How Methods and Levels of Policing Affect Road Casualty Rates

by M Elliott & J Broughton

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CONTENTS

Executive summary

In London in 2002, over 41,000 people were injured in road accidents, more than 5,500 of whom were killed or seriously injured. Road traffic law is one of the main tools available to society to reduce the number and severity of road accidents, by defining behaviour which is held to be unduly risky - such as drink-driving - as illegal. These laws are only effective if they are obeyed. The likelihood of an offender being caught depends on the level of enforcement of traffic laws, by human policing and increasingly by automatic equipment such as speed cameras. Moreover, a significant level of enforcement is likely to have a deterrent effect and to persuade potential offenders to observe traffic laws. This report presents the results of a review of the relevant technical literature that was undertaken by TRL on behalf of Transport for London (TfL) to investigate "How Methods and Levels of Policing Affect Road Casualty Rates".

The main aims of the review were:

- To evaluate the findings from existing literature in order to determine whether increasing the level of traffic policing is likely to reduce the number of casualties in road accidents and

- To summarise the main pieces of work and draw conclusions, including any quantitative relationships between the level of enforcement and the numbers of accidents and casualties.

In order to identify relevant material for inclusion in the review the TRL knowledge base (which comprises a number of databases, including the main catalogue of publications held both in the TRL library and elsewhere) was searched. In total 66 studies were included in the review: 30 were studies of speed or primarily speed enforcement campaigns, 5 were UK studies of speed camera enforcement, 13 were studies of drink-driving enforcement, 14 studies of red light camera enforcement, and 4 studies of seatbelt enforcement. In addition, three studies that have been conducted recently to investigate the mean effects of increased enforcement generally on accident rates were included in the review.

The main findings were as follows:

- The great majority of studies in the literature have found that increasing the level of traffic policing reduces the number of road accidents and traffic violations.

- Theory suggests that the relationship between levels of policing and accident/casualty rates is non-linear. At zero enforcement level, accidents and casualties are expected to be at their highest levels. Increases in enforcement will have no noticeable effect at first but at a certain level, when drivers become aware of the increased police presence, accidents and casualties can be expected to begin to fall. Once a saturation point is reached, however, further increases in enforcement levels can be expected to have little or no effect. The challenges for road safety researchers are to establish the levels of policing that are required to bring about the initial decrease in accidents or casualties and to reach the saturation point, and to establish the accident and casualty reductions that can be achieved with these levels of policing.

- Unfortunately, it is difficult in practice to establish the relationship between levels of policing and accident or casualty rates. It has not proved possible to establish the relationship by generalising from studies in the literature because appropriate information about enforcement levels is not given consistently by the different studies. The difficulty in establishing the relationship in London is compounded by the fact that the majority of studies in the literature were conducted outside the UK and that few studies assessed the effects of traffic policing in busy urban areas such as London. Those studies that were conducted in the UK were either small scale, having investigated the effects of policing on a limited number of roads, or were conducted many years ago. Therefore, new research appears to be required in order to establish how the

level of policing in London affects the number of accidents and casualties. The results of the research would allow the likely implications for accidents and casualties to be taken into account when adjusting the level of traffic policing in any part of London.

- Despite the difficulty of establishing the precise relation between policing levels and accident or casualty rates, some studies have provided limited information about the levels of enforcement required to improve safety. It seems as though stopping 1 in every 6 speeding offenders, for example, should have a noticeable effect.

- On the basis of the literature it is also possible to discriminate between stationary and mobile methods of traffic policing. Each method can involve visible policing in either marked or unmarked police vehicles. Stationary and highly visible policing appears to be the most effective method for reducing violations and accidents, although stationary enforcement in unmarked vehicles has also been found to be effective. Mobile policing methods appear less effective, especially when unmarked police vehicles are used.

- The effects of increased stationary enforcement seem to last for a limited amount of time after the police presence has been removed. The largest time ‘halo’ appears to be 8 weeks, although sustained police presence is required to produce such large effects. The distance halo of stationary policing appears to be in the range of 1.5 miles to 5 miles from the enforcement site.

- There is evidence in favour of deploying traffic police largely at random over the whole road network. Theoretically it is likely to increase deterrence. In practice, the random allocation of stationary policing methods to different locations on the road network has been found to be effective, producing substantial impacts on accident rates and reductions in mean speeds and large distance halo effects. The main advantage of this method of traffic policing is that it requires relatively low levels of police manpower.

- Speed cameras have been found to be particularly effective enforcement tools. They appear to be more effective than physical policing methods in reducing mean speeds and accidents. However, physical policing methods have still been found to be effective and the effects of speed cameras appear to be mainly limited to the speed camera site. On the basis of the literature reviewed, the minimum distance halo associated with physical policing is about 5 times greater than the minimum associated with speed cameras.

- Studies of the enforcement of the drink-drive law have also shown that increased policing tends to reduce accidents and casualties.

- Red light running cameras have been found to be very effective in reducing accidents and casualties. The best estimate for the effects of red light cameras is a reduction of between 25-30% in injury accidents.

- Although few studies have investigated the effects of seat belt enforcement on accidents, a number have found that increased enforcement of seatbelt laws can increase wearing rates, which is likely to reduce casualties.

1 Introduction

In Great Britain in 2002 over 300,000 people were killed or injured in over 220,000 road traffic accidents, with the majority occurring on roads where the speed limit was at most 40 mph (Department for Transport, 2003). In London, there were over 41,000 casualties with more than 5,500 involving fatal or serious injuries (Transport for London, 2003). Road traffic law is one of the main tools available to society to reduce the number and severity of road accidents. Traffic laws attempt to improve driving standards by defining as illegal those types of behaviour which are held to be unduly risky, such as drink-driving or driving too fast. Research conducted over the last decade or so has established the strength of the links between such risky driving behaviour and accident liability (e.g. Finch et al., 1994; Taylor et al., 2000; Parker et al., 1995).

These laws are only effective if they are obeyed, but drivers frequently violate traffic laws without being caught. The likelihood of an offender being caught depends on the level of enforcement of these laws by human policing and increasingly by automatic equipment such as speed cameras. The level of human policing is influenced by many factors, including the overall number of officers available and the demands on police time for non-traffic duties.

There have been press reports that the number of officers being employed on traffic duties in Great Britain has fallen over recent years, with several Police Forces disbanding their specialist traffic police units. At the same time there has been anecdotal evidence that standards of driving behaviour have tended to fall. Falling driving standards might be linked to a fall in the level of enforcement, since the perception that the risk of being caught had fallen could lead some drivers to be more willing to violate traffic laws.

Recent developments in France have provided powerful evidence of the potential effectiveness of increased enforcement in reducing accidents and casualties. No scientific assessment of this evidence has so far been completed because of the very short timescale, but this account has been compiled from official statistics and advice from French colleagues. Following a widely publicised motorway accident in late 2002, President Chirac ordered a major increase in enforcement of existing traffic laws together with a range of other measures that would take longer to implement. The number of people killed on French roads in January 2003 was 33% less than in January 2002, and the number of casualties fell by 30%. Provisional estimates of the 2003 totals are 22% and 18% less than the 2002 totals respectively. National reductions on such a scale are virtually unprecedented, and greater enforcement of existing laws (or, at the least, a perception among French drivers that enforcement had increased) is likely to have been the principal cause.

This report presents the results of a review of the relevant technical literature that was undertaken by TRL on behalf of Transport for London (TfL) to investigate “How methods and levels of Policing affect road casualty rates”.

2 Aims

The main aims of the review were:

- To evaluate the findings from existing literature in order to determine whether increasing the level of traffic policing is likely to reduce the number of casualties in road accidents and

- To summarise the main pieces of work and draw conclusions, including any quantitative relationships between the level of enforcement and the numbers of accidents and casualties.

Section 3 of this report describes the methods that were used to identify appropriate literature for inclusion in the review. Section 4 defines the scope of the review. Section 5 outlines some general issues regarding studies of police enforcement. Subsequent sections outline the main findings. Section 6 discusses the relationship between policing levels, on the one hand, and violation, accident and casualty rates, on the other, and section 7 deals with methods of enforcement. The summary and conclusions are presented in section 8. Finally, a proposal for a new study to investigate how levels of policing affect road accidents and casualties in London in presented in Section 9.

3 Literature searches

Searches of the TRL Knowledge Base were conducted in order to identify literature to be reviewed. The Knowledge Base comprises a number of databases, including the Transport Research Abstracting & Cataloguing System (TRACS). This is the main catalogue of publications held both in the TRL library and elsewhere. It contains bibliographic references and abstracts of English and foreign language articles from journals, books and research reports. It is the English language version of the world-wide ITRD database (International Transport Research Documentation) and contains abstracts from publications in the USA, Australia, Scandinavia, the Netherlands and Canada in addition to UK material. The database has been updated daily since 1972 and now comprises some 260,000 items. This is the prime literature resource for transport research. The Knowledge Base also includes the PROJEX database that contains summaries of current and recently completed research projects undertaken in ITRD member countries. In addition, the Knowledge base includes the TRLINFO database, which contains information about TRL including the full text of all Broadcasts issued since they were started in 1995 together with all Intranet Announcements and News Items. The searches of the Knowledge Base were conducted using a number of combinations of the following key words, including: enforcement, police/policing, casualties, accidents, and violation terms (e.g. speed/speeding, drink-driving, red light running).

As well as searching the TRL Knowledge Base, studies were also identified by browsing (e.g. using the reference lists of other publications to identify relevant pieces of work) and, where possible, researchers working in the field of law enforcement were contacted for advice and assistance with identifying appropriate literature.

Details of all studies reviewed are provided in a separate Technical Annex. This report summarises the findings generally and gives details of specific studies where appropriate. The next section of the report describes the scope of the review and provides details of the types of studies reviewed and the number of studies reviewed.

4 Scope of the review

Studies included in the review related the level of police presence to any subsequent effects on accident, casualty or violation rates. Studies examining the effect of automatic methods of policing (e.g. speed and red light cameras) were also included so that comparisons can be made between automatic and “physical” policing methods. Although a number of studies were identified from the literature searches that related to the effects of harsher penalties for traffic offences (e.g. increased fines, imprisonment and driver rehabilitation programmes) and to the public acceptability of legislation and enforcement, these studies were outside the scope of this project and were therefore not included in the review.

In addition to searching for literature on the effects of conventional policing on violations, accidents and casualties, we also searched for studies of such alternatives to conventional traffic policing. For example, there are anecdotal reports that positioning empty police vehicles at the side of the road or on motorway flyovers can affect drivers’ behaviour. Similarly, the use of card-board cut outs of police vehicles or personnel has been mentioned as having a deterrent effect. However, no such studies were identified.

The use of safety cameras for traffic related enforcement activity other than speeding or red light violations are beginning to be introduced. In London, safety cameras for bus lane enforcement are being introduced and they will be used to enforce moving vehicle violations and parking violations in the near future. Given this is a new application for enforcement no studies have been conducted to evaluate the effects of these methods. However, this is a potential avenue for future research.

The main aim of this review was to explore how methods and levels of traffic policing affect *casualty* rates. However, almost all of the studies in the literature have examined the effect of policing on *accident* rates, so this review focused on the effects of enforcement on accidents in the most part. Information about casualties are given where possible in this report but where it was unavailable it may be presumed that any reduction in the accident rate due to increased enforcement will tend to reduce the casualty rate.

Research has demonstrated that the frequency and extent of driving violations is related to the risk of a road traffic accident (e.g. Taylor et al., 2000). Thus, reducing the frequency and extent of driving violations will have considerable safety benefits in terms of accident and casualty savings and studies using violation rates as the dependent safety measure provide useful information about the effectiveness of traffic policing on safety. A number of such studies were included in this review.

Ideally, this literature review would have focused on studies that have been conducted in busy cities throughout the world, so that the results could be generalised to London. However, the literature searches soon demonstrated that much of the research had been conducted on motorway or rural roads and relatively little specifically in busy urban areas. Therefore, this review included studies across a range of road and area types, and information regarding these characteristics in the various studies has been provided in this report where possible.

A requirement of this project was to consider using meta analysis techniques to establish any quantifiable relationships between levels of enforcement and casualty reductions. Meta-analysis is the statistical analysis of a large collection of results from individual studies. The aim is to pool the findings from similar research studies in order to determine the mean effect size of interest across those studies (in this case, the effect of levels of policing on casualty rates). In the present study, a meta analysis would require information from a number of studies about the numbers of accidents occurring before and after an enforcement intervention along with information about the levels of police enforcement. Ideally, information about the numbers of accidents for a control group would also be required. Unfortunately, such a meta analysis was not feasible because information about levels of enforcement was not provided by many studies and it was not possible to combine the few studies that did provide information about enforcement levels because enforcement levels were defined and measured differently across the different studies. This conclusion has previously been reached by other researchers (e.g. Elvik, 2001) and this issue is discussed in detail in section 6 of this report.

A number of meta analyses have been conducted recently to investigate the mean effects of increased enforcement generally on accident rates. With respect to police enforcement of speed limits, a recent report by Zaidel (2002) cited a meta analysis of 17 international studies conducted by Elvik et al (1997). Another recent meta analysis, which is currently being conducted by SWOV institute for road safety in the Netherlands, included 31 studies of police enforcement of speed limits. Elvik et al. (1997) also conducted a meta analysis to investigate the effects on accident rates of increased police enforcement of drink-driving violations, which included 26 international studies, and the effects of speed cameras, which included 9 international studies. Finally, a recent meta analysis of the effect of red light violation cameras on accidents was conducted by Retting et al. (2003). Particular attention is given to the results of these meta analyses in the appropriate sections of this report and evidence from specific studies is used to provide additional information where appropriate[1]. In addition to the meta analyses reported above, there were 66 individual studies included in this review: 30 were studies of speed or primarily speed enforcement campaigns, 5 were UK studies of speed camera enforcement, 13 were studies of drink-driving enforcement, 14 studies of red light camera enforcement, and 4 studies of seatbelt enforcement.

[1] Given the large number of studies on enforcement that have been conducted, one may ask “Why do these meta analyses include a small proportion of the total number of studies that have been conducted?” The answer is that not all of the studies are suitable to be included in a meta analysis because they do not contain the appropriate information about either accidents or enforcement procedures. The recent SWOV analysis, for example, initially identified over 70 studies but 44 of those studies were excluded on this basis.

5 General issues regarding studies of police enforcement

Much of the research evidence that was reviewed in this project came from evaluations of small scale enforcement efforts, e.g. investigating the effect of a limited number of police patrols (typically, 1 or 2) on a limited number of roads or road sections. Though these studies provide useful insights into the effectiveness of police enforcement on violation, accident and casualty rates, evaluations of area wide, larger scale enforcement efforts are perhaps more useful for the present purpose. Although a number of such evaluations have been conducted, only a few were in busy cities which are comparable to London. In addition, almost all of the research identified in this review was conducted abroad. Those studies conducted in the UK were either small scale studies of the kind mentioned above or were conducted about 30-40 years ago. Given the changes in driving conditions and behaviour over the past 40 years, it would seem that new research conducted in the UK is required. More specifically, research conducted in London is required to fully answer the question of how methods and levels of policing affect road traffic casualties in London. A proposal for an appropriate research project is provided in Section 9 (see also Section 6).

Enforcement programmes are rarely conducted without accompanying publicity and education campaigns. Indeed, publicity and enforcement are seen as mutually reinforcing methods of deterrence (Hakinen, 1988), e.g. using publicity to make drivers aware of an increased enforcement effort in an area. Without publicity, enforcement may not have much effect on perceived risk of being apprehended for violating. If drivers are not aware of the enforcement, however, they may believe that they are unlikely to be caught for committing traffic violations, so actual police enforcement is needed to back up the claims of the publicity. In cases where enforcement and publicity go hand-in-hand, it is impossible to assess the independent effects of enforcement on violation and accident rates. It should be borne in mind when reading the following sections that almost all studies have used media campaigns to publicise the enforcement programme that has been evaluated.

A number of studies in this area are flawed by their failure to recognise ‘regression to the mean’. With any type of phenomenon that occurs over time, such as road accidents in a specific area, there is a tendency for a high number (relative to the long-term mean) in one interval to be followed by a decrease in the following interval – even if nothing has been done to reduce the number (Rothengatter, 1982). Therefore, when enforcement campaigns are directed at sites or areas selected on the basis of their high accident counts (which in many cases they are), the full reduction in accidents cannot be attributed to the programmes themselves. In order to control for regression towards the mean effects, it is necessary to use sophisticated statistical modelling techniques, for example as described by Zaidel (2002). Few studies in the literature actually control for regression towards the mean in this way. However, many studies do attempt to reduce the effect by using accident data from several years before the implementation of an enforcement programme. The yearly, monthly or daily accident rates are then compared with the accident rates that occur during the programme. It should be noted that although regression to the mean may potentially be a limitation of many studies in this area, it is likely that at least some of the observed accident reductions will be due to enforcement.

A recent report by the European Transport Safety Council (1999) stated that the main objective of traffic law enforcement is to deter drivers from committing offences and not to maximise the number of drivers caught for offending. The underlying mechanism of deterrence is that road users’ behaviour can be modified by making them fearful of the consequences of committing traffic violations (Zaal, 1994). Road users are deterred from committing illegal acts (e.g. speeding or drink-driving) to a greater extent if they perceive that they are more likely to be apprehended, prosecuted and convicted for doing so, and if they perceive that the eventual penalty will be severe and swiftly administered. A person’s perceived risk of apprehension for committing road traffic offences is related to their perceptions about the intensity of police enforcement activities. Objective risk of apprehension relates to the actual risk of apprehension. The perceived risk of detection for committing a traffic offence is often dependent upon the objective risk but the relationship is not necessarily a direct one.

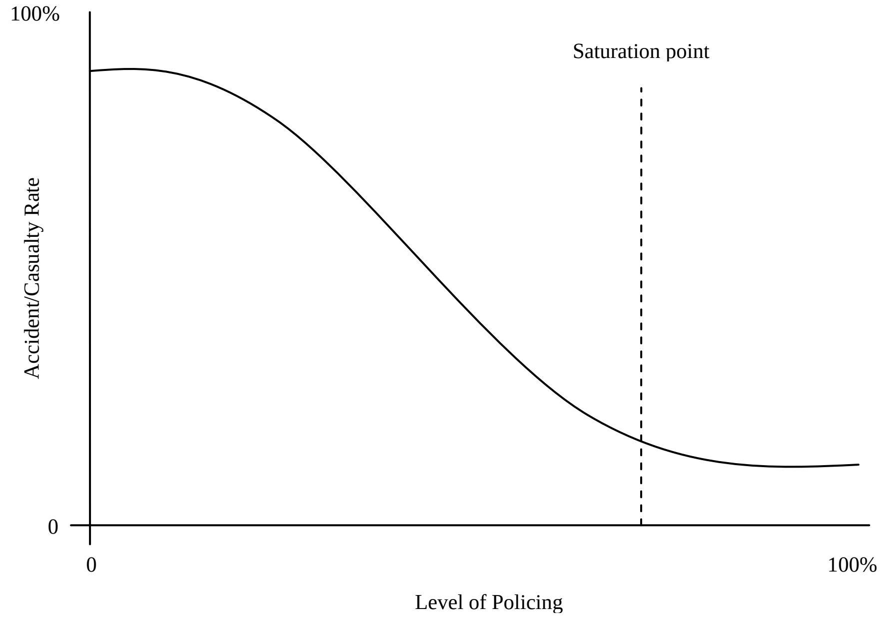
The most desirable situation occurs when a driver's perceived risk is greater than the objective risk. One way of achieving this would be to deploy traffic police largely at random over the whole road network, so that drivers would be unable to predict where and when they might be observed by police. This approach contrasts with the more common approach of targeting police resources on roads where traffic violations are known to be most likely (e.g. where traffic speeds are known to exceed the posted speed limits). Thus, the goal of maximising deterrence may conflict with the goal of catching as many offenders as possible. The 'random' approach to traffic policing is discussed in detail in Section 7.1.1, which discusses a number of studies that have found it can reduce violations and accident rates with relatively low levels of police man-power.

6 The relationship between enforcement levels and accident and casualty rates

The relationship between levels of policing, on the one hand, and accident or casualty rates, on the other, is not easy to establish. A theoretical relationship is provided in Figure 6.1. Policing levels are shown on the x axis and accident and casualty rates are shown on the y axis. The relationship is not linear: an S-shaped curve is hypothesised (e.g. Oei, 1996). At zero enforcement level, accidents and casualties are expected to be at their highest levels. An increase in enforcement would have no noticeable effect at first. However, drivers will become aware of the police presence at a certain level of enforcement and can be expected to modify their behaviour (i.e. reduce their violations), so the number of accidents and casualties would start to drop. As enforcement increases, the numbers of accidents and casualties can be expected to decrease, but only up to a certain point – after which increased enforcement would have little or no effect because of a saturation effect.

A similar relationship is hypothesised with respect to policing levels and violations, except that it is likely that violation rates can be reduced to a greater extent than can accident or casualty rates. Enforcement could theoretically be increased so far that every violation of the traffic laws would be detected; the violation rate would probably fall to almost zero (it is likely that some drivers would still occasionally violate). However, accidents and casualties would not fall so far since accidents are caused by a multitude of factors both related and unrelated to violations of traffic laws.

Figure 6.1 Theoretical relationship between level of policing and accident or casualty rates



The challenge for road safety researchers is to establish the levels of policing that are required to bring about the initial decrease in the curve and to reach the saturation point. It is also important to establish the violation, accident and casualty reductions that can be achieved with these levels of policing. The information about enforcement levels that would be needed to plot the relationship shown in Figure 1 may differ depending on the driving violation under consideration. For example, in the case of speeding, which is a relatively easy driving violation to detect, an ideal measure of enforcement would be the proportion of traffic or road network under police surveillance. If this information were available it could be related to proportion of speeding violations observed (in road side surveys, for example), or the number of accidents or casualties in an area. However, on the basis of the existing literature it is not possible to extract details about the proportion of the road network under police surveillance. In terms of drink-driving, which is more difficult to detect in moving traffic, information about the proportion of the road network under police surveillance is probably less appropriate. The ideal measure for this violation, albeit very difficult to obtain, would be the proportion of those driving with illegal alcohol levels who are actually breath-tested by the police. It is not surprising that none of the studies reviewed had included such details.

In the context of this review, one would ideally like to be able to extract information from each study on the policing levels used and relate it to the observed violation, accident or casualty reductions. Unfortunately, this is not possible for a combination of reasons:

- Many studies do not quantify the enforcement levels - such studies may merely state that enforcement was increased.

- Some studies may state the percentage increase in enforcement efforts from the before period, but this is of limited value without knowing the prior enforcement levels used. For example, the impact on casualty rates expected from a 50% increase in enforcement would depend on where the prior enforcement level lay on the x axis on Figure 1.

- Different studies have defined enforcement in different ways. For example, some reports provide information about enforcement levels in terms of police hours devoted to traffic policing, whereas others provide information in terms of the numbers of citations or arrests made during the enforcement period, or details about the numbers of drivers' prosecuted for offending. It is not possible to compare between these groups of studies.

- Although information is often provided about the enforcement effort under study (e.g. the number of police hours devoted to traffic policing), it is often of limited value because of a failure to report the area over which the enforcement was applied. 100 extra hours of police traffic surveillance, for example, may have little impact on violations, accidents or casualties when spread over a large area, but a larger effect when concentrated in a smaller area.

In sum, it is not practical to generalise across the previous research studies using meta analysis procedures in order to investigate the relationship between levels of policing and road accident or violation rates. It is possible, however, to identify a limited number of studies that provide some information about the enforcement levels required to bring about a reduction in accidents. The studies reviewed below were the main ones identified in this review that provided the most appropriate information about the effects of levels of policing.

A study by De Waard and Rooijers (1994) in the Netherlands investigated the effects of three levels of intensity of police enforcement on driving speed and speeding violations on motorways in the Netherlands. The enforcement method involved stopping at the roadside every 100th offender, every 25th offender or every 6th offender. Driving speed data were collected at a control site and at the treatment sites for 2 consecutive weeks prior to the enforcement effort, for 4 consecutive weeks during the enforcement period and for 4 consecutive weeks after the enforcement period ended. Table 6.1 has been adapted from De Waard and Rooijers (1994) and shows that there was a small increase in mean driving speeds at the control site, which was not statistically significant. The table also shows that there was no effect on driving speeds when the enforcement method involved stopping every 100th offender. When every 25th offender was stopped by the police, there was a small but statistically significant effect on driving speeds. Mean speeds reduced by between 0.6km/h (0.4mph) and 1.2km/h (0.8mph) in the right and left lanes of the motorway, respectively. When every 6th offender was stopped, there was a larger effect. Speeds reduced by between 2.7km/h (1.7mph) and 5.2km/h (3.3mph) in the right and left lanes, respectively. When the enforcement period ended, mean speeds increased to what they were before the enforcement period in the 1:100 and 1:25 conditions. However, when every 6th offender was stopped mean speeds remained 2km/h slower than they were pre-enforcement. Table 6.2, which has also been adapted from De Waard and Rooijers (1994), shows that similar effects were found when the percentage of vehicles exceeding the speed limit was studied. By far the largest reduction in the proportions of vehicles exceeding the speed limit was in the 1:6 condition where the proportion of vehicles exceeding the speed limit dropped from 19.9% pre-enforcement to 14.4% during the enforcement period. Overall, this study suggests that rather high levels of policing are required to bring about reductions in mean speeds and in speeding violations.

Table 6.1 Mean speeds of vehicles in pre-, during and post-enforcement periods (De Waard & Rooijers, 1994)

Condition	Lane	Mean speed (km/h)		
		Pre-enforcement (2 weeks)	During enforcement (4 weeks)	Post-enforcement (4 weeks)
Control (no enforcement)	Right	106.6	107.1	107.3
	Left	117.4	118.2	118.2
Stopping every 100th offender	Right	108.2	108.8	108.8
	Left	116.6	116.4	116.5
Stopping every 25th offender	Right	112.5	111.9	112.9
	Left	121.1	119.9	121.4
Stopping every 6th offender	Right	114.9	112.2	113.6
	Left	125.3	120.1	121.8

Table 6.2 Percentage of vehicles exceeding the speed limit in pre-, during and post-enforcement periods (De Waard & Rooijers, 1994)

Condition	Lane	% vehicles exceeding speed limit		
		Pre-enforcement (2 weeks)	During enforcement (4 weeks)	Post-enforcement (4 weeks)
Control (no enforcement)	Right	7.3	8.3	7.2
	Left	15.5	18.0	16.6
Stopping every 100th offender	Right	Not given	4.3	3.6
	Left	Not given	14.7	13.5
Stopping every 25th offender	Right	9.0	8.1	12.2
	Left	23.3	22.7	26.9
Stopping every 6th offender	Right	19.9	14.4	17.8
	Left	Not given	24.4	30.6

Another study by Henstridge et al. (1997) was conducted to assess the effects on accidents of random breath testing (RBT) in Australia. Fatal, serious and single vehicle accident data from 1976 to 1992 were obtained along with data on enforcement levels since the introduction of RBT in December 1982. Increases in testing levels from 100 to 6000 per day were plotted against percentage reductions in serious and single vehicle night-time accidents (it was not possible to do the same for fatal accidents due to the lack of statistical power caused by the small numbers). For both serious and single vehicle night-time accidents, a non-linear relationship between enforcement levels and accidents was found. For serious accidents, an increase in the daily testing rate from zero to 1000 resulted in a 5.9% reduction in accidents and an increase from zero to 3000 tests per day resulted in a 16.6% accident reduction. For single vehicle night-time accidents (accidents typically associated with drink-driving), an increase of 1000 tests per day resulted in a 19.3% reduction and an increase of 3000 tests per day resulted in a 47.3% reduction.

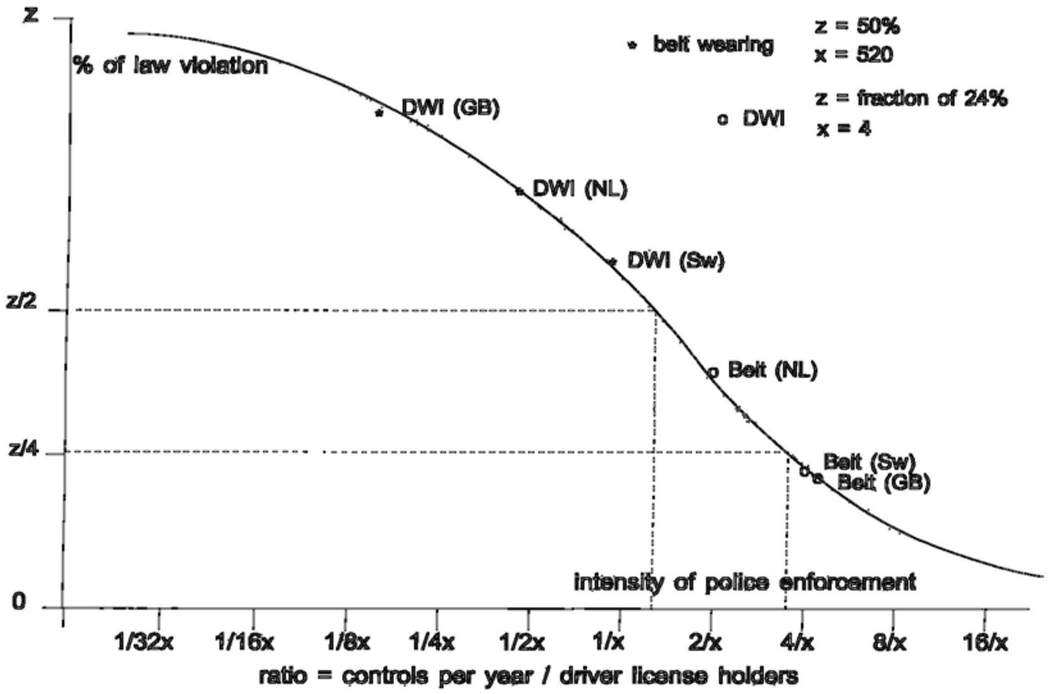
A report by Koornstra et al. (2002) compared the development of road safety in three countries. Police enforcement was one aspect considered and a relationship between the intensity of police enforcement and the level of traffic law violations was presented. The authors acknowledged that establishing this relationship requires detailed information on enforcement levels, road user behaviour and accident rates and that further empirical research would be required to establish a definitive relationship. Nevertheless, the report presents a powerful example of how, once sufficient data had been collected, it would be possible to predict the effect of increased enforcement on the level of violations and casualties.

Figure 6.2 reproduces the report's Figure B.1; this was fitted to the following national data from Sweden, the Netherlands and Great Britain:

- seatbelt violations (the proportion of drivers who do not wear belts, found from roadside surveys) and the number of convictions expressed as the number per driver per year (these data are labelled 'Belt' in the Figure),
- drink-driving violations (complicated by different legal limits in the 3 countries, so measured by the proportion of drivers who died with BAC exceeding 100mg/100ml of blood) and the number of drivers breath-tested per year expressed as a proportion of the national total (these data are labelled 'DWI' in the Figure).

The violation measure (not the intensity of police enforcement as claimed by the axis label) is plotted on the x axis, while the rate of violations is plotted on the y axis. In order to combine the two distinct types of violation, the measures are scaled using different values of x (the confusing use of the symbol x for the scaling factor comes from the original report). For Sweden, for example, 1 in 130 drivers per year are fined for this offence; 1/130=4/520 so the point representing seatbelt violations in Sweden is plotted with abscissa=4/x. 10%=50%/5 of drivers fail to wear their belts, so the point 'Belt(Sw)' is plotted at (4/x, z/5). Although the labelling of the x axis is unfamiliar, the axis actually has a conventional log scale, with 'police enforcement' activity increasing as the abscissa increases.

Figure 6.2 Relationship between enforcement intensity and law violation levels (Koornstra, 2002)



As an example of the results that can be achieved, the report estimates that if the level of breath-testing were to be increased nine-fold in Great Britain then the proportion of drivers who died with BAC in excess of 100mg/100ml of blood would fall from 20% to 12%. There would also be (unquantified) benefits for other groups of casualties in drink/drive accidents. While the report acknowledges the limitations of the data currently available, it does show how the benefits of increased enforcement could be calculated – once the necessary information had been collected by appropriate research. The violation rate could be used as an interim measure of enforcement, but it is far from ideal since it is an index of output rather than input. The benefits could then be compared with the costs, as part of a rational approach to determining the optimal level of enforcement.

Of course, it is difficult to establish whether these effects on casualties due to such an increase in police enforcement would also apply to London because, as mentioned above, information is required about the existing level of enforcement to establish where London lies on the curve. Research is needed in London in order to estimate the increase in policing that would be required to bring about any specific reduction in casualties in London, and a brief proposal for such research is given in Section 9.

7 Methods of enforcement

Assessing the effect of different enforcement *methods* on violations, accidents and casualties is an easier task than is assessing the impact of *levels* of enforcement. That said, many studies in the literature have also not given precise descriptions of the enforcement methods used. In addition, many studies have investigated the effects of more than one method which make it difficult to determine the effectiveness of any one specific method (European Transport Safety Council, 1999). However, on the basis of the literature reviewed, it is possible to discriminate between the following methods, for which at least some evidence is available:

Physical policing methods:

- Stationary and highly visible:

  This method involves the use of visible police units positioned at the road side. In many cases, but not all, automatic speed measuring devices (e.g. photo radar) are used to record drivers' speeds. Speeding drivers are stopped and issued either warnings or speeding fines. This method is also used in the enforcement of drink-driving (e.g. Random breath testing).

- Stationary and hidden:

  This method involves the use of unmarked police vehicles hidden at the roadside. Typically, police officers will operate photo-radar instruments from the unmarked vehicle and record drivers' speed. Rather than stopping drivers when they commit speeding offences, the photo evidence is processed and fines and notification of penalty points are sent to the vehicle owner.

- Mobile enforcement in marked police cars

  This method involves allocating a stretch of road or an area for enforcement by police operating from marked police cars. Police will stop drivers who commit road traffic violations and take the appropriate action.

- Mobile enforcement in unmarked police cars

  This method is similar to the one mentioned above (mobile enforcement in marked police vehicles), but involves police officers operating from unmarked police vehicles.

Fully automated methods

- Speed cameras.
- Red light cameras.

7.1 Methods used to enforce speed limits

Summaries of studies investigating the effects of physical police enforcement on speeding violations and on accident rates are presented in Appendix A.

7.1.1 Stationary and visible enforcement

The effect of stationary enforcement on accidents is encouraging. In a recent review of the literature on enforcement and accidents, Zaidel (2002) presented a meta analysis of 17 international studies of stationary enforcement methods (either stationary methods only or stationary methods used in combination with other methods), which was conducted by Elvik et al. (1997). The results are summarised in Table 7.1, which has been adapted from Zaidel (2002).

Table 7.1 Results of a meta analysis of the effects of physical police presence using stationary speed enforcement (Elvik et al., 1997)

Accident type	Percentage change in the number of accidents	
	Best estimate[2]	Confidence interval (95%)[3]
All accidents	-2	-1 to -4
All fatal accidents	-14	-8 to -20
All injury accidents	-6	-4 to -9
All property-damage only accidents	+1	+3 to -1

The meta analysis showed that the overall effect of mainly stationary methods of physical policing was a statistically significant reduction in the number of accidents by 2%. This reduction may seem small but the effect of enforcement on fatal accidents was found to be a 14% reduction and the effect on injury accidents was found to be a 6% reduction (both results were statistically significant). The meta analysis also found a small, but not a statistically reliable, increase in property damage only accidents.

A current research project by the Institute for Road Safety Research (SWOV) is also attempting to quantify the relationship between speed enforcement and accident reductions. Information about this research has been provided in the form of a summary leaflet, which has been recently received by TRL. A meta analysis of 31 studies has been carried out and the results appear to show greater benefits than were found by Elvik et al. (1997). Overall, a mean reduction in all accidents by 15% has

[2] Any estimate of an effect that is based on a finite data set has an inherent uncertainty which is indicated by its standard error or variance (the square of the standard error). In meta analysis, when several studies give a range of estimates of the treatment effect (in this case the effect of increased traffic policing), the best estimate of the effect is the mean of the study effects weighted to take account of the variance (or uncertainty) of each result.

[3] A confidence interval is an interval that indicates the likely size of a population parameter. It gives an estimated range of values (calculated from a given set of sample data) that has a specified probability of containing the parameter being estimated. The 95% confidence interval is widely used; there is a 1-in-20 chance that the true value lies outside of the interval specified, or a 19-in-20 chance that the true value lies inside the interval specified.

been found. For serious injury accidents and fatal accidents, reductions of 24% and 17%, respectively, have been found.

It is not clear why the recent meta analysis conducted by SWOV found substantially greater effects of speed enforcement than the Elvik et al. analysis in 1997, though it is possible that the SWOV analysis will provide more reliable estimates of the effects of policing on accidents due to the greater number of studies that are included. Nevertheless, the picture that emerges from both meta analyses is clear: stationary speed enforcement does seem to have a desirable impact on accident rates. This finding is also borne out by inspecting the individual studies presented in Appendix A. In most studies, increases in enforcement have led to accident reductions, and some studies suggest that large reductions can be achieved in the total numbers of accidents, in fatal accidents and in serious accidents (e.g. Leggett, 1988; Munden, 1966; Newstead et al., 2001; Sali, 1983).

Only one study identified in this review investigated the effect of stationary enforcement on casualties (Fuller, 2002). Significant net reductions in serious casualty rates (compared with a control area) were found (18% reduction). In addition, a 9% net decrease in slight casualties was found due to enforcement. However, the study did not find a net reduction in fatal casualties.

As well as having desirable impacts on accident rates, increased enforcement using stationary and visible methods has also been shown to have desirable impacts on speeding violations. The studies presented in Appendix A show that reductions in mean speeds typically appear to be around 3mph. Absolute reductions in the proportions of drivers exceeding the speed limit can range from 3% to 64%. Studies in which control groups have been used have shown that speed violations on the enforced sections of road have decreased whilst speed violations on control roads have increased or that violations on the enforced sections have decreased to a greater extent than on control roads. When net reductions in speeding violations have been calculated (i.e. the decrease in violations in the enforced area compared with a control area), they have been in the range of 2.6% to 34%. Only two of the studies reviewed found no effect of enforcement on speeding violations or mean speeds.

7.1.2 Effects of enforcement over time and distance

In addition to assessing the effects of stationary enforcement on speed behaviour at the enforcement site during police presence, some studies have investigated the time and distance “halo effects” of enforcement. “Time halo” refers to the length of time that the effects of enforcement on drivers’ speed behaviour continued after the police presence was removed. “Distance halo” refers to the distance that the effects of enforcement last after drivers pass the enforcement site. Appendix B summarises the studies that have investigated the time or distance halo effects of enforcement.

With respect to time halo effects, research has shown that the effect of police presence on driving speeds can last between 1 hour and 8 weeks after police activity has ceased. It seems as though the studies in which larger time halo effects have been found are associated with longer periods of police presence. It is, however, difficult to establish the duration of police presence that is necessary to bring about long-lasting effects. On the basis of the studies reviewed it would appear that less than 6 days of police activity at a given location will have little or no effect on drivers’ behaviour after the enforcement effort has been removed. Even when police presence lasts for longer periods of time, the time halo effect can be expected to last for a limited period only. This suggests the need for sustained enforcement efforts to influence drivers’ behaviour.

The distance halo effects of police presence on speed behaviour that have been found also vary between studies. It seems that the effects of police presence on driving speeds last between 1.5 and 5 miles after drivers have passed the enforcement site. Hauer et al. (1982) estimated that the effects of visible and stationary policing on driving speeds are halved for every 900 metres (0.6 miles) downstream of the enforcement site.

Two studies, however, showed that police enforcement can have considerable distance halo effects (Edwards & Brackett, 1978; Brackett & Beecher, 1980). In these studies, visible stationary enforcement was used in a “random” fashion in an attempt to create a sense of a large scale enforcement effort. It involved dividing the roads in the study areas into sections and the hours of the day into blocks of time. Road sections to be visited by the police and the time when they were to be visited were chosen at random. These studies found a distance halo effect of 14 miles from the enforcement sites. These large halo effects are likely to be due to the fact that random policing makes it difficult for drivers to predict where and when police will be present. If drivers perceive a high level of enforcement, this is likely to increase the deterrence effect and increase compliance with traffic laws over more of the road network. The issue of randomisation of enforcement is discussed further below.

7.1.3 Randomisation of stationary and visible policing

Zaidel (2002) states that most attempts to increase the impact of police traffic enforcement involve substantially increasing police presence. However, this approach is limited because the limitations on resources for traffic policing often means that increases in enforcement can only be short term. Short term, high intensity policing is referred to as a “blitz” approach. Edwards and Brackett (1978) suggested an alternative approach in which low levels of policing could be used to achieve long-term and wide spread benefits in terms of violation and accident reductions. The approach involves the deployment of traffic police at random over the whole road network.

Theoretically, the randomisation of enforcement is likely to enhance the deterrent effect because it would give the *impression* of a large-scale enforcement effort. In addition, motorists would not know where or when the police would be present and so drivers may be more inclined to modify their behaviour across the whole road network as opposed to modifying their behaviour at specific sites where they know the police will be present (through experience). In other words, this method of traffic policing is likely to increase motorists’ perceived risk of apprehension for violating, even though the objective risk of apprehension is unlikely to change substantially. Such an approach would clearly be beneficial because, if effective, then the benefits in terms of violation and accident reductions “could be maintained routinely and indefinitely from normal levels of police manpower, overcoming the drawback of the blitz approach” (Leggett, 1988).

A number of studies have shown that the randomisation of policing has desirable effects in practice (Edwards & Brackett, 1978; Brackett & Beecher, 1980; Leggett, 1988; Newstead et al., 2001). In these studies similar methods were used. The total lengths of the roads investigated were divided into smaller (typically 1km long) sections and marked police vehicles visited those sections for approximately 2 hour periods. The section of road to be visited and the time at which it was to be visited were chosen at random.

In the USA, Edwards and Brackett (1978) evaluated the effectiveness of this method along a total 27km rural road and found a 4.8km/h (3mph) reduction in mean speeds at various measuring points across the route. Brackett and Beecher (1980) also evaluated this method on 24 experimental roads compared with 24 matched control roads in Texas, USA. The experiment lasted for 18 months. It was found that across all experimental roads net mean speeds reduced by 1.8% and the proportions of drivers exceeding the speed limit (55mph) reduced by 9%.

In Australia, Leggett (1988) investigated the effectiveness of this technique on three stretches of rural highway over a two year period. During the hours of enforcement the mean speeds across all experimental sites reduced by 3.6km/h (2.3mph) whereas in matched control sites speeds reduced by 0.5km/h (0.3mph) only. Accidents during the 5 years prior to the study were compared with accidents during the two years of the study. Fatal and serious accidents reduced by 58% compared with a 4.2% reduction in fatal and serious accidents in the control areas. Though there was an increase in all accidents at the experimental sites during the enforcement programme, there was also an increase in the total number of accidents in the control areas which was of greater magnitude (12% compared with 27%).

In Queensland (Australia) an enforcement programme called Random Road Watch (RRW) was progressively introduced into all eight of Queensland police regions between 1992 and 1997. The programme was based upon the principle of low intensity random enforcement. The hours of 06:00 to 00:00 were divided into 2 hour periods and each police jurisdiction was divided into sections. The sections to be visited and the time at which they were visited were chosen at random. 279 police stations in Queensland participated in RRW. Each police station operated their own programme that covered as many routes as possible in its territory. 55% of the accidents that occurred across all the police regions in the 12 months before the introduction of RRW occurred on the routes that were included in the RRW programme.

Newstead et al. (2001) evaluated the effects of RRW on accidents. These researchers used accident data from the beginning of 1986 (i.e. 6 years before RRW started to be introduced) to mid-1997. The evaluation involved a before-after time series analysis (which took into account the fact the RRW was introduced in the different police regions at different times) with control group comparison. The accident data during the RRW hours (i.e. 06:00 to 00:00) was compared with the accident data for the remaining period of the day and accident data for the roads enforced under the RRW programme was compared with the accident data for all other roads in Queensland. The estimated accident reductions due to RRW were large and statistically significant for both urban and rural areas taken together and for urban areas separately. Overall, it was estimated that fatal accidents had decreased by 31% (26% in urban areas), serious accidents requiring hospitalisation decreased by 13% (21% in urban areas) and slight accidents requiring medical/first aid treatment decreased by 9% (13% in urban areas).

Using data provided by Newstead et al. (2001), Zaidel (2002) calculated that the total RRW deployments per year in Queensland equalled 40,000 hours and that this provided about 4 hours (or two deployments) per site per year. Thus, it can be seen that very small levels of enforcement can bring about substantial safety benefits if police resources are used in the random manner used in RRW.

Overall, studies of low intensity random police enforcement have demonstrated that this method can bring about reductions in mean speeds in the order of 2mph to 3mph and can have substantial impacts on accident rates. In addition to the impacts on speeds and accidents, the distance halo effects associated with random policing are large (see above).

7.1.4 Stationary and hidden enforcement

Studies that have evaluated this method of policing have come from New Zealand (Keall et al, 2001, 2002) and Canada (Chen et al., 2000, 2002). Each study has evaluated the effects of stationary and hidden policing in terms of speed and accident reductions. Keall et al. (2001) evaluated the effectiveness of speed cameras (radar guns) operated by police from unmarked vehicles hidden at the road side in one police region in New Zealand. This method of policing replaced the “traditional” method which involved highly visible and stationary (physical police) enforcement. The trial began in June 1997 and the evaluation covered the first year of the programme operation. All speed camera areas were on 100km/h (62.5mph) open roads. Speed and injury accident data were collected from the enforced roads and from all other open roads in the trial area. These data were compared with speed and injury accident data obtained from all open roads in New Zealand that were outside the trial area. One month of speed data were collected before the trial and compared with the monthly average speeds that were collected over several months during the trial. Accident data were collected from 1993 and statistical models were used to calculate the estimated accident reductions due to the enforcement programme. It was found that mean speeds at the sites where police operated the hidden speed cameras reduced by 2.3km/h (1.4mph), and mean speeds reduced by 1.6km/h (1mph) on all open roads in the trial area. It was estimated that injury accidents were reduced by 22% at the enforcement sites and casualties were reduced by 29% (both results statistically significant at the 10% level). On all open roads in the trial area, accidents were reduced by 11% and casualties by 19%.

In a follow-up study to evaluate the impact of the hidden speed camera programme over the first two years of its operation, Keall et al. (2002) found that mean speeds reduced by 1.3km/h (0.8mph) on all open roads generally (results for speed reductions at the enforcement sites were not given). Injury accidents had reduced by 17% and casualties had reduced by 31%.

At face value, these studies would appear to suggest that replacing highly visible stationary policing with hidden policing provides beneficial impacts on safety. However, it should be noted that during the hidden speed camera trial in New Zealand, the number of drivers photographed for exceeding the speed limit increased from 1% before the trial to 5% during the first year. Thus, one cannot suggest that hidden stationary enforcement is better that visible enforcement because the change in the enforcement levels provides a confounding factor. In addition, extensive publicity accompanied the trial and it may have been the case that there was no publicity associated with the general enforcement activities before the trial.

A similar evaluation of hidden stationary enforcement to that conducted by Keall et al. was conducted in British Columbia by Chen et al. (2000). Speed and accident data were collected before and after the introduction of the “photo radar programme” which involved enforcing speed limits across the whole state using photo radar (mobile speed cameras) operated by police officers in unmarked vehicles. The study evaluated the effectiveness of the programme over the first 12 months. Speed data were collected for the three months prior to the introduction of the programme and for each month during the study. Mean speeds reduced by 2.4km/h (1.5mph) at the photo radar sites throughout the state and the proportion of drivers exceeding the speed limit reduced by 50%. Across 19 independent monitoring sites within British Columbia that were not near the photo radar sites the proportion of drivers exceeding the speed limit reduced from 69% before the programme to 61% during it. Statistical modelling showed that speed related daytime accidents reduced by 25% during the first year of the programme and casualties reduced by 11%. Fatal casualties reduced by 17%.

In a later study, Chen et al. (2002) evaluated the effectiveness of photo radar programme after 2 years since its introduction on one highway corridor (a 22km long, 4-lane divided highway with 80-90km/h speed limits running through rural and light residential land). Mean speeds reduced by 2.8km/h (1.8mph). Accident modelling using two years of accident data prior to the enforcement programme and the first two years of accident data during it showed that the photo radar programme reduced accidents by 16% across the whole road.

In summary, these studies of stationary and hidden policing methods suggest that comparable reductions in accidents can be found to those that can be found using highly visible methods. However, the speed reductions associated with the visible method seem to be around 1mph greater than those using the hidden method. It should be noted that based on such a small number of studies, it is difficult to conclude firmly that the stationary hidden method is as beneficial as the stationary visible method.

7.1.5 Mobile enforcement

As mentioned above, a number of studies have investigated the effects of mobile enforcement methods in combination with stationary methods. However, stationary enforcement has been the primary method used and it is not possible to draw any conclusions about mobile enforcement on the basis of these studies. Only a few studies do provide information on the effects of increased mobile enforcement. Although none of the studies identified in this review investigated the effects on accidents or casualties, some investigated the effects on violations, which enables some conclusions to be drawn about the effectiveness of increased mobile enforcement methods.

Christie and Downing (1989) investigated the effects of increasing police presence on four motorways in the UK. Two of the motorways (M4 and M6) experienced a larger increase in enforcement and the other two (M1 and M3) experienced a smaller increase in enforcement (definitions of what was meant by ‘high’ and ‘low’ enforcement were not provided). The two lower enforced motorways experienced reductions in mean speeds in the centre and near-side lanes during the enforcement effort of less than 1mph. However, in the offside lane on both motorways mean speeds increased. On the higher enforced motorways, mean speeds reduced in all three lanes. On the M6 mean speeds reduced by less than 1mph in each lane. On the M4, mean speeds were reduced by less than 1mph in the nearside lane but by 1.2mph in both the centre and offside lanes. Even in the high enforcement conditions, these speed reductions appear to be much smaller than those that can be achieved using stationary methods (see above).

Perhaps the most useful information about the comparative effects of mobile enforcement was provided by a study conducted in the USA by Hool et al. (1983). These researchers compared the effects of stationary and mobile enforcement methods on speeding violations on two roads (a dual lane highway and a four lane interstate), each matched with a control road where no enforcement was present. In one experimental condition a single stationary marked patrol vehicle was used on each of the experimental roads. The police vehicle was randomly moved to different locations and was present at each of the locations for 30 minute intervals. In a second experimental condition, a single moving marked patrol vehicle was used on each road. They patrolled the length of the roads at 40-45mph. In a third experimental condition, a single moving unmarked patrol vehicle was used on each road. As with the marked police vehicle, the unmarked vehicles patrolled the length of the roads at 40-45mph. The results of the study have been summarised in Table 7.2. They showed that on the 2-lane highway there was little difference between the visible stationary method and the mobile marked patrol method. However, the unmarked mobile police vehicle was less effective. On the 4 lane interstate the stationary method was more effective at reducing speed violations and mean speeds than was either of the mobile methods. The mobile method of enforcement in unmarked police vehicles had no effect on this road type. This result is in support of Shinar and McKnight (1985) who also found no effect of mobile enforcement in unmarked vehicles.

Table 7.2 Comparative effects of stationary and mobile enforcement methods (Hool et al., 1983)

Method	**2 lane highway**		**4 lane interstate**	
	Percentage change in drivers exceeding the speed limit	**Percentage change in mean speeds**	**Percentage change in drivers exceeding the speed limit**	**Percentage change in mean speeds**
Visible stationary	-3.3	-1.8	-2.6	-1.6
Mobile in marked police vehicle	-3.5	-1.9	-1.5	-0.9
Mobile in unmarked police vehicle	-2.6	-1.4	No change	+0.1

Although it is acknowledged that Hool et al. (1983) found that mobile policing in marked cars was as effective as stationary policing on the 2-lane road, the overall conclusion on the basis of the available literature summarised above is that mobile enforcement is not as effective as stationary enforcement.

In particular, the effect of mobile enforcement in unmarked vehicles does not compare favourably with highly visible policing methods. From a psychological perspective, this can be partially accounted for by the deterrence process (see section 5). It is unlikely that policing will deter many drivers from violating if it is not visible because it would have little effect on drivers' perceived risk of apprehension. Highly visible methods, on the other hand, are likely to increase perceived risk because drivers can actually see the police effort occurring.

7.1.6 Speed cameras

A meta analysis of 9 studies on the effect of speed cameras on accidents was conducted by Elvik et al. (1997). The results are presented in Table 7.3. The table shows that the increased enforcement achieved an average of 19% reduction in all accidents. Injury accidents were found to reduce by 17% (no detail about the effects on fatal accidents was provided because the accident data did not allow such an investigation). Speed cameras were found to be less effective in reducing accidents in rural areas than in urban areas. In rural areas there was found to be a mean reduction in all accidents of 4%. In urban areas, the effects were found to be a 28% reduction in all accidents. This finding is consistent with the results of the recent meta analysis conducted by researchers at SWOV who have found a 24% reduction in accidents due to speed cameras. These meta analytic results are also comparable with studies of the effects of speed cameras that have been conducted in Great Britain specifically, which are summarised in Appendix C. These studies have found reductions in accident rates at speed camera sites of between 14% and 35% following the introduction of cameras, and casualty reductions in the region of 20% to 55% have also been found. In addition, studies in Great Britain have shown that mean speeds reduce by around 5mph at speed camera sites.

Some critics of speed cameras have argued that the violation, accident and casualty reductions found at speed camera sites represent a regression to the mean effect. Regression to the mean might be a potential problem in many studies, because the accident rates following the introduction of speed cameras have been compared with a few years of prior accident data only. However, a paper by the Parliamentary Advisory Council for Transport Safety (2003) cited a study by Imperial College of the effects of speed cameras over a 12 year period in Cambridgeshire (Hess, 2004) which enabled the researchers to eliminate the effects of regression to the mean. This study found that speed cameras can reduce collisions involving injury by around 45%.

The research by Hess also suggested that speed cameras are associated with lower but still significant reductions in accidents within a 2 kilometre (1.2 mile) radius of a speed camera. This finding is supported by research from Finland which shows that the effects of speed cameras extend to between 4km (2.4 miles) and 10km (6 miles) from the speed camera site (Makinen & Rathmayer, 1994; Makinen & Oei, 1992). Other research, however, suggests that the distance halo effects of speed cameras are not as large as those reported by Hess. Keenan (2002), for example, found that by 500 metres after passing a speed camera mean speeds increased to the same levels they were 500 metres before the camera. At these points, around 80% of drivers were exceeding the speed limit. This finding is consistent with research by Nilsson (1992) who also found that the distance halo effect due to speed cameras was 500 metres. On the basis of the studies reviewed in section 7.1.1, the minimum distance halo effect due to stationary visible policing is 2.4km (1.5 miles) (Hauer et al., 1982). This is almost 5 times greater than the minimum distance halo effect that has been found due to speed cameras (i.e. 500 metres).

In summary, the evidence for the impact of speed cameras seems to indicate that they are more effective than physical policing methods at reducing violation and accident rates. However, the impact of speed cameras appears to be limited mainly to the speed camera site with the distance halo effects being about 500 metres. Larger distance halo effects seem to be associated with physical policing, especially if the policing method is "randomised" (see section 7.1.2) and the literature indicates that physical policing methods are still effective at reducing violation and accident rates.

Table 7.3 Results of a meta analysis of the effects of automatic speed enforcement (Elvik et al., 1997)

Accident type	Percentage change in the number of accidents	
	Best estimate	Confidence interval (95%)
All accidents	-19	-18 to -20
All injury accidents	-17	-16 to -19
All accidents in urban areas	-28	-26 to -31
All accidents in rural areas	-4	-2 to -6

7.2 Methods used in drink driving enforcement

A selection of studies identified in this review that have evaluated the policing of drink-driving are summarised in Appendix D. The studies show that the effects of drink-driving enforcement on violations are associated with large decreases in violation rates and each study found net decreases in accident rates following enforcement campaigns.

Most studies in the literature that have evaluated policing methods used to enforce drink driving laws have studied the effects of random breath testing on accident rates. This involves providing enforcement in a random manner – i.e. there is no requirement to suspect drink driving before stopping a driver to apply a breath test.

In a recent review on enforcement and accidents, Zaidel (2002) presented the results of a meta analysis of 26 studies conducted by Elvik et al. (1997). The majority of these studies were conducted in Europe, Australia and New Zealand. The results are summarised in Table 7.4, which has been adapted from Zaidel (2002). The table shows that police enforcement of drink-driving has resulted in statistically significant reductions in most types of accident. The only exception was accidents involving pedestrians – there was no effect of enforcement found on this type of accident.

Table 7.4 Results of a meta analysis of the effects of drink-driving enforcement (Elvik et al., 1997)

Accident type	**Percentage change in the number of accidents**	
	Best estimate	**Confidence interval (95%)**
All accidents	-4	-3 to -4
All fatal accidents	-9	-6 to -11
All injury accidents	-7	-7 to -8
All fatal and injury accidents at night-time/single vehicle	-7	-5 to -9
All fatal and injury accidents in day time hours	-12	-9 to -15
All accident in urban areas	-3	-2 to -4
All accidents in rural areas	-3	-2 to -4
All accidents involving pedestrians	0	+2 to -3

7.3 Methods used to detect red light violations

A number of studies investigating the effects of cameras which detect red light violations were identified, but none that involved human traffic police officers. The paper by Retting et al. (2003) is perhaps the most useful; it provided a comprehensive review of the international literature on the effects of red light cameras on violations and accidents. The tables presented in Appendix E are adapted from this paper and summarise the studies that have investigated the effects on red light violations (Table E1) and on accidents (Table E2). The conclusion is that red light cameras are associated with substantial reductions in violation rates at camera sites. Though all studies have found that the total number of injury accidents at camera sites has decreased due to the red light cameras, it appears that red light cameras are associated with an increase in the proportion of rear-end accidents. Presumably this is related to drivers stopping suddenly to avoid being caught for committing red light violations, though there is no direct evidence for this. In most studies, it appears that red light cameras have resulted in a reduction in the total number of accidents at camera sites. However, in two studies (Mann et al., 1994; Andrassen, 1995) the overall effect was an increase in the total number of accidents at camera sites.

Retting et al. (2003) conducted a meta analysis on the studies listed in Table E2 to show the overall effects of red light cameras on injury accidents. It was concluded that although results vary between studies, the results indicate that red light cameras have a beneficial impact on injury accidents, with the best estimate being a 25% to 30% reduction at camera sites

7.4 Enforcement of seat belt laws

Few evaluation studies have been conducted to assess the direct effects of seat belt enforcement on accidents or casualties. Zaidel (2002) concluded that estimating the separate effect of policing seat belt laws on accidents was impractical based on the literature. However, Zaidel also stated that two U.S. studies (Wells et al., 1992; Williams et al., 1996) reported reductions in accidents of 4% to 8% as a direct consequence of police seat belt enforcement. However, these reductions were not statistically significant.

Other U.S. studies have also shown that enforcement of seat belt laws leads to increases in wearing rates (e.g. Jonah et al., 1982; Jonah & Grant, 1985). In particular, Streff et al. (1992) found that a combined education and enforcement campaign over a 13 month period led to an increase in wearing rates. Before the campaign, wearing rates were measured at 56.7%. During the campaign they reached 65.1%, which reduced slightly to 62.7% after the campaign.

In Europe a study by Gundy (1988) examined the effect of an enforcement campaign that was conducted over a 2 month period. It included police enforcement plus an extensive media campaign. On the basis of the Gundy (1988) paper it was difficult to identify the levels of policing used in the campaign. The author stated that the amount of police time devoted to enforcement varied widely from week to week and varied between jurisdictions with the study area. However, it was found that the increased enforcement effort led to a 25% increase in wearing rates and, at 6 and 12 months after the enforcement period ended, the wearing rates were still 15% higher than they had been before the campaign. Two years after the campaign, wearing rates remained higher than before the campaign. However, the researchers could not conclude that this was due to the enforcement programme alone because another seat belt enforcement programme ran after the end of the first year of the original campaign.

Countries which have succeeded in raising seatbelt wearing rates, for example when wearing became compulsory in the front seats of cars and vans in Great Britain in 1983, have experienced considerable casualty reductions which demonstrate the benefits that can be achieved by raising the wearing rates. Thus, in spite of the apparent lack of research evidence on this point, increases in wearing rates due to policing are likely to be accompanied by reduced casualties in road accidents.

8 Conclusions and Recommendations

8.1 Levels of police enforcement

- The majority of studies in the literature have found that increased levels of traffic policing have reduced road accidents and traffic violations. However, it is difficult in practice to establish the relationship between levels of policing and violation, accident or casualty rates. Unfortunately, it is not possible to establish the relationship by generalising across the studies in the literature because appropriate information about enforcement levels is not given consistently across the different studies. Some studies do provide limited information about the levels of enforcement required to have an effect on safety. It seems as though stopping every 1 in 6 offenders, for example, will have a noticeable effect (see section 6).

- Theory suggests that the relationship between levels of policing and accident/casualty rates is non-linear (see section 6). At zero enforcement level, accidents and casualties are expected to be at their highest levels. Increases in enforcement will have no noticeable effect at first but at a certain level, when drivers become aware of the increased police presence, accidents and casualties can be expected to drop up until a saturation point is reached, after which further increases in enforcement levels can be expected to have little or no effect.

- It will be a challenging and important task to establish the form of the relationship. This information will allow the likely implications for accidents and casualties to be taken into account when setting the level of traffic policing in an area. Section 9 outlines the type of research that would be needed to establish the relationship between policing levels and accident/casualty rates in London.

8.2 Methods of police enforcement

- On the basis of the literature it is possible to discriminate between stationary and mobile methods of traffic policing. Each method can involve visible policing in marked police vehicles or can involve the use of unmarked vehicles (see section 7). Stationary and highly visible policing appears to be the most effective method for reducing violations and accidents (see section 7.1.1), although stationary enforcement in unmarked vehicles has also been found to be effective (see section 7.1.2). Mobile policing methods are less effective, especially when unmarked police vehicles are used (see section 7.1.3).

- The effects of increased stationary enforcement of speed limits seem to last for a limited amount of time after the police presence has been removed. The largest time halo effects appear to be 8 weeks. However, sustained police presence is required to produce such large effects (see section 7.1.1). The distance halo effects of stationary policing appear to be in the range of 1.5 miles to 5 miles of the enforcement site (also see section 7.1.1).

- There is evidence in favour of deploying traffic police largely at random over the whole road network. Theoretically it is likely to increase deterrence. In practice, the random allocation of stationary policing methods to different locations on the road network has been found to be effective, producing substantial impacts on accident rates and reductions in mean speeds and large distance halo effects. The main advantage of this method of traffic policing is that it requires relatively low levels of police manpower.

- Speed cameras (see section 7.1.4) have been found to be particularly effective enforcement tools. They appear to be more effective than physical policing methods in reducing mean speeds and accidents. However, the effects of speed cameras appear to be mainly limited to the speed camera site and physical policing methods have still been found to be effective. On the basis of the reviewed literature, the minimum distance halo effects associated with physical policing are about 5 times greater than the minimum distance halo effects associated with speed cameras.

- Studies of the enforcement of drink-driving violations (see section 7.2) have also shown that increased policing using random breath testing tends to reduce violations and accidents.

- Red light running cameras have been found to be very effective in reducing violations and accidents (see section 7.3). The best estimate for the effects of red light cameras is between 25 to 30% reduction in injury accidents at speed camera sites.

- Though few studies have investigated the effects of seat belt enforcement on accidents, a number of studies have found that increased enforcement of seatbelt laws can result in increased wearing rates, which is likely to reduce the numbers of road accident casualties (see section 7.4).

9 Proposal for a project to investigate how levels of policing affect road accidents and casualties in London

As described earlier in this report, new research is required to fully answer the question of how levels of policing affect road traffic casualties in London. A proposal for an appropriate research project will now be presented.

9.1 Background and objectives

Transport for London wishes to know how increasing the level of traffic policing is likely to affect the numbers of road accidents and casualties in London. It has been found, however, that the relationship between an increase in the level of policing and a reduction in accidents or casualties cannot be derived from the existing literature. It is impractical to generalise from previous research studies using meta analytic techniques because measures of enforcement levels are not consistently provided by the different studies. Furthermore, the majority of studies in the literature have been conducted outside the UK and few studies have assessed the effects of traffic policing in busy urban areas such as London. Those that have been conducted in the UK are either small scale studies that investigated the effects of policing on a limited number of roads (e.g. Holland & Conner, 1996) or were conducted many years ago (e.g. Munden, 1960).

New research conducted specifically in London is needed to identify how the level of policing in London affects the number of accidents and casualties. The results of this research would allow the likely implications for accidents and casualties to be taken into account when adjusting the level of traffic policing in any part of London. The research would require the commitment and co-operation of the Metropolitan Police Service and the City Police, working in partnership with TfL and possibly other stakeholders.

9.2 Research method

The first phase of the research would be to investigate what statistics are currently collected by the police that would allow the level of traffic policing to be measured within each operational area. On the basis of this research, an appropriate measure of enforcement would be defined.

A number of study areas in London would then be selected for the main phase of the research. Analysis of past accident and casualty data will help to identify the number and size of areas that would be required to identify changes with an appropriate level of statistical confidence. These ‘treatment’ areas would be subject to various increases in traffic policing (e.g. 2x, 3x, 4x their base levels) over a substantial period of time (e.g. 3 months). At the end of this period, traffic policing would return to its previous level. Suitable control areas in London would also be identified in which the level of police activity would not change.

The following data would be needed from the treatment and control areas:

- Information about the base level of traffic policing in each area (i.e. prior to any increase in enforcement levels).
- Information about the levels of traffic policing in each area during the experimental phase (i.e. once enforcement levels had risen in the treatment areas).

- Accident and casualty data for each area for several years prior to the experimental phase (available from the regular STATS19 accident reporting system).
- Accident and casualty data for each area during the experimental phase to establish the changes associated with the increased enforcement.
- Accident and casualty data in each area for a number of months after the experimental phase to establish how long the effects of the increased policing last once the policing levels return to their base levels.
- Corresponding accident and casualty data from areas adjacent to the treatment areas.

Appropriate Time Series Models would be fitted to the accident and casualty data to identify the changes that had occurred in each treatment area. The results would be compared with the measures of traffic policing, to produce a function of the form illustrated in Figure 1. These models would also show whether there had been time halo effects, i.e. safety benefits that lasted after the end of the increased policing. Modelling of accident and casualty data from areas adjacent to the treatment areas would show whether there had been distance halo effects, i.e. safety benefits in areas where policing had not increased.

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Appendix A. Summary of stationary and visible methods for enforcing speed limits

The majority of studies have examined the effects of stationary and visible methods of physical policing on speeding violations and accidents. Table A1 summarises the results of the studies conducted to investigate the effects on speeding violations and mean speeds. Table A2 summarises the studies in which the effects of enforcement on accident rates have been investigated. It should be noted that, in some studies, other methods of enforcement have been used in combination with the stationary methods. However, the stationary method of policing comprised the majority of the enforcement effort and assessing the effectiveness of the other methods independently of the stationary enforcement is not possible on the basis of these studies. It should also be noted that some of the studies have evaluated enforcement programmes designed to target violations generally, not only speeding. However, speed enforcement has been a major part of these programmes and it is not possible on the basis of these studies to estimate the accident reductions due to the enforcement of different types of driving violations separately.

Table A1. Effects on speed violations

Study	Road/area type	Condition	Percentage change in proportion of drivers exceeding speed limit	Changes in mean speeds
De Waard & Rooijers (1994) The Netherlands	Motorway	Treatment Control	-3 to -30 +12 to +14	+0.6km/h to -5.2km/h +0.5km/h
Sisiopiku & Patel (1999) USA	70mph highway	Treatment compared with control	-	-4.8km/h to -8.0km/h
Leggett (1988) Australia	3 110km/h rural highways	Treatment Control	- -	-3.6km/h -0.5km/h
Hool et al. (1983) USA	55mph 2-lane highway and 55mph 4-lane interstate	Treatment groups compared with control groups	-3.3 and -2.6	-1.8mph and -1.6mph
Brackett & Beecher (1980) USA	55mph roads	Treatment compared with control	-9	-1.8%
Vaa (1997) Norway	60km/h and 80km/h roads through rural and urban areas	Treatment groups compared with control groups	-12 to -34	-
Salusjarvi & Makinen (1988) [a]	60km/h and 80km/h roads	-	-7 to -25	-
Hauer, Ahlin & Bowser (1982) Canada	60km/h semi-rural 2-lane roads	Treatment compared with control	-	-14.4km/h to -15.9km/h
Holland & Conner (1996) UK	40mph urban road	Treatment	-56 to -64	Not given
Stuster (1995)	2 residential communities	Treatment Control	-10 to -19 -3	- -
Munden (1966) UK	30mph urban roads	Treatment Control	-35 +10	- -
Roop & Brackett (1980) USA	Rural roads	Treatment	-15	-1.8km/h
Edwards & Brackett (1978) USA	Rural roads	Treatment	-	-4.8km/h
Aberg (1983) [a]	Unknown	-	No effect	No effect
Ekstrom, Kritz & Stromgren (1966) [a]	Unknown	-	-13	-

[a] = Information about these studies was not obtained from the original report but from other references which did not specify the exact enforcement methods used (studies that have been classified as those using mainly stationary enforcement methods may have used stationary methods only).

Table A2. Effects on accidents

Study	Area	Percentage change in all accidents	Percentage change in fatal accidents	Percentage change in serious accidents	Percentage change in slight accidents
Leggett (1988) [a] Australia	3 110km/h highways	-17	-28	-62	+50
Brackett & Beecher (1980) [a] USA	55mph roads	-11.5	-15	-	-
Munden (1966) [a] UK	30mph urban roads	-24	-21		-25
Hakkert et al. (2001) [a] Israel	700km of urban roads	-	+10 to -48		-
Hauer & Cooper (1977) [b] Canada	Road in Metropolitan Toronto	-3	-	-	-
Sali (1983) [a] USA	City wide enforcement in Boise (Idaho)	-17	-	-	-
Carr et al. (1980) [b] USA	City wide enforcement in Kansas	No effect	No effect	No effect	No effect
Fuller (2002) [a] Ireland	One police divisional area in Ireland	-	No effect	Casualties reduced by 18%	Casualties reduced by 9%
Stuster (1995) [b] USA	2 residential communities	-1.1 to -10.3 (note that a control area = +3.4)			
Roop & Brackett (1980) [a] USA	Rural roads	-16 to -18	-6		-
O'Brien (1980) [a]	Rural roads	-	-27		-

Table A2 continued

Study	Area	Percentage change in all accidents	Percentage change in fatal accidents	Percentage change in serious accidents	Percentage change in slight accidents
Newstead, Cameron & Leggett (2001) [a] Australia	All urban areas in Queensland All rural areas in Queensland	-15 to -21 -4.8 to +5.1	-26 to -60 -34 to +133.5	-4.1 to -20.6 -4.1 to -7.8	- -
Aberg (1983) [c]	Unknown	-11 to -19	-	-	-
Engdahl & Nilsson (1983) [c]	Unknown	+11	-	-	-
Salusjarvi & Makinen (1988) [c]	Unknown	+2 to -11	-	-	-

[a] = net change in accidents (i.e. in relation to control sites)

[b] = Simple before/after change in accidents (i.e. no control site comparison)

[c] = Study cited for a secondary source – not known whether there was a control site

Appendix B. Summary of studies of time and distance halo effects

Table B1. Time and distance halo effects

Study/Country	Area	Enforcement details	Time halo effect	Distance halo effect
Hool, Maghsoodloo, Veren & Brown (1983) USA	2-lane highway 4-lane interstate	Visible stationary		3-5 miles
Sisiopiku and Patel (1999) USA	2- lane highway	Visible stationary for 6 days	1 hour	
Cooper (1975) USA	Urban junctions	Visible Stationary	No halo effect	
Holland & Conner (1996) UK	Urban	Visible stationary enforcement for one week	2 weeks	
Edwards & Brackett (1978) USA	rural	4 weeks of low intensity random enforcement	-	22km (14 miles)
Brackett & Beecher (1980) USA	rural	18 months of low intensity random enforcement	-	22km (14 miles)
Hauer, Ahlin & Bowser (1982) Canada	rural	Visible/Stationary enforcement for 5 days Visible stationary enforcement for 2 days separated by 3 days	6 days 3 days	2.4 km Effects of enforcement reduced by half for every 900 metres after enforcement site
Vaa (1997)	rural & urban	6 weeks of enforcement. Several enforcement techniques used	2-8 weeks No time halo effect between 0600-0900hrs	
Engdahl & Nilsson (1983) Sweden	unknown	Several enforcement techniques used	14 days	

Appendix C. Summary of studies of speed cameras

Table C1. A selection of studies evaluating the impact of speed cameras

Study	Country	Percentage change in speeding violations/ reductions in mean speed	Percentage change in injury accidents	Percentage change in casualties
Swali (1993)	England (London)	-5mph	-19 (All)	-29 (Fatal/serious) -20 (All)
Leithead (1997)	England (London)		-36 (Fatal/serious) -8 (Slight) -14 (All)	
London Accident Analysis Unit (1997)	England (London)			-55 (All)
Gains (2001).	England	-71 / -5.6mph	-35 (All)	-47 (Fatal/serious)
DfT (2003)	England			-35 (Fatal/Serious)
Hess (2004)	England		-45 (All)	

Appendix D. Summary of studies of drink-driving enforcement

Table D1. Effects of drink-driving policing (study summaries)

Study	Percent change in violations	Percentage change in accidents
Ross (1977) [b] UK	-	All serious or fatal accidents: -28% All serious or fatal accidents during drinking hours: -35% All serious or fatal accidents during non-drinking hours: -2%
Cameron et al. (1981) [a] Australia	-	Fatal night time accidents at weekends: -54% Serious night time injury accidents (no differences between different nights of the week): -25% Casualties from single vehicle accidents: -18% Casualties from multi vehicle accidents: -10%
Cameron & Strang (1982) [a] Australia	-	Serious night time accidents: -24%
Amick & Marshall (1983) [b] USA	-	Night time injury accidents: -4.6% (0% to +4.5% at control sites)
Arthurson (1985) [c] Australia	-	Fatal night time accidents: -21%
Federal Office for Road Safety (1986) [a] Australia	-	Fatal accidents: -42% Injury accidents: -29%
Voas & Hause (1987) [b] USA	-43%	Night time weekend accidents: -15% (-8% to +10% at control sites) Night time weekday accidents: -10% (-2% to +8% at control sites)
Kearnes et al. (1987) [a] Australia	-	All fatal accidents: -20% All night time week end accidents: -40%
Homel (1988) [a] Australia	-	All fatal accidents: -20.6

Table D1 continued

Study	Percent change in violations	Percentage change in accidents
Verschuur & Noordzij (1988) [b] The Netherlands	-30% control = +164%	-
Span & Stainislaw (1995)[a] Australia	-	All accidents in Sydney: -27.5% All accidents in NSW: -23.5% All injury accidents in NSW -24.5%

[a] = net change in accidents (e.g. in relation to a control site or in the case of night time accidents, a net reduction could be in relation to daytime accidents in the same area);

[b] = simple before after change in accidents (i.e. no control group; but note that details of changes in accidents/violations in control sites are provided for some of these studies in the table)

[c] = Study cited from a secondary source – not known whether there was a control site

Appendix E. Summary of studies of red light cameras

Table E1. Studies of effects of red light cameras on violations (Retting et al., 2003)

Study	Country	Study sites	Percentage change
Chin (1989)	Singapore	23 camera sites	-42
		20 non-camera sites	-27
		14 control sites	+17
Thompson et al. (1989)	Great Britain	Camera site 1	-22
		Camera site 2	+13
Arup (1992)	Australia	3 camera sites	-78
		3 non-camera sites	-67
Oei et al. (1997)	The Netherlands	4 camera sites	-56
Retting et al. (1999a)	USA	5 camera sites	-44
		2 non-camera sites	-34
		2 control sites	+5
Retting et al. (1999b)	USA	9 camera sites	-40
		3 non-camera sites	-50
		2 control sites	-4

Table E2. Estimated percentage change in accidents due to red light cameras

Study	Country	Treatment sites	Comparison sites	Total accidents	Injury accidents	Right-angle accidents		Rear-end accidents	
						Total	Injury	Total	Injury
South et al. (1988)	Australia	46 camera sites	46 non-camera sites	-	-7	-	-32	-	-31
Office of Road Safety (1991)	Australia	15 camera sites	All other signalised junctions in area	-8	-23	-38	-54	+14	+25
Mann et al. (1994)	Australia	8 camera sites	14 non camera sites	+6	-20	+8	-26	+12	-1
Queensland Transport (1995)	Australia	79 camera sites	All other signalised junctions in area	-48	-46	-	-	-	-
Andrassen (1995)	Australia	41 camera sites	All other signalised junctions in area	+7	-	-13	-	+20	-
Hillier et al. (1993)	Australia	16 camera sites	16 non-camera sites	-8	-26	+29	-	+108	-
Ng et al. (1997)	Singapore	42 camera sites	42 non-camera sites	-	-9	-	-10	-	+6
Retting & Kyeychenko (2002)	USA	125 signalised junctions where 11 junctions were equipped with cameras	Non-signalised junctions in same area & in 3 other cities	-7	-29	-32	-68	+3	-

Appendix F. Technical Annex

This technical annex provides summaries of all studies of police enforcement that were reviewed for this project.

Table F1: Studies mainly investigating the effect of policing on speeding violations and accidents

Reference and country of study	Study details Enforcement type and level (if specified)	Results
Aberg (1983) Sweden	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of enforcement on speeding violation rate and the change in accident rate.	Increase in enforcement of a factor of 2-3. 11% reduction in accident rate. Increase in enforcement of a factor of 3-5. 12% reduction in accident rate. Increase in enforcement of a factor of 5-8. 19% reduction in accident rate. No change in speed violations but very high speeds reduced.
Brackett & Beecher (1980) Texas, USA	Cited in European Transport Safety Council report (1999). The effect of stationary enforcement was investigated. The enforcement of speed by stationary radar (operated from a visible marked police car) was used on 24 roads. These test roads were compared with 24 roads where this police activity was not present (amount of enforcement on control roads not stated). On the test roads, the enforcement sites and the time of day when enforcement was provided were chosen at random. The study lasted 18 months.	1.8% reduction in driving speed was found. There was a 9% reduction in the number of drivers exceeding the speed limit (55mph). Injury accidents were reduced by 11.5% Fatal accidents were reduced by 15% Property damage only accidents were reduced by 3% The effects of enforcement on speeds extended to 14 miles from the enforcement sites.
Brackett & Edwards (1977) USA	Cited in Bjornskau and Elvik (1992). Low intensity enforcement on rural roads was used. A marked police car moved from site to site in a random fashion in order to give the impression of massive enforcement (stationary/visible enforcement). Vehicle hours of patrol per day = 0.86. Km enforced per vehicle hour per day = 31.5 Length of patrolled routes = 27km Programme evaluated for 4 weeks	The effects of enforcement extended to 22km from each site where the vehicle was parked. Speed reductions = 4.8km/h
Carr, Schnelle & Kirchner (1980)	Retrospective quasi-experimental reversal design used to examine effects of increases and decreases in police traffic enforcement on the frequency and	Results given in graphs – not possible to extract numbers.

USA	severity of traffic accidents in a metropolitan area. Publicity = YES Control group used = NO	But the authors conclude that there was no effect of enforcement levels on accidents.
Chen et al (2000) Canada	Automatic Speed enforcement investigated in British Columbia Special speed enforcement police teams operating 30 unmarked vans equipped with photo-radar linked to a laptop computer. Speed violators (11km/h over speed limit) sent fine in post. First 5 months – drivers issued warning letters. After this time, violation citation tickets issued. In the 1st year of operation photo-radar units were deployed for approx. 30,000 hours and issued 250,000 citations. Accident data for 4.5 years prior to the enforcement programme were collected and compared with accident data during the 1st year of programme operation. A major education and media campaign accompanied the programme.	Speeds as measured at enforcement sites: Reduced from 66% of people exceeding posted speed limit to 33% during programme. At 19 independent monitoring sites not near the enforcement (sites in the same province), 69% of people exceeding posted speed limit to 61% during programme 2.4km/h reduction in mean speeds at selected monitoring sites Estimated that: 25% reduction in speed related accidents 17% reduction in fatalities 11% reduction in serious casualties
Chen et al. (2002) Canada	Automatic Speed enforcement investigated in British Columbia Special speed enforcement police teams operating 30 unmarked vans equipped with photo-radar linked to a laptop computer. Speed violators (11km/h over speed limit) sent fine in post. This study conducted 2 years after start of programme to investigate its effects on a selected highway corridor (22km long – 4-lane divided highway with speed limits 80-90km/h running through rural and light residential land). 9 locations used for parking the enforcement van and 1km each side was considered to be the photo-radar zone of influence. Enforcement random in time and location. Control group = non photo-radar zones (i.e. in between the photo-radar zones) & another group of roads were used from highways similar to the experimental one.	Mean speeds reduced by 2.8km/h (3% reduction) Taking the control roads into account: The enforced segments of the corridor experienced an accident reduction of 14% (+-11%) The non-enforced segments of the corridor experienced an accident reduction of 19% (+-10%) The corridor as a whole experienced an accident reduction of 16% (+-7%)

	Deployment hours = 1312.9 Analysis = all accidents (collisions) 2 years before compared with accidents 2 years after programme started.	
Christie & Downing (1989) UK	In July 1988 the Police launched a campaign to improve drivers' behaviour on motorways and help reduce accidents. It involved publicity and increasing levels of police presence and enforcement on motorways. Mean speeds of vehicles and % of traffic close following (headway between vehicles of less than 2 seconds) were recorded before the campaign and during at sites on the M6, M3, M4 and M1. The enforcement level on the M6 and M4 was defined as being "high" and on the M4 and M3 and M1 it was defined as being "low". No definition of what was meant by "high" and "low" enforcement was provided in the report. Mean speeds and % of total flow close following in the off-side, centre and nearside lanes of the motorways measured	Mean speed changes: M6 (High enforcement level) • Offside lane = 0.82mph reduction • Centre lane = 0.30mph reduction • Nearside lane = 0.12mph reduction M3 (Low enforcement level) • Offside lane = 0.6mph increase • Centre lane = 0.13mph reduction • Nearside lane = 0.06mph increase M4 (High enforcement level) • Offside lane = 1.16mph reduction • Centre lane = 1.2mph reduction • Nearside lane = 0.44mph reduction M1 (Low enforcement level) • Offside lane = 6.74mph increase • Centre lane = 1.04mph reduction • Nearside lane = 0.52mph reduction Changes in % of total flow close following: M6 (High enforcement level) • Offside lane = 2.6% increase • Centre lane = 4.4% increase • Nearside lane = 1% increase M3 (Low enforcement level) • Offside lane = 0.81% increase • Centre lane = 1.8% increase • Nearside lane = 0.34% increase M4 (High enforcement level) • Offside lane = 0.56% reduction • Centre lane = 1.92% increase • Nearside lane = 0.65% increase M1 (Low enforcement level) • Offside lane = 5.07% reduction • Centre lane = 3.5% reduction • Nearside lane = 0.97% reduction
Cooper (1975) USA	Highly visible Police motorcycle officers used at urban intersections. The number of officers stationed at an intersection at any given time was limited to a maximum of two. Duration of enforcement – 3 levels: 60, 120, 180 minutes per day Magnitude of effort – 1 or 2 officers This gave 6 signalised junctions chosen for study (in addition 1 control junction was used) 2 weeks of data collection prior to intervention 4 weeks of data collection during intervention 2 weeks of data collection after intervention	Data presented in graphs and no numbers provided in the text. Control location showed no change in numbers of violations per day. At the study sites, on the days of police presence, the numbers of violations per day reduced from what they were before and what they were after (for 3 sites, the results were statistically significant). The decreases due to police presence were immediate as were the increases after police presence was removed, suggesting no time halo effect. At the study sites, at the times of police presence, the numbers of violations per day reduced from what they were before and what they were after. The difference between violation rates when police were present and when they were not present was statistically significant for 3 sites.

		There was a significant reduction in violation rate due to 60 minutes per day of enforcement with one police officer (about 27%). There was no further decreases in violation rates due to having 120 or 180 minutes per day of enforcement with more than one police officer.
De Waard and Rooijers (1994) The Netherlands	The study examined the effects of intensity and method of law enforcement on driving speeds on motorways. Three levels of enforcement intensity were examined. Each involved physical police presence – stopped speeding offenders at the road side: (1) stopping every 100th offender (2) stopping every 25th offender (3) stopping every 6th offender Two methods of law enforcement were examined: (1) stopping every 6th offender at the roadside (2) sending every 6th offender a speeding fine in the post (3) sending every 6th offender a speeding fine in the post preceded by a feedback letter (a letter sent as soon as possible after the offence stating that they were about to receive a speeding fine) The enforcement period lasted one month. Speed data were collected for vehicles travelling in the right ("slow lane") and left ("fast lane") lanes of the motorway. Speed data were collected for 4 weeks during the enforcement, two weeks prior to enforcement and 4 consecutive weeks after the enforcement period had finished.	At the control site (no enforcement) there was a small non-significant increase in mean driving speeds (between 0.5 and 0.8km/h). The %age of cars travelling faster than 130km/h was between 7.3% and 15.5% pre-enforcement and during enforcement it was between 8.3% and 18%. Post-enforcement, the %age of cars travelling faster than 130km/h was between 7.2% and 16.6%. There was no effect of enforcement on driving speed when every 100th offender was stopped by the police. Speed changes from pre-enforcement to during enforcement were between 0.6 increase and 0.2km/h decrease. Figures on the %age of card travelling faster than 130km/h were not given for the pre-enforcement period. When every 25th offender was stopped, there was a significant effect. Speed reductions from pre-enforcement to during enforcement were between 0.6 and 1.2. Before the enforcement period, the %age of cars travelling faster than 130km/h was between 9.0% and 23.3%. During the enforcement period it was between 8.1 and 22.7%. After the enforcement period ended, it was between 12.2% and 26.9%. When every 6th offender was stopped the average speed was reduced by between 2.7 and 5.2km/h. The %age of cars travelling faster than 130km/h was 19.9% (in the right lane only – data for the left lane were not given due to missing data). During the enforcement period it was 14.4% and after the period it was 17.8%. After the enforcement period ended, mean speeds began to increase to what they were pre-enforcement but in the 1:6 condition mean speeds remained about 2km/h slower than they were pre-enforcement. When every 6th offender was sent a speeding fine in the post the speed reduction was between 1.4 and 2.6km/h. However, the mean speeds increased after the enforcement period ended to what there were pre-enforcement. The proportion of people speeding (130km/h or more) was between 9.4% and 23.8% pre-enforcement, between 5.6 and 16.2 during enforcement and between 7.8% and 21.9% post enforcement. When every 6th offender was sent a speeding fine preceded by a feedback letter the

		speed reduction was between 2.7 and 5.5 but mean speeds increased after the enforcement period ended to what there were pre-enforcement. The proportion of people speeding (130km/h or more) was between 8.1% and 23.9% pre-enforcement, between 5.4 and 17.6 during enforcement and between 9.4% and 24.3% post enforcement.
Ekstrom, Kritz & Stromgren (1966)	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of enforcement on speeding violation rate (but enforcement was directed towards all violations) and on accident rate.	Increase in enforcement of a factor of 3 Reduction in speeding violation rate of -13% Reduction in accident rate = 21% to 37%.
Engdahl & Nilsson (1983)	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of speed enforcement on accident rates.	11% increase in accident rate. Drivers who pass an enforcement site reduce their speed when passing the same site for a period of 14 days. Enforcement conducted by means of unmarked cars did not produce any lasting effects
Fuller (2001) Ireland	Evaluation of Operation Lifesaver – a high visibility enforcement campaign implemented in one area in the Republic of Ireland (covering urban, rural and motorway roads). Hours of road traffic enforcement was 7% greater in the treatment area compared with a control area. Increases in the number of traffic offences for which proceedings taken and in the proportion of speeding detections and prosecutions for non-wearing of seatbelts (details given in graphs for treatment and control areas). Media campaigns = YES	Before/after effects: 39% drop in fatalities 24% drop in serious injuries 26% increase in minor injuries 4.5% increase in compliance with speed limits Before/after effects compared with control site no change in fatalities 18% drop in serious injuries (NS) 9% drop in slight casualties (NS) Compliance with speed limits on motorways in treatment versus control areas = 7.7% increase and 3.3% increase, respectively.
Hakkert, Gitelman, Cohen, Doveh & Umansky (2001).	Concentrated police enforcement by National Traffic Police (NTP) on “preferred” road sections – about 700km (some 20%) of interurban roads which contained some 60% of all interurban accidents and about half of all severe rural accident locations	Violation rates before and during project: • Speed data measured before project only – cannot identify speed changes.

Israel	11-14% increase in police staff and vehicle fleet 15% supplement of enforcement tools General enforcement programme – all violations. Accompanying publicity used. Project monitored for 1 year. The 700km of project roads divided into: Highest priority (AA; 270km;), and High priority (A). B-priority given to all roads outside project area. Police intensity figures given in paper: 1. no. of patrol units in project area during a regular weekday shift = 60 2. no. of patrol units in project area during a regular weekend shift = 30+ 3. no. of patrol units in project area during a regular night shift = 9-12 4. Average monthly amount of patrol units in all shifts was 4000 – in project area = 2700 5. In about 28% of the shifts, an electronic enforcement device was used 6. Every road section in project area was patrolled for about1800 hours per month 7. Not possible to work out the % of mobile versus stationary – most violations though were apprehended by stationary enforcement methods 8. Average monthly citations in project area = 24000 (82% of the total number of citations made by NTP (9 citations per shift on average in the project area compared with 7.7 in the whole territory under the NTP responsibility; these do not include automatic enforcement citations) 9. 5.3 citations per shift produced by laser speed gun and 2.7 per shift with a radar speed metre. Police resources – during the shifts on the project roads = 70% devoted to field enforcement, 4% to traffic directing, 2% to accident treatment. The rest of the time was spent on other operations. Violations and accidents were measured before project and during project	• Signalling for turning = 27% / 28.5% • Compliance to “yield” sign = 32.7% / 19.5% • Turn performance = 9.1% / 4.3% • Compliance with “stop” sign = 34.2% / 30.5% • Drivers’ use of seat belts = 12% / 5.3% • Front seat passenger use of seat belts = 13.9% / 4.9% Accidents – serious and fatal: Odds ratios calculated for project roads and non-project roads (after/before). Compared with comparison group the results for the project roads showed a: • 10% increase in accidents in northern areas of the NTP territory where higher enforcement took place • 39% reduction in accidents in central areas NTP territory where higher enforcement took place • 22% reduction in accidents in southern areas NTP territory where higher enforcement took place • 17% reduction in accidents in northern areas NTP territory where lower enforcement took place • 48% reduction in accidents in central areas NTP territory where lower enforcement took place Note: No definition of what was meant by “higher” and “lower” enforcement was given.
Hauer & Cooper	Area-wide effects of selective enforcement on accidents investigated	After locations appeared on the HAL list, there was a reduction in accidents of

(1977) USA	Accident records of 1800 locations over a 4 year period examined in Metropolitan Toronto. The top 20 accident locations put on a list (High Accident Location List – HAL) and given to police districts every 28 days. Police pay special enforcement attention to those locations (no details available about levels of enforcement and methods)	approximately 3%.
Hauer, Ahlin and Bowser (1982) Canada	Four experiments were conducted, each with its own control site (with no enforcement), to test the effects of stationary enforcement. In each experiment a marked police car was used that had a window mounted radar unit fully visible to passing motorists. Police did not issue any speeding tickets. Speeds were measured at the "enforcement site" and at sites "upstream" and "downstream" (1-2.5km) from the enforcement site. All experiments took place on semi-rural 2-lane roads. In each experiment speed data were collected for 2.5hrs per day for 5 weeks (weekdays only). Experiment 1. Police car visible well in advance (915 metres). Police car present for 1 day. Speed limit = 80km/h. Upstream site was 1938 metres from enforcement site; downstream site was 1398 metres. Speed data collected between 7.00-9.30am. Experiment 2. Police car visible 308 metres before passing over speed censors. Police car present for 1 day. Speed limit = 80km/h. Upstream site was 571 metres from enforcement site; downstream site was 2338 metres. Speed data collected between 4.00-6.30pm. Experiment 3. Police car visible 193 metres before passing over speed censors. Police car present for 5 consecutive days. Speed limit = 60km/h. Upstream site was 504 metres from enforcement site; downstream site was 1124 metres. Speed data collected between 7.00-9.30am. Experiment 4. Police car visible 237 metres before passing over speed censors. Police car present for 2 days with 3 days in between with no police presence. Speed limit = 60km/h. Upstream site was 290 metres from enforcement site; downstream site	Due to insufficient data a number of speed measures were not possible to calculate from experiments 1 and 2. Full data were available from experiments 3 and 4. Experiment 3. At enforcement site: • Mean speeds before police presence = 73.7km/h • Mean speeds during police presence = 59.3km/h • Mean speeds after police presence = 67.4km/h At downstream site: • Mean speeds before police presence = 74.5km/h • Mean speeds during police presence = 68.3km/h • Mean speeds after police presence = 70.8km/h Time halo effect = speed reductions lasted 6 days after the last day of police presence. Experiment 4. At enforcement site: • Mean speeds before police presence = 78.2km/h • Mean speeds during police presence = 62.3km/h (day1) and 60.6km/h (day2) • Mean speeds after police presence = 76.9km/h At downstream site: • Mean speeds before police presence = 74.5km/h • Mean speeds during police presence = 68.3km/h • Mean speeds after police presence = 70.8km/h Time halo effect = speed reductions lasted 3 days after police presence.

	was 742 metres. Speed data collected between 2.30-5.00pm.	On the basis of all experiments, it was calculated that the distance halo effect = the effect of police presence is reduced by a half for every 900metres downstream from the police presence.
Holland & Conner (1996) UK	Investigated the effect of police warning signs ("Police Speed Check Area") alone and with police presence. A busy urban road selected for study (2 mile stretch of dual carriageway with speed limit of 40mph). Eastbound direction – drivers were coming from several miles of 30 or 40 mph roads. Westbound direction – drivers were coming from a 70mph 'bypass'. The speeds of vehicles travelling along the road were measured: (1) prior to any intervention (week 1), (2) following the erection of police warning signs (2 signs in each direction; week 2), (3) following the introduction of police presence and activity (in both directions of the road) and continued presence of warning signs (week 3), (4) following the removal of police presence (i.e. signs remained; week 4), (5) following removal of signs (week 5). There was then a 6 week interval. Speeds were again measured with no intervention (week 12). Warning signs were re-erected and speed measures were taken (week 13). POLICE PRESENCE & ACTIVITY = individual police officers recorded speeds of vehicles exceeding speed limit using radar equipment operated from stationary police vehicles and noted the age and sex of drivers they stopped. Drivers were given either a verbal warning, fine at point, or report for prosecution.	In the east bound direction, the %age of drivers exceeding the speed limit by 5mph or more was: (1) 30.9% in the week prior to intervention (week 1) (2) 21.2% in the week following the erection of the police signs (week 2) (3) 13.5% in the week of police activity (week 3) (4) 17.9% in the week following the removal of police activity (week 4) (5) 24.1% in the week where the signs were removed (week 5) (6) 27.0% in the week where speeds were again measured with no intervention (week 12) (7) 27.9 when warning signs were re-erected (week 13) In the west bound direction, the %age of drivers exceeding the speed limit by 5mph or more was: (1) 29.6% in the week prior to intervention (week 1) (2) 15.9% in the week following the erection of the police signs (week 2) (3) 10.7% in the week of police activity (week 3) (4) 14.1% in the week following the removal of police activity (week 4) (5) 24.3% in the week where the signs were removed (week 5) (6) 27.8% in the week where speeds were again measured with no intervention (week 12) (7) 28.5 when warning signs were re-erected (week 13)
Hool, Maghsoodloo, Veren and Brown (1983) USA	Selective enforcement effects on rural traffic speeds investigated A dual-lane highway and a four-lane interstate investigated with matched control groups (all with 55pmh speed limits). Enforcement increase = funds were provided for overtime employment of 28 officers for a total of 3721 hours. Media advertising used.	Net speed reductions: 2-lane road: • SSM = 3.3% / 1.8mph • SMM = 3.5% / 1.9mph • SMU = 2.6% / 1.4mph • SSMM = 2.4% / 1.3mph • DSMM/MU = 2.2% / 1.2mph • DMM/MU = 1.3% / 0.7mph

	Methods used were: (1) Single stationary marked patrol vehicle (one vehicle randomly moved to different locations for 30 minute intervals) (SSM) (2) Single moving marked patrol vehicle (one vehicle moving at 40 to 45 mph patrol speed) (SMM) (3) Single stationary-moving marked patrol vehicle (combination of the above 2 methods – one vehicle stationary for 5 minutes then moved to random locations) (SSMM) (4) Single moving unmarked patrol vehicle (same as 2 but in unmarked an vehicle) (SMU) (5) Dual moving marked/moving unmarked patrol vehicle (combination of 2 and 4 – one marked and one unmarked vehicle) (DMM/MU) (6) Dual stationary-moving marked/moving unmarked patrol vehicle (combination of 3 and 4 – one of each). (DSMM/MU)	4-lane road: • SSM = 2.6% / 1.6mph • SMM = 1.5% / 0.9mph • SMU = % Figure not given because not statistically a significant reduction / 0.1mph increase • SSMM = 2.3% / 1.4mph • DSMM/MU = 2.5% / 1.5mph • DMM/MU = 1.5% / 0.9mph Significant differences were found between the enforcement methods. Distance halo effect of stationary enforcement: 2 lane road: Mean speeds gradually reduced from 5 miles upstream (i.e. as traffic approached the enforcement location), the gradually increased from 1 to 5 miles downstream. Halo effect was at least 5 miles on the downstream side and about 3-4 miles on the upstream side. 4 lane road: Mean speeds approximately 0.15mph/mile from 5 miles to 1 mile upstream, the dropped sharply with 0.5 miles of the police vehicle. Mean speeds increased about 0.7mph/mile after vehicles passed the police vehicle and the halo effect diminished after approximately 3 miles downstream.
Keall et al. (2001). New Zealand	Before/After study with control group comparison. Hidden speed cameras (operated from manned unmarked police vehicles) used on 100kn/h speed limit (rural) roads. They replaced the traditional visible ones There was a 4% increase in the numbers of vehicles photographed speeding following installation of the cameras but "ticketing rates" not known. Publicity accompanied the intervention Accidents, mean speeds and 85th, 90th and 95th percentile speeds measured. The effects on speeds and accidents evaluated over the first year of the study compared with the four previous years.	*Net speed reductions (i.e. reductions at trial area compared with control area)* In speed camera areas: • Mean speeds reduced by 2.3km/h ($p < .01$) • 85th %ile speeds reduced by 2.9km/h ($p < .01$) • 90th %ile speeds reduced by 2.3km/h ($p < .01$) • 95th %ile speeds reduced by 2.3km/h ($p < .01$) On all roads in trial area: • Net mean speeds reduced by 1.6km/h ($p < .01$) • Net 85th %ile speeds reduced by 4.0km/h ($p < .05$) • Net 90th %ile speeds reduced by 4.5km/h ($p < .05$) • Net 95th %ile speeds reduced by 3.5km/h ($p < .05$) *Net Accident reductions (i.e. reductions at trial area compared with control area)*

		In speed camera area: • Accidents reduced by 22% ($p < .10$) • Casualties reduced by 29% ($p < .10$) • Casualties per accident reduced by 9% ($p < .01$) On all road in trial area: • Accidents reduced by 11% ($p < .05$) • Casualties reduced by 19% ($p < .01$) • Casualties per accident reduced by 8% ($p < .05$)
Keall et al. (2002). New Zealand	Before/After study with control group comparison. Follow-up to the above study with the effects on speeds and accidents evaluated over the first two years of the study compared with the four previous years.	*Net speed reductions (i.e. reductions at trial sites compared with control sites)* At speed camera sites: • Results over first year only were given (see above) On all roads in trial area: • Net mean speeds reduced by 1.3km/h ($p < .05$) • Net 85th %ile speeds reduced by 4.3km/h ($p < .01$) • Net 90th %ile speeds reduced by 5.0km/h ($p < .01$) • Net 95th %ile speeds reduced by 3.7km/h ($p < .01$) *Net Accident reductions (i.e. reductions at trial sites compared with control sites)* At speed camera sites: • Accidents reduced by 17% • Casualties reduced by 31% ($p < .05$) • Casualties per accident reduced by 11% ($p < .01$) At speed camera sites: • Accidents reduced by 11% ($p < .05$) • Casualties reduced by 19% ($p < .01$) • Casualties per accident reduced by 9% ($p < .01$)
Leggett (1988) Australia	Evaluated the effects on accidents of low intensity, long term police enforcement. One visible stationary police vehicle was used on each of three stretches of rural highway. On each of the three stretches, the police vehicle was randomly moved between different locations and was present for a two hour period during high accident frequency times of day. The enforcement programme lasted 2 years. Length of patrolled routes = 43km vehicle hours of patrol per day = 2.02	Enforcement period = 1500-2300hrs Non-enforced period = 2301-1459 All accidents (property damage, slight, serious, fatal): Trial sites during enforcement period = 12% increase Trial sites during remaining period = 54% increase Other rural sites during enforcement period = 27% increase Other rural sites remaining period = 53% increase Serious/Fatal accident:

	km enforced per vehicle hour per day = 21.2 There was no associated publicity.	Trial sites during enforcement period = 58% reduction Trial sites during remaining period = 33% increase Other rural sites during enforcement period = 4.2% reduction Other rural sites remaining period = 13.3% increase Mean speeds: Trial sites during 1900-2000hrs = 3.6km/h reduction Trial sites during 1100-1200hrs = 0.3km/h increase Other rural sites during 1900-2000hrs = 0.5 reduction Other rural sites during 100-1200hrs = 2.0km/h reduction
Lund & Jorgensen (1974)	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of enforcement on violation rate (enforcement was directed towards all violations but speeding an important part) and the change in accident rate.	Increase in enforcement of a factor of 3 Reduction in violation rate = no change Change in accident rate = no change
Lund, Brodersen & Jorgensen (1977)	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of enforcement on violation rate (enforcement was directed towards all violations but speeding an important part) and the change in accident rate.	Increase in enforcement of a factor of 5.5 Reduction in violation rate = 37% to 45% Change in accident rate = not given
Munden (1966) UK	Study examined the effect of enforcement on speeding violation rate and the change in accident rate. 6 urban and suburban sections of road used (30mph speed limits) with control groups. 1 road was subject to a change in speed limit which was likely to have produced a confounding factor and so has been excluded from this review. Same methods of police enforcement used in the study period as before (car and motorcycle patrols). Police man-hours increased by between 3.5 times at one site to 14 times at another during the first month of the study and generally these levels were maintained throughout the study. Period of enforcement = 12 months (8am to 11pm) For accident analysis, the before period was the previous 12 months (injury and damage accidents). For speed analysis, speeds were measured on each road on one day per month	Speed reductions across all sites: 35% reduction in mean speeds for cars and light goods vehicles. 24% reduction in mean speeds for heavy goods vehicles. In a control site, mean speeds increased over the same period, but no details were given in the paper about the control site – it is unlikely that it would have served as an appropriate comparison group for all 6 study roads. Accident reductions across all sites: Serious and fatal accidents: 21% Slight accidents: 29% All injury accidents: 26% Net accident reductions across all sites (i.e. compared with all control sites):

	during the study period and one day per month for the preceding three months. No publicity used.	Serious and fatal accidents: 21% Slight accidents: 25% All accidents: 24% Accident reductions (all injury accidents) by site by increase in enforcement level (increase in police man-hours) (Note that details of enforcement levels taken from graphs in the report and are approximate only. Also note that when the accidents before and during enforcement were split by site, the numbers were low. Thus the following results should be treated as indicative only): Site 1: 36% increase (3.5x increase in police man-hours) – control area = 7% reduction Site 2: 18% reduction (6x increase in police man-hours) – control area = 5% reduction Site 3: 26% reduction (7x increase in police man-hours) – control area = 9% reduction Site 4: 39% reduction (13x increase in police man-hours) – control area = 19% increase Site 5: 39% reduction (14x increase in police man-hours) – control area = 4% reduction
Newstead, Cameron & Leggett (2001) Australia	Low intensity random enforcement in Queensland called Random Road Watch (RRW) Involves dividing each police jurisdiction into a number of sections and the week into a number of time blocks. 0600 to midnight divided into 2 hour segments for enforcement. Sector to be visited and the time to be visited are assigned randomly. Enforcement involves conspicuous stationary marked police vehicle – may involve speeding detection device. From 1992 to 1997 RRW progressively introduced. Total hours of enforcement and number of offences detected not given in the ESCAPE paper = but it was reported that they did not have a significant impact on accidents.	Average net effect of RRW on accident frequency: All accidents: Non-metropolitan regions Rural areas: 4.8% reduction Urban areas: 15.0% reduction All areas: 11.2% reduction Metropolitan south regions Rural areas: 5.1% increase Urban areas: 20.8% reduction All areas: 17.4% reduction Fatal accidents: Non-metropolitan regions Rural areas: 34.3% reduction

		Urban areas: 25.7% reduction All areas: 31.0% reduction Metropolitan south regions Rural areas: 133.5% increase Urban areas: 60.0% reduction All areas: 14.3% reduction Serious accidents (hospitalisation): Non-metropolitan regions Rural areas: 4.1% reduction Urban areas: 20.6% reduction All areas: 13.2% reduction Metropolitan south regions Rural areas: 7.8% reduction Urban areas: 4.1% reduction All areas: 5.3% reduction Property damage accidents: Non-metropolitan regions Rural areas: 1.3% reduction Urban areas: 13.1% reduction All areas: 8.9% reduction Metropolitan south regions Rural areas: 33.9% increase Urban areas: 32.3% reduction All areas: 24.8% reduction
O'Brien (1980)	Cited in Leggett (1988) Routine enforcement at high accident times and locations (6 month evaluation) Vehicle hours of patrol per day = 266 Km enforced per vehicle hour per day = 8.4	Relative accident reduction (serious and fatal) = 27%

	Length of patrolled routes = 2226km Publicity - YES	
Roop & Backett (1980) USA	Cited in Bjornskau and Elvik (1992) & LEGGETT (1988). Study examined the effect of enforcement on speeding violation rate and the change in accident rate. Rural road. 1 year evaluation period. Routine enforcement at high accident times and locations. vehicle hours of patrol per day = 128 Km enforced per vehicle hour per day = 11.8 Length of patrolled routes = 1509km Publicity campaign also used	15% reduction in speeding violations. 1.8km/h reduction in mean speeds 16% to 18% reduction in accident rate. 6% relative reduction in serious and fatal accidents
Sali (1983) USA	Area-wide selective traffic enforcement project conducted in Boise (Idaho) – City. Enforcement and an extensive media campaign to reduce accidents used Evaluation conducted to determine accident reductions in first 22 months of programme. Enforcement directed at moving traffic violations generally. 8 officers hired in addition to the 4 officers already on staff to form a 12-man unit (supervised by 3 sergeants). 4 teams used which were assigned to specific geographic areas in the city (areas not specified). Citations for hazardous moving violations was estimated to have increased by about 100% and DUI arrests increased by about 200% per month during the study period.	17% reduction in injury accidents from the baseline compared with control group.

	Accidents in Boise compared with accidents occurring in the rest of Idaho	
Salusjarvi & Makinen (1988)	Cited in Bjornskau and Elvik (1992). Original report not in English. Study examined the effect of enforcement on speeding violation rate and the change in accident rate.	Increase in enforcement of a factor of 2.5 to 3.0 Reduction in 60km/h speed violations by 7% Reduction in 80km/h speed violations by 25% Change in accident rate = 2% increase to 11% reduction.
Shinar & McKnight (1985) USA	Cited in European Transport Safety Council report (1999). Effects of mobile enforcement in unmarked police cars	No evidence for an effect
Sisiopiku & Patel (1999) USA	Before/After study with control group Highway with a 70mph speed limit (2 lanes in each direction) Study covered 45km of the road Speed limit increased from 65mph to 70mph. 6 days of police enforcement – 2 patrol cars circulating in both directions of the highway at selected times (times not specified) Speeds measured when no police presence and when a marked highly visible stationary car was present in the same area.	Net changes in mean speeds across 4 sites: Site 1 (counter 3): 1 mile each side of police presence = 6.4km/h reduction 2 mile each side of police presence = 4.8km/h reduction 3 mile each side of police presence = 1.6km/h reduction Site 2 (counter 4): 1 mile each side of police presence = 8.0km/h reduction 2 mile each side of police presence = 6.4km/h reduction 3 mile each side of police presence = 1.6km/h increase Site 3 (counter 5): 1 mile each side of police presence = 4.8km/h reduction 2 mile each side of police presence = 8.0km/h reduction 3 mile each side of police presence = 6.4km/h reduction Site 4 (counter 6): 1 mile each side of police presence = No change 2 mile each side of police presence = 3.2km/h increase 3 mile each side of police presence = 3.2km/h increase Time halo effect: 1 hour after police presence
Stuster (1995) USA	Area-wide Speed enforcement programme in California – effects on speeds and accidents investigated.	In the experimental communities there was a 19% and 10% reduction in the number of vehicles exceeding the speed limit.

	3 comparable and separated communities took part in project which lasted 6 months In two communities police implemented special speed enforcement programmes (6 zones in each community) 3rd community was a control group. In experimental communities officers spent about 8 hours each week conducting manual speed enforcement (stationary) in each of the special enforcement zones. There were also public information and education activities related to the enforcement.	In the control community there was a reduction of 3% In experimental communities speed related accidents reduced by 10.3% and 1.1%. In the control community accidents increased by 3.4%.
Vaa (1997) Norway	Speeds were measured on a stretch of road (35-km in length located near Oslo) throughout a 16-week period: 2 weeks before enforcement, six weeks of enforcement and 8 weeks after period. The road mostly consisted of 80km/h speed limits in a semi-rural, agricultural area, interspersed with some 60kn/h speed limit zones through small, more densely populated communities. Over the 6 weeks of enforcement there was a total of 380 hours of enforcement activity (on average, 9.04 hrs per day). Stationary methods accounted for 233.4 hours (on average, 5.56 hrs per day), surveillance by mobile marked police cars accounted for 88.2 hours (on average, 2.10 hrs per day) and the use of an empty marked police car accounted for 58.3 hours (on average, 1.38 hrs per day). During the 8 months before the programme, there was 16 hours, in total, of police activity. A similar control section of road was used for comparison purposes. On this road there was 2.5 hours of police activity (not specified) during the experimental enforcement programme. During the 8 months before the programme, there was 9 hours, in total, of police activity on the control road.	In both the 60km/h and 80km/h there were significant ($p < .01$) reductions in mean speeds during the enforcement period at all times of day. Speed reductions were in the magnitude of 0.8km/h to 4.8km/h (results presented in graphs; numbers not provided; not possible to extract numbers from the figures provided with accuracy). Changes in the % of drivers speeding (exceeding the speed limit by 10km/h) as follows: In 60km/h areas the maximum reductions were found between 0.00-6.00am: Before period: 30% During enforcement: 20% In 60km/h areas the minimum reductions were found between 3.00-7.00pm: Before period: 11% During enforcement: 8% The largest time halo effect lasted 8 weeks after enforcement was withdrawn (between 9.00am-3.00pm). Between 0.00 and 6.00am, and between 3.00pm and 12.00pm, the time halo effect lasted 2 weeks. There was no time halo effect during 6.00 to 9.00am – i.e. the effects of enforcement did not last. In 80km/h areas the maximum reductions were found during night-time hours (presumably between 7.00pm-6.00am): Before period: 54% During enforcement: 43% In 80km/h areas the minimum reductions were found during night-time hours (presumably between 6.00am-7.00pm):

		Before period: 33% During enforcement: 29% There was no effect of enforcement between 6.00 to 9.00am (commuter traffic). The largest time halo effect lasted 6 weeks after enforcement was withdrawn (between 7.00pm-12.00). Between 0.00 and 6.00am, and between 3.00pm and 7.00pm, the time halo effect lasted 2 weeks.

Table F2: Studies investigating the effect of policing on drink-driving violations and accidents

Reference and country of study	Study design Enforcement type and level (if specified)	Results
Amick & Marshall (1983) USA	Drink-driving enforcement programme in Bonneville County Involved coordination of education programmes, enforcement, sentencing and parole processes and rehabilitation programmes. 2 control counties used A two-man drink-driving selective traffic enforcement project was created. Each team worked shifts and geographic areas that were related to high alcohol involvement. Patrols worked at night and in the early hours of the morning. There was a 50% increase in the referral of DUI offenders to rehabilitation programmes during the programme.	During the programme there was a reduction of 4.6 night-time injury accidents per months compared with pre-intervention levels. In one of the control counties there was no change in the numbers of night-time injury accidents. In the other control county there was an increase in the numbers of night-time injury accidents (4.5 accidents per month).
Arthurson (1985) Australia	Evaluation of RBT in New South Wales 1985	Proportion of fatal accidents occurring late at night or on weekends declined from 42% pre-RBT to 33% post RBT. Proportion of dead drivers with BAC levels over .05 declined from over 40% to 33%.
Cameron & Strang (1982) Australia	RBT Evaluation in Melbourne Before/after study Before = average of 8 hrs of RBT per week in Melbourne Metropolitan areas RBT = 3 periods of increased RBT on Thurs, Fri, and Sat nights 1st = 100 hrs of RBT per week of operation (7 weeks of operation over a period of 3 months) 2nd = 93 hrs of RBT per week of operation (4 weeks of operation over a period of 2 months) 3rd = 74 hrs of RBT per week of operation (8 weeks of operation over a period of 4 months) Changes in serious and fatal night time accidents examined for the three periods	**CHANGES IN SERIOUS ACCIDENTS** **1st study period (accident changes in RBT period + 2 weeks after):** In RBT areas: • Night-time accidents = 20.3% reduction • Net change in relation to day time accidents = 27.8% reduction In nearby areas: • Night-time accidents = 5.9% reduction • Net change in relation to day time accidents = 9.0% increase **2nd study period (accident changes in RBT period + 4 weeks after):** In RBT areas: • Night-time accidents = 8.0% reduction

	combined. Publicity used Increased penalties for drink-driving.	• Net change in relation to day time accidents = 20.7% reduction In nearby areas: • Night-time accidents = 1.0% reduction • Net change in relation to day time accidents = 8.9% reduction increase **3rd study period (accident changes in RBT period + 4 weeks after):** In RBT areas: • Night-time accidents = 14.7% reduction • Net change in relation to day time accidents = 24.8% reduction In nearby areas: • Night-time accidents = 8.7% reduction • Net change in relation to day time accidents = 13.2% reduction increase **3 study periods combined:** Night time accident changes: In RBT areas: • During RBT = 15.2% reduction • 1+2 weeks after RBT = 12.9% reduction • During RBT and 1+2 weeks after = 14.0% reduction • 3+4 weeks after RBT = 4.4% reduction • During RBT and 1-4 weeks after = 11.0% reduction In nearby areas: • During RBT and 1+2 weeks after = 6.4% reduction • During RBT and 1 to 4 weeks after = 6.7% reduction Net reductions (i.e. night time accident changes compared with day time accident changes during the same periods): In RBT areas: • During RBT = 24.0% reduction • 1+2 weeks after RBT = 22.8% reduction • During RBT and 1+2 weeks after = 23.4% reduction • 3+4 weeks after RBT = 5.9% reduction • During RBT and 1+2 and 3+4 weeks after = 18.3% reduction

		In nearby areas: • During RBT and 1+2 weeks after = 10.6% reduction • During RBT and 1 to 4 weeks after = 11.4% reduction Net reduction in RBT area during RBT and 1+2 weeks after compared with nearby areas over the same period = 14% reduction. **CHANGES IN FATAL ACCIDENTS** **3 study periods combined:** Night time accident changes: In RBT areas: • During RBT = 33.3% reduction • 1+2 weeks after RBT = 14.3% reduction • During RBT and 1+2 weeks after = 23.8% reduction • 3+4 weeks after RBT = 25.0% reduction • During RBT and 1+2 and 3+4 weeks after = 24.2% reduction In nearby areas: • During RBT and 1+2 weeks after = 12.0% reduction • During RBT and 1 to 4 weeks after = 9.3% reduction Net reductions (i.e. night time accident changes compared with day time accident changes during the same periods): In RBT areas: • During RBT = 36.8% reduction • 1+2 weeks after RBT = 8.9% reduction • During RBT and 1+2 weeks after = 23.8% reduction • 3+4 weeks after RBT = 11.6% reduction • During RBT and 1+2 and 3+4 weeks after = 20.3% reduction In nearby areas: • During RBT and 1+2 weeks after = -2.0% reduction • During RBT and 1 to 4 weeks after = 12.0% reduction Net reduction in RBT area during RBT and 1+2 weeks after compared with nearby areas over the same period = 14% reduction.

Cameron et al. (1981) Australia	RBT in Victoria evaluated	Net reduction in all fatal accidents = 32.7 Net reduction in Thurs-Sat night fatal accidents = 54.2 Net reduction in Sun-Weds night fatal accidents = 0.8 Net reduction in all serious injury accidents = 32.7 (no differences between days of week) Net reduction in single vehicle casualties = 18% Net reduction in multi-vehicle casualties = 9.7
Federal Office for Road Safety (1986) Tasmania	RBT introduced in 1983 in Tasmania and accompanied by extensive publicity In 1985 there were more than 200,000 road tests carried out (population of Tasmania at the time = 268,887) Accidents in the 6 years before RBT compared with accidents in the 3 years after.	Fatal accidents due to alcohol reduced by 42% Alcohol related casualty accidents reduced by 29%
Henstridge, Homel, & Mackay (1997) Australia	Evaluation of impact of RBT in Australia – visible enforcement. In New South Wales serious, fatal and single vehicle accident data collected from 1976 to 1992. RBT introduced in Dec 1982. Data on enforcement levels were also collected. Note: 3 other states were investigated in the study but data on enforcement levels were deemed to be too unreliable to drawn any valid conclusions about the effects of levels of enforcement on accidents. Extensive publicity accompanied RBT enforcement.	A non-linear relationship between enforcement levels and accidents was found. Increases in testing levels from 100 to 6000 per day were plotted against % reductions in serious injury accidents. An increase of 1000 in the daily testing rate related to a 5.9% reduction in accidents. An increase of 3000 tests per day related to a reduction in accidents of 16.6%. It was not possible to estimate the effects of enforcement levels on fatal accidents due to lack of statistical power. For single vehicle night-time accidents, an increase of 1000 tests per day related to a 19.3% reduction in accidents and an increase of 3000 tests per day related to a reduction of 47.3% in accidents.
Homel (1988) Australia	RBT introduced in 1982 in New South Wales and extensive publicity All fatal accidents in 6 years prior to 1982 compared with 4 years after reported In first 12 months of RBT – nearly one million tests performed by police – in subsequent years testing continued at higher levels (not specified)	Monthly average in 6 years prior to RBT = 95.7 fatal accidents Monthly average in 4 years after introduction of RBT = 76.0 fatal accidents Reduction in all fatal accidents = 20.6%

Kearns, Vazy, Carseldine & Arthurson (1987) Australian	Evaluated police enforcement as a countermeasure against drink-driving in New South Wales. RBT introduced in December 1987 and the study evaluated the effects on accidents over the subsequent 3 years.	Since December 1987, the number of fatal traffic accidents was reduced by over 20%. Night-time accidents on Thursday, Friday and Saturday – the number has reduced by over 40% The number of day-time accidents has hardly changed (but drink-drive accidents are known to mainly occur at night so this is perhaps not surprising) The number of fatal accidents where the driver/rider had a BAC of 0.5% or over, reduced by almost 40%
Mercer (1985) Canada	A correlational examination of 54 months of data from British Columbia on: (a) the number of vehicles stopped in police drink-driving roadchecks (b) the number of driving while impaired charges laid (c) the number and percent of alcohol-related traffic casualties in the months of police activity (d) extent of media coverage on drinking and driving (number of "press clippings) in the months of police activity (e) the number and percent of alcohol-related traffic casualties in the month after police activity (f) extent of media coverage on drinking and driving (number of "press clippings) in the month after police activity Zero order and partial correlations examined	Correlation between % of casualty alcohol –related accidents and number of DWI charges in the month of police activity = 0.45 (partial correlation = .50) Correlation between number of casualty alcohol –related accidents and number of DWI charges in the month of police activity = 0.71 (partial correlation = .66) Correlation between % of casualty alcohol –related accidents and number of vehicles stopped in road checks in the month of police activity = -0.18 NS (partial correlation = .19 NS) Correlation between % of casualty alcohol –related accidents and number of vehicles stopped in road checks in the month of police activity = -0.17 NS (partial correlation = .10 NS) Correlation between % of casualty alcohol –related accidents and number of press clippings in the month of police activity = -0.58 (partial correlation = -.56) Correlation between % of casualty alcohol –related accidents and number of press clippings in the month of police activity = -0.51 (partial correlation = -.31) Correlation between % of casualty alcohol –related accidents and number of DWI charges in the month after police activity = 0.12 NS (partial correlation = -.09 NS) Correlation between number of casualty alcohol –related accidents and number of DWI charges in the month after police activity = 0.49 (partial correlation = .28) Correlation between % of casualty alcohol –related accidents and number of vehicles stopped in road checks in the month after police activity = -0.26 (partial correlation =

		.04 NS) Correlation between % of casualty alcohol –related accidents and number of vehicles stopped in road checks in the month after police activity = -0.36 (partial correlation = .03 NS) Correlation between % of casualty alcohol –related accidents and number of press clippings in the month after police activity = -0.61 (partial correlation = -.51) Correlation between % of casualty alcohol –related accidents and number of press clippings in the month after police activity = -0.70 (partial correlation = -.50) In the month of police activity, no relationships were found between the number of vehicles stopped in drink-driving road checks and the number and % of alcohol related casualty accidents. In the month after police activity relationships *were* found between the number of vehicles stopped in drink-driving road checks and the number and % of alcohol related casualty accidents. However, when controlling for the effects of other variables (e.g. media), no significant effects were found.
Ross (1977) Cheshire, UK	Drink-driving enforcement No control group During 4 weeks in September 1975 a 'blitz' enforcement campaign was used which involved increasing police efforts to breathalyse drivers (presumably this involved RBT – visible stationary police presence – but may have also involved stopping drivers suspected of driving while under the influence of alcohol based on their driving behaviour using mobile enforcement methods) No publicity was planned but the enforcement campaign was leaked to the press and became highly publicised. During 1974 and early 1975, the numbers of breath tests performed by the police were between 100 and 250 per month. In July 1975 there were 450 tests conducted. During the blitz campaign in September there were over 1,600 tests performed. From October 1975 to March 1976, the level of tests remained higher than before the blitz, varying from 250 to 350 per month.	**Changes in all serious and fatal accidents:** Sept 1975 (month of 'blitz') compared with Sept 1974 = 39% reduction Sept 1975 compared with previous month 1975 = 41% reduction September 1975 compared with monthly average for the 17 previous months = 28% reduction Lasting effects = numbers of accidents increased during the following 6 months after the 'blitz' **Changes all accidents during drinking hours (10pm to 4am):** Sept 1975 (month of 'blitz') compared with Sept 1974 = 45% reduction Sept 1975 compared with previous month 1975 = 37% reduction September 1975 compared with monthly average for the 17 previous months = 35%

		reduction Lasting effects = numbers of accidents increased during the following 6 months after the 'blitz'. **Changes all accidents during non-drinking hours (7-10am to 4-5pm):** Sept 1975 (month of 'blitz') compared with Sept 1974 = 30% reduction Sept 1975 compared with previous month 1975 = 12% increase September 1975 compared with monthly average for the 17 previous months = 2% reduction Lasting effects = numbers of accidents increased during the following 6 months after the 'blitz'.
Span & Stainislaw (1995) Australia	Drink driving enforcement – RBT New South Wales introduced RBT in December 1982 as a countermeasure to drink-driving. High level of visible, state-wide enforcement activity throughout the year and extensive state-wide publicity (no specific details provided about the level and types of enforcement activity). Examined changes in accidents. Predicted accidents using a number of variables: introduction of RBT, no. of breath tests, type of breath testing (stationary and mobile), other safety interventions (e.g. speed camera programme) and change in legal alcohol limit from .08% to .05%. Experimental = accidents occurring in drinking hours Control = accidents occurring in non-drinking hours (defined as 0600-1700 on weekends and 0500 to 1900 on week days)	Introduction of RBT and the lowering of the legal BAC had significant impacts on accidents. Net % change in drinking hour accidents following RBT provided (i.e. reductions in drinking hour accidents compared with reductions in non-drinking hour accidents). Statistics given for men and women. The following takes the average of the two groups: All accidents in NSW = 23.5% reduction All accident in Sydney = 27.5% reduction All accidents in rest of NSW = 25.5% reduction All injury accidents = 24.5% reduction Tow-a-way accidents = 22% reduction
Verschuur & Noordzij (1988)	Evaluated a small scale RBT programme that was implemented in 1986 in the City of the Hague.	In the test area (the Hague):

The Netherlands	For 8 months, every Friday and Saturday night either one or two patrol units (each with 2 police officers) were on the road (visible & stationary RBT) from 2200hrs to 0400hrs. Police instructed to stop and test as many drivers as they could. Start of programme (April 1986) was announced in the local press and media. End of programme was November. During the programme a total of 70 patrol units had stopped and tested a total of 3,600 drivers. Before the start of the programme another 300 drivers were stopped and tested. The ratio of test:drivers in the Hague during this time was 1:60. A sample of drivers was obtained during a period of 10 weeks before the start of the programme; a sample of drivers was obtained during a period of 10 weeks at the beginning of the programme (first 10 weeks); a sample of drivers was obtained from the last 10 weeks of the programme. Similar control samples were used from the City of Rotterdam where there was no RBT.	• The proportion of drivers stopped in the 10 weeks before the programme with a BAC of 0.2 or over was 23% • The proportion of drivers stopped in the first 10 weeks of the programme with a BAC of 0.2 or over was 21% • The proportion of drivers stopped in the last 10 weeks of the programme with a BAC of 0.2 or over was 16% In the control area (Rotterdam) • The proportion of drivers stopped in the 10 weeks before the programme with a BAC of 0.2 or over was 14% • The proportion of drivers stopped in the first 10 weeks of the programme with a BAC of 0.2 or over was 19% • The proportion of drivers stopped in the last 10 weeks of the programme with a BAC of 0.2 or over was 23%
Voas & Hause (1987) USA	Evaluation of drink-driving enforcement patrols in Stockton (a city with a population of 120,000 in the central valley of California) During a 3 and a half year period three enforcement "experiments" were conducted separated by short periods of no special enforcement. Casualty accident data were collected for three years prior to the enforcement experiments and for 2 and a half years after. Enforcement patrols (10 member special patrol force) operated during weekend nights (Friday and Saturday – 8pm to 4am). Driver BACs were measured for 3 months before the enforcement programme and during the programme. Data were collected from four control cities in California.	In the control areas there was, on average, a 32% increase in arrests made between before the programme and during the first year of the programme. In the experimental site, there was a 203% increase in arrests made. No evidence was found for an effect of enforcement during daytime hours – there was an increase in daytime accidents in the region of 12%. In the control sites, there was on average a 7% increase in daytime accidents. For weekend night-time accidents there was overall a 15% reduction during the enforcement programme. In the control sites, there was on average a 10% increase in weekend night-time accidents. For weekday night-time accidents there was overall a 10% reduction during the enforcement programme. In the control sites, there was on average a 2% increase in weekday night-time accidents. The average BAC of drivers declined by 20%. The % of drivers with BAC of 0.1 or higher reduced from 8.8% before enforcement to 5% after (43% reduction).

Table F3: Studies investigating the effect of policing on seat belt wearing rates

Reference and country of study	**Study design** **Enforcement type and level (if specified)** **Output variable**	**Results**
Gundy (1988) The Netherlands	Seat belt enforcement Enforcement campaign conducted over a period of 2 months in Friesland. The police invested 2,800 hours in surveillance, controlled about 40,000 motorists and issued about 1,300 tickets. About 1% of total police surveillance capacity for this two-month period was actually deployed, about 12% of what was actually budgeted. The amount of police time varied widely from local jurisdiction to jurisdiction and from week to week. Extensive media campaign accompanied the programme. 28,688 observations made over 6 measurement periods – divided equally between the experimental site and a control site and divided equally between built-up and non-built-up areas: 1. prior to the programme 2. during the programme 3. during the programme 4. 6 months after end of programme 5. 12 months after end of programme 6. 2 years after programme	Seat belt wearing rates improved. 25% increase in wearing rates during the programme in both the built-up and non-built-up areas. At 4^{th} and 5^{th} measurement points (i.e. after programme) 15% higher seat belt wearing rate above the base rate. There was a small improvement in wearing rates in the control area (not stated) Two years after the campaign, wearing rates were similar to what they were 6 months after the campaigns but the authors could not conclude that the programme led to this lasting effect because another large scale seat belt enforcement campaign ran between their 5^{th} and 6^{th} observation points.
Jonah & Grant (1985)	Cited in European Transport Safety Council report (1999). Not original reference.	Increase in seatbelt use due to enforcement
Jonah, Dawson & Smith (1982)	Cited in European Transport Safety Council report (1999). Not original reference.	Increase in seatbelt use due to enforcement
Streff, Molnar &	Seat belt enforcement	Belt use increased from a baseline of 56.7% to 65.1% during the programme

Christoff (1992) USA	Combined education/publicity and enforcement programme to increase seat belt use along a highly travelled corridor in three Michigan counties. Hours devoted to police patrol activities increased by about 3x to 5.5x over a 13 month period.	before reducing slightly to 62.7% after the intensive enforcement and publicity/education declined. Before the campaign = 56.7% wearing rate (Sept 1989) and about 125 police patrol hours; about 300 speeding citations; about 60 seatbelt non-use citations and about 80 seatbelt non-use warnings (October 1989) April 1990 = 56.2% wearing rate (about 650 police patrol hours; about 610 speeding citations; about 150 seatbelt non-use citations and about 240 seatbelt non-use warnings) June 1990 = 65.1% wearing rate (about 575 police patrol hours; about 550 speeding citations; about 160 seatbelt non-use citations and about 240 seatbelt non-use warnings) July 1990 = 67.4 wearing rate (about 600 police patrol hours; about 820 speeding citations; about 160 seatbelt non-use citations and about 240 seatbelt non-use warnings) August 1990 = 67.6% wearing rate (about 475 police patrol hours; about 590 speeding citations; about 110 seatbelt non-use citations and about 160 seatbelt non-use warnings) October 1990 = 61.7% wearing rate (about 420 police patrol hours; about 400 speeding citations; about 110 seatbelt non-use citations and about 180 seatbelt non-use warnings) December 1990 = 63.6% wearing rate (no information about enforcement levels) Increases and decreases in the amount of publicity (in terms of no. of articles and column inches) followed a similar pattern to the increases and decreases in enforcement.

Table F4: Studies investigating the effect of speed cameras.

Reference and country of study	Study design Enforcement type and level (if specified) Output variable	Results
Cameron & Vulcan (1998) New Zealand	Cited in Keall et al. Estimated accident savings in New Zealand the from the additional resources devoted to alcohol and speed countermeasures (speed camera programme an important part – visible speed cameras)	Serious urban casualty accidents = 26% reduction Serious rural casualty accidents = 14% reduction
Cameron et al (1995) Australia	Cited in Keall et al. Effects of speed cameras Control group = no details	32% reduction in accidents on Melbourne arterial roads 23% reduction in towns 14% reduction on rural highways
Cannell (2001) Brazil	Article about speed cameras Urban Photographic speed enforcement using 40 fixed camera rotated around 160 sites Control group = No	22% reduction in non-fatal casualties 31% reduction in fatal casualties
Elvik (1997) Norway	Cited in Chen et al. (2002). Original report not in English Speed cameras in Norway. Before / after study of effect of programme on accidents. Empirical data collected from 64 road sections and Bayes method used in model construction and analysis. Did not look at effects on speed	20% reduction in injury collisions. Variation by sites: Sites with higher accident rates beforehand, the greater the effect of speed cameras
Gains (2001). UK	Before/After study with control group comparison. Study tested the effect of "netting off" (to use fine income from speed and re-light cameras to fund additional camera enforcement) in Cleveland, Essex, Lincolnshire, Nottingham, Northamptonshire, South Wales, Strathclyde and	Net accident reduction across all camera sites: • 35% reduction in PICs (379 fewer PICs) • 47% reduction in KSIs (109 fewer KSIs)

	Thames Valley, over the first year of operation. Data on Personal Injury Collisions (PIC) and numbers of people Killed or Seriously Injured (KSI) collected for over 250 camera sites (1) at all camera sites and (2) for the wider partnership areas (to explore the wider effects on accidents - i.e. not only at the camera sites) Speed data collected before and at various time intervals after camera introduction, at over 100 camera sites (involving over 800 separate speed surveys throughout the year).	Net accident reduction across all wider partnership areas: • 5% reduction in PICs (123 fewer PICs) • 18% reduction in KSI (119 fewer KSIs) Net speed reductions: • % of drivers exceeding speed limit reduced by from 55% to 16% • % of drivers exceeding speed limit by 15mph reduced by from 5% to 1% • Average speeds reduced by 5.6mph
Keenan (2002) UK	Speed cameras Leeds (Urban dual carriageways) 2 roads with 40mph limits Road 1 = one speed camera covering one direction (GATSO) Road 2 = two speed cameras covering both directions (GATSO) Nottingham (urban dual carriageway): 1 road with 40mph speed limit (SPECS) Lincolnshire (urban single carriageway): 1 road with 60mph speed limit (GATSO) Accident data (all accidents) 1-2 years before and after camera installation recorded (no control groups used)	Speed data for Lincs and Nottingham not given. Mean speeds at Leeds 1 (% > 40mph): 500m before camera: 44.6 mph (79) At camera: 36.6mph (14) 500m after camera: 44.5mph (81) Mean speeds at Leeds 2 camera 1/direction 1 (% > 40mph): 500m before camera: 39.6 (38) At camera: 37.3 (18) 500m after camera: Not measured Mean speeds at Leeds 2 camera 1/direction 2 (% > 40mph): 500m before camera: 43.2 (73) At camera: 38.1 (22) 500m after camera: Not measured Mean speeds at Leeds 2 camera 2/direction 1 (% > 40mph): 500m before camera: Not measured At camera: 35.9 (9) 500m after camera: 41.0 (53) Mean speeds at Leeds 2 camera 2/direction 2 (% > 40mph): 500m before camera: Not measured At camera: 36.7 (14) 500m after camera: 40.6 (45)

		Accident data: Leeds site 1: Before: 4 accidents After: 9 accidents Leeds site 2: Before: 13 accidents After: 22 accidents Nottingham site: Before: 33 accidents After: 21 accidents Lincolnshire site: Before: 6 accidents After: 7 accidents
Leithead (1997). UK	Before/After study with control group comparison. Speed cameras installed in West London on the principle approach roads to central London. Numbers of accidents in the year before installation of the cameras were compared with the number of accidents in the year following installation (in relation to changes in accidents over the same period on all roads in London) at (1) the camera sites and at (2) all other roads in the same areas.	Net accident reduction across all camera sites: • Fatal = 36% reduction • Slight = 8% reduction • Total = 14% reduction Net accident reduction across all other roads in area: • Fatal = 7% increase • Slight = no %age change • Total = 6% increase
Makinen & Oei (1992) Finland	Cited in European Transport Safety Council report (1999). Not original reference. Distance halo effects due to speed cameras investigated	Observed halo effects 4km and 10km from the sites of speed cameras
Makinen & Rathmayer (1994) Finland	Cited in European Transport Safety Council report (1999). Not original reference. Distance halo effects due to speed cameras investigated	Observed halo effects 4km and 10km from the sites of speed cameras
Mara et al (1996) New Zealand	Cited in Keall et al. Effectiveness of the New Zealand speed camera programme specifically (visible speed cameras operated on manned police vehicles supplemented by a small number of fixed cameras operated from boxes on poles)	13% reduction in fatal and serious accidents in urban areas, on road generally 23% reduction in urban speed camera areas 11% reduction in all injury accidents in speed camera areas Average reduction at all sites = 20% Accidents Nationwide fell by 10%
Nilsson (1992)	Cited in European Transport Safety Council report (1999). Not original	500m from the speed cameras effected in urban areas; 1000 metres in rural areas

	reference. Distance halo effects due to speed cameras investigated	
Oei (1996) The Netherlands	Speed cameras Four 2-lane rural roads (80km/h). Publicity campaign was used Phase 1 = fixed warning signs (indicating safe travelling speeds and maximum speeds) and automatic warning signs (showing same thing but only lighting up when vehicles exceeding speed limit – and some saying “you are driving too fast”) installed. Phase 2 = 3-4 cameras installed on each road (fixed – not police operated). Speeds monitored before, at phase 1 and at phase 2 and compared with a control area	Mean speeds on experimental roads: Before: 78.2km/h Phase 1: 75.2km/h Phase 2: 72.9km/h Mean speeds on control roads: Before: 78.7km/h Phase 1: 80.2km/h Phase 2: 78.9km/h % exceeding speed limit on experimental roads Before: 38.2% Phase 1: 28.0% Phase 2: 11.4% % exceeding speed limit on control roads Before: 40.9% Phase 1: 50.2% Phase 2: 44.4% Injury accidents on experimental roads: Before: 22 Phase 1+2: 14 Damage only accidents on experimental roads: Before: 128 Phase 1+2: 67 All accidents on experimental roads: Before: 150 Phase 1+2: 81 All accidents on control roads: Before: 284 Phase 1+2: 237 Accident reduction = 46% Net accident reduction = 30%
Palmer (1999) UK	Article about speed cameras in London Motorways M20 and M1	Reduction in the number of speed vehicles = 30% Reduction of 50% in the associated cost of accidents compared with National

	Control Group = No	average
Swali (1993)	Effect of speed cameras on traffic speeds and accidents in West London. Speed camera with warning signs introduced on trunk roads in West London. Control groups used.	Mean speeds reduced by 5mph Net accident reductions: 19% reduction in all accidents 20% reduction in casualties 29% reduction in serious and fatal casualties
Totton (2000) UK	Article about speed cameras in Nottingham Cites Home Office Research	HO research shows speed cameras resulted in a 28% reduction in accidents
Whitworth (1999) UK	Article about speed cameras Lincolnshire (urban) 26 camera sites and 6 cameras rotated between them. Control group = no	Speed related accidents reduced by 14% in 12 months

Table F5: Studies investigating the effect red light cameras

Reference and country of study	Study design Enforcement type and level (if specified) Output variable	Results
Andereassen (1995) Australia	Follow up to the South et al. (1988) study. 41 of the 46 camera sites were used and compared with all other signalised junctions in Metropolitan Melbourne. Data for the study covered 11 years during which there were many changes made to the junctions (camera and comparison sites). There was also an extensive area wide speed enforcement programme during this time.	Net changes in accidents at camera sites: • All accidents = 7% increase • Right-angle accidents = 13% reduction • Rear-end accidents = 20% increase
Arup (1992) Australia	Cited in Retting et al. (2003) Red light running violations monitored at 3 camera sites 3 non camera sites in same area	Red light running violations: • 78% reduction at camera sites • 67% reduction at non-camera sites in same area
Chen et al. (2001) Canada	Cited in Retting et al. (2003) Red light running violations monitored at 4 non-camera sites 1 month and 6 months after the installation of red light cameras in two cities.	Red light running violations: • 69% reduction at non-camera sites after 1 month • 38% reduction at non-camera sites after 6 months
Chin (1989) Singapore	Cited in Retting et al. (2003) Red light running violations monitored at 23 camera sites 20 non camera sites in same area (but had camera signs) 14 control sites (in same area but did not have camera signs)	Red light running violations: • 42% reduction at camera sites • 27% reduction at non-camera sites in same area • 17% increase at control sites
Hillier et al. (1993) Australia	16 intersections with red light cameras were monitored before and after installation in Sydney, New South Wales Camera warning signs used at all sites and publicity used	Net changes in accidents at camera sites: • All accidents = 8% reduction • All injury accidents = 26% reduction • Right-angle accidents = 29% increase

	16 matched non-camera sites in Sydney were used	• Rear-end accidents = 108% increase
Mann et al. (1994) Australia	8 red light camera sites in Adelaide used. Camera warning signs used at all sites and publicity used 14 high-volume signalised junctions used as comparison sites	Net changes in accidents at camera sites: • All accidents = 6% increase • All injury accidents = 20% reduction • All right-angle accidents = 8% increase • Right angle injury accidents = 26% reduction • All rear-end accidents = 12% increase • Rear-end accidents = 1% reduction
Ng et al. (1997) Singapore	Before/After study with control group The effect of red light violation cameras was investigated. Casualty accidents were examined at a sample of 125 junctions where cameras were installed, 3 years before and after installation. A comparative analysis was also undertaken for a sample of control junctions (i.e. junctions where traffic cameras were not installed). 42 treatment junctions were compared with 42 control junctions. Installation of cameras accompanied by a "RED LIGHT CAMERA" sign.	Net changes in injury accidents at camera sites: • All accidents = 8.8% reduction • Head to side accidents = 10% reduction • Head to rear accidents = 6.2% increase • Head on/Sideswipe = 8.1% reduction • Other accidents = 16.2% reduction
Oei et al. (1997) The Netherlands	Cited in Retting et al. (2003) Red light running violations monitored at 4 camera sites	Red light running violations: • 56% reduction at camera sites
Queensland Transport (1995) Australia	Cited in Retting et al. (2003) 79 red light camera junctions in Queensland used. Warning signs used. All other signalised junctions in Queensland used for comparison.	Net changes in accidents at camera sites: • All accidents = 48% reduction • All injury accidents = 46% reduction
Retting & Kyrychenko (2002) USA	Cited in Retting et al. (2003) 11 signalised junctions in one city (Oxnard) in California had red light cameras installed. Cameras were publicised. All signalised junctions in the city (125) were monitored before and after installation and compared with junctions in 3 other Californian cities and all non-signalised junctions in Oxnard.	Net changes in accidents at camera sites: • All accidents = 7% increase • All injury accidents = 29% reduction • All right-angle accidents = 32% increase • Right angle injury accidents = 68% reduction

		• All rear-end accidents = 3% increase • Rear-end accidents = not given Changes at 11 camera sites in Oxnard: • All injury accidents = 25% reduction Changes at other signalised junctions in Oxnard: • All injury accidents = 19% reduction
Retting et al. (1999a) USA	Cited in Retting et al. (2003) Red light running violations monitored at 5 camera sites 2 non camera sites in same area 2 control sites	Red light running violations: • 44% reduction at camera sites • 34% reduction at non-camera sites in same area • 5% increase at control sites
Retting et al. (1999b) USA	Cited in Retting et al. (2003) Red light running violations monitored at 9 camera sites 3 non camera sites in same area 2 control sites	Red light running violations: • 40% reduction at camera sites • 50% reduction at non-camera sites in same area • 4% reduction at control sites
Retting et al. (2003)	Conducted a meta analysis of 7 studies which investigated the effect of red-light cameras on injury accidents (all reviewed here).	Weighted mean effect on accidents was between 10% and 39%. The best estimate given was about 25-30% reduction in injury accidents.
South et al. (1988) Australia	Before/After study with control group. The effect of red light violation cameras was investigated in Melbourne. Over a period of 31 months Victoria had an average of 7 cameras in use which were rotated between 46 study sites. One camera housing and flash housing was installed at each site and "RED LIGHT CAMERA AHEAD" signs were used on the approach to each arm of the junctions. Accident data before	Net changes in injury accidents at camera sites: • All accidents = 6.7% reduction • Right-angle accidents = 32.0% reduction • Right-angle turning accidents = 25.0% reduction • Right against accidents = 2.0% reduction • Rear end accidents = 30.8% reduction • Rear end turning accidents = 28.2% increase

	and after the camera installation were compared with 46 comparison sites. Extensive publicity campaign used.	• Other accidents = 2.2% reduction
Steel (1990). Uk	Before and after study with no control group. Red light running cameras (Gatsometer RLC 36 MS) installed at two junction sites in the city of Nottingham, where accidents were known to occur as a result of traffic light contraventions. After widespread publicity, the cameras were introduced in December 1987. The numbers of accidents occurring in 1987 (i.e. before installation) were compared with the numbers of accidents in 1988 (i.e. after installation) and the first 6 months of 1989. Red light running was also monitored by comparing data collected from the month after camera installation (January 1988) and the moth before installation (November 1987).	Accident changes: • Before (all of 1987) = a total of 17 accidents involving personal injury at the two sites. • After (all of 1988) = a total of 8 accidents involving personal injury at the two sites. • After (first 6 months of 1989) = a total of 7 accidents at the two sites. Red light running violations: • 64% reduction at one site • 57% reduction at second site.
Thompson et al. (1989) UK	Cited in Retting et al. (2003) Red light running violations monitored at 2 camera sites	Red light running violations: • 22% reduction at one camera site • 13% increase at second camera site