RAC Foundation

Mobility • Safety • Economy • Environment

The Effectiveness of Average Speed Cameras in Great Britain

Owen, Ursachi and Allsop

September 2016

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

Registered Charity No. 1002705

RAC Foundation

Mobility • Safety • Economy • Environment

The Effectiveness of Average Speed Cameras in Great Britain

Owen, Ursachi and Allsop

September 2016

About the Authors

Richard Owen is one of the founding directors of Road Safety Analysis (RSA) and has a strong background in enforcement management having previously held the post of Operations Manager at the Thames Valley Safer Roads Partnership (TVSRP). Richard's work for TVSRP ranged from national co-ordination and liaison with the Department for Transport, to local oversight of partner budgets and operational delivery. As a director of RSA, Richard has worked on dozens of independent analysis projects covering different road user groups at a national and local level for various clients.

George Ursachi is a former academic associate professor and has a strong background in market analysis, research, and project management. He joined RSA, in 2015 and has already been involved in a number of important projects. His background in research synthesis has been deployed in preparing updates on a number of topics for the Road Safety Observatory; and his knowledge of advanced statistical techniques has been implemented in independent evaluations of road safety schemes such as 'Safe Drive Stay Alive'.

Richard Allsop is Emeritus Professor of Transport Studies at UCL, where he played a senior role in transport research and teaching between 1976 and 2005. Since then he has continued to contribute to research, advisory work and professional development in transport. As part of his continuing commitment to road safety work in Britain and across Europe, through PACTS and ETSC and as an individual, he has been involved in previous research into the effectiveness of safety cameras.

Acknowledgements

The authors would like to thank Jenoptik and 3M for the information supplied regarding the deployment of systems in the UK. The authors would also like to thank the police forces, local authorities, road safety partnerships and national bodies who responded to information requests regarding the average speed cameras in their areas.

The authors would like to thank other team members at Road Safety Analysis for their support in creating the database and carrying out the collision analysis for this work, notably Andrew Hartley, who devised the technique for matching collisions to camera sites. The authors would also like to thank Dr Anneka Lawson, Research Analyst at the RAC Foundation, for her support and assistance in editing and preparing this report for publication.

The authors and the RAC Foundation would like to thank the peer reviewers for their helpful comments on drafts of the report.

Disclaimer

Contents

Figures list

Tables list

Foreword

Speed-limit enforcement, in particular the use of camera based prosecution systems, has been a contentious issue for some years. In 2010 the RAC Foundation published a report by Professor Richard Allsop (revised in 2013) which analysed the effectiveness of speed cameras. The report focused on the use of ‘spot’ cameras, the most widely used camera technology at the time, finding that cameras could be a valuable part of the road safety armoury.

Technology has now moved on and more authorities are looking to average speed cameras – systems that measure the speed of a vehicle over a stretch of road – to ensure speed limit compliance. It therefore seemed timely to commission a similarly rigorous look at how these systems are performing.

We had hoped to be able not just to discern whether average speed cameras were proving to be effective in preventing injury accidents, but also to look at the specific circumstances – the nature of the road, the traffic and the road safety risk – that had led to the choice of this technique, assess the wisdom of that choice and start to develop guidance on their future deployment. From the limited number of locations offering a sufficient record of before-and-after data it has not yet proven possible to carry out this level of analysis.

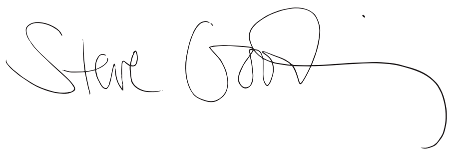
Two things do stand out from this research, however.

First, there is cause for optimism about the overall collision reduction benefits of average speed cameras. Taking account of overall trends and regression to the mean, permanent average speed camera sites were found to, on average, reduce injury collisions, particularly those of highest severity.

Second, we need the right data to be logged and made available by all highway authorities adopting average speed camera technology. This research has established the format of a database that could hold this data, identifying all the different elements needed to conduct a robust assessment. Ideally this database would be held nationally, perhaps by the Department for Transport.

We urge highway authorities to make sure that they are capturing the relevant data from their schemes in order that lessons can be learnt, and decisions made about the appropriate level and extent of average speed camera deployment.

Steve Gooding



Director, RAC Foundation

Information relating to **51** permanent average speed camera sites, installed **between 2000 and June 2015**, was collected as part of this study.

25 average speed camera were **analysed in detail** with **294 km of road** covered by these sites.

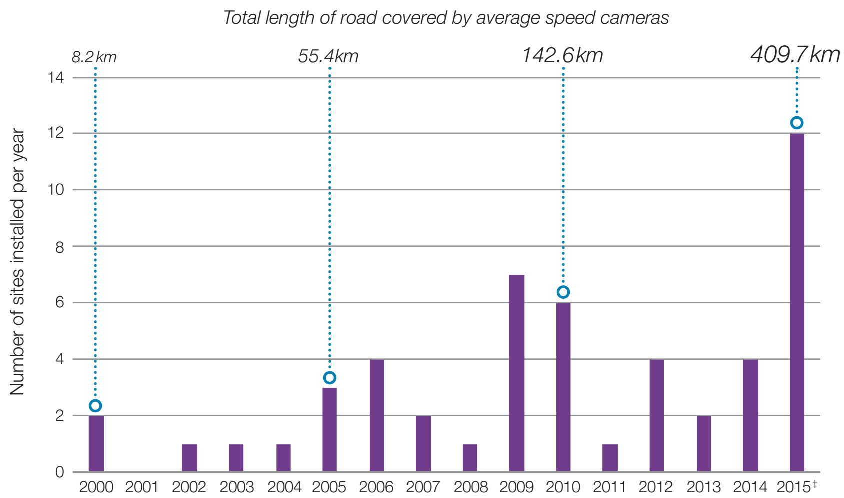
On average, the permanent average speed camera sites analysed saw **reductions** in injury collisions, **especially** those of a **higher severity**.

Fatal and serious collisions fell, by **25-46%** while **personal injury** collisions fell, by **9-22%**.

Permanent average speed camera sites are estimated to have cost up to **£1.5m per mile** in **2000** but **today** cost an **average of £100,000 per mile**.

The number of average speed camera sites are likely to **increase** as **installation costs** continue to **decrease**.

Installation costs are **declining** due to the **falling cost of technology** and **increased competition** in the market.



‡ To June 2015

Executive Summary

The effectiveness of speed enforcement programmes and technologies in Great Britain has long been a subject of significant debate and analysis. The quest to reduce collisions and casualties on the roads has previously been supported by Government and is still a priority for the Transport Department. For all those involved in seeking effective interventions understanding how the deployment of automated enforcement technologies has contributed to reducing collisions is very important. There is a strong evidence base regarding the most common forms of enforcement technology – spot speed cameras and mobile units – but there is little evidence about the impact of average speed cameras (ASCs).

The measure used throughout this report in considering the effectiveness of ASCs is the change in injury collisions in the post-installation periods. ASC effectiveness may also be considered in terms of changes in compliance with speed limits or long-term changes in offence rates, neither of which are considered within the scope of this study.

Although the UK's first permanent ASC system was installed in 2000, the uptake of installations was relatively slow, almost certainly as a result of the initial high costs, sometimes as high as £1.5 million per mile. This research has catalogued the vast majority of permanent ASCs on the roads of Great Britain, and has revealed a significant increase in their deployment over the last few years. There were a total of 51 ASC sites commissioned and installed between 2000 and 2015, with 12 of those installed in 2015 alone. The surge in popularity of these systems is likely to continue as prices tumble, owing to both the falling cost of the technology and increased competition in the market. There may also be a role for ASC systems in replacing ageing fixed-camera infrastructure which is close to the end of its life.

The research has not only catalogued the location of installations, but also introduced an independent methodology for reviewing site boundaries and the collisions that have taken place within them since 1990. Using the official Department for Transport collision records, it has been possible to create, on a month-by-month basis, the collision history for each site. These outputs have been used to review the effectiveness of ASCs in reducing collisions at the combined sites.

Previous reviews of evidence have been critical of the lack of independence or scientific methodology in the analysis undertaken. This research has introduced a degree of scientific rigour through the use of two elements: firstly, a large set of similar comparator roads to allow for the wider trend in collision reduction since 1990; and, secondly, a number of candidate sites were identified that act as a pseudo-control, as they were not ultimately progressed with the installation of ASCs. A total of 25 sites were used in the final analysis, which between them had a total measured enforced section length of 294 km.

An analysis of the effect of temporary systems, such as those at roadworks sites, is not included in this report as there is insufficient information available about the locations and durations of use of such schemes. These temporary schemes are also usually associated with a reduction in speed limit – the reasons behind the exclusion of such schemes are discussed in section 3.2.

The primary set of results looked at the change in collisions at those ASC sites that were suitable for inclusion within the study. A number of the proposed sites had been removed to obtain this set, because of the presence of previous enforcement equipment, or changes in speed limits which could have affected the results. As well as taking into account trend, the statistical methodology – adapted from previous work for the RAC Foundation by Professor Richard Allsop – also removes the so-called 'site-selection period' (SSP) from the pre-installation data. Where the site selection period is known, this achieves the aim of accounting for 'regression to the mean', the phenomenon that describes the consequence of unusually high levels of collisions at sites during the identification period.

The standout result from the analysis shows, after accounting for SSPs and trend, a **36.4% (95% confidence interval: 25-46%) reduction in the mean rate of fatal and serious collisions in the post-installation period**. The change in personal injury collisions of all severities was less pronounced, **with a 16% (95% confidence interval: 9-22%) reduction**. Both results were classified as highly statistically significant according to the analysis, meaning that they almost certainly did not arise by chance or through random variation.

Further analysis of the cohort of sites split the sample into two parts: one looking at the difference between sites installed before April 2007 and those installed after that date; and a second that divided the sites by speed limit, based on 'low' speed limits (40 mph or less), and 'high' speed for all others. These results did not show significant differences in the post-installation effect for the subgroups and it is therefore not possible to conclude any difference in the effectiveness of the installations relating to the camera age or the expected traffic speed.

One other output of the analysis was a measurement of the difference in collisions recorded in the SSP versus all other pre-installation periods. For the major cohort this was estimated to be an increase in fatal and serious collisions of 24.9%, and 16.7% in collisions of all severities. These increases were accounted for (i.e. their effects were removed) in the main results, but the existence of this 'site selection effect' is a significant point of interest to those wishing to independently evaluate the impact of other interventions. More specifically, this research indicates that where sites are chosen for treatment due to high collision rates, then it can be expected that a certain proportion of the post-installation collision reduction could reasonably be attributed to this phenomenon. The presence and measurement of site selection effects should be reviewed at other enforcement locations, or even where engineering works have taken place, and is worth further consideration by the road safety profession.

The small control group of candidate sites exhibited a reduction of only 3% in collisions post-identification. This result did not pass the significance test and so could have occurred by chance.

During the process of carrying out this research, it became clear that finding out the initial reasons for installation was somewhat difficult, especially in the case of older sites. The publication of evidence on websites is patchy, although some (such as that published at A9road.info) are very good. With a study of this nature, there is a high reliance on organisations to have information available in an appropriate format, and to have published or be willing to share that information. Accuracy can always be improved with greater co-operation, but this in no way diminishes the independence of the analysis. With more information and a growing number of sites at which ASCs are installed, it will be possible in the future to delve deeper into the effectiveness of this technology, perhaps answering other questions about deployment and suitability on different types of road. The approach can also be repeated for other camera technologies, with the aim of comparing the performance of different systems.

In conclusion, the research shows quite clearly that the implementation of ASCs in the locations that have been assessed in this report has had the effect of reducing injury collisions, and especially those of a higher severity. Even taking into account other influencing factors, the reductions are large and statistically significant.

1. Introduction

1.1 Why this research has been commissioned

The use of automated speed enforcement technology in the UK has been subject to immense scrutiny and debate for over two decades following the first installation of a Gatso camera on the A316 in London in 1992 (Gibbs, 2012).

The most comprehensive analysis of the effectiveness of speed cameras in Great Britain was published in 2005 (PA Consulting / UCL, 2005) and showed a 42% reduction in the number of people killed or seriously injured at sites where safety cameras were introduced. This report used data from thousands of camera sites, but these were mostly spot speed cameras: either permanent 'Gatso'-type units, or mobile enforcement – often located in a van or on a motorbike equipped with combined detection and recording systems.

A review in 2013 (Soole et al., 2013) was critical of the relatively poor levels of scientific rigour associated with the current body of literature, specifically citing that:

- comparison/control sites have not been employed in any evaluations included in the literature review;
- confounding factors (e.g. exposure, regression to the mean) are rarely controlled for; and
- statistical significance testing is, typically, not performed.

Furthermore, the reports have been carried out largely by manufacturers of equipment or those undertaking the enforcement, and lack independence.

The RAC Foundation has published reports authored by Professor Richard Allsop looking at the effectiveness of speed cameras (Allsop, 2010) as well as how to analyse the data appropriately (Allsop, 2013). Following feasibility discussions with RSA, the Foundation has commissioned this report with the principal aim of estimating the effectiveness of average speed cameras (ASCs) deployed in Great Britain over the last 15 years.

The measure used throughout this report in considering the effectiveness of ASCs is the change in injury collisions in the post-installation periods. ASC effectiveness may also be considered in terms of changes in compliance with speed limits or long-term changes in offence rates; neither of which are considered within the scope of this study.

1.2 Objectives

Three main objectives were set for this study, which would all help to address concerns about previous studies:

- to assemble available information relating to ASC sites in Great Britain, that may be used to create a national database of ASC sites;
- to establish a suitably large and appropriate control group of sites to enable an understanding of the difference in collision reduction between potential ASC sites with and without such enforcement; and
- to establish levels of occurrence of collisions before and after ASC installation (with consideration given to site-selection period, pre-installation and post-installation periods).

Although creating an independent database does require input from those involved in the installation, management, and maintenance of camera systems in order to determine ASC site locations, all collision matching and analysis has been carried out separately on the basis of data acquired from https://data.gov.uk. The collision results for individual camera sites (stretches of road along which automated camera enforcement is undertaken) may therefore differ from those published locally by police forces, highway authorities, or safety camera partnerships (SCPs). This may arise due to differing definitions of site section boundaries. The definition of site section boundaries used in this analysis is discussed further in Chapter 4.

2. Background

2.1 Average speed camera technology

Average speed camera systems differ from fixed, single-point systems in that they use pairs of cameras to measure vehicles' average speeds along a clearly defined and accurately measured stretch of road that could be anywhere between a few hundred metres and many miles in length. In the UK the shortest measured site section is 390 metres and the longest 46 kilometres. A traditional spot speed camera[1], on the other hand, measures only the speed at a single point on the road, using either radar or inductive loops under the road surface. It has been argued by manufacturers and others that ASCs, by enforcing over a longer stretch of road, will be more effective in achieving compliance with the prevailing speed limit than spot speed cameras.

ASCs are clearly distinguishable from spot speed cameras, and are usually mounted on gantries or cantilever poles high up to enable the automatic number plate recognition (ANPR) cameras to work effectively. The most visible use of the systems (although not one that falls within the scope of this analysis) is at roadwork schemes with temporary lower speed limits, where they have become a common sight over the last decade. It is argued that the use of

1 The term 'spot speed camera' is used to describe enforcement equipment that measures a vehicle's speed at a single point on the road. The term 'fixed speed camera' is also in common use and describes enforcement equipment that is installed at a set location. As this would encompass ASCs, the term 'spot speed camera' is the most appropriate to differentiate other technology.

these systems, rather than spot speed cameras, achieves a greater level of compliance and improved traffic flow where a temporary limit is in place (Scott Wilson, 2008: 42, 44).

All ASC systems make use of ANPR technology to identify and record vehicles at the start and end of the enforced section with their entry and exit times, which, together with the known distance travelled, is used to calculate an average speed.[2] When a vehicle's average speed exceeds a set threshold, the offence is recorded by the system and may ultimately, following a review by police staff, result in a Notice of Intended Prosecution (NIP) being sent to the registered keeper of the vehicle. All ASC systems are digital and do not require film to be loaded, unlike older spot speed cameras. The early ASC systems required the installation of roadside cabinets with write-once, read-many (WORM) drives to record offence data digitally for transfer to a police office for processing. New devices obviate the need even for a site visit, as they use wireless communications, such as 3G, to transmit offence information in real time.

The first technology approved for use in the UK was the SPECS™ system, manufactured by Speed Check Services, now part of Jenoptik Traffic Solutions. It received type approval from the Home Office in 1999, and the first cameras went live in Nottingham in 2000 (PR Newswire, 2000). There are now three other manufacturers with approved systems in the UK: 3M, Siemens, and Red Speed International. The overwhelming majority of permanent installations are currently provided by Jenoptik, however, with newer versions of their SPECS system now named VECTOR™.

2.2 Previous analysis

As mentioned in the introduction, there have been many studies of the effectiveness of automated speed enforcement. A Cochrane Review[3] of 28 individual studies in 2010 concluded that "speed cameras are a worthwhile intervention for reducing the number of road traffic injuries and deaths" (Cochrane, 2010). The review also concluded: "More studies of a scientifically rigorous and homogenous nature are necessary, to provide the answer to the magnitude of effect." The studies within the synthesis showed that crashes resulting in fatalities or serious injuries saw reductions of between 11% and 44%.

UK studies, including those commissioned by Department of Transport (DfT), have often separated out spot speed cameras, such as the aforementioned Gatso camera, and deployment of mobile units which operate on a temporary basis for a few hours at a time. Hitherto, there has not, however, been an independent study into the effectiveness of ASCs on their own.

Results published by SCPs have claimed reductions in serious collisions or injuries as high as 82% (Speed Check Services, 2009: 1). These simple analyses of before-and-after data have been criticised as misleading by opponents of camera enforcement, who say that they

---

2 ASC sites rely on pairs of cameras registering where a vehicle enters and departs a route over which speed is being measured. Multiple pairs may be used on long routes.

3 Cochrane Reviews are systematic reviews of primary research in human health care and health policy. They investigate the effects of interventions for prevention, treatment and rehabilitation.

do not take into account the background trend in road collision reduction, or the influence of site-selection bias which introduces the ‘regression to the mean’ effect. These matters are discussed in more detail later in this report.

A summary of research into speed cameras is held on the Road Safety Observatory website (www.roadsafetyobservatory.com). It is an excellent resource for those wishing to discover more about the available evidence on a number of road safety topics, and therefore it is not within the principal objectives of this report to repeat this work.

2.3 Context of use

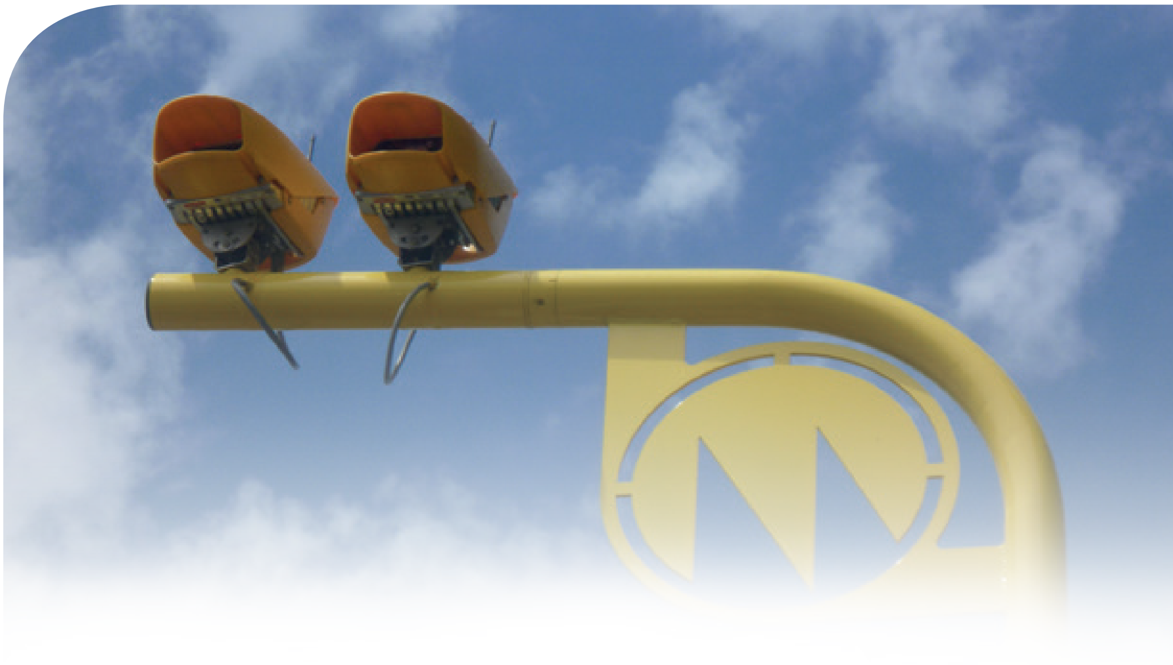
There is no legal restriction on where ASCs can be placed, although certain practical criteria need to be met – for example, the presence of an electrical supply, adequate lighting, and a suitable location to place the associated street furniture. Sites should not have many entry and exit points owing to the nature of the systems, which only detect speeds once a vehicle has passed both the points. The operational responsibilities for cameras are often shared between police forces and highway authorities, sometimes working together as a SCP, or more recently as a ‘road safety partnership’.

These SCPs and road safety partnerships, many of which still exist today, were formed between 2000 and 2007 across most of England and Wales following the national roll-out of a successful pilot scheme by DfT. The financial basis of this roll-out was often referred to as ‘netting-off’ or ‘hypothecation’, and was effectively a period of reimbursement of the costs of enforcement and related activities (in accordance with a business case), subject to oversight by Government. A separate system was formed in Scotland and is still in place. Prior to 2000, cameras were installed solely by highway authorities at their own expense and with no formal guidelines. These were all spot speed cameras.

During the time of hypothecation, a local SCP could be established, and – assuming the DfT rules were followed – a proportion of the fine revenue was then recovered to pay for the cost of operations, the remainder staying with the Treasury. These operations would typically include the detection and processing of offences, together with public information activities and – crucially – the installation and maintenance of camera technology.

This period of hypothecation resulted in a rapid expansion in the number of cameras on UK roads, from 1,672 in 2001 to 4,737 by 2007 (Hansard, 2008). These new cameras required approval under the rules of the scheme introduced in 2001 with the national roll-out of the hypothecation scheme, and the majority were installed at locations where there was a defined collision problem. The precise criteria varied during the period of DfT oversight, but typically there needed to be four fatal or serious collisions per kilometre over a three-year period, plus other less-serious collisions, high speeds, evidence of speed being a contributory factor in the causation of collisions, and/or in their severity, and consideration of other methods of intervention such as engineering as an alternative (DfT, 2005).

3. Average Speed Camera database



3.1 Data collection

In order to carry out an independent analysis of ASCs, that is a review of the collisions data without reference to collision figures provided by manufacturers or operators, it was necessary to collect as much information as possible about the permanent systems currently installed. An analysis of the effect of temporary systems, such as those at roadworks sites, is not included in this report as there is insufficient information available about the locations and durations of use of such schemes. These temporary schemes are also usually associated with a reduction in speed limit – the reasons behind the exclusion of such schemes are discussed in section 3.2. The following information was requested from the four manufacturers:

- location of individual camera units and poles;
- installation dates; and
- current speed limit.

Only two of the four manufacturers, Jenoptik and 3M, supplied information. Siemens and Red Speed International did not participate, but as the number of sites in which their devices are installed is understood to have been very small until recently, this is likely to affect the study only marginally. The information collected about the extent of ASC deployment has been provided to the Foundation in the form of a spreadsheet and shapefile. This 'database' can be kept up to date and used for further research or scrutiny if required.

It is worth noting at this point the definitions used to describe the equipment and its use:

Term	Description
Camera	When describing an ASC system, the term refers to the entire unit used to read number plates. There are often several camera *pods* on a single pole. For a spot-speed system the camera actually means the photographic equipment located within a fixed housing, which can in some systems be moved from housing to housing.
Dummy	A dummy camera/housing is one that gives the impression of being able to enforce the speed limit but does not actually contain the required equipment to detect offences. This term could be used to describe a spot-speed housing that has no camera installed, or an ASC pod with no internal detection equipment.
Pole	For ASC systems, a cantilever pole is commonly used for the purpose of attaching cameras. Cameras can also be mounted to other street furniture such as gantries.
Site	Camera sites are defined more clearly later in the report, but a simple explanation would be that it is the stretch of road over which the presence of enforcement equipment is deemed to have a potential effect.
Site section	Stretches of road within the site boundary that are separated into sections for several reasons (see section 4.1)

Once the location information was received, it was verified using satellite and road images (from Google Street View), and site boundaries were plotted using a digital mapping tool. Local SCPs, highway authorities and police forces were then contacted to confirm that the information was correct, and supplementary questions were asked, including:

- the initial reason for the installation;
- whether a collisions analysis was used to justify the site installation, and, if so, what site-selection period collision data was used;
- whether any previous enforcement was undertaken using spot speed cameras; and
- whether there was any change in the speed limit at the site before or after installation.

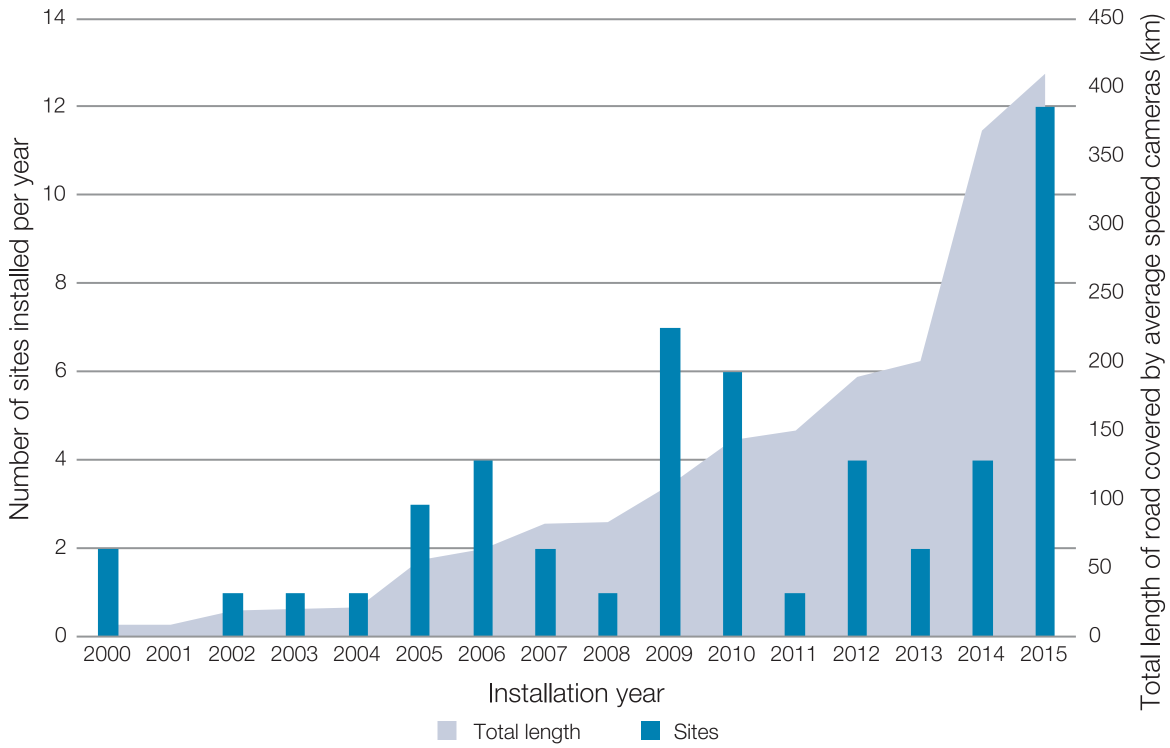
The majority of those contacted were able to supply some or all of this information, although this provision of information does not necessarily indicate support or endorsement of the research on the part of the authority or police force.

There are a number of sites within the study that were installed for reasons other than collision reduction. This may seem strange given the focus on using cameras to reduce collisions, but moderating vehicle speeds can provide benefits such as traffic smoothing (one purpose being to reduce emissions in air quality management areas); reducing vehicle noise; and reducing likely damage to sensitive road structures because vehicles are travelling at lower speeds.

3.2 Average speed camera sites and installation dates

There were a total of 51 ASC sites commissioned and installed between 2000 and 2015, with a total length of 410 km according to the site boundary rules developed for this study (see section 4.1). The date associated with each site is usually the date of operation, not the date the first offence was detected or the date that works started. It is therefore possible that some of the infrastructure could have been at the roadside prior to the official operating date.

Figure 3.1: Installation history for average speed cameras in Great Britain



Source: Authors' own

The number of permanent ASC systems has grown fairly slowly (see Figure 3.1), certainly compared to the aforementioned very large increase in spot speed cameras between 2000 and 2007. The distance covered by the systems leapt significantly in 2014 when the A9 site from Dunblane to Inverness was installed (A9 Safety Group, undated), although 2015 saw the largest ever number of individual sites put in place, with 12 new locations entering the database. The surge in popularity of these systems is likely to continue as the cost of the technology falls and there is increased competition in the market.

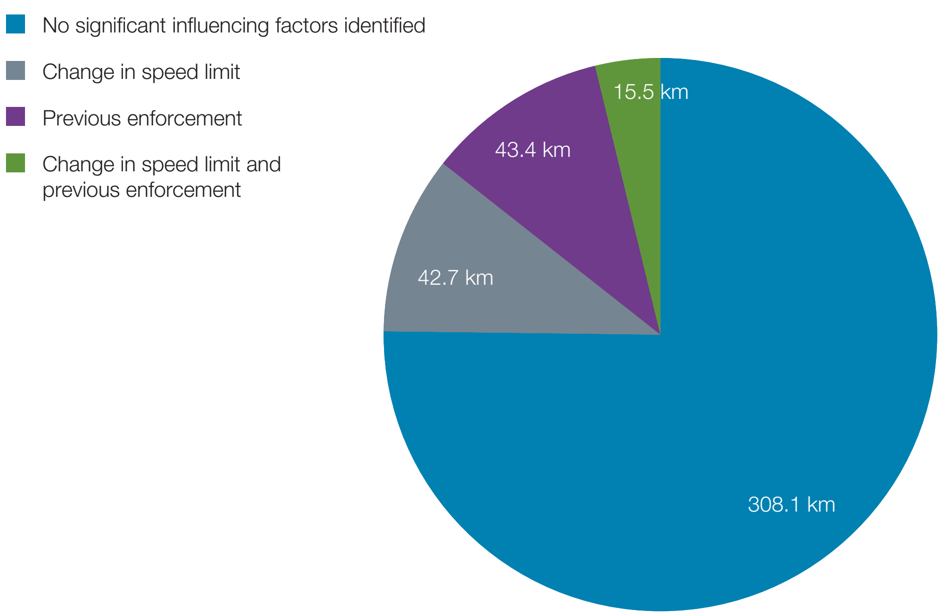
There are a large number of factors within the road environment that could influence changes in collision occurrences. Factors such as changes to signing or road markings, resurfacing, changes to maintenance of roadsides and street furniture, and changes to street lighting can all have an impact on collision occurrences, but information relating to these factors is generally difficult to collect, and therefore the impact of such factors cannot be individually considered in modelling.

Instead, these factors can be considered in this analysis by the inclusion of ‘comparison’ lengths of road, to allow for trend and systematic changes in collision occurrences. Inclusion of these comparison roads is important in accounting for the general downward trend in the number of recorded injury collisions, with a 29% fall between 2005 and 2015 (RSA, using MAST Online (data extracted 1 August 2016)). Factors such as improved vehicle design, better trauma care, road engineering, road user education and enforcement all contribute to this decrease in collisions and casualties, as well as in the severity of injuries sustained.

Two factors were identified that are likely to have had a significant impact on collision occurrences at ASC sites, but separately determining the impact of these factors from that of the ASC system itself was not possible, and these ASC sites were excluded from further analysis. The factors resulting in exclusion were changes in speed limit in the period immediately before, or after, the installation of an ASC system; and the presence of previous enforcement – spot speed cameras or mobile cameras with accompanying warning signs. An example of the presence of previous enforcement is that on the A14 section between Huntingdon and Girton, which was previously covered by a number of spot speed cameras.

Information provided by authorities relating to these factors led to the exclusion of 17 ASC sites from further analysis. Figure 3.2 presents the total enforcement lengths of excluded ASC sites in relation to all identified sites.

Figure 3.2: Significant factors precluding sites from analysis



Source: Authors’ own

4. Collision Analysis

4.1 Site boundaries

Organisations and individuals wishing to monitor changes in collisions along a stretch of road first of all have to define the site boundaries. Rather than relying on local information, as definitions may differ from one SCP to another, the site boundaries are defined here in a standardised manner based on the expert knowledge of the authors.

The width of a site extended 50 to 150 metres either side of the centre of the roadway section being considered, varying depending on the type of road (number of traffic lanes etc.), to ensure that mapping captured all collisions occurring on the road section.

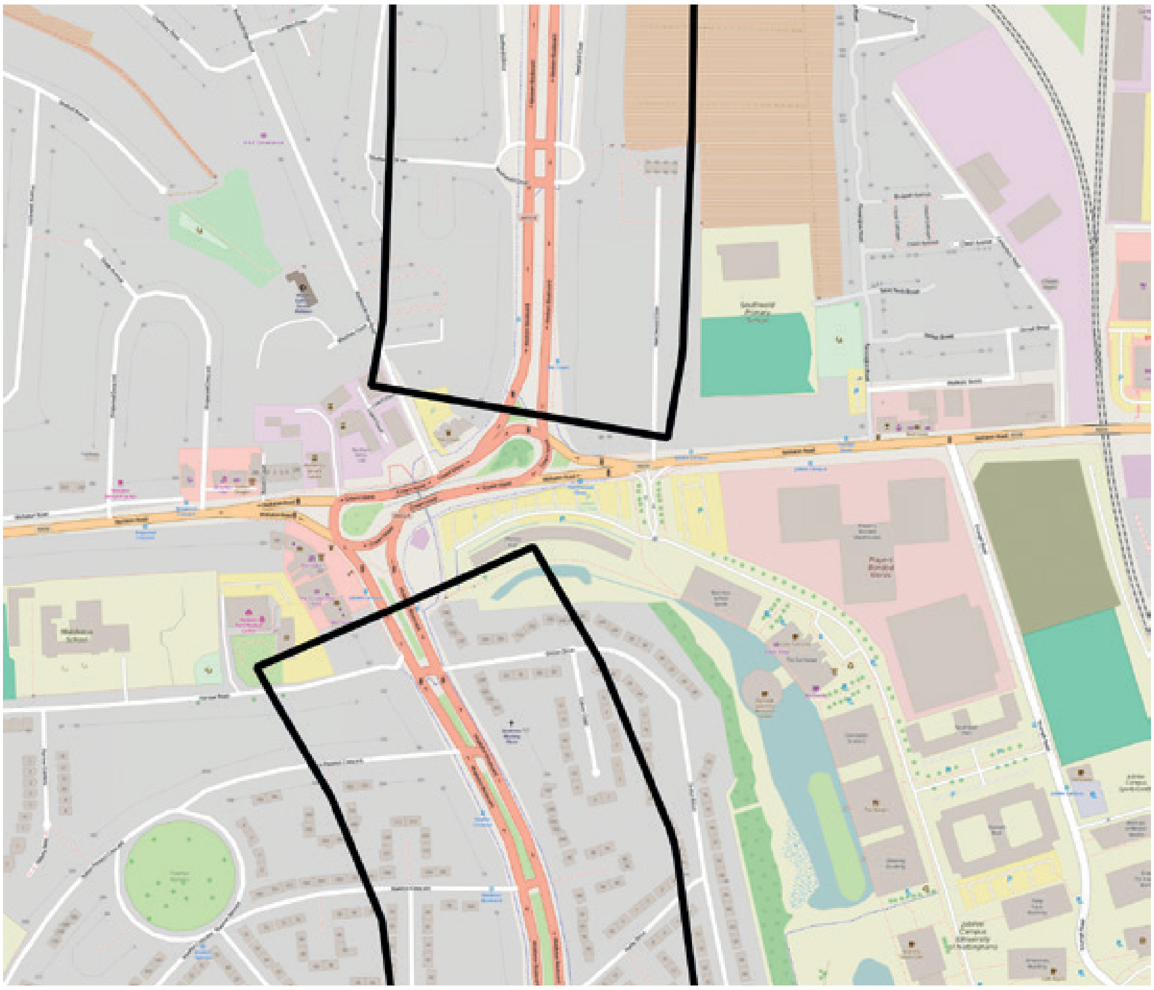
The length of the site was defined as the distance between the first camera and the second camera, plus an additional calculated distance before the first camera and after the second camera. This calculated distance was dependent on the speed limit on the road section and was calculated as the distance travelled in a 15-second interval at this speed limit – so for 30 mph roads, the site boundary ends 201 metres past the last camera and starts 201 metres before the first camera.

Sites were split into *sections* where there was a change along the road in either speed limit or road type (i.e. dual to single carriageway). It was also decided that sites would be split into separate sections at significant intersections such as roundabouts and traffic lights, as shown in Figure 4.1.

If there was a change in speed limit or road type, or presence of an intersection then the 15 seconds travel rule was ignored and the site was deemed to stop at that point.

For some sites there turned out to be a single site section, while for others there were up to eight sections – stretches of road belonging to the same site often but only slightly separated, nevertheless sometimes totalling up to several kilometres.

Figure 4.1: Sample map demonstrating site and site section boundaries



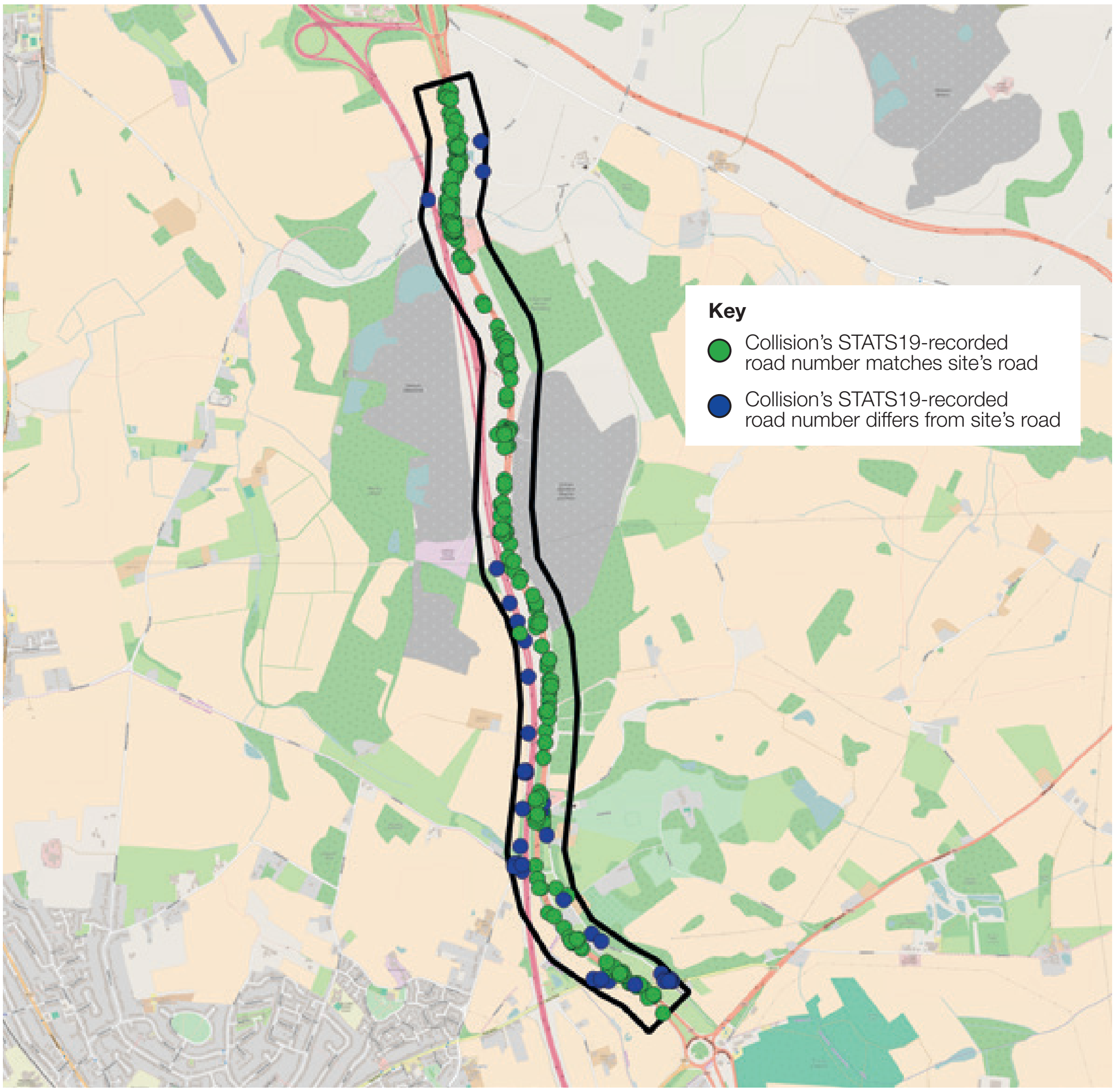
© OpenStreetMap contributors
Source: Authors' own

4.2 Collision matching

Collision data from 1990 to 2014 together with provisional 2015 data (January to June) obtained from DfT was plotted in the geographic information system program QGIS, using the co-ordinates in STATS19 data, the national database of police-reported injury road collisions in Great Britain. Collisions were then matched to a site in QGIS by location and by road number. Road number matching was carried out so that collisions on bridges and tunnels of crossing roads were not erroneously included; collisions on nearby roads with inaccurate co-ordinates were also thereby excluded. This was especially important given the wide buffers used at some sites.

Figure 4.2 shows collisions in a site on the A38 that are colour coded by whether the road number recorded in STATS19 matches the road number of the site: green if it matches, blue if it does not and is therefore excluded. It shows that there are a number of collisions on the adjacent M6 Toll road which were not on the A38 and are therefore excluded from the analysis.

Figure 4.2: Sample map demonstrating collision matching



© OpenStreetMap contributors
Source: Authors' own, adapted from STATS19 data

4.3 Control sites

The aforementioned review of literature (Soole et al., 2013) mentioned the lack of reference to controls or comparison sites, which is where the second objective of this research has relevance:

To establish a suitably large and appropriate control group of sites to enable an understanding of the difference in collision reduction between potential ASC sites with and without such enforcement.

This report looks at two different ways of providing a 'control' for the ASC sites, using information sourced about collisions on roads that were not subject to ASC enforcement.

4.3.1 Candidate sites

As part of the initial data gathering exercise, information was provided which indicated that some sites were initially considered for treatment with ASCs by several SCPs, but at which the treatment was subsequently not implemented because of the high costs of installation in relation to the budget available. They will have been identified as a result of a collision analysis by local road safety organisations. These sites are not a true control in the statistical sense, and to avoid confusion are thus referred to as 'candidate sites' in this report. They are reviewed separately within the results.

A total of seven sites with nine sections were identified, covering 24.89 km, all but one of which were in police force areas where no permanent ASCs had been introduced on other roads. It is highly likely that there are more sites of this nature, but without a more exhaustive survey of authorities it would not be possible to increase the sample size. At the request of the data provider, the precise location of these individual sites is not exposed in the research.

4.3.2 Comparison roads

The second way of comparing changes in collision numbers is by looking at collisions on other roads in the same area. As mentioned previously, the number of collisions on most types of road have dropped substantially since 2000 when the first ASC was installed, and this general trend needs to be taken into account. This was achieved by obtaining collision statistics for similar roads in the same authority area for the same periods as the data used from the camera sites. The data from the ASC sites was excluded from these comparison roads.

The definition of 'similar road' used in the report is one which fits a simple match of road classification, for example 'A-roads'. This is not a perfect selection methodology and, if suitable data was made available (as well as more time), a better set of comparison roads could be selected using information about traffic flows, number of lanes per carriageway, speed limit, junction density, or any other potential classification measure.

Nevertheless, the sample size is very large, with the comparison roads measuring a total of 60 times the length of the ASC sites included in the study.

4.4 Initial analysis

Traditionally, local analyses have focused on determining the change in collision rates from before to after installation of the cameras – indeed, this was something encouraged during the period of DfT oversight. Whilst this does have its place for some types of collision-reduction intervention – high friction road surfaces, for example (Simpson, 2005) – it does not take account of selection bias (where sites with abnormally high numbers of collisions were chosen in the first place), or the general trend of collision reduction as a result of external influences. A basic before-and-after analysis of ASC sites produces these findings, but without modelling fully, all or most of these reductions could well be due to site-selection bias and/or the general trend. Sections 4.5 and 4.6 of this report outline the methodology used later on to allow for these sources of apparent reduction.

Figure 4.3: Simple before-and-after analysis methodology

Source: Authors' own

Figure 4.3 illustrates a typical approach to a before-and-after analysis. It excludes the calendar month of installation and then looks at collision numbers in the two 36-month periods pre- and post-installation. Collisions are all classified as a 'personal injury collision' (PIC), where at least one person in or on any vehicle, or a pedestrian, was injured; and potentially as a 'fatal or serious collision' (FSC), which excludes collisions where only 'slight' injuries were sustained.

A simple analysis using this typical methodology was undertaken for the sites in the database. Some sites were removed, namely those that do not have three years of post-collision data or those excluded because of significant influencing factors (see section 3.2). This narrowed down the length of road suitable, which then stood at 116.85 km, a great reduction from the total of over 406 km within the total dataset. This is largely due to the high proportion of ASC installations that have taken place over the last three years. A full list of all sites included within the different parts of this report is included in Appendix C.

Table 4.1: Simple analysis results of collisions at ASC sites

PIC before	PIC after	% change	FSC before	FSC after	% change
526	392	–25%	146	73	–50%

Source: Authors' own

The results in Table 4.1 appear to be impressive, showing large reductions in both PICs and FSCs. However, for all of the reasons mentioned earlier in this section, they should not be taken as the final result and will be referred to at the end of the report in the discussion.

4.5 Generalised linear model

The principal analysis within this report uses a statistical model adopted by Professor Richard Allsop, in a form adapted from that used in the 2013 study of spot speed camera data for the RAC Foundation (Allsop, 2013). That report covers the technical details of the model, some of which are repeated here in Appendix A. The basis of the model is a regression, a statistical method for modelling the relationship between a dependent variable (in this case the number of collisions at a site) and one or more independent, explanatory variables. In this case the independent variables are the dummy variables to indicate the presence or absence of operational ASCs and to indicate the declared site-selection period (SSP); and the number of collisions on comparison roads, which is used to enable the number of collisions at a site to be adjusted for trend and other general changes in collision occurrence on relevant roads in the area in which the site lies.

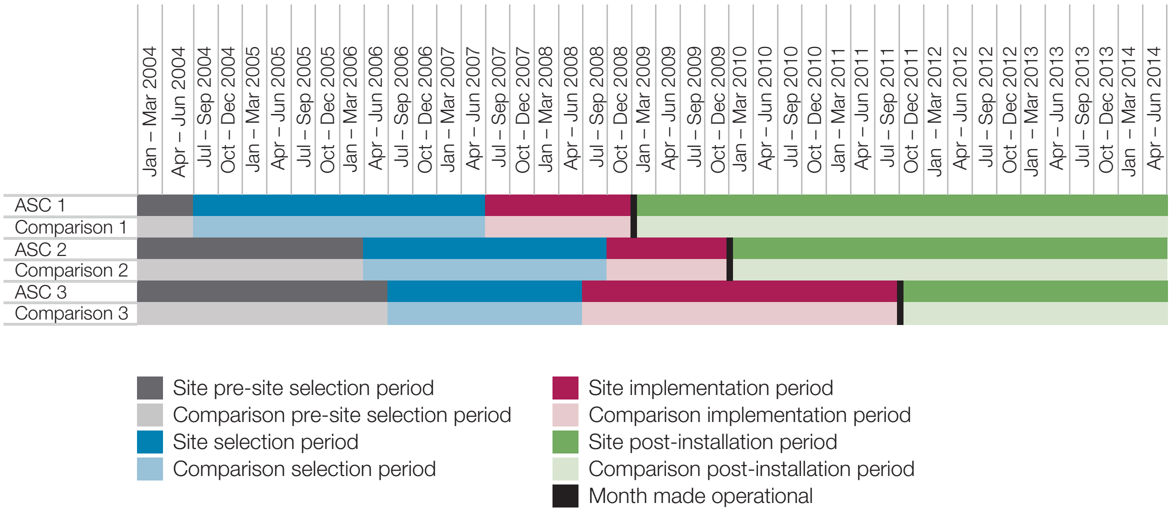
The model uses monthly data for each site section, together with corresponding data for comparison roads, from January 1990. The data was sourced from the official closed DfT STATS19 dataset – any local alterations to the collision records, including additions or deletions, will therefore not have been taken into account. This approach takes all of the available datapoints for all camera sites in the study over the last 25 years, although the sample has been restricted to sites installed before the end of 2014. Each site will therefore have some post-installation data, which will vary from eight months to almost 15 years. Unlike the simple before-versus-after analysis, the full post-installation dataset is used in this model.

Rather than use annual data, as was done in a number of previous studies, this model makes use of the monthly information, which was only possible because of the independent matching of collisions. As mentioned in section 4.3.2, it also incorporates the trend data for similar comparison roads in an authority area.

The final consideration is the effect of regression to the mean (RTM). In road safety, regression to the mean is the explanation for the situation where a road has a high number of crashes in a particular period (in this case three years, a period not long enough for the figures to ‘average out’), but because of the random factors involved in the causes of those crashes, it is more likely than not that there will be fewer at the same site in subsequent years, irrespective of whether there has been road safety treatment. Put simply, by deliberately choosing a site with an unusually high level of crashes in the first place, one is predisposing the results in subsequent years to show a drop in collisions at that site.

In order to allow for RTM, the model analyses and excludes any identified SSPs when comparing the collision numbers at sites post-installation with the numbers in all pre-camera periods. The pre-camera period at each site includes the implementation period between site selection and the camera becoming operational.

Figure 4.4: Various periods use for analysis within the model



Source: Authors' own

Figure 4.4 shows the relationship between the different periods for three fictitious sites, including the corresponding periods for the respective comparison roads.

In the example the three sites all have different installation dates with varying SSPs and pre-installation period durations. The comparison data is matched to these periods for each individual site month by month (the diagram shows months grouped together into quarters for simplicity). There is a one-month installation period shown in black, which is excluded from the analysis.

4.6 Site-selection period data

The Site Selection Period (SSP) is defined here as the collision analysis period used to identify the site for treatment with a speed enforcement intervention. During the period of DfT oversight this period would be recorded and submitted as a part of the annual 'operational case'. As stated in the previous section this period of time is used in the model to allow for the effect of regression to the mean (RTM), the phenomenon that describes collision levels returning to 'normal' following a period of untypically high levels. This phenomenon is likely to happen at sites that have been selected for high collision rates according to some site-selection criterion.

Information about SSPs is not commonly available on the websites of organisations operating the ASCs. The questionnaire sent to all operators was useful in obtaining information about the presence of an SSP, and sometimes where a site was not installed for collision-reduction reasons. In a few cases the original collision analysis that led to the site being selected was included on a website, an excellent example being the A9road.info website produced by Transport Scotland. There were still significant holes in the data, however, and two approaches to estimating the SSP were used for sites where no explanation was put forward. The first method was applied to sites that were installed during the period of DfT oversight, the period of hypothecation. During this time ‘handbooks’ were issued to SCPs, explaining how camera sites should be selected and what collision data was required. These handbooks were used by partnerships to put forward formal operational cases for approval, setting out proposed enforcement activity at existing sites and all proposed new sites. A sample timeline for this process might be as follows:

- October 2005: Operational case submitted, including collision data from the previous three years
- April 2006: Operational case approved
- March 2007: Latest date by which the camera site could be installed

In the example above, the SSP would usually be expected to be 2002–4, as data from 2005 would have been incomplete at the time of submission. By using the date of installation, the earliest possible operational case date was calculated together with the associated analysis period.

For sites that were installed post-DfT oversight, the SSP and implementation periods have been estimated using averages from all other sites. This was not carried out for sites installed for non-collision-reduction reasons – these were removed from the sample for possible separate analysis.

The average length of the SSP in the model is three years and one month, with the average implementation period being just over two years. A total of 14 sites where cameras were installed for collision-reduction reasons have recorded SSPs, and SSPs have been estimated for a further 11 such sites.

5. Results

The results of the generalised linear modelling are presented in the five sets of analyses as follows:

Set 1: All ASC sites installed for collision-reduction reasons

Set 2: Comparison of ASC sites installed before and after April 2007

Set 3: Comparison of high and low-speed sites

Set 4: Sites installed for non-collision-reduction reasons

Set 5: Candidate sites

Each set was then reviewed with respect to the changes in PICs and FSCs between months where enforcement was present and months where it was not, excluding the SSP. This calculation is referred to as the *installation effect*. A further analysis of the SSP versus the other pre-installation months is also undertaken to review the *site-selection effect*.

The sites comprising each of these sets are listed in Appendix C. The full statistical outputs, including 95% confidence intervals, are also given in Appendix B. Collision data for individual months on a site-by-site basis does not form a part of this report.

5.1 Set 1: All ASC sites installed for collision-reduction reasons

This application of the model selects all ASC sites from the database with the following exceptions:

- sites installed from 2015 onwards;
- sites with a prior history of speed camera enforcement;
- sites where the speed limit was changed during the study period;
- sites that were decommissioned after a period of operation (e.g. Northamptonshire); and
- sites that were installed for non-collision-reduction reasons.

The total number of sites in the sample was 25, which had between them a total measured enforced section length of 294 km. This measurement does not cover the entire length of the signed route but only the sections covered by visible enforcement equipment. Comparison roads sampled covered 13,160 km in total. Results were provided both for FSCs, i.e. those where at least one casualty was killed or seriously injured, and for all PICs.

5.1.1 Installation effect

A 36.4% (95% confidence interval: 25-46%) reduction in the mean rate of FSCs was estimated in the post-installation period. The change in PICs was lower, with a 16% (95% confidence interval: 9-22%) reduction; both results classified as highly statistically significant according to the model. These results allow in part for any RTM through the removal of SSP data from the pre-installation period. They also take into account the ‘trend’ data from the comparison sites.

5.1.2 Site-selection period effect

The other effect estimated in the model is the level of collisions in the SSP relative to the level in the rest of the pre-installation period. The results here show an increase in FSCs of 24.9%, and 16.7% for PICs. This supports the view that the SSP typically exhibits higher-than-normal collision numbers; again, both results were highly significant when tested in the model.

It should be borne in mind that the SSP effect has already been taken into account for in the *installation effect* analysis.

5.2 Set 2: Comparison of ASC sites installed before and after April 2007

As previously mentioned, April 2007 saw a change in the funding regime and level of control from DfT in managing site selection and approval. Although guidelines remained, there was no longer any requirement to follow these rules – operating authorities were from then on able to site ASCs wherever they chose, to address quantified or perceived road safety problems, or other issues such as air quality.

This analysis takes the sites from Set 1 and splits them into two subsets:

- installation pre-April 2007 (10 sites, 62.91 km total length);
- installation post-April 2007 (15 sites, 231.36 km total length).

5.2.1 Installation effect

For the cameras installed before April 2007, the camera installation effect is estimated to be a 36% reduction in FSCs per month. For the cameras installed after April 2007, this effect is estimated to be a 43.3% reduction in FSCs per month. Both results passed the significance test used in the model. It is worth noting, however, that the difference between these two estimates is less than two thirds of its standard error (see Appendix B) and could therefore well arise from random variation. It cannot therefore be said with any certainty that there was a true difference in the installation effect between the two subsets.

For PICs, the difference between the estimated ASC installation effects for cameras installed before and after April 2007 is somewhat greater than the difference for FSCs, with estimated reductions of 20.1% before and 8.7% after that date. The reduction of 20.1% is statistically highly significant, but the reduction of 8.7% is in itself significant only at the 20% level and quite likely to be the result of random variation. The difference between the two reductions is significant at almost the 10% level, giving a slight indication that the reduction was greater in the earlier period

5.2.2 Site-selection period effect

There is an interesting difference between site-selection effects for cameras installed in the two periods. For cameras installed before April 2007, this effect is estimated to cause an increase of only 8% in FSCs per month compared to other pre-installation months, and the test of significance shows that this could very well have arisen from random variation. For sites installed after April 2007 the effect is much larger, showing an increase of 37.4% (which is also statistically highly significant). The estimated SSP effect for PICs in cameras installed before April 2007 is similar to that for FSCs, but the effect for cameras installed after April 2007 is smaller than for FSCs, at 21.7% (compared with 37.4%). As with the FSC figures, the pre-April 2007 finding is not statistically significant.

5.3 Set 3: Comparison of high- and low-speed sites

The final analysis of the sites from Set 1 splits them into two groups based on the speed limits being enforced. Sites with 20 mph, 30 mph and 40 mph limits are classed as ‘low speed’, with the remainder as ‘high speed’.

5.3.1 Installation effect

For FSCs the ASC installation effects at low- and high-speed sites were estimated reductions of 42.2% and 32.3% respectively, both being highly significant. The difference in the two results in itself was not significant, and could well have arisen from random variation. The PIC installation effect at low-speed sites was strong, with a 25% reduction at a high level of significance. The results for high-speed sites was lower at 7.9%, but this was statistically significant only at the 20% level and thus may have arisen through random variation.

5.3.2 Site-selection period effect

For the low-speed sites both the FSC and PIC results were statistically insignificant. The estimated increase of 9% (for FSCs) and 5% (for PICs) compared to the rest of the pre-installation months could therefore have happened through chance. The results at high-speed sites were significant, and display increases of 30.2% for FSCs and 21.8% for PICs in the SSP compared to other pre-installation periods.

5.4 Set 4: Sites installed for non-collision-reduction reasons

There were two sites in the database that were known to have been installed for non-collision-reduction reasons – both of these were installed to reduce speeds in order to protect structures such as bridges and tunnels. With this in mind, the SSPs were set to zero, as it was known that these sites were not selected for reasons related to collisions in any specific time period.

5.4.1 Installation effect

The estimated FSC reduction of 20% was not statistically significant because of the wide difference between reductions at the two sites, although the 24.2% PIC reduction was highly significant when tested in the model. However, comparison of the 95% confidence intervals for these two estimated reductions with those for the corresponding reductions for the sites in Set 1 provides no evidence that the reductions in collisions at these two sites differ from the reductions at the other 25 ASC sites that were selected based on a high collision record.

5.5 Set 5: Candidate sites

The final objective of the research was to identify a suitably large and appropriate control group of potential ASC sites to understand the difference in collision reduction between ASC sites with and without this form of enforcement. During the scoping part of the project, six sites were identified as being originally selected for ASC deployment but not subsequently progressed. Although the number of sites is fairly small, an analysis of these non-progressed sites was undertaken using a modified model and using data from a set of comparator roads in the same way as the ASC sites.

The only effect estimated is that of the decision **not** to proceed with an ASC installation. No information is available on whether an alternative intervention was introduced after the decision was made.

5.5.1 Effect

Both FSC and PIC results showed an estimated 3% reduction in collisions after the decision compared with before, relative to the numbers on the comparison roads. The significance test shows that this reduction could very well have arisen by chance. Therefore, these sites show no evidence of a counterpart reduction in collisions to that found at the ASC sites.

6. Discussion

6.1 What the results show

The report's results can be split into two sections, the setting up and population of the database, followed by the analysis of the collision data.

6.1.1 The database

The first objective of the study was to establish a list of the installed average speed camera (ASC) sites around Great Britain. This was largely a success, as was the establishment of a set of additional information about the sites, including information about site-selection periods (SSPs). There are a small number of sites missing, because either the manufacturers or the suppliers did not take part in the study. More information about SSPs would have been helpful, and several methods had to be employed to calculate the periods and the effect of regression to the mean may well not have been fully accounted for. Nevertheless, the amount of information was enough to allow a robust analysis of ASC sites installed for collision-reduction reasons.

The database already contains information about sites installed in 2015, and it is clear, following conversations with those involved in the report, that this expansion in permanent ASC sites is continuing in 2016. Repeating this analysis with new sites, or if and when more data about reasons for site selection or SSP is obtained, would be a relatively simple task now that a consistent methodology has been designed.

Furthermore, this methodology can also be applied to other speed camera technologies, or perhaps other interventions where a specific period of time was used to carry out a collision analysis that led to the selection of sites for treatment.

6.1.2 The results

After deriving the methodology for data collection and collision analysis, a simple before-and-after collision analysis was undertaken, very similar to the analyses carried out by local analysts in police forces, safety camera partnerships, and highway authorities. Although the sample size was reduced compared to the main body of the work, the results here showed reductions in fatal or serious collisions (FSCs) of 50% and personal injury collisions (PICs) of 25%. These very high reductions do not, of course, take into account other influencing factors, something completed later in the main body of results.

Set 1, which looked at all ASC sites installed for collision-reduction reasons, showed that collision reductions were significant at 36.4% for FSCs and 16% for PICs. This gives an indication of the typical combined effect of site-selection bias, together with the overall collision-reduction trend during the period of operation. This notable difference should act as a warning to those seeking to review the benefits of similar interventions: the true impact on road safety may be considerably lower than the initial results show.

However, it is also worth mentioning that the results given here are robust, benefiting as they do from an independent approach together with fairly complex statistical analysis. It may not be possible to repeat this methodology at a local level, owing to the lack of a suitably large sample size.

Turning to other analysis sets, no statistically significant difference in the impact of FSCs emerged between sites with high and with low speed limits, whereas there was an impact on PICs at lower-speed sites.

The other analyses – those of sites installed pre- and post- April 2007, and for non-collision-reduction reasons – did not yield significant results in terms of difference from the combined cohort.

The analysis excluded sites where no information could be obtained for the SSP. For those where information was obtained, an increase in the rate of reported collisions was observed during the SSP, suggesting the presence on bias in site selection. The existence of this ‘site selection effect’ is a significant point of interest to those wishing to independently evaluate the impact of other interventions. More specifically, this research indicates that where sites are chosen for treatment due to high collision rates, then it can be expected that a certain proportion of the post-installation collision reduction could reasonably be attributed to this phenomenon. The presence and measurement of site selection effects should be reviewed at other enforcement locations, or even where engineering works have taken place, and is worth further consideration by the road safety profession.

The review of candidate sites – those used as a pseudo-control group – was encouraging, as it identified a reduction of only 3% in collisions, a reduction that could have arisen through chance.

6.2 Further research

It is a common outcome for analytical reports to bemoan the lack of data, and it is true that there is always something that could be made better with more data and higher-quality information. In this case several areas for future development have been identified, as follows.

6.2.1 Control sites

Obtaining information about sites that could be used as a suitable control proved difficult. Only a handful were identified, and these were largely from a different area from any of the ASC sites. A much closer dialogue with enforcement agencies responsible for identifying, installing, and enforcing sites may have yielded more data.

Questions would in any case still remain about maintaining a ‘clean’ control environment. The influence of other factors – such as road surface treatments, junction realignments, maintenance regimes or even other forms of speed management – could have played a part in influencing the results. This can equally be the case for the comparator roads used in the study too.

6.2.2 Comparator roads

The use of ‘similar’ roads in this study permits the influence of background trend in the overall collision data to be allowed for. The selection of these roads was reasonably broad, relying on the simple method of road classification (A-roads etc.). An improved model would select these roads based on traffic flows, the number of lanes per carriageway, speed limit, junction density, and potentially other features.

6.2.3 Comparison with other interventions

Previous analysis by the RAC Foundation (Allsop, 2013) using a similar methodology revealed similar FSC and PIC reductions at sites in Warwickshire (a fall of 38% in FSCs, 25% in PICs). It would be possible for a new analysis to be undertaken, assuming reliable information about site selection and commissioning were available, of spot speed camera sites, enabling the difference in installation effect between the two technologies to be determined. A similar analysis could also be carried out for mobile enforcement sites.

6.3 Conclusions

The results show that ASC systems are effective in reducing collisions, especially those of a high severity. Even after allowing for the effects of trend and regression to the mean, highly significant reductions are noted. There is no evidence for the existence of any optimum speed limit that leads to the installations achieving greater collision reduction – they appear to be as suitable for deployment in higher speed limits as in lower ones.

During the process of writing this report it has become clear that the number of systems installed recently, or planned for installation soon, is increasing very rapidly. Understanding the cost:benefit ratio of these systems would seem to be a sensible next step for authorities and organisations wishing to consider their use.

References

A9 Safety Group (undated). *Dunblane to Perth.* Retrieved 25 July 2016 from http://a9road.info/route-information/dunblane-to-perth/

Allsop, R. (2010). *The Effectiveness of Speed Cameras: A review of evidence*. Retrieved 25 July 2016 from www.racfoundation.org/assets/rac_foundation/content/downloadables/efficacy_of_speed_cameras_allsop_181110.pdf

Allsop, R. (2013). *Guidance on Use of Speed Camera Transparency Data: Updated November 2013*. Retrieved 22 July 2016 from www.racfoundation.org/assets/rac_foundation/content/downloadables/speed_camera_data_revised-allsop-nov2013.pdf

Cochrane (2010). *Do Speed Cameras Reduce Road Traffic Crashes, Injuries and Deaths?* Retrieved 25 July 2016 from www.cochrane.org/CD004607/INJ_do-speed-cameras-reduce-road-traffic-crashes-injuries-and-deaths

DfT (Department for Transport) (2005). *Handbook of Rules and Guidance for the National Safety Camera Programme for England and Wales for 2005/06.* Retrieved 25 July 2016 from http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/roadsafety/speedmanagement/nscp/bookofrulesandguidancefo4581.pdf

Gibbs, N. (2012). *Speed cameras: 20 years on.* The Daily Telegraph, 22 May. Retrieved 25 July 2016 from www.telegraph.co.uk/motoring/road-safety/9272478/Speed-cameras-20-years-on.html

Hansard: House of Commons (2008). *Written Answers*. 6 May 2008, c736W. Retrieved 25 July 2016 from www.publications.parliament.uk/pa/cm200708/cmhansrd/cm080506/text/80506w0005.htm#08050625000551

RSA (Road Safety Analysis). *MAST Online.* Data retrieved 1 August 2016 from http://www.roadsafetyanalysis.org/mast-online/

PR Newswire (2000). *New generation of SPECS speed cameras goes live in Nottingham today.* Press release, 28 July. Retrieved 25 July 2016 from www.prnewswire.co.uk/news-releases/new-generation-of-specs-speed-cameras-goes-live-in-nottingham-today-156095915.html

Scott Wilson (2008). *Speed Camera Technology at Roadworks.* Retrieved 25 July 2016 from http://tna.europarchive.org/20120703124527/http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Safety%20Camera%20Technologies%20at%20Roadworks%20-%201258.pdf

Simpson, C. (2005). *Performance of High Skid Resistant Surfaces.* Retrieved 25 July 2016 from http://saferroadsconference.com/wp-content/uploads/2016/05/Cassandra-Simpson_32_V1_2008131.pdf

Soole, D. W., Watson, B. C. & Fleiter, J. J. (2013). Effects of Average Speed Enforcement on Speed Compliance and Crashes: *A review of the literature. Accident Analysis & Prevention,* 54: 46–56.

Speed Check Services (2009). *SPECS3: Network enforcement.* Retrieved 25 July 2016 from www.speedcheck.co.uk/SPECS3_overview.pdf

PA Consulting / UCL (2005). *The National Safety Camera Programme: Four-year evaluation report*. London: PA Consulting.

University of Windsor (2016). *What is SPSS?* Retrieved 25 July 2016 from https://www.uwindsor.ca/its/sites/uwindsor.ca.its/files/What%20is%20SPSS.pdf

Appendix A: Methodology

Adapted from *Guidance on Use of Speed Camera Transparency Data*, Richard Allsop, University College London, first issued June 2013, Updated November 2013

Note: the equation used in modelling was stated incorrectly in Allsop's 2013 report and this error has been corrected here; the error was one of description only, and did not affect the calculations reported either in that report or this.

The data was analysed by means of the widely used technique known as generalised linear modelling, or GLM, applied first to the natural logarithm (logarithm to the base e, where $\mathrm{e} \approx 2.718$) of the ratio:

$$\frac{\text{Number of PICs at a given site in a given month}}{\text{Number of PICs on comparison roads in the same month}}$$

This was done with the aim of estimating how the ratio was affected multiplicatively by:

- (A1.1) whether that month was one of the months from which the numbers of collisions or casualties may have been taken into account in deciding where to establish the camera; and
- (A1.2) whether the camera was established and might therefore have been in operation throughout that month;

whilst having regard to the general level of occurrence of PICs at that site and the random variation in the number of PICs at the site in a month.

These multiplicative relations are expressed as additive ones by taking natural logarithms to give Equation (A1.3) as follows:

A.1 Equation A1.3

$$\ln\mu_{ny} = \ln P_{ny} + c_n + ub_{ny} + vc_{ny}$$

is used to estimate single values of effects (A1.1) and (A1.2) across all cameras where:

the cameras are coded with a Unique Site ID n

μ_{ny} = estimated mean of the Poisson distribution of the number of PICs at site n in month y

P_{ny} = number of PICs on comparison roads for site n in month y

c_n = fitted indicator of general level of collisions at site n

b_{ny} = 1 if month y was one from which the numbers of collisions or casualties may have been taken into account in deciding where to establish site n and 0 if not

u = fitted indicator across all N sites of the general level of collisions at the sites in months from which the numbers of collisions or casualties may have been taken into account in deciding where to establish the site relative to the level in other months before the site was established

c_{ny} = 1 if site n was established throughout month y and 0 if not

v = fitted indicator across all N sites of the general level of collisions at the sites in months throughout which sites might have been in operation relative to the level in months before sites were established other than the months from which the numbers of collisions or casualties may have been taken into account in deciding where to establish the sites.

The range of values of y is from 0 in January 1990 to 300 in December 2014 (a period of 25 full years, 300 months) for every site.

The values of the fitted indicators are calculated by the software so that they approximately maximise the likelihood of the recorded numbers of PICs having occurred at each site and in each month if all influences upon these numbers were represented by Equation (A1.3).

Similarly, the method is used for fatal or serious collisions (FSCs), with numbers of PICs replaced by numbers of FSCs throughout.

The primary results are the estimates of u and v and their standard error for the two kinds of collision. $100\exp(v)$ is the estimated collision rate per month at the set of sites after installation as a percentage of the collision rate before installation, so that 80 would indicate a 20% reduction. This estimate allows for trend and any bias by selection and associated regression to the mean resulting from untypically high numbers of collisions in the SSPs.

In the notation used by the model-fitting software, the fitted model provides estimates for the two variables analysed, as follows:

Exp(B) for Post-installation represents $\exp(v)$, the common estimate of the multiplier by which the number of collisions per month after installation of cameras is higher or lower than the average number before (excluding the SSP), and

Exp(B) for SSP represents $\exp(u)$, the common estimate of the multiplier by which the number of collisions per month during the SSP is higher or lower than the average number before installation but excluding the SSP.

A.2 Candidate Sites

For this analysis, the equation is modified by omitting the term connected to SSP. The interpretation of the other terms remains similar, except that there are no months from which the numbers of collisions or casualties may have been taken into account in deciding where to establish the sites.

A.3 Equation (A1.4)

$$\ln\mu_{ny} = \ln P_{ny} + c_n + v c_{ny}$$

where:

the cameras are coded with a Unique Site ID, n

μ_{ny} = estimated mean of the Poisson distribution of the number of PICs at site n in month y

P_{ny} = number of PICs on comparison roads for site n in month y

c_n = fitted indicator of general level of collisions at site n

c_{ny} = 1 if month y is a month after the decision for site n was made and 0 if month y is a month before the decision for site n was made

v = fitted indicator across all n sites of the general level of collisions at the sites in months after the decision was made relative to the level in months before the decision was made.

The range of values of y is from 0 in January 1990 to 300 in December 2014 for every site.

The values of the fitted indicators are calculated by the software so that they approximately maximise the likelihood of the recorded numbers of PICs having occurred at each site and in each month if all influences upon these numbers were represented by Equation (A1.4).

Similarly, the method is used for FSCs, with numbers of PICs replaced by numbers of FSCs throughout.

The fitted model provides estimate for the Post-decision variable analysed, as follow:

Exp(B) for Post-decision represents $\exp(v)$, the common estimate of the multiplier by which the number of collisions per month after the decision **not to** have an installation of cameras is higher or lower than the average number before.

Appendix B: Calculations

Note: the tables below are adapted from the output from the statistics software, Predictive Analytics Software the new name for SPSS statistical analysis software (University of Windsor, 2016). In terms of effect, the most important column is the one headed Exp(B), which contains the common estimators across all sites in the set of multipliers for the two variables (rows) in the model, site-selection period (SSP) and Post-installation. Values under 1 represent decreases and values above 1 represent increases relative to the pre-installation periods that fall outside of the SSP.

Table B.1: Set 1 parameter estimates for FSC

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.452	.0803	31.715	1	<.001	.636	.543	.745
SSP	.222	.0650	11.654	1	<.001	1.249	1.099	1.418

Table B.2: Set 1 parameter estimates for PIC

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.175	.0384	20.630	1	<.001	.840	.779	.906
SSP	.154	.0391	15.536	1	<.001	1.167	1.081	1.260

Table B.3: Set 2 parameter estimates for FSC, before April 2007 (A)

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.447	.0935	22.846	1	<.001	.640	.533	.768
SSP	.077	.1066	.517	1	.472	1.080	.876	1.331

Table B.4: Set 2 parameter estimates for FSC, after April 2007 (B)

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.567	.1676	11.441	1	<.001	.567	.408	.788
SSP	.318	.0816	15.160	1	<.001	1.374	1.171	1.613

Table B.5: Set 2 parameter estimates for PIC, before April 2007 (A)

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.225	.0470	22.865	1	<.001	.799	.729	.876
SSP	.084	.0624	1.793	1	.181	1.087	.962	1.229

Table B.6: Set 2 parameter estimates for PIC, after April 2007 (B)

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.091	.0688	1.732	1	.188	.913	.798	1.045
SSP	.196	.0502	15.259	1	<.001	1.217	1.103	1.342

Table B.7: Set 3 parameter estimates for FSC, low-speed sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.549	.1207	20.686	1	<.001	.578	.456	.732
SSP	.086	.1330	.422	1	.516	1.090	.840	1.415

Table B.8: Set 3 parameter estimates for FSC, high-speed sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.390	.1079	13.090	1	<.001	.677	.548	.836
SSP	.264	.0744	12.612	1	<.001	1.302	1.126	1.507

Table B.9: Set 3 parameter estimates for PIC, low-speed sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.288	.0545	27.873	1	<.001	.750	.674	.835
SSP	.049	.0705	.477	1	.490	1.050	.914	1.206

Table B.10: Set 3 parameter estimates for PIC, high-speed sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.071	.0541	1.742	1	.187	.931	.837	1.035
SSP	.197	.0470	17.553	1	<.001	1.218	1.110	1.335

Table B.11: Parameter estimates for FSC, non- collision-reduction sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.223	.2555	.761	1	.383	.800	.485	1.320

Table B.12: Parameter estimates for PIC, non-collision-reduction sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-installation	–.277	.0887	9.761	1	.002	.758	.637	.902

Table B.13: Parameter estimates for FSC, candidate sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-decision	–.030	.1643	.033	1	.855	.970	.703	1.339

Table B.14: Parameter estimates for PIC, candidate sites

Parameter	B	Std. error	Test of significance			Exp(B)	95% confidence interval	
			Wald chi-square	df	p		Lower	Upper
Post-decision	–.030	.0827	.132	1	.717	.970	.825	1.141

Appendix C: Site List

Site ID	Site name	Installation date	Site section length	Speed limit	Site selection period start	Site selection period end	Suitability restriction	Analysis sets							
								SSP	Simple	Set 1	Set 2a	Set 2b	Set 3a	Set 3b	Set 4
CA1	A14 Huntingdon to Girton, Cambridgeshire HA	Mar-07	11.48	70	01/01/2002	31/12/2004	Spot cameras	Supplied							
CA2	B1096 Ramsey Forty Foot, Cambridgeshire	Jul-10	6.27	50	01/01/2003	31/12/2005	Changed limit	Estimated							
CA3	A14 Girton to Fen Ditton, Cambridgeshire HA	Mar-11	6.87	70	08/11/2005	07/02/2009		Calculated	Yes	Yes		Yes		Yes	
CA4	A1139 Fletton Parkway, Cambridgeshire	Jul-15	1.54	60				Follow-up							
CH1	A537 Cat and Fiddle, Cheshire	Apr-10	15.54	50	01/01/2001	31/12/2006	Changed limit I mobile cameras	Supplied							
CU1	A66 Bass Lake, Cumbria	Jan-10	2.80	60			Mobile cameras	None							
ES1	A127 Arterial Road, Essex	Jan-09	8.55	50/70	01/01/2003	31/12/2005	Changed limit	Supplied							
ES2	A130 Canvey Way, Essex	Apr-09	3.98	50	01/03/2005	29/02/2008	Changed limit	Supplied							
ES3	Marine Parade, Southend, Essex	Mar-12	0.73	20	01/12/2008	30/11/2011	Changed limit	Supplied							
ES4	A120 Pelhams Corner, Essex	Feb-15	2.95	50	01/08/2011	31/07/2014	Changed limit	Supplied							
ES5	A13 Aveley to Thurrock	Feb-15	5.65	40/50			Changed limit	Follow-up							
ES6	A12 Kelvedon Bypass, Essex	Mar-15	7.20	70	01/01/2012	31/12/2014		Supplied							
HU1	A16 Peaks Parkway	Jul-13	1.92	40	01/01/2008	31/12/2012	Changed limit (Increased)	Supplied							
LI1	A15 Metheringham, Lincs	Jun-15	4.09					Follow-up							

Site ID	Site name	Installation date	Site section length	Speed limit	Site selection period start	Site selection period end	Suitability restriction	Analysis sets							
								SSP	Simple	Set 1	Set 2a	Set 2b	Set 3a	Set 3b	Set 4
LI2	A52 Ropsley, Lincolnshire	Dec-09	8.72	60	01/01/2004	31/12/2008		Supplied	Yes	Yes		Yes		Yes	
LO1	Blackwall Tunnel, London	Jul-09	2.48	20			Not casualty reduction	None							Yes
LO2	Dartford Free-Flow	Jun-15	5.76	50			Not casualty reduction	Follow-up							Yes
LO3	Rotherhithe Tunnel, London	Jun-09	2.00	20	09/02/2004	11/05/2007		Calculated	Yes	Yes		Yes	Yes		Yes
LO4	Tower Bridge, City of London	Sep-03	0.67	20	N/A	N/A	Not casualty reduction	None							
ME1	A228 Isle of Grain, Kent	Nov-07	7.31	40	01/08/2002	31/07/2005	Speed limit lowered during site selection period (Nov 2003)	Supplied							
NO1	A6514 Ring Road, Nottingham	Aug-00	6.37	40	01/01/1997	31/12/1999		Supplied	Yes	Yes	Yes		Yes		
NO10	B6004 Oxclose Lane, Nottinghamshire	Apr-08	0.99	40	10/12/2002	11/03/2006		Calculated	Yes	Yes		Yes	Yes		
NO11	A611 Annesley, Nottinghamshire	Nov-09	1.07	30	01/01/2003	01/01/2005		Supplied	Yes	Yes		Yes	Yes		
NO12	A631 Beckingham Bypass, Nottinghamshire	Nov-09	1.03	50	01/01/2005	01/01/2007		Supplied	Yes	Yes		Yes		Yes	
NO13	A60 London Road, Nottingham	Sep-10	0.39	30	01/01/2004	31/12/2006		Supplied	Yes	Yes		Yes	Yes		
NO14	A60 Mansfield Road, Nottingham	Sep-10	1.06	30	01/01/2004	31/12/2006		Supplied	Yes	Yes		Yes	Yes		
NO15	A614 Old Rufford Road, Nottinghamshire	Jan-12	19.09	50	01/01/2007	01/01/2009		Supplied	Yes	Yes		Yes		Yes	

Site ID	Site name	Installation date	Site section length	Speed limit	Site selection period start	Site selection period end	Suitability restriction	Analysis sets							
								SSP	Simple	Set 1	Set 2a	Set 2b	Set 3a	Set 3b	Set 4
NO16	A6097 Epperstone Bypass, Nottingham	Apr-13	10.37	50	01/01/2009	01/01/2011		Supplied		Yes		Yes		Yes	
NO17	A6097 (A614 East Bridgford), Nottingham	Feb-14	3.07	40	01/01/2010	01/01/2012		Supplied		Yes		Yes	Yes		
NO18	A60 Chuckney Hill, Nottinghamshire	Mar-14	2.01	50	01/01/2009	01/01/2011		Supplied		Yes		Yes		Yes	
NO19	A38 Alfreton Road to Sherwood, Nottinghamshire	Feb-15	4.15	50				Follow-up							
NO2	A610 Bobbers Mill, Nottingham	Sep-00	1.80	30	01/01/1997	31/12/1999		Supplied	Yes	Yes	Yes		Yes		
NO20	Bells Lane, Nottingham	May-15	0.66	30	01/01/2009	31/12/2013		Supplied							
NO21	Winchester Street, Nottingham	May-15	0.59	30	01/01/2009	31/12/2013		Supplied							
NO22	South Church Drive, Nottingham	Nov-15	2.44	30				Follow-up							
NO3	A46 Fosse Road, Nottinghamshire HA	Dec-04	1.45	40	01/01/2000	31/12/2002		Estimated	Yes	Yes	Yes		Yes		
NO6	A46 Cotgrave, Nottinghamshire HA	Jan-06	-	60	01/01/2001	31/12/2003	Removed	Estimated	Yes						
NO7	A52 Bingham, Nottinghamshire HA	Jan-06	3.85	60	01/01/2001	31/12/2003		Estimated	Yes	Yes	Yes			Yes	
NO4	A631 Gringley on the Hill, Nottinghamshire	Jan-05	3.18	50	01/01/2000	31/12/2002		Estimated	Yes	Yes	Yes			Yes	

Site ID	Site name	Installation date	Site section length	Speed limit	Site selection period start	Site selection period end	Suitability restriction	Analysis sets							
								SSP	Simple	Set 1	Set 2a	Set 2b	Set 3a	Set 3b	Set 4
NO5	A631 Scaftworth, Nottinghamshire	Mar-05	2.38	50	01/01/2000	31/12/2002		Estimated	Yes	Yes	Yes			Yes	
NO8	A52 Radcliffe Road, Nottinghamshire	Jan-06	3.23	70	01/01/2001	31/12/2003		Estimated	Yes	Yes	Yes			Yes	
NO9	A52 Saxondale, Nottinghamshire	Jan-06	1.05	60	01/01/2001	31/12/2003		Estimated	Yes	Yes	Yes			Yes	
SC1	A77 Ayr to Stranraer, Transport Scotland	Jul-05	28.66	50/60	01/01/2001	31/12/2003		Estimated	Yes	Yes	Yes			Yes	
SC2	A9 Dunblane to Inverness, Transport Scotland	Oct-14	158.60	60/70	01/01/2007	31/12/2011		Supplied		Yes		Yes		Yes	
ST1	A38 Shenstone to Bassetts Pole, Staffordshire	Jun-10	5.37	60	01/07/2005	30/06/2008	Changed limit	Supplied							
ST2	A515 Duffield Lane, Staffordshire	Jun-15	5.51	50	01/07/2009	30/06/2012	Mobile cameras	Supplied							
ST3	A519 Woodseaves, Staffordshire	Jun-15	1.09	30	01/07/2009	30/06/2012	Mobile cameras	Supplied							
SY1	A61 Sheffield to A616 (T) South Yorkshire HA	Nov-12	6.67	50				Follow-up							
SY2	A616 Stocksbridge, South Yorkshire HA	Dec-02	10.93	60	01/01/1998	31/12/2000		Estimated	Yes	Yes	Yes			Yes	
WA1	A465 Head of the Valleys, Wales	May-12	12.73	60	01/04/2008	31/03/2011		Supplied	Yes	Yes		Yes		Yes	
WA2	M4 J40-41a Port Talbot HA	Oct-14	3.37	50	01/04/2009	31/03/2012		Supplied		Yes		Yes		Yes	

RAC Foundation

Mobility • Safety • Economy • Environment

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

Registered Charity No. 1002705

Designed and printed by
The Javelin Partnership Ltd
Tel: 0118 907 3494

Produced on paper from a managed
sustainable source which is FSC certified
as containing 50% recycled waste.

Main proofreader:
Beneficial Proofreading Services
Tel: 07979 763116