The Effectiveness of Speed Cameras

A review of evidence

Richard Allsop
November 2010

RAC Foundation

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About the author

Professor Richard Allsop has extensive experience of research, training and advisory work on road safety, traffic management and other aspects of transport policy. He has a first in Mathematics from Cambridge, and a PhD and DSc from UCL (University College London), where he is Emeritus Professor of Transport Studies, having been Professor since 1976 and Director between then and 1997 of what is now the Centre for Transport Studies.

He has a longstanding involvement in road safety research and policy, including being a Director of PACTS (the Parliamentary Advisory Council for Transport Safety). He is a Board Member of the European Transport Safety Council (ETSC) and leads its European road safety performance index programme PIN. He has also provided inputs to road safety policy in Australia, Hong Kong, Japan, New Zealand and Poland.

He was made an OBE in 1997 for services to traffic management and road safety, is a Fellow of the Royal Academy of Engineering and holds the IHT Award for professional excellence.

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Foreword

If there is one subject which divides drivers like no other it is speed cameras. Are they a mechanism for saving life or a method of raising revenue? Have they, as some contend, actually increased the casualties on our roads?

What follows in the body of this report is a thorough, independent, statistical evaluation of the facts as we have them.

It is not a simple read, because this is not a simple subject to analyse, yet the conclusions of Professor Richard Allsop of University College London are strikingly clear: fixed and mobile speed cameras save lives – and a lot of them.

The current crisis in funding for speed cameras – and for road safety in general – leaves road users at real risk. Put more starkly, the overwhelming evidence is that if speed cameras were to be decommissioned across Great Britain, about 800 more people a year could be killed or seriously injured. This country should be proud of the progress it has made in reducing deaths on the roads over recent years. However, there is a real risk of this trend being reversed if we do not find the funds to continue operating cameras or some equally effective alternative.

Professor Allsop has no axe to grind and no vested interest in the success of speed cameras. He is a respected academic with many years of analytical experience in this field; it was for this reason that the RAC Foundation approached him to undertake this study.

He has looked at data from a range of speed camera efficacy studies. He has also examined previously unpublished information from a number of road safety partnerships. The findings are unambiguous. Cameras, historically, have saved lives. They continue to save lives. And should they be removed, speeds will rise and accidents with them.

Professor Allsop's work also demonstrates that cameras are not significant revenue raisers for the General Exchequer. In 2006–7 for example, from each £60 penalty notice there was a mere £4 surplus after the cost of camera operations was met.

Other researchers looking at the efficacy of speed cameras have reached similar conclusions. In October 2010 the Cochrane Review of 35 studies into their effectiveness worldwide said that while different methodologies meant an order of magnitude was impossible to deduce, nevertheless:

> '…the consistency of reported reductions in speed and crash outcomes across all studies show that speed cameras are a worthwhile intervention for reducing the number of road traffic injuries and deaths.'

While this report fully lays out the background to the introduction of speed cameras and the need for speed limits, its job is not to justify why the national limits are what they are; a review of speed limits to see whether they are soundly based is for another day. What it has done is to show that at camera sites, speeds have been reduced, and that as a result, collisions resulting in injuries have fallen.

The government has said that a decision on whether speed cameras should be funded must be taken at a local level. With the current pressure on public funds, there will be – indeed there already are – those who say that what little money there is can be better spent. This report begs to differ. The devices are already there; they demonstrate value for money, yet are not significant revenue raisers for the Treasury; they are shown to save lives; and despite the headlines, most people accept the need for them.

Speed cameras should never be the only weapon in the road safety armoury, but neither should they be absent from the battle.

S. Glaister.

Professor Stephen Glaister
Director
RAC Foundation

Executive Summary

Background

Speed cameras were first used for enforcement in Great Britain in 1992, having been recommended by a review of road traffic law in 1988. Their rollout was accelerated between 2001 and 2005 in a national safety camera programme under the 'safer speeds' theme of the road safety strategy 2000–2010. Speed camera partnerships – joint ventures between police forces, highway authorities and magistrates' courts – were formed to implement this, and have since taken on a wider role as road safety partnerships.

Sources of information

This report pulls together a range of analyses of the effectiveness of speed cameras, and some more recent data, to provide a considered and comprehensive assessment of their contribution to road safety. The sources of information include the four-year camera evaluation report published in December 2005; related work by Mountain, Hirst and Maher; studies in London; national statistics on traffic speeds, collisions and casualties, and international research on relationships between them; and recent figures from road safety partnerships.

Changes in speed

The four-year evaluation report mentioned above looked at 2,000 sites (urban and rural, using fixed and mobile cameras) where speed measurements were taken both before and after camera deployment. Analysis showed that once the cameras were operational, there was:

- a substantial improvement in compliance with speed limits;
- a particular reduction in extreme speeding;
- a marked reduction in average speed at fixed sites; and
- an appreciable, though more modest, reduction at mobile sites.

Casualty reduction at speed camera sites

But these changes in speed are not an end in themselves. The laws of motion imply that lower speeds just before and at the instant of collision are associated with more time for the driver to take avoiding or mitigating action, lesser exchange of energy and momentum during the collision, and consequently lower forces imposed on the bodies of people involved, resulting in lower severities of injury.

It is clear that collisions and casualties decreased substantially at the more than 4,000 sites covered by the four-year evaluation. However, not all of the decrease can be attributed to the speed cameras.

Some decrease would have been expected because of the downward national trend in casualty numbers. Another part of the reduction is likely to have resulted from the phenomenon of Regression to the Mean (RTM). This is because many cameras were installed at sites that had just previously recorded untypically high numbers of casualties, which would be explicable by chance, and only partly because of inherently dangerous conditions at those sites. The numbers of casualties would therefore have been expected to fall anyway, owing to the effect of RTM. Allowance for RTM is important but hard to estimate.

Some of the reduction might also have been attributable to drivers diverting to avoid cameras, but the overall reduction might well have been greater had it not been for some collisions being caused by drivers suddenly braking and then accelerating in the vicinity of cameras.

But after allowing for all these factors, the judgement can be made that in the year ending March 2004, camera operations at more than 4,000 sites across Great Britain prevented some 3,600 personal injury collisions (PIC), saving around 1,000 people from being killed or seriously injured (KSI):

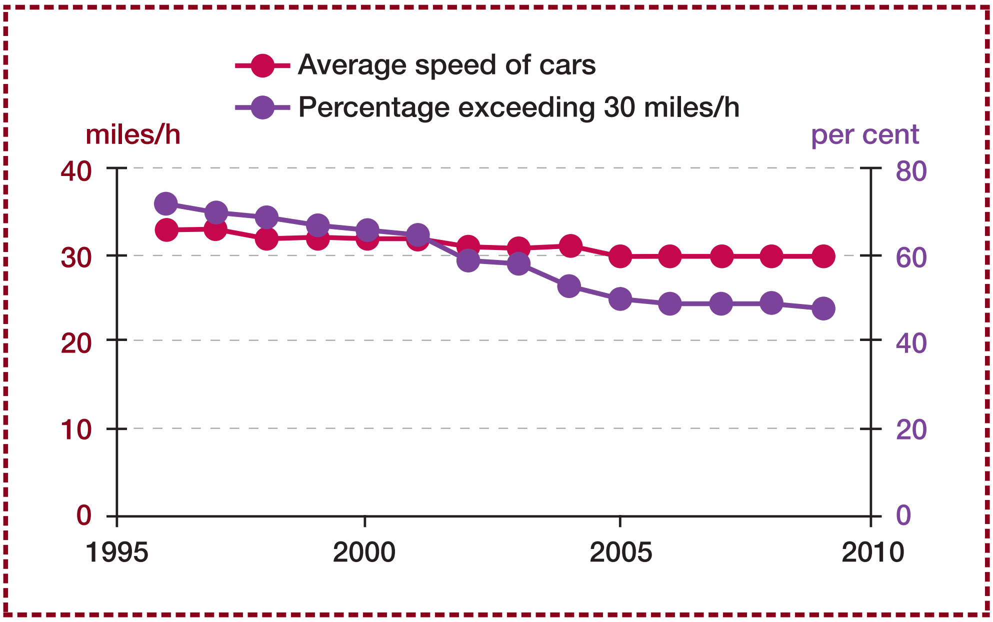
Type of site	Number prevented in year ending March 2004	
	PIC	KSI
Fixed urban Fixed rural	Between 1700 and 2200 Between 170 and 300	Between 500 and 560 Between 60 and 140
Mobile urban Mobile rural	Between 1000 and 1400 Between 180 and 300	Between 150 and 400 Between 90 and 200
All sites	Between 3050 and 4200	Between 800 and 1300

These figures are broadly consistent with what one might expect to see at sites like these in light of the internationally accepted power model of the relationships between changes in numbers of collisions and casualties on a stretch of road, and changes in the average speed of traffic.

Wider changes in speed and numbers of casualties on all roads

National speed surveys show that in free-flowing traffic on all roads with a 30 miles/h limit, the average speed of cars fell from 33 to 30 miles/h between 1997 and 2005. The proportion exceeding the limit also fell. While there have been other moderating influences on speed, such as traffic calming and public information campaigns, the period of steepest decline (between 2001 and

2005) in the proportion of drivers exceeding the 30 miles/h limit coincided with the rollout of camera enforcement:



Trends in average speed of cars, and percentage exceeding the speed limit, in free-flowing traffic on roads with a 30 miles/h limit

There is no evidence of corresponding reductions in speed between 1997 and 2005 on roads with speed limits higher than 30 miles/h. However, numbers of casualties fell similarly on both urban and rural roads. A major contributor to casualty reduction in both cases has been improved car occupant protection. Whilst car drivers and passengers made up two thirds of casualties on rural roads, they made up only one third on urban roads. So a bigger reduction might have been expected on rural than on urban roads because of improved occupant protection. The decrease in speeds and speeding on 30 miles/h roads may well have helped the fall in casualties on urban roads to match that on rural roads.

The key findings of this report

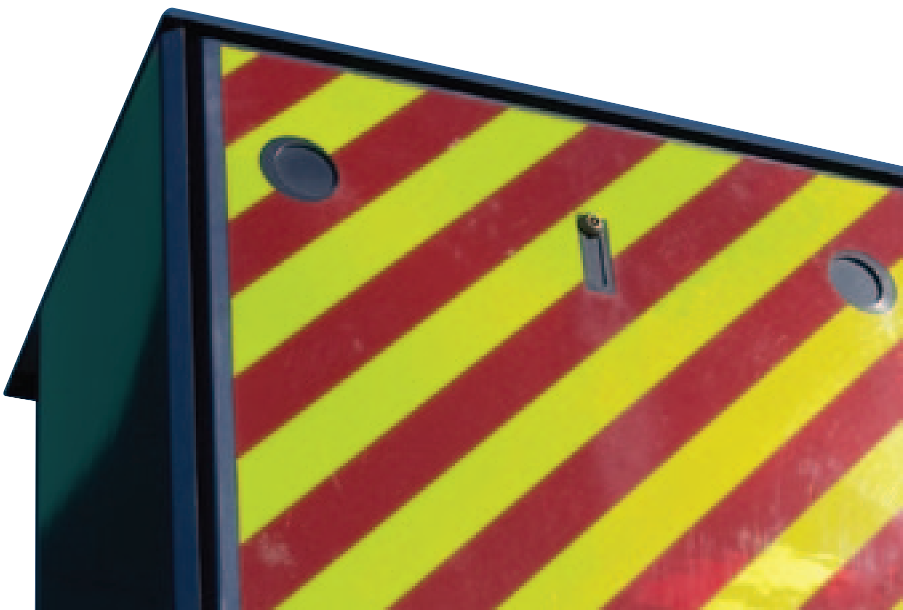
- Deployment of speed cameras leads to appreciable reductions in speed in the vicinity of the cameras, and substantial reductions in collisions and casualties at those locations over and above that which is attributable to regression to the mean effects.
- Percentage reductions in collisions and casualties differ between fixed and mobile, and between urban and rural camera sites. Judging from the evidence, the operation of cameras at over 4,000 sites of all types resulted in around 1,000 fewer people being killed or seriously injured in the vicinity of cameras in the year ending March 2004.
- National surveys indicate clear and sustained falls in the average speeds of cars on 30 miles/h roads, and in the proportion of cars exceeding the limit, which are likely to have contributed to concurrent reductions in collisions and casualties on built-up roads.

- The evidence from a study in West London is that speed cameras led to a reduction in casualties not only at camera sites, but across the wider road network also.
- Majority public acceptance of cameras was widespread at the height of the national camera safety programme. Subsequent annual surveys by the AA indicate that it has remained so, with three quarters of those questioned in October 2010 regarding the use of cameras as acceptable.
- Increases in speeds and speeding at various sites where cameras were visibly out of action have been recorded over the years since 2004.
- Data for 2007–2009 supplied by a number of road safety partnerships, while not covering the whole country, suggest that big falls in fatal or serious casualties at camera sites have persisted over time.
- National decommissioning of cameras could result in about 800 extra people across Great Britain being killed or seriously injured each year.
- In the year ending March 2004 the benefit/cost ratio of camera enforcement was about 2.3. Data for 2006–07 show that the cost of camera enforcement was being covered by penalties paid by detected offenders, with only a modest surplus to the Exchequer of less than £4 out of each £60 penalty paid.

This review is confined to the British experience of speed camera enforcement, but a recently updated Cochrane Review of 35 speed camera studies worldwide concluded:

> '…the consistency of reported reductions in speed and crash outcomes across all studies show that speed cameras are a worthwhile intervention for reducing the number of road traffic injuries and deaths.'

The findings of this review for the RAC Foundation, though reached independently, are essentially consistent with the Cochrane Review conclusions. They are also broadly consistent with the findings of a meta-analysis of 16 studies on the effects of fixed cameras on numbers of collisions and casualties, reported in the respected *Handbook of Road Safety Measures.*



1. Background

Safer speeds is one of the ten themes of Britain's road safety strategy for the decade to 2010 (DETR, 2000b). This part of the strategy was based firmly upon the results of a year-long speed policy review which began in October 1998 in response to widespread concerns (e.g. those expressed in PACTS, 1996) about the contribution of inappropriate speed to death and injury on the roads. The review took extensive account of research, and was reported upon concurrently with the launching of the strategy in March 2000 (DETR, 2000a).

The review recommended a strategic approach to speed management to gain 'the co-operation and understanding of drivers and their respect for the system of speed limits' (ibid.: Chapter 4), to provide a foundation both for working to change drivers' attitudes and behaviour, and for a more general acceptance of enforcement action against those who nevertheless fail to comply with speed limits.

This is the context in which the use of speed cameras, which were introduced in 1992 on the recommendation of the *Road Traffic Law Review Report* (Department of Transport & Home Office, 1988), was extended rapidly in Britain between 2001 and 2005, and has remained widespread since then.

1.1 The need for speed management

Speed gets people and goods to their destinations sooner, but at a cost, especially in terms of death, injury and damage in collisions, and in the emission of carbon dioxide (CO_2). Prevailing speeds stem from the choices that drivers and motorcyclists make on each stretch of road as they find it. As drivers, we see ourselves as gaining immediately from higher speed through earlier arrival, and possibly the pleasure of going faster. We do bear some of the cost ourselves (mainly increased running costs and personal risk), but we tend to underperceive these costs. And in most cases we do not ourselves bear any of the human costs to others of collisions, or much of the resulting damage to the environment. For these reasons, it is inherent in the road traffic system that many of us tend to go somewhat faster than is good for ourselves or society.

It would thus be wrong for each of us to be free to choose how fast to drive. Responsible government rightly seeks to manage speed, usually by moderating it. This does not just mean reining in a less responsible minority of blatant speeders; it requires all of us who drive to do our bit – even if we are tempted to think of ourselves as very responsible citizens. Most of us are liable to go faster than is appropriate to the circumstances, and the ultimate aim of speed management is to achieve appropriate speeds by all drivers and motorcyclists everywhere.

1.2 Speed limits and appropriate speed

Imposing a speed limit on a stretch of road addresses the aim of achieving appropriate speeds only indirectly and incompletely, by setting a maximum permitted speed that is reasonable for that stretch of road, in the expectation that speeds chosen by road users having regard to the imposed limit are more likely to be appropriate than would otherwise be the case. Where there is a speed limit, as there has been on every public road in Britain since 1965, speed higher than the limit is described as 'excess speed', and it is driving with excess speed that constitutes an offence. Driving with inappropriate speed within the limit constitutes an offence only if the speed is so inappropriate as to amount to careless, inconsiderate or dangerous driving within the meaning of the Road Traffic Act 1991.

The relationship between excess speed, as defined and addressed by imposing a speed limit, and inappropriate speed, which speed management ultimately seeks to address, is illustrated by the following table, which shows the resulting four possibilities in respect of the speed chosen by a driver or rider in given circumstances.

	Speed appropriate	Speed inappropriate
Speed within the limit	No problem	Not addressed by the limit
Speed above the limit (excess speed)	The law requires the speed to be reduced for the common good even though it is appropriate	Addressed by the limit only in so far as bringing speed below the limit makes it appropriate

Only in hypothetical circumstances could a speed limit by itself achieve the aims of speed management without requiring anyone to travel more slowly than is appropriate in the circumstances. All speeds that drivers and riders might choose would have to fall in the upper left or lower right hand cells of the table, and those who were inclined to choose speeds in the lower right cell would have instead to comply with the limit and thus choose a speed in the upper left cell. This will never be the case in practice, but the degree of approximation to it may be a useful criterion in judging how reasonable an existing or proposed limit is for a given stretch of road and its traffic. In other words, a reasonable limit is one below which speeds are usually appropriate when the way ahead is clear, and speeds above which are inappropriate for most drivers and riders in most circumstances. When this is achieved, relatively few are denied the right to travel at speeds which, though above the limit, are nevertheless appropriate (the situation corresponding to the lower left cell), and it does not happen very often that a speed within the limit is nevertheless inappropriate when the road is clear (the situation corresponding to the upper right cell) – though this is bound to happen sometimes, notably when weather or other conditions call for greater caution than is usual for that stretch of road.

Speed limits cannot address all kinds of inappropriate speed, but this is no reason for failing to use them to full effect to deal with the kinds of inappropriate speed that they do address – namely speeds that are usually inappropriately high for the stretch of road concerned. If speed limits are to be effective, and respect for them as traffic law is to be maintained (or, where it has been lost, regained), they need to be understood and either to be largely self-enforcing (like 20 miles/h limits made so by the road layout), or perceived by the majority of drivers and riders to be reasonable and to be enforced, so that they cannot be widely exceeded with impunity.

1.3 Information, attitudes and enforcement

The need for public understanding of speed limits is one of the key issues addressed by the national publicity campaign *THINK!* from the Department for Transport (DfT), and an example of its achievements is that the proportion of motorists regarding it as unacceptable or highly unacceptable to drive at 40 miles/h where the limit is 30 miles/h rose from 60% in 1998 to 76% in 2003 (DfT, 2006b). The work of *THINK!* both supports and is augmented and complemented by the education, training and publicity activities of local road safety partnerships, including speed awareness courses, and of other organisations concerned for road safety.

The need for speed limits to be perceived as reasonable requires them to be set with care and kept under review, especially in the light of changing traffic conditions and public expectations concerning the safety of various kinds of road user. These needs have been addressed during the years of widespread use of speed cameras by a wide-ranging public consultation between November 2004 and February 2005, followed by the issue in August 2006 of fresh guidance to local highway authorities on the setting of local speed limits (DfT, 2006a). Since then, these authorities have been proceeding with systematic reviews of speed limits on their roads.

Drivers and riders on the road are informed about the prevailing speed limit and the deployment of speed cameras by signs and markings in accordance with the Traffic Signs Regulations and General Directions, augmented in places by vehicle-activated signs (VAS) which can alert drivers who are exceeding a limit to their speed of approach to the sign (DfT, 2003). VAS can help law-abiding drivers to comply with speed limits, but present no threat of sanctions to those who intentionally exceed the limits.

Research which has investigated drivers' choices of speed is exemplified by the findings from a survey of drivers in 2006 (Stradling et al., 2007), which identified three types of driver:

- 'speed limit compliant drivers', who said they only rarely exceeded the limit and then by only modest margins – these made up just over half of the sample;
- 'moderate speeders', who almost all said that they had exceeded the 30 miles/h limit by 5 miles/h, and of whom upwards of a third said they sometimes drove up to 10 miles/h above the prevailing limit, but hardly any of whom said they drove faster than that – these made up about one-third of the sample;
- 'excessive speeders', half of whom said they had exceeded 60 and 70 miles/h limits by 20 miles/h, and a quarter of whom said they had exceeded 30 miles/h limits by the same margin – these made up the remaining one-seventh of the sample.

These findings indicate the mix of drivers with which speed management has to deal, and from which the range of attitudes to it, and in particular attitudes to speed cameras, stem.

Whichever, if any, of these types we see ourselves as belonging to, we all need the discipline of enforcement to help us to keep the limits in mind and to try to comply with them. The *Road Traffic Law Review Report* set out the principle that enforcement should be proportionate. It should bear hard upon blatantly irresponsible offenders, whilst responding to occasional lapses by basically law-abiding drivers with penalties which they can view as sharp but justified reminders to keep their driving up to the mark.

The Review recommended introducing speed cameras because the objective of reducing death and injury

> 'amply justifies the police making use of the best available means within the law to deter and detect offenders… [including]… using the latest technology… [targeted] … as precisely as possible on those most likely to be in breach of the law.'

But detection of a driver who is in breach of the law need not always, or only, lead to imposition of a penalty; it may also, or instead, provide an opportunity for driver improvement, either through the use of discretion to give a warning rather than a penalty, or through requiring the driver to take a course as all or part of a penalty, or as a discretionary alternative to all or part of a penalty.

1.4 The introduction of speed cameras

Following the recommendation of the Road Traffic Law Review, the Road Traffic Act of 1991 made provision for the use of speed and red-light cameras, and after completion of type approval the first cameras came into use in 1992. Their numbers increased slowly over the remainder of the 1990s, giving time for initial studies of their impact and of drivers' response to them.

An early monitored trial was the West London Speed Camera Demonstration Project, in which speed cameras were installed at 21 sites on trunk roads in an area of West London in October 1992. Changes in accident occurrence in this area over the preceding and succeeding three years were compared with changes elsewhere in London. The results indicated substantial reductions in the numbers and severity of accidents and casualties (London Accident Analysis Unit, 1997) and are discussed here in Section 3.1.

Early research into drivers' response to speed cameras (Corbett, 1995) identified four categories of drivers closely related to the three types identified later by Stradling in the context of choice of speed:

- ‘conformers’, who reported normally complying with speed limits so that cameras would make no difference to them – akin to Stradling’s ‘compliant’,
- ‘deterred’, who reported reducing their speed to avoid being caught by cameras – akin to Stradling’s ‘moderate speeders’,
- ‘manipulators’, who reported learning to slow down briefly at known camera sites, but otherwise drove as before, and
- ‘defiers’, who reported carrying on as before, driving well above the limit whenever they thought fit.

Manipulators and defiers together are akin to Stradling’s ‘excessive speeders’, and tended to deny any link between speed and risk of accident. In recruiting samples for a subsequent early study, manipulators and defiers were found to be thin on the ground, which is consistent with Stradling finding only a small proportion of excessive speeders. No doubt as speed cameras became widespread, defiers had to learn to adopt the response of one of the other three categories.

Important findings of that research (Corbett & Simon, 1999) were that those who reported reducing their speeds on roads where they knew there to be cameras reported also reducing their speeds on other similar roads, and that these reported changes in behaviour persisted over time. Most of the drivers from all four categories approved of the idea of speed cameras. Even conformers reported needing to change, because their responses indicated that they had been used to taking speed limits simply as guidance for constructing their own rules as to appropriate speed, and seeing themselves as complying with the law if they kept to their own rules. For them, cameras had the effect of making the posted limit the rule to be complied with.

1.5 Partnerships

Early experience with speed cameras indicated that their use could be cost-effective in terms of casualty reduction, but the rate of deployment was limited by the resource costs both of the installation and operation of the cameras and of the processing of detected offences. To address this problem, and in anticipation of the recommendations of the review of speed policy, HM Treasury set financial rules for a two-year pilot scheme starting in April 2000 in eight police force areas, under which these costs were repaid to the organisations bearing them from the money paid in penalties by the detected offenders, with the intention that a wider system would follow if the pilot scheme proved successful.

Under this scheme the police forces set up partnerships with the highway authorities and magistrates’ courts in their areas to intensify the use of existing speed and red-light cameras, and to install additional cameras on the basis that the costs of doing this and of processing the detected offences would be repaid from the income derived from penalties paid by the offenders detected by the cameras. A board was set up by central government in 1999 to run the pilot scheme and oversee the work of the resulting partnerships. This meant that the pilot scheme could go ahead as one of the first actions in the implementation of the government's road safety strategy after its launch in March 2000, thus also acting on one of the main recommendations of the review of speed policy.

Evaluation of the pilot scheme over the period April 2000 to March 2002 was completed in February 2003 (PA Consulting Group & UCL, 2003), but it became clear enough by the spring of 2001, after only one year of the scheme, that extension was justified under a *National Safety Camera Programme* to any police force area where the police force, the highway authorities and the courts were ready to form a partnership and present an operational plan to the government board. This was provided for in the Vehicles (Crime) Act 2001. The partnerships became known as *Safety Camera Partnerships*, and the board became the *National Programme Board*.

The objectives of the national programme (DfT, 2004) were to:

- reduce deaths and serious injuries on Britain's roads by reducing the level and severity of speeding and red-light running;
- prevent and detect offences; and
- encourage changed driver behaviour

through the nationally approved work of local safety camera partnerships.

The partnerships worked in the following way.

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

- Audited direct costs of operation were refunded to the partnership by the DfT from penalty income.

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

Evaluation of this programme led to a three-year report covering 24 partnerships up to March 2003, and a four-year report covering 38 partnerships up to March 2004 (PA Consulting Group & UCL, 2004; 2005). The four-year report looks right back to the beginning of the pilot scheme and forms the main body of evidence about the efficacy of the programme; it is therefore discussed in some detail in Section 2.

By 2005 almost all the police force areas in Great Britain had formed safety camera partnerships, and these continued to operate as such until March 2007, when refunding of costs from penalty income ceased. From April 2007 they became road safety partnerships with continuing responsibility for safety cameras within a wider responsibility for local road safety work, and with local funding augmented until the summer of 2010 by a road safety grant from central government in place of the refunding of the costs of camera operation from penalty income. Since the summer of 2010, the costs of camera operation have had to be found from general budgets by partnership members, notably local authorities. It remains the case, however, that public expenditure on camera enforcement is broadly matched by the income to the exchequer from the resulting fixed penalty payments. Contrary to a reportedly widespread misapprehension, it is not and has never been to the financial advantage of partnerships or any of their member organisations to increase the number of fixed penalties imposed on the basis of camera detection.

2. The four-year evaluation report

The four-year evaluation report analysed data provided by 38 partnerships for periods of different lengths all ending March 2004, at a total of more than 4,100 sites at which cameras had been installed at various dates. Speed camera sites are of two types: a 'fixed site' is a stretch of road between 0.4 km and 1.5 km in length on which a camera is permanently installed, and a 'mobile site' is a stretch of road between 0.4 km and 5.0 km in length on which a mobile camera is deployed from time to time, not necessarily always at the same place. Sites where the speed limit is 30 miles/h or 40 miles/h are referred to as 'urban sites', and those where the limit is higher as 'rural sites'. The combinations of fixed or mobile, and urban or rural, mean that there are four kinds of site.

The analysis described in the report was concerned mainly with speeds and numbers of collisions and casualties at the sites, with some attention also paid to public attitudes to cameras and their use, and to the finances of the programme.

The contents of the report are discussed here on the basis that:

(a) changes in speed at camera sites between surveys made before and after the deployment of cameras can be attributed to the operation of the cameras; whereas

(b) in the case of changes in the numbers of collisions and casualties, a combination of statistical analysis and judgement is required to assess how much of the recorded changes should be attributed to the operation of the cameras.

2.1 Changes in speed

There were nearly 2,000 sites at which a speed camera had been deployed after the partnership responsible for the site had joined the programme and at which speed surveys had been conducted before and after deployment. About 500 of these were fixed sites, nearly 90% of them urban, and of the nearly 1,500 mobile sites, 75% were urban. It is these sites which provide measurements of the changes in speed associated with camera deployment. Partnerships were not in a position to provide such measurements for sites at which cameras had already been deployed prior to joining the programme.

Average speed was reduced by an average of 5.3 miles/h at fixed sites, urban and rural alike; by an average of 1.4 miles/h at mobile urban sites; and by 1.0 miles/h on average at mobile rural sites.

The 85th percentile speed was reduced by an average of 7.7 miles/h at fixed sites and 1.6 miles/h at mobile sites, with slightly greater average reduction at urban than at rural sites.

The proportion of vehicles exceeding the speed limit was reduced by an average of 72% at fixed urban sites and 51% at fixed rural sites, and by an average of 18% at mobile sites, urban and rural alike.

The proportion of vehicles exceeding the speed limit by 15 miles/h or more was reduced by an average of 94% at fixed urban and 62% at fixed rural sites, and by an average of 36% at mobile sites, with slightly greater average reduction at urban than at rural sites.

The fact that changes were generally smaller at mobile sites than at fixed sites is understandable, because cameras were deployed at mobile sites for only a proportion of the time, and the conspicuity requirements of the programme meant that passing drivers could see whether or not a camera was deployed at the time.

Table 2.1 of the four-year evaluation report presents these average changes at all kinds of site taken together for each of the 33 partnerships that had sites for which the relevant data were available. The average changes vary considerably between partnerships, but the great majority of the average changes for individual partnerships were in the same direction as the overall average changes.

These results indicate a substantial improvement in compliance with the speed limits; a particular reduction in extreme speeding; a marked reduction at fixed sites in average speed; and an appreciable, though more modest, reduction at mobile sites.

All these changes are consistent with the objectives of introducing speed cameras, but they are not an end in themselves. The purpose of changing speeds and the core objective of the camera programme was to reduce casualties, and before turning from evidence of changes in speed to evidence of changes in numbers of casualties at the camera sites, it is useful to consider what kind of changes in numbers of casualties might be expected from observed changes in speeds.

Following a line of investigation opened up by Solomon (1964) and developed by other researchers, notably from 1977 onwards by Nilsson (2004), numbers of collisions and casualties of different severities on stretches of road have been found to vary, other things being equal, as different powers of the average speed of traffic – according to the so-called ‘power model’. The power model is a synthesis of widespread empirical findings from observations of changes in speed and their aftermath on roads of many kinds. It is strongly supported by the laws of motion, which imply undeniably that higher speed just before and at the instant of any collision is associated with shorter time available to the drivers involved to take avoiding or mitigating action, greater exchange of energy and momentum during the collision, and consequently greater forces imposed on the bodies of people involved – and thus greater severity of injury to them (Richards, 2010).

A meta-analysis by Elvik et al. (2004) of 98 relevant previous studies (drawn, using criteria of research quality, from an even larger literature concerned with the estimation of these powers) was extended by Elvik (2009) to cover 115 studies. The 2004 report leads to the conclusion that in the years covered by the four-year evaluation, the number of personal injury collisions (PIC) of all severities was approximately proportional to the square of the average speed, and the number of those killed or seriously injured (KSI) was approximately proportional to somewhat more than the cube of the average speed. These values are broadly supported for British conditions at that time by the work of Taylor and colleagues (Taylor et al., 2000; 2002), except that their work indicates a somewhat higher power than the square for the number of PIC. Elvik's 2009 report estimates that some of the powers are now lower, and this is taken into account in Section 3.4 of this report.

It follows that numbers of PIC and KSI at speed camera sites could be expected to vary as at least the square and cube respectively of average speed.

Applying the power model to a reduction in average speed in the period covered by the four-year evaluation

Suppose that the average speed on a stretch of road falls from 30 miles/h to 27 miles/h.

This is a reduction of 10%, and the average speed is multiplied by 0.9, so other things being equal, according to the power model the number of PIC on this stretch of road could be expected to be multiplied by at most $0.9 \times 0.9 = 0.81$, and thus fall by at least 19%.

Moreover, the number of KSI could be expected to be multiplied by at most $0.9 \times 0.9 \times 0.9 = 0.729$, and thus fall by at least 27%.

To apply these relationships exactly to the speed changes observed at the camera sites would require access to the data for each of the nearly 2,000 sites where changes in speed were measured. This is because the average changes in speed across sets of sites that are given in the four-year evaluation report do not tell us exactly the corresponding averages of the square or the cube of the ratio of the new speed to the previous speed, which would be needed to indicate the expected changes in numbers of PIC and KSI. Fortunately, however, it is possible to verify from Table 2.1 of the report that the observed percentage changes in speed are such that the required mean square and cube are well approximated by the square and cube of the mean ratio.

From examining Tables 2.2, 2.3 and 2.4 of the report together, it can be inferred that the average percentage reductions in speed at fixed urban and fixed rural sites were about 16% and 8% respectively, and those at mobile urban and mobile rural sites were about 3.5% and 2% respectively. The corresponding mean ratios of the new speed to the previous speed are 0.84, 0.92, 0.965 and 0.98 respectively.

On this basis, it follows that, according to the power model, if speed camera sites were typical stretches of road, the numbers of PIC and KSI at fixed urban sites would be expected to be multiplied on average by about $(0.84)^2 = 0.71$ and $(0.84)^3 = 0.59$ respectively, i.e. reduced by about 29% and 41% respectively, as a result of the reductions in average speed brought about by the cameras. Corresponding calculations for the other three kinds of site lead to the percentage reductions shown in Table 1.

Table 1: Percentage reductions in PIC and KSI that would be expected, according to the power model, from percentage reductions in average speed observed at camera sites in the four-year evaluation, if these sites were typical stretches of road

Type of site	Percentage reduction (%)	
	PIC	KSI
Fixed urban Fixed rural	29 15	41 22
Mobile urban Mobile rural	7 4	10 6

These percentages are only approximate and indicative, but they provide an input to consideration of the recorded changes in numbers of PIC and KSI.

2.2 Changes in numbers of injury collisions and fatal or serious casualties

Partnerships provided, for each camera site, the numbers of PIC and KSI in each month after the site became operational up to and including March 2004, and the total numbers for a baseline period – usually of three years – before the camera became operational. For most camera sites, the corresponding numbers of pedestrian and child PIC and KSI were also provided.

Total numbers of PIC and KSI on all urban and all rural roads in each police force area in Great Britain, for each quarter from January 1997 until April 2004, were used in a preliminary analysis to estimate trends and variation by quarter of the year in these numbers, as a basis for allowing for these sources of variation in the main analysis of data from the camera sites – such sources include, for example, the effect of trends in the amount of traffic and in the levels of reporting of collisions.

Log-linear models were used to estimate for each site the numbers of PIC and KSI that would have been expected in the year ending March 2004 if collisions and casualties had continued to occur at the rates per year prevailing in the baseline period, subject only to the trends and seasonal variations estimated in the preliminary analysis. For this purpose the method of modelling used is thorough and appropriate. The modelling allowed for the date on which the partnership concerned entered the national programme; the date from which the camera became operational at the site; and, for fixed sites, the date on which the camera was made conspicuous in the way required by the programme. It also distinguished between fixed and mobile, and between urban and rural sites, and would have distinguished red-light camera sites from speed camera sites if this difference had been significant in terms of changes in numbers of PIC and KSI associated with the camera being operational.

The preliminary analysis and modelling were carried out separately for all PIC and KSI, for pedestrian PIC and KSI, and for child PIC and KSI; however, only the results for all PIC and KSI are discussed here, because the results for pedestrians and children separately, though informative about these kinds of collision and casualty, do not add substantially to the evidence on overall efficacy of the cameras.

The numbers of PIC and KSI that would have been expected in the year ending March 2004 if collisions and casualties had continued to occur at the rates per year prevailing in the baseline period, subject only to trend and seasonal variation, were estimated in order to enable these numbers to be compared with the numbers actually recorded at the sites in the year ending March 2004, so as to provide a starting point for estimating the effect that the cameras had had on these numbers. The percentage differences found using data from about 4,400 sites for PIC and nearly 4,200 sites for KSI are shown in Table 2, which is drawn from Tables 3.2 and 3.3 of the four-year evaluation report.

Table 2: PIC and KSI at camera sites in year ending March 2004 – percentage reduction to numbers recorded from numbers expected at rates per year prevailing in the baseline period, after allowing for trend and seasonal variation

Type of site	Percentage reduction (%)	
	PIC	KSI
Fixed urban Fixed rural	22.4 33.2	46.8 62.4
Mobile urban Mobile rural	22.4 15.5	34.9 33.8

In relation to the efficacy of cameras in reducing collisions and casualties at camera sites, the question is: how much of the percentage reductions in Table 2 should be attributed to the cameras?

It was concluded in Section 2.1 of this report that applying the power model of relationship between average speed and occurrence of collisions and casualties to the reductions in average speed observed after the speed cameras came into operation would lead us to expect the percentage reductions in PIC and in KSI shown in Table 1 at the four kinds of camera sites, provided that these were indeed typical stretches of road. Except for fixed urban sites, these percentages are a good deal lower than those in Table 2, and suggest that not all of the reductions in Table 2 should be attributed to the cameras.

Another important reason why not all of the reductions in Table 2 should be attributed to the cameras is that two of the criteria for selection of sites for cameras were that there should have been at least certain numbers of PIC and KSI respectively at the sites in recent years, and in many cases the periods from which collision and casualty data were used to apply these criteria overlapped substantially with the baseline period used in the evaluation analysis. This implies a tendency for the selected sites to have had, by chance, numbers of PIC and KSI in the baseline period that were above average for the sites concerned, which in turn implies that the numbers to be expected at those sites in subsequent years would tend to be lower than the numbers estimated from the baseline period, even had no camera been deployed there. This tendency in such circumstances for expected numbers in subsequent years to be lower than the numbers estimated from the baseline period is known as 'regression to the mean' (RTM), and is discussed fully in the context of evaluation of road safety measures by Hauer (1997).

It had been a criticism of the evaluation of the pilot scheme, and of the three-year evaluation report on the safety camera programme, that they made no allowance for RTM, and the issue of allowing for it was therefore addressed during the work on the four-year evaluation report. Hauer shows (see text box) how such allowance can in principle be made in evaluation of measures like the deployment of safety cameras, and that has led some commentators to suggest that allowance for RTM is a simple matter that should routinely form part of any such evaluation. But this is in practice by no means the case: the difficulty in doing so has been aptly expressed by one analyst, who said in the context of speed cameras, 'Give me an appropriate mean, and I will gladly allow for regression to it!'

Allowance for regression to the mean by the Empirical Bayes method

Allowance for RTM is needed when a site is chosen for application of a safety measure on the grounds that it has recently had untypically many collisions, and it is required later to estimate how the number of collisions has been affected by applying the safety measure. For this purpose it is necessary to estimate the typical rate of occurrence of collisions at that site without the safety measure, for comparison with the rate at which collisions occur there with the measure in place.

To make this estimate by the Empirical Bayes method requires knowledge of the probability distribution of rates of occurrence of collisions at sites in a *reference population* from which the site being considered can be regarded as having been drawn. Given this probability distribution, the typical rate of occurrence of collisions at the site being considered is estimated to be an appropriately weighted average of the mean of the distribution and the observed rate of occurrence on which the selection of the site was based.

The principal difficulty in applying this method in practice is to identify an appropriate reference population, and observe (or model) the associated probability distribution.

Allowance for RTM in the analysis in the four-year evaluation report by the method Hauer describes would require, for each camera site, an estimate of the probability distribution of the average numbers of PIC and KSI per year, in the absence of cameras, at sites in a 'reference population' of candidate sites from which that site could be regarded as having been selected. Early in the four-year evaluation, Mountain et al. (2004a) had published a study of effects of speed cameras at 62 sites with 30 miles/h limits, in which they allowed for RTM by using reference populations based on predictive models for numbers of PIC and 'fatal or serious collisions' (FSC) derived from all sections of 30 miles/h classified roads in six counties. (Numbers of FSC were modelled, rather than numbers of KSI, for statistical reasons, but the two are closely related.) Application of these models, and related models for roads with other speed limits, in the four-year evaluation would have required partnerships to provide substantial additional data about their camera sites over and above the data they were being expected to supply for the purposes of the evaluation. Partnerships were invited to provide this additional data if they felt able to do so, and Mountain and Maher agreed to make such estimates of the contribution of RTM to reduction in collisions as the data permitted. Their work is reported in Appendix H of the four-year report.

In the event, the required data were provided for a subsample of only 216 urban sites and 101 rural sites, and data for rural sites indicated that the available predictive models would not be suitable for application to these sites. The estimation of the effect of RTM was therefore confined to the 216 urban sites, for which the effects of RTM on numbers of PIC and FSC were estimated for fixed and mobile sites separately. Appropriate allowance was made for trend in a rather different way from in the analysis leading to Table 2, without explicit allowance for seasonal variation. The results are shown in Table 3; this is arranged to match Table 2, but before embarking on any comparison it is necessary to discuss a number of aspects of the subsample of sites, and the appropriateness of the reference population.

Table 3: PIC and FSC at the subsample of 216 urban camera sites in year ending March 2004 – percentage reduction to numbers recorded from numbers expected at rates per year prevailing in the baseline period, after allowance for trend, and for trend and RTM

Type of site and effect allowed for	Percentage reduction (%)	
	PIC	FSC
Fixed urban Trend only Trend and RTM	 18.8 16.6	 38.9 23.5
Mobile urban Trend only Trend and RTM	 26.0 19.4	 51.6 17.6

The subsample of 216 urban sites consisted of 52 fixed sites and 164 mobile sites. All but one of the fixed sites were from just three of the partnerships. Two-thirds of them were from Staffordshire, which was quite exceptional in the changes in numbers of PIC and KSI at its sites, showing in the main analysis a reduction of only 7.6% in PIC and an increase of 5.2% in KSI in contrast to the overall reductions of 22.4% and 46.8% shown in Table 2. Another six sites were from South Wales, which showed a reduction of only 1.8% in PIC and whose sites were excluded from the main analysis of numbers of KSI because of possible effects upon recording of KSI casualties of a change in definition. The mobile sites were drawn from eight partnerships, seven of which showed a rather typical range of reductions in PIC and KSI in the main analysis, but more than one-third of the mobile sites were from South Wales. In discussing the subsample, the four-year report notes that the average number of KSI per fixed site in the baseline period was only 59% of the average for the whole sample, and the average reduction in KSI per fixed site in the subsample was only 42% of the average for the whole sample. For PIC the corresponding percentages were 73 and 58 respectively, so for both PIC and KSI the reductions at the subsample sites were substantially below the average for the whole sample, and by amounts that could only partly be accounted for by there being fewer in the baseline period.

The authors of Appendix H recognise that the subsample they were able to work with was not representative of all urban camera sites nationally, but it should be noted that the subsample is unrepresentative not only geographically and in the proportions that are fixed or mobile, but also in the PIC and KSI reductions recorded at fixed sites in it, and across some of the partnership areas from which the subsample was drawn.

Concerning the reference population, the authors of Appendix H recognise that to provide sound estimates of the effect of RTM, the reference population should reflect all the site characteristics which, together with previous numbers of collisions or casualties, have influenced the selection of sites. This is so that the reference population for each site is one from which the selected site can be regarded as having been drawn. In the national safety camera programme, the sites at which speed cameras were deployed were required not only to have had certain numbers of PIC and KSI in the baseline period, but also

- to have had a history of speed-related collisions;
- to show certain levels of speeding;
- to be suitable in various ways for camera deployment; and
- to be unsuitable for the application of other viable safety engineering treatments.

The reference populations used in Appendix H reflect only traffic flow, length of the site and number of minor intersections within that length. For urban sites they are representative of all stretches of classified road in six counties which have speed limits of 30 miles/h and 40 miles/h. The authors argue that it does not matter that they do not explicitly represent sites with the required levels of speeding, because the levels observed at the camera sites are not untypical of speeding on roads with limits of 30 miles/h or 40 miles/h nationally.

However, the camera sites were required also to have a history of speed-related collisions, and to be suitable for camera deployment and unsuitable for other safety engineering measures. Moreover, they were the outcome of a process of selection, in general from among a larger number of candidate sites meeting all the criteria, by engineers and police officers familiar with the local road network. The writer finds it hardly conceivable that the resulting sets of sites were typical, in all respects other than recent numbers of PIC and KSI, of all stretches of road with 30 miles/h and 40 miles/h speed limits respectively in the partnership areas. As the writer commented (Allsop, 2004) on Mountain et al.'s earlier study (2004a):

> '…it remains a matter of speculation whether the means for candidate sections were higher or lower than… [those]… used by the authors. But the writer can think of a number of reasons why the means for candidate sections may have been higher, and has so far thought of no reason why they may have been lower. It is therefore the writer's view that the authors' estimate of the effect of RTM is much more likely to be an overestimate than an underestimate, and may well be a substantial overestimate. It is therefore also his view that their estimate of the impact of speed cameras on safety… is much more likely to be an underestimate than an overestimate, and may well be an appreciable underestimate.'

That opinion predated the work reported in Appendix H of the four-year report, but it is just as relevant to that work as to the earlier study, and indeed many of the arguments advanced in Appendix H in support of the authors' choice of reference population are already to be found in their response (Mountain et al., 2004b) to the foregoing comment.

In the writer's opinion, therefore, the estimates of the effect of RTM on numbers of PIC and FSC that are quoted in Table 3 should be viewed with considerable caution, even in relation to the subsample of 216 sites, and with even greater caution in relation to the whole sets of fixed and mobile urban sites to which the percentage reductions in PIC and KSI in Table 2 relate.

Nevertheless, alongside indicative percentages that have been derived earlier in these pages from other sources, it is useful to adjust the percentage reductions in Table 2 by using those in Table 3 *as if* the latter were accepted as appropriate to all urban sites, which they are not.

For PIC at the fixed urban sites in the subsample, of the 16.6% estimated reduction after allowing for trend, 16.6% still remained after allowing also for RTM. To use these percentages to obtain an indication of how much of the corresponding 22.4% reduction after allowing for trend and seasonal variation in Table 2 would remain after allowing also for RTM, suppose that the proportion x of the reduction that is attributable to RTM is the same for PIC at all fixed urban sites as for those in the subsample. It is shown in Appendix 1 that this proportion is $x = 100 \times (18.8 - 16.6) / (18.8 \times (100 - 16.6)) = 0.14$. This leaves a proportion 0.86 of the 22.4%, or 19.3% attributable to the effect of the cameras.

This 19.3% is a percentage of the number of PIC that would have been expected at the camera sites without the cameras, allowing only for trend and seasonal variation. To estimate the percentage reduction in PIC attributable to cameras at fixed urban sites after allowing for RTM, the reduction needs to be expressed instead as a percentage of the number of PIC that would have been expected without the cameras after allowing for RTM and for trend and seasonal variation. It is shown in Appendix 1 that this is achieved by multiplying the 19.3 by 100/(100 – (0.14 × 22.4)) = 1.03, to give 19.9%.

Corresponding calculations for PIC at mobile sites and for KSI at each kind of urban site on the further assumption that estimates for FSC in Table 3 can be applied to percentages for KSI in Table 2, lead to the indicative percentage reductions shown in Table 4.

Table 4: PIC and KSI at camera sites in year ending March 2004 – indicative percentage reduction to numbers recorded from numbers expected at rates per year prevailing in the baseline period, after allowance for trend, seasonal variation and RTM

Type of site	Indicative percentage reduction (%)	
	PIC	KSI
Fixed urban	19.9	29.8
Mobile urban	16.5	9.7

In the context of recent developments in the funding of road safety partnerships, data have been supplied by some partnerships which provide strong support for the supposition that RTM is indeed likely to have contributed to the percentage reductions in PIC and KSI in Table 2. A number of partnerships covering various mixes of urban and rural areas in various parts of the country have been able to provide, alongside total numbers of PIC or casualties of all severities (CAS), and KSI or FSC, at camera sites in their respective three-year baseline periods, total numbers at the same sites in the three years preceding the baseline period. These are summarised in Table 5.

Table 5: Numbers of collisions or casualties at camera sites in six partnership areas in baseline periods and in the preceding three years

Partnership	PIC or CAS		KSI or FSC	
	Pre-baseline	Baseline	Pre-baseline	Baseline
A	1362	1646	226	241
B	1604	1485	259	268
C			132	177
D	379	480		
E	1028	1219	140	224
F	201	154		
Total	4574	4984	757	910

In the period to which the bulk of these data refer, the national total numbers of PIC and CAS showed no clear upward or downward trend, and the numbers of KSI and FSC were falling by about 3.5% per year. So if there had been no tendency for the selected sites to have had, by chance, numbers of collisions and casualties in the baseline period that were above average for the sites concerned, the baseline total of 4,984 PIC or CAS should have been about 4,574 and the baseline total of 910 KSI or FSC should have been about 0.9 × 757, or about 681 (the multiplier 0.9 representing three years of decrease at about 3.5% per year compound). If the data in Table 5 were representative of the baseline data on which the four-year evaluation was based and the corresponding pre-baseline periods, which they are not, this would imply that the expected numbers on which the percentage reductions in Table 2 are based should be reduced by a factor of about 410/4984, or about 8%, for PIC, and about 229/910, or about 25%, for KSI.

Like the implications of the power model in Section 2.1, these percentages too are only approximate and indicative, but they provide a further input to consideration of the recorded changes in numbers of PIC and KSI, in that they give another indication of the possible scale of the contribution of RTM to the reductions in Table 2. This can be obtained by reducing the expected numbers of PIC and KSI on which those percentages are based by 8% and 25% respectively *as if* the data in Table 5 concerning numbers in baseline periods and the preceding three years were representative of corresponding figures for the partnerships and periods for which the four-year evaluation was conducted. The effect of doing this is to replace each percentage X by $100 - (100 - X)/p$, where $p = .92$ for PIC and $p = .75$ for KSI as shown in Appendix 1. The results are given in Table 6.

Table 6: PIC and KSI at camera sites in year ending March 2004 – percentage reduction to numbers recorded from numbers expected at rates per year prevailing in the baseline period, after allowing for trend and seasonal variation, and reducing the resulting expected numbers by 8% for PIC and 25% for KSI

Type of site	Percentage reduction (%)	
	PIC	KSI
Fixed urban Fixed rural	15.7 27.4	29.1 49.9
Mobile urban Mobile rural	15.7 8.2	13.2 11.7

The foregoing discussion has brought together from the four-year evaluation report and other sources a range of quantitative evidence relevant to the question: by what percentages can deployment of a speed camera be expected on average to reduce the number of personal injury collisions (PIC) and the number of people killed or seriously injured (KSI) in such collisions at the site where the camera is deployed? The available information enables this question to be addressed for each of four kinds of site: ‘fixed urban’, ‘fixed rural’, ‘mobile urban’ and ‘mobile rural’, where fixed and mobile refer to the way in which the camera is deployed, urban indicates a speed limit not exceeding 40 miles/h and rural a speed limit exceeding 40 miles/h. The evidence is by its nature imprecise and incomplete, and its interpretation requires subjective judgement as well as objective calculation. The various pieces of evidence are next mobilised in order to offer a judgement as to what can be said about the unknown true values of each of the eight missing average percentages in the following table

Type of site	Percentage reduction (%)	
	PIC	KSI
Fixed urban Fixed rural	? ?	? ?
Mobile urban Mobile rural	? ?	? ?

The language used in the following is deliberately chosen to avoid implying precision, because the available evidence, though substantial, is not of a kind which is able to support precise estimates.

The four-year evaluation report estimates the percentages shown in Table 2, but recognises that the resulting estimates will in all probability have exaggerated the effect of cameras because of regression to the mean. In other respects, the reported analysis is methodologically sound. The true percentages are thus unlikely to be higher, and may well be appreciably lower, than those in Table 2.

The same report estimates the mean percentage changes in average speed of traffic following deployment of cameras at the four kinds of site, and this analysis is methodologically sound. Taken with the widely accepted power model of relationship between average speed and occurrence of collisions and casualties on typical stretches of road, the estimated changes in average speeds at the four kinds of site lead to an expectation that PIC and KSI would be reduced by the percentages in Table 1 if the camera sites were typical stretches of road. But the camera sites have been chosen partly on the basis of having a history of speed-related collisions, so that reducing speed at camera sites might be expected to reduce collisions and casualties there more than on typical stretches of road. This suggests that the true percentages are likely to be higher than those in Table 1.

For all except fixed urban sites, then, the true percentages seem likely to lie between the (lower) values in Table 1 and the (higher) values in Table 2. This cannot be the case for PIC at fixed urban sites because the percentage for PIC in Table 1 exceeds that in Table 2, and it may not be the case for KSI at fixed urban sites either, because although the percentage for KSI in Table 1 is lower than that in Table 2, they are, at 41% and 46.8%, not far apart.

It remains to consider what little is known about how much the percentages in Table 2 are likely to have been exaggerated by regression to the mean. For the two kinds of urban sites, the analysis in Appendix H of the four-year evaluation report, which is methodologically sound but applies to an unrepresentative subsample of sites and uses a debatable reference population, leads to the four percentages shown in Table 4. Reservations about the chosen reference population indicate that the percentages in Table 4 are more likely to be underestimates than overestimates, because the effect of regression to the mean is more likely to have been overestimated than underestimated. For the two kinds of urban sites, therefore, the true percentages are likely to be somewhat higher than those in Table 4.

The other rather serendipitous indication available about the possible scale of the effect of regression to the mean comes from collision and casualty data from some partnerships for the years preceding the baseline periods used in the choice of camera sites, and in the conventional estimation of collision and casualty reduction. These data cannot be regarded as representative, but they lead to percentages in Table 6 which are, for urban sites, not dissimilar from those in Table 4, and thus corroborate them in general terms. They also point to percentages for rural sites which are between the lower values in Table 1 and the higher values in Table 2.

This consideration of the percentages in the various tables leads to the judgement in Table 7 as to where the true percentages are likely to lie. Each true percentage is the central value of a distribution reflecting sampling error; the available data do not enable any judgement to be offered as to the ranges of sampling error, but they are likely to be a good deal wider than the ranges in the table, which simply reflect uncertainty in judgement about the central value.

Table 7: Likely percentage reduction in PIC and KSI at speed camera sites following the deployment of cameras (additional to any effect of regression to the mean resulting from choice of sites having unusually high recent collision and casualty numbers)

Type of site	Percentage reduction (%)	
	PIC	KSI
Fixed urban Fixed rural	Between 20 and 25 Between 20 and 30	Between 35 and 40 Between 30 and 50
Mobile urban Mobile rural	Between 15 and 20 Between 10 and 15	Between 15 and 30 Between 15 and 30

The wider ranges for rural than for urban sites are consistent with the fact that the evaluation covered about four times as many urban sites as rural sites.

Applying these percentages to the data in the four-year evaluation report leads to the round-figure judgement in Table 8 as to the numbers of PIC and KSI prevented in the year ending March 2004 at the more than 4,000 sites covered by the evaluation.

Table 8: Likely numbers of PIC and KSI prevented in the year ending March 2004 at camera sites by the deployment of cameras

Type of site	Number prevented in year ending March 2004	
	PIC	KSI
Fixed urban Fixed rural	Between 1700 and 2200 Between 170 and 300	Between 500 and 560 Between 60 and 140
Mobile urban Mobile rural	Between 1000 and 1400 Between 180 and 300	Between 150 and 400 Between 90 and 200
All sites	Between 3050 and 4200	Between 800 and 1300

It should be noted that these estimates take no account of the possibility that some of the reduction in PIC and KSI at camera sites may have resulted from diversion of traffic to alternative routes as a result of drivers wishing to avoid the cameras. At the 62 sites studied by Mountain et al. (2004a), about 5% of traffic was estimated to have been diverted for no other apparent reason. The writer is not aware of evidence as to whether such diversion continued to occur as the numbers of camera sites increased, drivers became more accustomed to them, and the availability of camera-free alternative routes declined.

Another issue not addressed explicitly in the four-year evaluation, but examined in detail by Mountain et al. (2004a), is the oft-raised question of the extent to which the behaviour of drivers who slow down, perhaps rather suddenly, on approaching a camera in order to comply with the speed limit at the site, and then accelerate away, gives rise to collisions which would not have occurred in the absence of the camera. Their analysis extended to 1 km either side of the camera locations and they concluded that there was no positive evidence of such collisions at the sites they studied. Their numerical findings show that if there were such collisions, their number was clearly exceeded by the reduction that followed deployment of the cameras. In the four-year evaluation, although this issue is not addressed directly, the lengths of road covered by monitoring at many of the camera sites were such that any collisions of this kind that may have occurred at those sites were likely to have been included in the collision and casualty counts on which the analysis is based.

To conclude this section, it is useful, for reasons such as comparison with operating costs of camera enforcement, to express average reductions in collisions and casualties in units of PIC per site-year and KSI per site-year. When the estimated reductions in Table 8 are divided by the corresponding numbers of sites given in Tables 3.2 and 3.3 of the four-year evaluation report, the round-figure estimates in Table 9 of average reductions per site-year after allowing for RTM are obtained.

Table 9: Likely reductions per site-year in PIC and KSI at speed camera sites following the deployment of cameras (additional to any effect of regression to the mean resulting from choice of sites having unusually high recent collision and casualty numbers)

Type of site	Reduction per site-year	
	PIC	KSI
Fixed urban Fixed rural	Between 0.8 and 1.1 Between 0.5 and 0.9	Between 0.25 and 0.30 Between 0.15 and 0.40
Mobile urban Mobile rural	Between 0.7 and 1.0 Between 0.3 and 0.6	Between 0.10 and 0.30 Between 0.20 and 0.40

2.3 Public acceptance of cameras

During the first four years of the programme, the partnerships commissioned independent surveys of opinion about camera enforcement in their areas, using a common set of seven questions designed to offer respondents the opportunity to express a wide range of views. Responses obtained from almost all partnerships at dates spread over 2003 and 2004, with a few in 2002, are summarised in Table 10. Apart from the exceptions mentioned in the table, the percentages in the various partnership areas are spread roughly evenly over the ranges mentioned. A wide range of responses across partnerships is understandable because of socio-demographic differences between their areas, and because different partnerships communicated differently with people in their areas about camera enforcement.

Partnerships also monitored local press coverage over the period of their participation in the programme up to March 2004, measured in column inches categorised as ‘positive’, ‘neutral’, or ‘negative’. There was a wide variation in amount of coverage, but the percentage categorised as positive or neutral ranged from 66% to over 90%, with an average of 85%.

Notwithstanding widely reported negative views that some hold about speed cameras, the picture that emerges is of a broad base of understanding and support for camera enforcement in the third and fourth years of the programme, and the almost unchanging response by AA members since then is consistent with this remaining the case.

Table 10: Summary of responses to questions in opinion surveys in each partnership area

Question: Do you agree that…	Percentage of respondents agreeing
…cameras are meant to encourage drivers to stick to the limits, not punish them?	Between 60% and 89% in all but two partnerships (exceptions 41% and 56%)
…fewer collisions are likely to happen on roads where cameras are installed?	Between 50% and 82% in all but one partnership (exception 89%)
…cameras are an easy way of making money out of motorists?	Between 35% and 74% in all but one partnership (exception 15%)
…cameras mean that dangerous drivers are more likely to get caught?	Between 44% and 80% in all partnership (exception 15%)
…the use of safety cameras should be supported as a method of reducing casualties?*	Between 67% and 89% in all but three partnerships (exceptions: 94%, 96% & 98%)
…the primary aim of cameras is to save lives?	Between 51% and 79% in all but three partnerships (exceptions: 85%, 92% & 93%)
…there are too many safety cameras in our local area?	Between 12% and 28% in all but nine partnership (exceptions: 5%, 6%, 7%, 32%, 35%, 38%, 39%, 40% & 41%)

* For the last nine years the AA has asked a sample of its members a similar question:

It is now common for the police to use speed cameras at the side of the road to identify vehicles involved in speeding offences. How acceptable do you think this is?

and has consistently found about 70% of respondents choosing one or other of the answers 'quite acceptable' or 'very acceptable'. In 2010 this figure was 75%.

3. Other evidence

3.1 The West London demonstration project

In contrast to the evaluation reports which confined attention to changes at camera sites, and in which it was understandably judged impracticable to identify control sites, the evaluation of the West London demonstration project (London Accident Analysis Unit, 1997) considered changes in numbers of collisions and casualties over the whole of a substantial affected road network in West London, using the rest of London as a control area.

On the 85 km of trunk roads in West London, 21 speed cameras and 12 red-light cameras were operational for three years from October 1992, and numbers of collisions and casualties in those three years were compared with numbers in the preceding three years. The comparison was made for two sets of roads. For trunk roads in the affected network, trunk roads in the rest of London were used as the control network for the first two years and (because cameras were then installed on some of these) non-trunk A-roads in the rest of London for the third year. For non-trunk roads in West London, non-trunk roads in the rest of London were used as the control network.

In summary, in the three years of camera operation there were 226 fewer FSC and 265 fewer KSI on the trunk roads in West London than would have been expected from numbers on trunk roads in the rest of London. Against these should be set about 75 extra FSC and 88 extra KSI on non-trunk roads in West London, indicated by the fact that reductions on these roads were smaller than on non-trunk roads in the rest of London. This adjustment includes any migration of collisions from trunk to non-trunk roads that may have resulted from drivers diverting to avoid camera sites. From the reductions on trunk roads should also be subtracted about 36 FSC and 42 KSI attributed to reduced red-running collisions and thus to red-light cameras rather than speed cameras.

The resulting net reductions of about 115 FSC and 135 KSI attributed to speed cameras represent reductions amounting about 6.4% on trunk roads in West London relative to those in the rest of London. They also correspond to about 1.8 FSC or 2.1 KSI per speed camera site-year. When the red-light cameras are included and the reductions attributed to reduced red-running collisions are added back, the rates are 1.4 FSC and 1.6 KSI per camera site-year.

These network-wide estimates of effect per site-year are substantially higher than the average at-site reduction of 0.30–0.35 KSI per urban fixed site-year derived at the end of Section 2.2 from estimates in the four-year evaluation report and other considerations. Although this difference probably arises partly from higher traffic flows and previous numbers of KSI per site in West London than across all sites nationally, it is also suggestive of a casualty-reducing effect of cameras that is more widespread than simply at the camera sites.

Although the West London road network is in no way representative of the network nationwide, the evaluation of use of cameras there has the advantage of estimating the effect of camera deployment upon numbers of collisions and casualties across the whole affected road network. The results are not subject to bias resulting from RTM because reductions due to this at sites which had above-average numbers in the preceding period are in expectation balanced across the network by increases at sites which had below-average numbers in those years. The results also take into account any possible relocation of collisions from routes on which cameras are deployed to alternative routes, as a result of drivers seeking to avoid camera sites.

3.2 Effects at camera sites across London

Concurrently with the evaluation studies of the national safety camera programme, a study of effects at camera sites of camera deployment across London was made for the *London Safety Camera Partnership* (Gorell & Sexton, 2004). The effects on numbers of PIC and FSC were estimated by comparing numbers in the three years before and the three years after deployment at 77 sites that met the criteria of the national programme with corresponding numbers at a set of control sites. Each control site was chosen to match one of the camera sites in terms of collision history over the 'before' years, traffic flow, length of site and location in London.

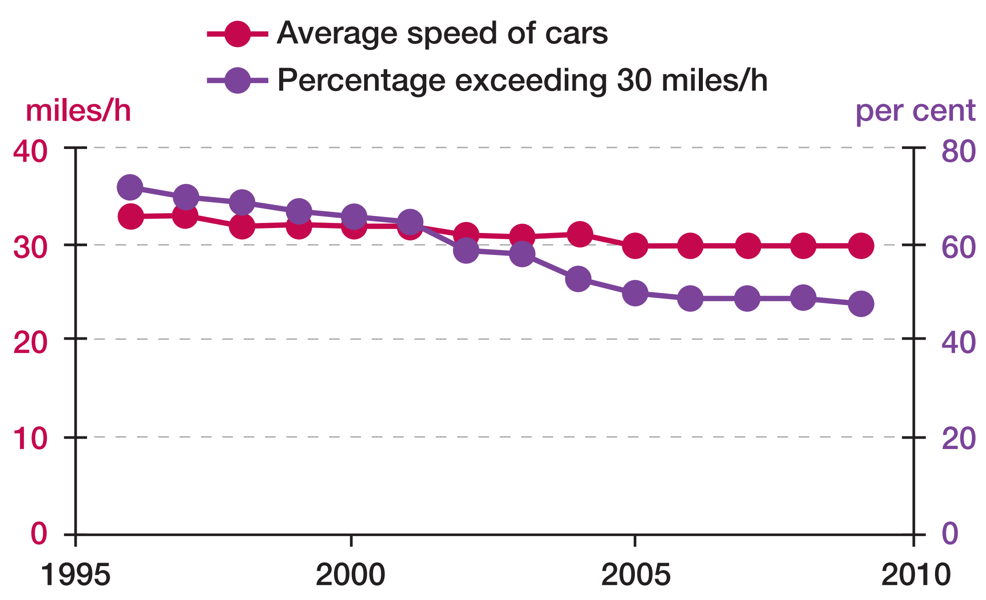
By comparing the changes in numbers of collisions at camera and control sites in ways that allowed for the effects of trend and RTM, reductions of 12% in numbers of PIC and 21% in numbers of FSC were attributed to cameras having been deployed. These percentages are lower than those for fixed urban sites nationally in Table 7, but they are broadly consistent with the percentage reductions in PIC and KSI estimated for the London Partnership in the four-year evaluation report when these are adjusted for the likely effect of RTM.

3.3 Wider changes in speeds and in numbers of collisions and casualties

The most systematic data concerning traffic speeds on the roads of Great Britain are the National Statistics time-series of average speeds in free-flowing traffic derived from automatic traffic counters at a national sample of sites and published in *Road Statistics: Traffic, Speeds and Congestion* (DfT, annually). It is important to remember that these are speeds in conditions where most drivers can choose how fast to go, as distinct from congested conditions in which most are constrained to follow the vehicle ahead.

The most marked change in these speeds since the mid-1990s has been on roads with the national urban speed limit of 30 miles/h. Figure 1 shows the average speed, to the nearest mile per hour, of cars on these roads in free-flowing traffic, and the corresponding percentage exceeding the limit, from 1996 to 2009.

Figure 1: Trends in average speed of cars, and percentage exceeding the speed limit, in free-flowing traffic on roads with a 30 miles/h limit



The average, which is given to the nearest mile per hour in the published tables, fell from 33 miles/h to 30 miles/h between 1996 and 2009 without any upward fluctuation. The percentage exceeding the limit also fell without upward fluctuation, from 72 in 1996 to 48 in 2009, with a period of steeper decrease between 2001 and 2005.

Of course there have been other important influences contributing to these trends alongside camera enforcement – notably traffic calming and public information – but it is interesting that the period of steeper decrease in the percentage exceeding the limit, between 2001 and 2005, coincided with the roll-out of camera enforcement under the national safety camera programme.

On roads with speed limits higher than 30 miles/h, with the major exception of rural single carriageways, there have been some modest signs of moderation in speeds in free-flowing traffic, but only in the last few years, subsequent to the main phase of the national safety camera programme, as indicated for each category of road in the text box.

Changes in speeds since 1996 on roads with speed limits higher than 30 miles/h

On roads with a 40 miles/h limit the average speed of cars has remained at 36–37 miles/h since 1995 and the percentage exceeding the limit varied between 25% and 28% until 2006, but was 24% in 2007 and 2008 and 23% in 2009, so only recently has there been some sign of moderation of speeds on these roads.

On rural single carriageways with the national limit of 60 miles/h, the average speed of cars varied between 45 miles/h and 47 miles/h until 2002, and has since remained at 48 miles/h. The percentage exceeding the limit has been either 9% or 10% every year except 2002, when it was 8%, and 2005 and 2006, when it was 11%. On these roads, the problem of larger percentages of drivers exceeding the limit seems to be localised, rather than being widespread as it is on 30 miles/h roads. This is evidenced by particular stretches of rural road meeting the criteria for siting of speed cameras, while the general level of compliance with the national speed limit is high.

On rural dual carriageways with the national limit of 70 miles/h, the average speed of cars varied between 69 miles/h and 70 miles/h until 2005, but has averaged 68 miles/h since 2006. The percentage exceeding the limit was in the low 50s in the 1990s but fell steadily after 2000 to 45% in 2007, and has been in the low 40s since then.

On motorways the average speed of cars was between 70 miles/h and 71 miles/h until 2006, but has been between 69 miles/h and 70 miles/h since 2007. The percentage exceeding the limit was in the mid-50s until 2006, but has been in the low 50s since 2007.

The reduction in average speed in free-flowing traffic on roads with the 30 miles/h limit from 33 miles/h to 30 miles/h, which represents a decrease of 9.1%, took place between 1997 and 2005, when there was no counterpart reduction in speeds on roads with higher speed limits. According to the power model, this would be expected to result in a reduction in collisions and casualties on built-up roads having no counterpart on non-built-up roads. In fact between 1997 and 2005, PIC fell nationally by about 18% and KSI by about 32% on both kinds of road alike. But statistical modelling by Broughton (2003) shows that an important contributor to reductions in car occupant casualties in that period was improvement in occupant protection in cars, and in 1997–2005, car occupants accounted for about two-thirds of all KSI on non-built-up roads, and only about one-third on built-up roads. The reduction in KSI from improved occupant protection would therefore have been expected to be greater on non-built-up than on built-up roads. A reduction in average speed of 9.1% could have been expected, according to the power model, to lead to reductions of about 17% in PIC and about 25% in KSI, and reductions of this order in free-flowing traffic on roads with the 30 miles/h limit may well have helped the overall reductions on built-up roads between 1997 and 2005 to match those on non-built-up roads, despite the improvement in car occupant protection having less effect on casualty numbers on built-up roads.

Another national statistic that is often quoted in discussion of speed, collisions and casualties is the percentage of reported PIC in which a police officer attends the scene and records as a contributory factor either exceeding the speed limit or travelling too fast for the conditions. In 2009 (DfT, 2010) this was 13% for all PIC, 15% for serious injury collisions and 26% for fatal collisions. This statistic has been recorded in its present form only since January 2005, so the time series is not yet well established, and it is not comparable with more limited data for earlier years, so it is not possible to comment on changes in it over the period since camera enforcement became widespread.

3.4 Persistence of reductions in fatal or serious casualties at camera sites

A number of road safety partnerships have recently summarised total numbers of KSI in the past three years at their speed camera sites, alongside numbers at the same sites in the relevant baseline periods. Without exception, the numbers show substantial percentage reductions, but these reductions include the effect of RTM and, moreover, need to be viewed against the background of national reductions in numbers of KSI; they are for these reasons not straightforward to interpret. The issue of RTM is essentially the same as was discussed in Section 2.2 in the context of the four-year evaluation report. Allowance for the national reductions is complicated because the baseline period for a camera site is usually taken as the three years before deployment of the camera, and the deployment dates of current cameras are spread over the last fifteen years, though with a concentration in the early years of the national safety camera programme from 2001. Some partnerships have also provided total numbers of KSI in their areas in the periods to which the numbers at their camera sites relate. In these cases the percentage reductions at camera sites can be compared with those for the whole area.

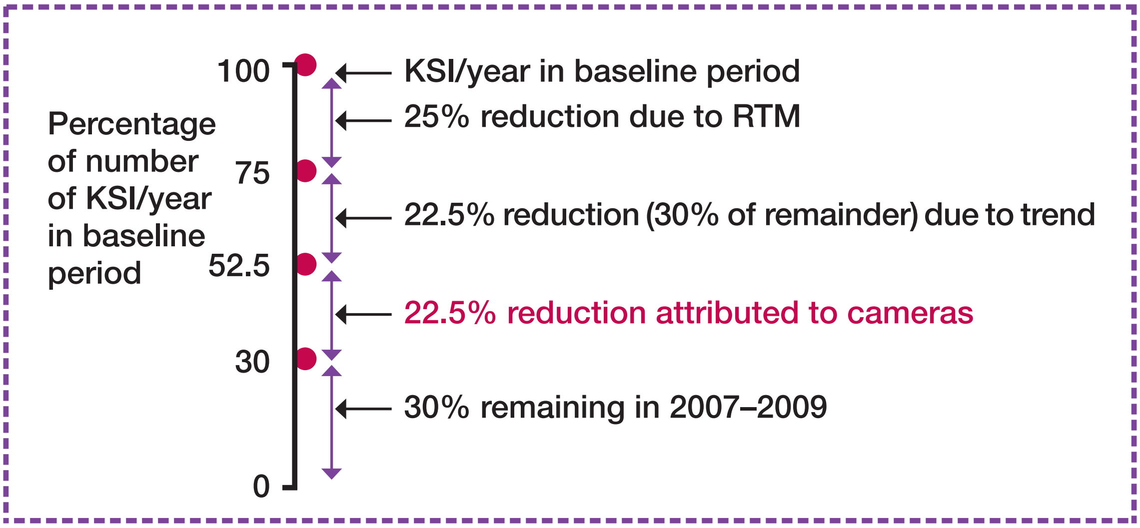
This information for 12 partnerships is given in Table 11, and, to indicate the national background, the percentage reduction in number of KSI in Great Britain between 2000 and 2008 is shown at the foot of the table. The reasons for choosing this period are that 2008 is the middle year of the three years to which the recent numbers relate, and 2001 is towards the end of the concentration of baseline periods associated with the national programme – towards the end because there are an unknown but appreciable number of later baseline periods among the cameras to which the reductions listed in the table relate.

Table 11: Percentage reductions in numbers of KSI at camera sites in 12 partnership areas in 2007–2009 from numbers in their baseline periods, with corresponding reductions for whole partnership area where available

Percentage reduction (%) in KSI	
At camera sites	In partnership area
26	13
46	
55	
56	
60	36
65	56
71	
71	35
72	39
73	47
74	
84	
Great Britain 2001–2008	30

These percentages indicate substantially greater percentage reductions in KSI at camera sites than the overall reduction for Great Britain in all but one of these partnerships, and in the one exceptional case, the reduction at camera sites is double that in the partnership area, i.e. 26% as compared with 13%. An unknown proportion of the extra reduction at camera sites will have been due to RTM, but the discussion of RTM in Section 2.2 suggests that it is reasonable to assume that RTM accounts for the first 25% reduction from the baseline period. On this basis, Figure 2 indicates how a typical reduction of 70% (the middle of the range 55%–85% in which most of the reductions in Table 11 lie) is likely to be made up of the effects of RTM, trend and camera deployment.

Figure 2: Sources of a typical reduction of 70% in numbers of KSI/year in 2007–2009 from numbers in the baseline year



Although the partnerships for which this information is available cannot be regarded as representative, there is no reason why the reductions they report should be untypical of the range of reductions across all partnerships, so camera enforcement can be seen still to be having a substantial effect in reducing numbers of KSI at camera sites.

Unless these partnerships are substantially atypical, Figure 2 indicates that the typical reduction in KSI attributable to cameras at camera sites in 2007–2009 is likely to have been in the range 20–25% of the numbers in the baseline period. For the year ending March 2004, it can be deduced from the central values of the KSI columns in Tables 7 and 8 that the corresponding reduction was about 30%.

There are several reasons why it is understandable that the percentage reduction attributable to cameras should have been somewhat lower in recent years than in 2003–2004. First, there has been an improvement in compliance with the 30 miles/h limit. Secondly, the increase in number of camera sites from around 4000 in 2003–2004 to around 6000 in recent years may well have included some deployment of cameras at sites where the scope for casualty reduction is more modest than at most sites operating in 2003–2004. Thirdly, Elvik's (2009) updated analysis of values of powers in the power model estimates that KSI on urban roads are now varying as rather more than the square of average speed, whereas in the period covered by the four-year evaluation they were varying as rather more than the cube of the average speed. Although this change is offset to a small degree by a slight increase in the corresponding power for rural roads, the full effect of these changes in power would be to reduce by about one quarter the percentage reduction in KSI that would be expected according to the power model. This matches closely the change from 30% to 20–25% indicated by Tables 7 and 8 and Figure 2, but the interval between 2003–2004 and 2007–2009 is probably too short for the full effect of this change in powers – if indeed it applied precisely in British conditions – to have worked through.

Taking these three reasons together, the percentages in Table 11 can be seen as indicating that the number of KSI prevented by camera operation per site-year may well now be about three-quarters of the number estimated in Section 2.2 for the year ending March 2004. Moreover, the number of KSI nationally has fallen by around 30% since that year. But the number of camera sites has increased to about 50% more than the number of sites that corresponds to the values in Table 8 showing estimates of KSI prevented.

An indication of the number of KSI per year that speed cameras have recently been preventing nationally can thus be obtained from the central estimate in Table 8 of 1,050 by multiplying this number by 0.75 × 0.7 × 1.5 to obtain 827, or roughly 800.

Therefore the decommissioning of speed cameras nationally could well result in about an extra 800 people being killed or seriously injured each year.

3.5 Changes in speeds when cameras are known to be out of action

When a site has met a partnership's criteria for deploying a speed camera, and monitoring has demonstrated subsequent changes for the better at the site, this does not imply that the camera should continue to be deployed there indefinitely. Changes in local circumstances or wider changes in driver behaviour may make it possible to cease camera deployment at that site without untoward consequences, and partnerships are alert to opportunities for doing so. In relation to the wider question whether, now that cameras have been deployed on their current scale for more than half a decade, and on an appreciable scale for a decade and a half, widespread removal without adverse effects might be possible, the conclusion reached in Section 3.4 that many extra KSI could well result is based on an assumption that if cameras were decommissioned, their speed-reducing effect would cease, so that speeds at camera sites would rise.

Support for this assumption is provided by evidence from a number of instances over the years in which partnerships have monitored changes in speed and speeding where cameras have been visibly out of action for some time.

In 2004, Partnership V allowed cameras at each of five rural sites that had been operational for at least six months to remain dormant for 12 months before resuming operation. At each site, the 85th percentile speed and the percentage of drivers exceeding the limit were monitored. At three of the sites, one with a 50 miles/h limit and two with 60 miles/h limits, these indicators showed, in the dormant period, only small changes from the previous operational period, even though the 85th percentile speed had fallen by at least 11 miles/h when the cameras were first deployed. This speed rose by only between 0.4 and 1.1 miles/h on average when the cameras became dormant, and the proportions of drivers exceeding the respective limits fell slightly. At the other two sites, with limits of 60 miles/h and 70 miles/h, the 85th percentile speeds were about 3 miles/h and 4 miles/h higher respectively, and the proportions of drivers exceeding the limits were 4.6 and 2.6 percentage points higher respectively in the dormant period than in the previous operational period. The camera housings at these sites remained in place, and it is not clear to what extent drivers were aware that the cameras were dormant; differences in awareness of this may have contributed to the variation in driver response among the sites.

Also in 2004, Partnership V decommissioned and removed a camera where the limit was 60 miles/h and measured speeds at the site one month before decommissioning and one year later. The average speed and the proportion exceeding the limit rose by 7.3 miles/h and 10.9 percentage points respectively.

Between 2006 and 2008, Partnership W monitored four urban camera sites and one VAS site, at each of which the equipment was visibly out of action for between two and eight months. At one of the camera sites, the deactivated camera, instead of being reinstated, was replaced by a VAS, after which the camera signs were at first left in place and then later removed. Average speeds and numbers of vehicles/day exceeding the Association of Chief Police Officers (ACPO) enforcement threshold (of 35 miles/h and 46 miles/h respectively at 30 miles/h and 40 miles/h sites) were monitored.

At two 30 miles/h sites, the average speeds were about 1.5 miles/h higher when the camera was out of action than previously and subsequently. Daily numbers of vehicles exceeding 35 miles/h rose from 16 to 209 and from 23 to 153 respectively. At a third and higher-flow 30 miles/h site, the average speed rose by more than 3.5 miles/h, and the daily number exceeding 35 miles/h rose from about 160 to about 1,800 vehicles. At another higher-flow 30 miles/h site, the average speed rose by 4 miles/h when the camera was deactivated, hardly fell at all when the deactivated camera was replaced by a VAS with camera signs still in place, and rose by a further 0.6 miles/h when the camera signs were removed. The daily number exceeding 35 miles/h was less than 100 with the camera in action, but rose to over 1,000 when the camera was out of action. With the VAS operational and camera signs still in place, it fell to about 750, but it rose again to over 1,000 when the camera signs were removed. The VAS site had a 40 miles/h limit, and there was little difference in average speed or daily numbers exceeding 46 miles/h between a two-month period when the VAS was out of action and the preceding and subsequent operational periods.

Between 2007 and 2010, Partnership V monitored five 60 miles/h sites and one 30 miles/h site at which camera housings were covered. Speeds were measured while the camera was still operational and within a few months of deactivation. Average speeds rose after deactivation by between 2 miles/h and 18 miles/h, and the proportions exceeding the limit by between 7 and 45 percentage points.

Partnership X had a camera out of action in August 2010 that had been installed in October 2004 at a 30 miles/h site adjacent to a speed monitoring site. This enabled speeds and numbers exceeding the limit with the camera out of action to be compared with corresponding data for August in earlier years. The average speed had been about 32 miles/h in the August before the camera was installed, between 24.8 and 25.5 miles/h in the Augusts of 2006, 2008 and 2009, and 27.5 miles/h in August 2010 with the camera out of action. The daily number exceeding the limit had been about 3,000 vehicles before the camera was installed, was about 60 with the camera in operation, and about 600 with the camera out of action.

In early summer 2009 and in the spring and early summer of 2010, Partnership Y monitored numbers exceeding the ACPO thresholds at one 30 miles/h site where a fixed camera was visibly out of action for six weeks. It did the same at each of four mobile camera sites with respective limits of 30 miles/h, 50 miles/h, 60 miles/h and 60 miles/h for several hours when a camera van was present and the same hours of the same day of a nearby week when it was not present. At the fixed-camera site, about 750 vehicles per week were observed exceeding the threshold with the camera operational and about 1,150 vehicles per week when it was out of action, out of a flow of about 55,000 vehicles per week. At the mobile camera sites, less than 20 vehicles exceeded the threshold in a six-hour period when the van was present, compared with between about 80 and about 170 when it was not present, out of six-hour flows which ranged from about 1,500 to about 4,200. The six-hour numbers at the mobile sites cannot be compared directly with the weekly numbers at the fixed site, but the two sets of numbers together suggest that the presence of the van at these mobile camera sites had a proportionately greater effect on numbers exceeding the threshold than did the camera being operational, rather than visibly out of action, at the fixed-camera site.

In August 2010 at five 30 miles/h fixed-camera sites where deactivation of cameras had been publicised, Partnership Z monitored daily numbers exceeding the ACPO threshold and compared them with the corresponding numbers in August 2009. After three weeks of deactivation, the daily number at three of the sites was about 180 compared with about 60 in 2009, and after four weeks at a different three of the sites it was nearly 200 compared with about 50 in 2009.

Results of observations at such a small and serendipitous set of sites can be no more than indicative, but for urban sites they suggest that deactivation of cameras may well result in marked increases in average speed and also in numbers exceeding the limit and numbers exceeding the ACPO threshold. Observations at mobile sites with and without a camera van in place indicate that not all of the effect of enforcement upon speeds at the site observed while the camera is in place carry over to times when it is not in place. This is consistent with the four-year evaluation report's plausible finding that effects of cameras on average speeds (over all time) at mobile camera sites, while appreciable, are smaller than at fixed-camera sites. The effects of deactivation at rural fixed-camera sites differed considerably among the sites for which observations were available. At a few of these sites there was little change in speeds, but there were other sites at which the changes in average speed were in the teens of miles per hour. Part of this variation may have resulted from differences in driver awareness of cameras being deactivated.

3.6 The finances of camera enforcement

Appendix F of the four-year evaluation report shows that in the fourth year of the programme (the year ending March 2004), the 35 participating partnerships in England and Wales had an income, almost entirely from payment of fixed penalties and remitted to the exchequer, of £113.6 million. They incurred eligible expenditure, reimbursed by the exchequer, of £91.9 million, roughly one-third capital and two-thirds revenue. This left the exchequer with a surplus of £21.7 million, or about £11.50 out of each £60 fixed penalty paid.

The corresponding annual figures continued to be published until the year ending March 2007, when reimbursement of eligible expenditure from the sum paid in penalties was replaced by a more general road safety grant to local authorities. The year ending March 2007 is therefore the last for which the finances of camera enforcement were published in a common format for all camera partnerships in England and Wales. In that year, there were three more partnerships in England and Wales than in the year ending March 2004. The total income was £104.6 million, eligible expenditure was £97.5 million, and the surplus to the exchequer was £6.5 million, or about £3.80 out of each £60 penalty paid.

Comparison of these two years provides a broadly stable picture with some indication of reduction in the imposition of fixed penalties, perhaps associated with greater use of speed awareness or similar courses as an alternative disposition, and in the surplus to the exchequer. The cost of enforcement is thus borne by the detected speeding offenders in the form of penalties, leaving a modest margin of surplus.

To establish how the finances of camera enforcement have evolved since April 2007 would necessitate assembling figures from the successor road safety partnerships. If this were done, it would be useful to express the cost of camera enforcement in the form of an average cost per site-year of operation, for the purposes of comparison with estimates of reductions in PIC and KSI per site-year.

The four-year evaluation report calculated the value of prevention of the PIC estimated to have been attributable to camera enforcement in the year ending March 2004 to be about £258 million. This figure was based on the then current average valuation of prevention of a PIC on the basis described each year in the annual report on road safety statistics (e.g. DfT, 2010). The number of PIC estimated to have been prevented included any reduction attributable to RTM, which can be shown from Table 8 in Section 2.2 to be likely to have been of the order of one-seventh of the estimated reduction used in the calculation of the value £258 million.

This indicates that after allowing for RTM, the value of the prevention of PIC is likely to have been about £220 million. The corresponding cost of camera enforcement, including that incurred by the three partnerships in Scotland that were included in estimating the number of PIC prevented, was £95.8 million, giving a benefit/cost ratio of about 2.3.

No more up-to-date estimate of this ratio can be made without detailed work to estimate numbers of PIC prevented in subsequent years.

4. Conclusions

Consideration of the background to camera enforcement in Britain; the four-year evaluation report; related work by Mountain et al.; the implications of the power model of relationships between average traffic speed and the occurrence of collisions and casualties; the report of the West London demonstration project; national statistics on traffic speed, collisions and casualties; and recent data from road safety partnerships, taken together, lead to the following conclusions.

- Deployment of speed cameras leads to appreciable reductions in speed in the vicinity of the cameras, and substantial reductions in collisions and casualties there over and above the likely effect of regression to the mean.

- Percentage reductions in collisions and casualties differ between fixed and mobile and between urban and rural camera sites; available evidence does not enable these percentages to be estimated definitively, but it does enable useful judgements to be made about the likely percentages and the consequent numbers of collisions and casualties prevented, and the writer has offered such judgements.

- National statistics on speed, collisions and casualties indicate clear and sustained falls in average speeds of cars and proportions of cars exceeding the limit on roads with a 30 miles/h limit, and that this is consistent with the falls in speeds having contributed substantially to the concurrent reduction in collisions and casualties on built-up roads, enabling reductions there to match those occurring on non-built-up roads where there was no counterpart reduction in speeds, but where improvement in occupant protection in cars affected a much larger proportion of casualties.

- Notwithstanding widely reported negative views, public understanding and acceptance of camera enforcement was widespread at the height of the national camera safety programme, and the indication from a subsequent annual survey by the AA is that this remains the case.

- Recent data from road safety partnerships, while not comprehensive, indicate that there continue to be substantial reductions in fatal or serious casualties in the vicinity of cameras, and that decommissioning of speed cameras across Great Britain could well result in about 800 extra people being killed or seriously injured each year.

- Recorded changes in speeds and in speeding when cameras are visibly out of action reinforce the indications from casualty data that widespread decommissioning of cameras is likely to have adverse consequences.

- At the time of the four-year evaluation, the benefit/cost ratio of camera enforcement after allowance for the likely effect of regression to the mean was about 2.3, and data for 2006–2007 show the cost of camera enforcement being covered by penalties paid by detected offenders, with a surplus to the exchequer of less than £4 out of each £60 penalty paid.

This review is confined to evidence from British experience of speed camera enforcement, but it came to the writer's attention at a late stage in the writing that a recently updated Cochrane Review (Wilson et al., 2010) of 35 studies worldwide – selected for quality of research and including several of those cited here – of the efficacy of speed cameras concluded that:

> 'the consistency of reported reductions in speed and crash outcomes across all studies show that speed cameras are a worthwhile intervention for reducing the number of road traffic injuries and deaths. However, whilst the evidence base clearly demonstrates a positive direction in the effect, an overall magnitude of this effect is currently not deducible due to heterogeneity and lack of methodological rigour.'

The findings of this report, though reached independently, are essentially consistent with the conclusion of the Cochrane Review. They are also broadly consistent with the findings of a meta-analysis by Elvik et al. (2009) of 16 studies, not including the four-year evaluation report, of the effects of fixed cameras on numbers of collisions and casualties.

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APPENDIX 1: Adjustment of the estimated percentage effect of cameras on numbers of collisions or casualties in the light of estimates of the effect of regression to the mean

In a subsample for which the effect of RTM is estimated for sites of a certain kind,

let E_T = expected number of collisions or casualties in period of camera operation if cameras were not deployed, after allowing for trend

P_T = estimated reduction in collisions or casualties attributable to cameras before allowing for RTM, as a percentage of E_T

E_R = expected number of collisions or casualties in period of camera operation if cameras were not deployed, after allowing for trend, seasonal effect and RTM

P_R = estimated reduction in collisions or casualties attributable to cameras after allowing for RTM, as a percentage of E_R

C_S = recorded number of collisions or casualties in period of camera operation

$R_S = E_T - C_S$

and

x = the proportion of the reduction R_S that is estimated to be attributable to RTM.

Then $P_T = 100\, R_S / E_T$, so that $R_S = P_T E_T / 100$

and $P_R = 100\,(1 - x)\, R_S / (E_T - x\, R_S)$

whence $x = 100(P_T - P_R) / P_T\,(100 - P_R)$.

Now suppose that the proportion x for all sites of this kind is the same as for the subsample,

and let

E = expected number of collisions or casualties at all sites of this kind in period of camera operation if cameras were not deployed, after allowing for trend and seasonal variation

C = recorded number of collisions or casualties at all sites of this kind in period of camera operation

$R = E - C$

P = estimated reduction in collisions or casualties attributable to cameras at all sites of this kind before allowing for RTM, as a percentage of E

Then $R = EP / 100$

and the reduction attributed to cameras after allowing for RTM, as a percentage of the number expected after allowing for RTM is

$$100(1 - x)\, R / (E - xR) = 100(1 - x)\, P / (100 - xP).$$

And if the effect of RTM in the subsample is estimated as in Appendix H of the four-year evaluation report, then P_T and P_R are the upper and lower percentages in the relevant cell of Table 4 of this paper, and P is the relevant percentage from Table 2.

Also, if the expected number E were reduced to pE, and the estimated reduction in collisions or casualties attributable to cameras were expressed as a percentage Y of pE, then

$$Y = 100(pE - C) / pE = 100\{R - (1 - p)E\} / pE = 100 - (100 - P) / p$$

on substituting for R in terms of P and E.

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