditions like direct incident sunlight direct view into or vehicle headlights.

10 In conclusion: Ten Rules of Speed Enforcement

Rule 1:
To maximize the road safety effects, traffic law enforcement should, first and foremost, prevent violations that are proven to be related with the number or severity of accidents.

Rule 2:
To achieve collective safety benefits by reducing speeds, a systematic, integrated speed management policy is necessary. Speed enforcement is one of the elements of an integrated speed management approach.

Rule 3:
Speed enforcement gains in effectiveness if it is targeted towards prioritised roads and areas, situations and times.

Rule 4:
The credibility of traffic enforcement should be part of enforcement policy and is to be considered as an important quality aspect of enforcement.

Rule 5:
Speed camera enforcement should be used for a large concentration of traffic accidents at high traffic volume locations, sections and areas. Physical policing can be a good alternative to safety

camera enforcement when accidents are scattered, and provided operations are randomised and applied to a large part of the network.

Rule 6:
To increase its effectiveness, speed enforcement must be supported by setting safe and credible speed limits, by publicity, by legislation facilitating effective enforcement, and by appropriate sanctions.

Rule 7:
Alternatives to negative sanctions (such as warning letters, educational courses, speed limiters) and the further development of these sanctions merit serious consideration of authorities, practitioners and researchers.

Rule 8:
Speed enforcement operations gain in effectiveness if they have specified objectives and success criteria, and are monitored in terms of both outcomes and outputs.

Rule 9:
Cooperation and partnerships between police, local authorities and data experts provides the best guarantee for problem-oriented, outcome-focused and evidence-based speed policing operations.

Rule 10:
To the extent that new technologies facilitate voluntary speed control, police speed enforcement can direct itself more at detecting extreme or repeated speed offenders.

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Notes

1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

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5. Please refer to this Report as follows:
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