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Locating and evaluating fixed safety cameras in South Australia

CN Kloeden, TJ Bailey, TP Hutchinson

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AUTHORS

CN Kloeden, TJ Bailey, TP Hutchinson

PERFORMING ORGANISATION

Centre for Automotive Safety Research
The University of Adelaide
South Australia 5005
AUSTRALIA

SPONSORED BY

Department of Planning, Transport and Infrastructure
GPO Box 1533
Adelaide SA 5001
AUSTRALIA

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ABSTRACT

Fixed safety cameras that detect red light running and speeding vehicles are known to be an effective method of controlling driver behaviour and producing road safety benefits. While no definitive best practice for choosing safety camera locations was found in the literature, there are a number of criteria that are frequently used and that make sense: locations with a high number of crashes (particularly injury crashes); locations with a high proportion of speeding vehicles; locations with high traffic volumes; locations with large numbers of unprotected road users (pedestrians and bicyclists); different camera types covering different areas of the road network; and deploying cameras widely throughout the road network. Evaluation of the effects of safety cameras on particular sites and as a whole can be attempted using a number of methodologies: changes in crash numbers before and after installation; changes in vehicle speeds before and after installation; and changes in offence detections from the time of installation onwards. There are limitations with each of these methodologies such that evaluating the effectiveness of an individual safety camera is often not possible. By tracking many safety camera sites for a long period of time, the effect of the safety cameras can be examined but there will always be other factors that may explain any observed changes. A true experiment could be conducted to determine safety camera effects but it would involve deliberate non-treatment of good candidate sites for many years. This study gives a reasonable set of principles for selecting safety camera sites and evaluating their effectiveness. However, the detailed processes for South Australia will depend on what data is available, the resources and funding that can be applied, and political and other considerations.

KEYWORDS

Speed, speeding, red light running, best practice, literature review

Summary

Fixed safety cameras that detect red light running and speeding vehicles are known to be an effective method of controlling driver behaviour and producing road safety benefits. They were first introduced in South Australia in 1988 and are now in operation at more than 150 locations around the State. Over time, the underlying technology has evolved allowing new methods and types of detection.

The purpose of this report is to examine how other jurisdictions select new safety camera sites and suggest practical principles for locating new safety cameras in South Australia and evaluating their effectiveness.

While no definitive best practice for choosing safety camera locations was found in the literature, there are a number of criteria that are frequently used and that make sense:

- Locations with a high number of crashes (particularly injury crashes)
- Locations with a high proportion of speeding vehicles
- Locations with high traffic volumes
- Locations with large numbers of unprotected road users (pedestrians and bicyclists)

The applicability of each of these criteria varies by the type of safety camera and consideration is given to each type in this report.

As the placement of safety cameras becomes more widespread, there are additional criteria that come into play:

- Different camera types cover different areas of the road network so a mix of camera types has the advantage of giving the perception of wider coverage to drivers
- Deploying cameras widely throughout the road network also gives drivers the perception of wider coverage so they are more likely to moderate their driving generally

Evaluation of the effects of safety cameras on particular sites and as a whole can be attempted using a number of methodologies:

- Changes in crash numbers before and after installation
- Changes in vehicle speeds before and after installation
- Changes in offence detections from the time of installation onwards

There are limitations with each of these methodologies such that evaluating the effectiveness of an individual safety camera is often not possible. By tracking many safety camera sites for a long period of time, the effect of the safety cameras can be examined but there will always be other factors that may explain any observed changes. A true experiment could be conducted to determine safety camera effects but it would involve deliberate non-treatment of good candidate sites for many years.

Random variation in the evaluation measures also means that a proportion of sites would be expected to appear worse after the installation of safety cameras even if the cameras are actually having a universal positive effect. This effect is exacerbated for sites with low numbers of crashes and offences. This means that there is no definitive method for detecting non-performing sites and relocating them. Since the major cost of an installation is the support infrastructure, decommissioning a site should really only be considered where changes in the environment would require major new infrastructure or where other treatments have been installed that prevent speeding behaviour.

Regular analysis of the crash and offence data for all safety camera sites as a group can give some indication of the safety benefits. As more sites are put into operation and current sites have been around for a longer time, the degree of certainty of any effects can be increased. However, the fundamental issues with attributing any observed changes to the safety cameras will remain and needs to be explained along with any analysis. Likewise, when reporting individual site effects, the role of random variations needs to be clearly pointed out.

This study gives a reasonable set of principles for selecting safety camera sites and evaluating their effectiveness. However, the detailed processes for South Australia will depend on what data is available, the resources and funding that can be applied, and political and other considerations.

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1 Introduction

Fixed safety cameras that detect red light running and speeding vehicles are known to be an effective method of controlling driver behaviour and producing road safety benefits (Wilson et al, 2010). They were first introduced in South Australia in 1988 and are now in operation at more than 150 locations around the State.

Over time, the underlying technology has evolved allowing new methods and types of detection. The criteria and methods for selecting new safety camera sites have also changed.

The purpose of this report is to examine how other jurisdictions select new safety camera sites and suggest practical principles for locating new safety cameras in South Australia and evaluating their effectiveness.

Section 2 contains a literature review exploring how other jurisdictions deploy and evaluate fixed safety cameras.

Section 3 explores the criteria in a South Australian context and suggests site selection criteria and evaluation methodologies that could be used, based in part on previous research conducted on safety cameras in South Australia.

Section 4 summarises the conclusions of this study.

2 Literature review

A literature review was conducted exploring how other jurisdictions deploy and evaluate fixed safety cameras.

2.1 Methodology

A search was conducted for literature concerning best practice findings, principles and guidelines on fixed safety camera deployment. The databases searched were the Transport Research International Documentation (TRID) database, the Barr Smith Library at the University of Adelaide and Google Scholar. The search terms were: fixed speed / safety camera(s), deploy(ment), site, and evaluation, and the search period was 2000 to 2017.

While there is a substantial amount of published research on the effects of speed cameras in reducing speeds and crashes per se, comparatively little addresses the placement of fixed cameras in detail. The research that does consider camera deployment methods tends to regard this as a side issue in studies generally aimed at demonstrating the speed and crash impacts of particular camera programs. The literature search produced sixteen reports, journal articles and policy papers that addressed the issue of camera placement. Of these, 10 were deemed of direct relevance to the project: 5 international papers and 5 of Australian origin.

While the South Australian Government prefers to use the term 'safety camera', this literature review uses the term 'speed camera', as this term is found consistently throughout the literature.

2.2 Australian literature

New South Wales

A report of an early evaluation (Carseldine, 2003) of New South Wales' fixed speed camera program appended the criteria at the time for siting such cameras, which were primarily based on crash and speeding data. The site selection criteria were employed for road sections of 1 to 2 km in length, with a minimum 2000 vehicles per day (as measured by automatic traffic counters). There were two criteria involving crash counts and one involving prevailing vehicle speeds. All three criteria needed to be met to justify camera installation.

- A crash rate (expressed as per 100 million vehicle kilometres over the previous 3 years) of >80 on urban roads, >40 on rural roads, and >25 on divided roads, freeways or motorways.
- An *injury* crash rate (per kilometre per year over the previous 3 years) of >0.5 on urban roads, >0.5 on rural roads, and >0.5 on divided roads, freeways or motorways.
- The 95th percentile of vehicle speed is in excess of the posted speed limit plus 10%; or the 85^{th} percentile speed is greater than the posted speed limit.

The NSW Government (Transport for NSW, 2012) has published a strategy for deploying various types of speed cameras, which includes coverage of the criteria for site selection. There are three main criteria for fixed speed cameras, only one of which needs to be met:

- A high frequency and severity of crashes over a road segment maximum length of 1000 m
- A school zone with a high frequency and severity of crashes and/or high risk of a pedestrian crash
- A high risk location that is difficult to enforce by other means.

The strategy document is more policy-oriented than operational in content and does not give a more specific indication of what constitutes high crash frequency or severity.

Additional provisos are that camera sites should not be within 300 m of a change down in speed limit, or on downhill slopes (unless there is an identified crash problem). Also, the cameras and their usage must comply with technical, operational and safety camera standards.

The NSW strategy does specify some criteria for measuring camera effectiveness. For fixed cameras, these are:

- A reduction in vehicles speeding within 500 m of the cameras
- An increase in compliance at camera location or reduction in infringement rates
- A reduction in casualties and crashes within 500 m of the cameras
- The level of risk continues to be reduced at the camera site (e.g. a low level of speeding and/or crashes in tunnels).

Western Australia

Cameron and Delaney (2006) developed a number of strategies for best practice in speed enforcement for Western Australia. They were primarily concerned with determining the best mixes of covert versus overt cameras, and mobile versus fixed detection for urban versus rural roads. While most of their recommendations concerned deployment of mobile cameras, in relation to fixed cameras, they recommended they be used on certain stretches of Perth freeways, noting that they had not been so far demonstrated to have an effect other than on localised casualty crashes. This finding echoes the need to be mindful of wider area effects rather than just near the camera site, as discussed in the international literature section. Supplementary research conducted by Cameron in 2008 examined point-to-point cameras as an optional alternative to fixed speed cameras on Perth freeways. His economic analysis identified forty road segments in the state where application of point-to-point cameras would bring benefit-cost ratios of ten or more. This notion is also pursued in some of the international literature.

Queensland

In 2010, the Queensland Government made a submission to Queensland Parliament's *Inquiry into the road safety benefits of fixed speed cameras* in which it outlined the guiding principles and rules for choosing camera sites. In that state, fixed speed cameras are used only where other forms of enforcement such as mobile cameras, laser guns and police patrols would be operationally of limited effectiveness, due to dangerous locations, tunnels, bridges, etc, or alternative engineering solutions are unworkable. The submission does not detail the specifics of the camera site selection criteria employed, but does mention a record of at least five crashes in the previous five years at or near the site. There is also flexibility where sites deemed of high risk, but which do not meet this criterion, may still be selected if they show potential for crashes, such as through excessive high risk driver behaviour generally, through high risk of speed-related crashes, inability to effectively enforce speed limits by other means, or through road environmental factors likely to increase crash severity.

2.3 International literature

United Kingdom

An early evaluation of speed cameras, conducted by the University of Leeds (Mountain, Hirst & Rose, 2004), examined a number of previous studies of speed cameras. The authors noted that evaluations of speed camera programs are open to the criticism that not all of any crash reductions found can be directly attributed to the effects of the cameras on vehicle speeds, and that there may be compensating increases of crashes elsewhere on the network. This can occur in two ways: (i) by drivers selecting an alternative route, and also (ii) by drivers sharply braking shortly before encountering the camera, or accelerating sharply after passing it, which can lead to crashes upstream or downstream from the camera (Mountain et al., 2004). Hence, this finding highlights an important factor to consider with respect to speed camera placement, namely that the selection of a site for placing a speed camera may lead to increases in speeds and crashes on alternative routes.

In Mountain et al. (2004)'s study, the effects of 62 fixed speed cameras placed on various 30 miles/h limit roads throughout the UK were measured before/after their deployment. It was found that mean speeds were reduced by 4.4 miles/h and that there was a reduction of 35% in speeds recorded above 30 miles/h, consistent with previous UK studies. Moreover, injury crashes fell by 25%, with 20% of that attributable to reduced vehicle speeds.

However, the authors noted that their findings may be influenced by the statistical phenomenon known as regression to the mean (RTM). They deduced if cameras are sited to target locations with large numbers of crashes, they may achieve a substantial reduction in observed crashes simply through RTM effects rather than the cameras directly reducing speed-related crashes. In a similar vein, newspaper articles have reported on 'worst camera sites' so named because more fatal and serious crashes occurred *after* camera installation than before it. Mountain et al. (2004) took pains to point out that the site selection for those cameras was not faulty or ill-advised (or 'costing lives' as newspapers phrased it), but were effects arising simply as a result of a reverse RTM effect in which there was an unexpectedly small number of crashes for a particular camera site before camera installation and the subsequent observed crash increase was simply due to the crash numbers regressing to the mean.

Mountain et al. (2004, p. 11) concluded with a key implication for best practice in speed camera site selection:

> "While the targeting of clearly visible cameras at serious accident 'blackspots' may appease some motorists (making it difficult for them to argue that the camera is designed to raise revenue), such targeting should not be to the exclusion of sites which have large numbers of less serious speed related accidents that could also benefit from increased speed enforcement (and which could prevent a fatal accident before it happens)."

Or, in fewer words (2004, p.11),

> "To realise the full potential safety benefits of cameras, what is needed is wider deployment and less emphasis on fatal and serious accidents in selecting locations for new cameras."

Finally, it is worth noting, that Mountain et al. (2004) found no evidence of sudden braking before a camera or rapid acceleration after passing it having any effect on safety. However, the impact of cameras on route choice resulted in a fall of 5% in injury crashes at the camera sites, creating the possibility of increased crashes on diversionary routes chosen by drivers.

It is possible that Mountain et al. (2004)'s advice about bearing in mind camera deployment for locations with large crash numbers but of less serious crashes was taken up in the development of the UK's National Speed Camera Program (NSCP) (Department for Transport, 2004). The NSCP Rules require every camera detection site (fixed, mobile and red light) to fall into one of three mutually exclusive categories:

(i) **core** sites that had cameras previously installed and new sites that meet the new guidelines;

(ii) **exclusive** sites that have high levels of injury crashes but insufficient killed & seriously injured crashes and there is community concern, concerns of potential increased fatalities if speeding is not addressed, or the roads are awaiting upgrades to meet minimum engineering requirements;

(iii) (temporary) **roadworks** sites.

The NSCP stipulates six rules or criteria for camera site selection:

1. Site length (the road distance in which crashes and speeds are detected and measured) is to be between 0.4 and 1.5 km

2. A minimum four fatal or serious injury crashes per km in the baseline period (3 years prior to camera installation)

3. Speed surveys show that 85% of traffic passing the site travels at speeds at or above the police enforcement tolerance applied to the speed limit for the particular road (85^{th} percentile rule)

4. At least 20% of all vehicles are exceeding the speed limit

5. Loading and unloading of the camera can take place safely

6. A road engineering survey confirms that no other cost effective engineering solution can be feasibly implemented along this road stretch.

(The NSCP) also stipulates criteria for the overt operations of a camera program: camera warning signs, their placement and minimum visibility distances for drivers.

Sites designated as “exclusive” attract an extra selection criterion: live camera enforcement hours at exclusive sites must not constitute a greater proportion than 15% of *total* live camera hours in an enforcement region (i.e. of the total live enforcement hours across fixed, mobile and red light cameras).

A more recent UK research paper was that of Hindle and Hindle (2011), who tended to reinforce and extend the findings of Mountain et al. (2004) with respect to camera deployment, rather than identify further criteria for camera deployment strategies. Unlike Mountain et al. (2004), however, Hindle and Hindle (2011)’s research looked at the effects of cameras deployed within and across 149 local authority areas in the UK, rather than the effects at representative single camera sites. While there were several reasons for this emphasis, a main rationale was the likelihood of changes in vehicle speeds and crash rates occurring on other roads near the site of a particular speed camera (i.e. problem migration), as noted by Mountain et al. (2004). Another reason was that Hindle and Hindle (2011) were also mindful of possible RTM effects. Aware that cameras are often deployed at or near accident blackspots as a consequence of political pressure rather than any other reason, they attempted to average out the ensuing speed and crash effects by examining them collectively over the broader local authority’s area. A third reason was happenstance. In 2007, the NSCP was disbanded as part of a nation-wide devolution of road safety responsibility to individual local authorities. Consequently, each local authority sought evaluation data to compare its road safety performance with other authorities, such as in Hindle and Hindle (2011)’s research.

Hindle and Hindle (2011) noted that, in the broader context of the likely impact of cameras being strongly influenced by prior injury crash rates, where the impact is predicted to be less than 10 such incidents over a 3-year period, it had not been possible to detect such impact statistically. This raised the issue of decommissioning cameras where there are no or minimal effects statistically discernible following installation. However, the researchers went on to note that the issue of camera removal is a politically highly charged one due to the fear of litigation should a crash subsequently occur at or near the site of a camera that had been removed. Fortunately, as most incidences of cameras yielding no or minimal demonstrable benefits tended to occur on rural roads, Hindle and Hindle (2011) were able to suggest that a better alternative to simply removing fixed cameras would be to replace them with point-to-point camera systems, which may prove to be a more cost-efficient alternative as well as a more effective speed reduction approach for larger rural areas.

Norway

Support for a lesser focus for camera installation on rural roads comes from Norwegian research. Høye (2015) evaluated the before/after safety performance of 223 fixed speed cameras on Norwegian roads installed between 2000 and 2010, with control for RTM effects. She found that use of speed cameras had greater effects on fatal and serious injury crashes on medium road stretches than on long road stretches. Medium road stretches were defined as 100 m before the camera and up to 1 km after the camera. Long stretches were defined as 100 m before the camera and up to 3 km after the camera. Not only were the injury reduction effects greatest on medium road stretches (22% reduction), but the effects on longer (and shorter) sections were smaller and not statistically significant. If the speed deterrent effect of a camera dissipates with increasingly longer road stretches more than 1 km (before another speed control device is encountered), this adds support to the use of point-to-point camera technology.

2.4 Components of best practice

The literature review has yielded a number of factors that could be considered when selecting sites for deploying speed cameras and when assessing their effects on traffic. While there does not appear to be, as yet, a definitive or even consensus-based list of best practice criteria: crash frequency, severity and levels of speeding appear to be common core features.

Siting of cameras

When selecting fixed camera sites, the following factors should be considered:

- Prior crash history (Carseldine, 2003; Queensland Government, 2010; NSW Government, 2012)
- Prior history of speeding offences (Carseldine, 2003; Queensland Government, 2010, NSW Government, 2012)
- Assessing the risk of problem migration, that is in generating higher vehicle speeds and/or increased crashes on alternative routes, or further along the same stretch of road (Mountain et al., 2004; Hindle & Hindle, 2011)
- Placing more emphasis on a wider area deployment of cameras (such as sites with large numbers of less serious crashes) rather than focussing predominantly on reducing high crash risk road segments (Mountain et el., 2004; Department for Transport, 2004; Queensland Government, 2010; Hindle & Hindle, 2011)
- Whether a point-to-point camera system would be a more effective approach than a series of fixed speed cameras, particularly over long routes where there are few entrances or exits (Queensland Government, 2010; Hindle & Hindle, 2011; Høye, 2015).

Measuring the effects of camera installation

When assessing the effects of fixed camera sites, the following should be considered:

- Site length (the road distance in which crashes and speeds are detected and measured) (Department for Transport, 2004)
- Effects on fatal/serious injury crash numbers (Department for Transport, 2004; NSW Government, 2012)
- Effects on prevailing vehicle speeds (Department for Transport, 2004)
- effects on the proportions of vehicles exceeding the speed limit (Department for Transport, 2004; NSW Government, 2012)
- Safety of loading and unloading cameras (Department for Transport, 2004; NSW Government, 2012)
- Whether any other cost-effective engineering measures, such as traffic calming treatments like speed humps or roundabouts, would be suitable (Department for Transport, 2004; Queensland Government, 2010)
- Evidence of problem migration, that is in generating higher vehicle speeds and/or increased crashes on alternative routes, or further along the same stretch of road (Mountain et el., 2004; Hindle & Hindle, 2011)
- Presence of regression to the mean (RTM) effects, particularly when camera sites are primarily selected on the basis of high levels of speeding and/or crashes (Mountain et el., 2004; Hindle & Hindle, 2011).

3 A methodology for South Australia

A number of criteria have been identified from the literature but with no definitive method of best practice. The following discussion explores the criteria in a South Australian context and suggests site selection criteria and evaluation methodologies that could be used.

3.1 Types of criteria for camera installation

Crash numbers

Deploying new fixed safety cameras at locations with the highest number of crashes is a logical and commonly employed practice. It targets an identified problem and arguably provides the greatest safety benefit for a given investment. It is also the practice most immune from “revenue raising” criticisms. For these reasons, it provides a solid starting point for deployment decisions. However, there are some caveats that need to be taken into account.

A location with a very high number of crashes may have fundamental design issues that are better treated with a redesign or traffic signal changes rather than a safety camera.

A particular high crash location may also have very few speeding vehicles and red light runners or very few crashes that are affected by speeding vehicles or red light running. In this case, a safety camera would have a much smaller effect than the raw number of crashes would imply.

Crash numbers, and particularly injury crash numbers, at a particular location tend to be small and are therefore subject to large random variation from year to year. So the location with the highest number of injury crashes in the previous year will not necessarily be the most inherently high crash location. This can be ameliorated somewhat by examining multiple years of historical data (typically 3-5 years) but this problem still remains and including more years of historical data can mask recent changes.

Injury crashes are typically used as a baseline measure as they represent the human cost of road crashes. They also tend to be more reliably and consistently reported and recorded compared to property damage only crashes. However, property damage crashes are more numerous than injury crashes (currently there are about two property damage crashes for each injury crash recorded in the South Australian crash database system) so they may be worth considering in situations where injury crash numbers are very low.

Speeding vehicles

Deploying new fixed safety cameras at locations with the highest number of speeding vehicles would be expected to deter or detect the greatest number of speeding drivers.

However, particular locations with high numbers of speeding vehicles may have low crash numbers meaning the potential to reduce crashes at that location through lower speeds could be less than at a higher crash locations with fewer speeding vehicles.

Measuring vehicle speeds at potential locations is also expensive and not practicable on a large scale. Speeding offences are not a viable alternative as there will be very few of them at particular sites and they will be inconsistently collected.

Traffic volumes

While there is solid evidence that safety cameras reduce speeds and crashes at the locations where they are deployed (eg Wilson et al, 2010), they also form part of the general deterrence against speeding. Each time a driver passes a marked safety camera location they will usually check their speed and be reminded that speed enforcement is something they can encounter. This may well influence their speeding behaviour in general, although this is much harder to quantify.

In this sense, the more vehicles that can be exposed to safety cameras, even if they are not speeding at the time, the better the general deterrence value of the camera. This argues for placing highly visible safety cameras in high traffic volume locations regardless of the number of crashes or level of speeding.

This reasoning is likely to have less public acceptance and the size of the effect is not clear. However, in practice, high volume locations also tend to have a high number of crashes. Thus, by selecting high crash locations, high traffic volume locations are also being selected.

3.2 Selection process for specific types of camera

In practice, applying the above criteria to the selection of fixed safety camera sites depends on the type of site being considered. This section suggests a selection process for each of the camera types currently employed in South Australia.

Signalised intersection cameras

The highest spatial concentration of crashes in South Australia is at intersections. Therefore, if specific crash locations are to be targeted, intersections have the greatest potential for crash reductions. Based on the general considerations above, the following site deployment process is proposed for selecting new intersection safety camera sites in South Australia.

Selection process:

- Identify and rank intersections based on the number of injury crashes in previous years of available crash data.
- Exclude intersections with safety cameras already installed or where safety camera installation is not feasible.
- Conduct speed surveys on each leg of high ranking intersections.
- Examine individual intersection leg crash and speed data to identify legs with both high numbers of crashes and high numbers of speeding vehicles.
- These are the intersection legs that should have safety cameras installed next.

Other factors to take into consideration:

- Are there other infrastructure treatments that can be applied.
- Will crash migration be a problem.
- May need to include property damage crashes if injury crash numbers are too low.

Signalised mid-block pedestrian crossing cameras

While crashes at signalised mid-block pedestrian crossings tend to be much rarer than at regular signalised intersections, they also tend to be more severe as they are more likely to involve an unprotected road user and potentially higher speeds. In practice, the number of crashes is too small to base site selection decisions on, so other criteria must be used.

The greatest specific benefits would be at crossings where there are large numbers of pedestrians using the crossing as pedestrian crashes will be more likely to occur. Some weight could also be given to the types of pedestrians using a crossing. Children, the elderly and intoxicated pedestrians are known to be over represented in pedestrian crashes, presumably because of impaired judgement.

The general benefit of a safety camera at a signalised mid-block pedestrian crossing is to slow vehicles down for some distance before and after the crossing and provide an increased level of safety for vehicles along that road section. In this sense, roads with both high traffic volumes and a high proportion of speeding drivers along the road would be expected to benefit the most from a camera being installed.

Selection process:

- Identify signalised mid-block pedestrian crossings on high volume roads where there is expected to be high pedestrian activity.
- Exclude crossings with safety cameras already installed or where safety camera installation is not feasible.
- Give priority to sites located near schools, where older people live and near where alcohol is served.
- Conduct surveys at promising sites to determine traffic and pedestrian crossing volumes, the speeds of passing vehicles and the frequency of red light running incidents.
- Identify crossings with high numbers of pedestrians, large traffic volumes and a high proportion of speeding or red light running vehicles.
- Also take into account the type of pedestrians using the crossing (old and young) and the proximity of schools, where older people live and where alcohol is served.
- These are the crossings that should have safety cameras installed next.

Signalised railway crossing cameras

While crashes at signalised railway crossings involving a vehicle being hit by a train are extremely rare, they have the potential to be extremely severe. In practice, the number of crashes of all types at signalised railway crossings is too small to base site selection decisions on, so other criteria must be used.

The greatest specific benefits would be at railway crossings where traffic volumes and vehicle speeds through the crossing are both high or where vehicles frequently cross the railway line after the signal is activated.

The general benefit of a safety camera at a signalised railway crossing is to slow vehicles down for some distance before and after the crossing and provide an increased level of safety for vehicles along that road section. In this sense, roads with both high traffic volumes and a high proportion of speeding drivers along the road would be expected to benefit the most from a camera being installed.

Selection process:

- Identify signalised railway crossings on high volume roads.
- Exclude crossings with safety cameras already installed or where safety camera installation is not feasible.
- Conduct surveys at promising sites to determine traffic volumes, vehicle speeds and the number of vehicles entering the crossing after the signal is activated.
- Identify crossings with large traffic volumes and a high proportion of speeding or red light running vehicles.

- These are the crossings that should have safety cameras installed next.

Mid-block cameras

Mid-block safety cameras cannot target specific locations of crashes as crashes tend to be distributed along road sections. However, they can cover part of road sections that have high crash numbers. They can also monitor vehicles that are all generally travelling at speeds around the speed limit and so have the potential to deter and detect many more speeding drivers than cameras at intersections.

Selection process:

- Identify high volume road sections with a high number of crashes.
- Exclude sections with safety cameras already installed or where safety camera installation is not feasible.
- Conduct surveys at promising sections to determine traffic volumes and vehicle speeds.
- Identify sections with large traffic volumes and a high proportion of speeding vehicles.
- These are the sections that should have safety cameras installed next.

Point to point cameras

Point to point cameras can detect all consistently speeding drivers travelling along a monitored section of road. This gives them the greatest potential to detect and deter speeding over a long stretch of road.

By concentrating on areas with a high number of crashes and speeding vehicles, they can have the biggest impact. However, not all road sections are suitable for point to point speed cameras. Road sections with multiple entries and exits, traffic controls or congested traffic generally preclude the use of point to point cameras. However, large sections of major arterial rural roads and highways are suitable.

Selection process:

- Identify high volume road sections with few entries and exits, no traffic controls and free flowing traffic with a high density of crashes.
- Exclude sections with safety cameras already installed or where safety camera installation is not feasible.
- Conduct surveys along promising sections to determine traffic volumes and vehicle speeds.
- Identify sections with high crash rates, high traffic volumes and a high number of speeding vehicles.
- These are the sections that should have point to point safety cameras installed next.

3.3 Strategic considerations for a safety camera program

The previous section gave suggested selection processes for the various fixed safety camera types. When considering the fixed safety camera program as a whole, other factors need to be taken into consideration.

Mix of camera types

Consideration needs to be given to the relative rollout of different safety camera types. From a specific safety perspective, signalised intersection cameras probably offer the greatest chance of crash reductions at the location of the camera. For a generalised deterrent effect, point to point cameras and mid-block cameras will monitor and detect the greatest number of speeding vehicles. As far as perceived danger goes, signalised railway crossing cameras and signalised mid-block pedestrian crossing cameras offer protection in obviously high risk situations (although the frequency of those risks is rare).

There is insufficient research available to quantify the relative effects of the different camera types. However, starting with mostly intersection cameras and expanding to point to point and midblock cameras with a few pedestrian and train crossing cameras roughly matches the probable returns.

Wide deployment

During the initial rollout of fixed safety cameras, the criteria in Section 3.2 are appropriate considerations on their own. However, once there are a significant number of cameras in the system, consideration needs to be given to how widely they are deployed. If the criteria concentrate cameras in particular geographic areas, drivers will be less likely to modify their behaviour outside of those areas. By selecting some sites outside of these areas, more drivers can be given the impression that their speeds and red light running behaviour is monitored more widely so they need to moderate their driving more generally. The benefits of this general effect could outweigh the loss of specific benefits due to choosing non-optimal locations.

External requests

Requests for safety cameras at a particular location are sometime made by the public, local governments or State governments. This should initially be taken as an indication to examine the site for suitability using the criteria in this report. Some extra weight could be given to the particular site due to the external request but this is a political decision rather than a methodological one.

Specific criteria for South Australia

This report has given general criteria for selecting new safety camera sites in South Australia using a ranking system based on a number of factors. It does not specify the relative importance of the various factors as there is insufficient information available to discern their relative effects. However, any reasonable system based on these criteria would be expected to select similar sites for treatment.

If purely objective criteria are required they can be developed by applying the criteria in South Australia and selecting relative weights that make sense in the context of the available data and political processes.

3.4 Evaluation of safety cameras

Even though it is well established that safety camera programs do reduce vehicle speeds and prevent crashes (Wilson et al, 2010) there is a natural desire by each jurisdiction to show that *their* safety cameras are effective both at a program level and at an individual camera level.

However, there are a number of methodological and statistical issues that limit the ability to discern effects for a small number of sites over a short period of time and to fully attribute effects in large scale analyses. These issues are discussed below for the various types of evaluation.

Crash effects

The primary goal of safety cameras is to reduce the number of crashes, so a logical method of evaluation is to count the number of crashes before and after installation and see if they have changed.

A fundamental issue with this approach is the low number of crashes at a particular location and the associated large random variation. For a site with an underlying rate of 9 crashes per year, actual yearly crash counts between 3 and 15 would be unsurprising. This natural variation in crash numbers is much larger than any expected effect of a safety camera so it is generally not possible to determine if safety cameras are effective at such a site by only looking at crash data just before and just after camera installation.

This problem can be ameliorated somewhat by considering multiple years of crash data before and after the safety camera is in place (typically 5 years before and 5 years after is recommended). However, the number of crashes will still be too small to definitively attribute any observed changes to the safety camera. This is especially so in South Australia, where there have been a number of changes in the threshold of reporting non-injury crashes into the police system. This means that only injury crashes can be reliably compared over time and there are many fewer injury crashes than all crashes.

While it is probably unreasonable to evaluate the effect of safety cameras at an individual site using crash data, the effect of safety cameras in general can be quantified by considering the overall change in injury crash numbers for a large number of sites over a long period of time. By combining the results from enough sites, the effect of the safety cameras can potentially be discerned from the inherent randomness of the individual sites.

Another issue is that of general changes in the underlying risk of an injury crash occurring (through such things as changes in traffic volumes, vehicle speeds and vehicle protection ability). If considering crashes at sites over a long period of time, the underlying risk may change which will give an apparent effect not related to the safety cameras. For example, modern cars offer more protection than older ones and are more common in recent times, so injury crashes would be expected to go down over time everywhere. This effect can be allowed for by using crash data at control sites to correct the observed changes in crash numbers. However, identifying control sites that are truly comparable is difficult and using only a small number of control sites adds extra variation to any analysis making finding statistically significant results harder. For intersection safety cameras where only one leg of the intersection is covered by a safety camera, crashes not involving any vehicle passing the safety camera can be used as a control for those crashes involving a vehicle that does pass the safety camera. Doing this assumes that there is no safety halo effect from the safety camera on legs of the intersection not covered.

The final issue for crash analysis is that of regression to the mean. If new sites are chosen based on having a recent history of a high number of crashes (which is suggested here and is common practice) then sites that randomly have more crashes than usual in the inspection period will tend to be chosen for treatment. After treatment their crash rates will probably be about average, even if there is no genuine change. That is, there is a reduction in the observed number, even if there is no genuine change in the underlying mean. This gives the appearance of the treatment having an effect even if there is none. This effect is extremely difficult to account for after the fact and makes attributing any observed reductions in crashes to the safety cameras suspect.

A crash analysis of 35 intersection safety cameras in South Australia was conducted by CASR in 2017 and is reported in Kloeden, Mackenzie and Hutchinson (2017). Reductions in injury crashes were found at intersection safety camera sites but after controlling for long term trends there were no statistically significant results and, for the reductions observed, regression to the mean effects could not be ruled out.

A true experiment based on crash data could be carried out as follows: select a large number of candidate sites where safety cameras could be installed; randomly allocate half of them to actually get safety cameras; count the number of crashes at all the sites for a number of years before and after installation at the treated sites; compare changes in crashes at the treated sites with those at the untreated sites; any change in crashes at the treated sites over and above the change at the untreated sites could them be attributed to the safety cameras. This methodology eliminates the problems of long term trends and regression to the mean. However, the inherent random variation in individual sites means that a large number of sites would be needed to detect a small but still meaningful effect of safety cameras. It would also require deliberate non-treatment of good candidate sites for many years.

In conclusion, crash numbers do not provide a viable method of evaluating individual or even a small number of safety camera sites. There may be some value in examining crash numbers for a long period of time for a large number of sites but given the inherent methodological problems in doing this without conducting a true experiment, the results will likely not be definitive.

Measured speed effects

The primary mechanism by which safety cameras improve road safety is by reducing vehicle speeds. Measuring vehicle speeds at the locations of safety cameras before and after installation gives an indication of their effectiveness in reducing speeds (and indirectly their resultant safety benefits). However, there are a number of issues that limit this method of evaluation.

Measuring speeds, typically through laying pneumatic tubes on the roadway, is expensive and disruptive to traffic when being installed or removed. Also, if speeds are to be tracked over time, each site will need to be measured multiple times.

Speed measurements need to be conducted before the cameras are installed at a location. This requires advance planning and allocation of resources and money for the speed measurements. While this may be possible going forward, it is now too late to get these measurements for current sites.

Vehicle speeds are known to vary by time of day and day of week, so typically a full week of speed measurements in each period is the minimum for evaluating vehicle speed changes. However, previous experience has shown that there is considerable random variation in vehicle speeds at a given site from week to week. Using multiple weeks of speed data before and after installation could provide a less variable measure but for very long periods there may be seasonal effects.

Given this, evaluating a single site for speed changes is probably not possible. However, if many sites have speed measurements taken just before and soon after installation an overall effect may be discerned. Ideally the installation date of the cameras would be considered in terms of speed measurements as it is known that vehicle speeds change during school holidays and on public holidays.

In conclusion, direct speed measurements may be useful for determining the effect of safety cameras on vehicle speeds over a number of sites. However, the cost and advance planning necessary means that this has rarely been done.

Offence effects

Once the safety cameras are in operation, they are collecting speed and red light running data on all passing vehicles as part of their operation. This is a valuable source of data. However, it is not clear if non-offending vehicle data is kept and if it is, for how long. Attempts to access the full raw data from police in the past have not been successful in South Australia.

What is readily available are the offences that are issued. Data on the offences are now publicly available that show the speeding or red light running of all detected vehicles at each of the sites over time. For speeding offences, the actual speed of detection is also recorded. If the number of offences declines over time, this is an indication that the safety cameras are becoming increasingly effective in preventing speeding or red light running behaviour.

However, there are some issues with this data source. There is no pre-installation data so the immediate effects of the cameras cannot be measured. There is no indication of changes in traffic flows so calculating a rate is not possible. There is no direct indication of when the cameras were non-operational (apart from extended periods of no offences). For sites with a low numbers of offences random variation will be greater than any change in the effect of the cameras and non-operational periods cannot be reliably detected.

A previous study of offences at South Australian safety camera sites during their first year of operation (Mackenzie, Kloeden and Hutchinson, 2013) found an overall reduction in both red light running and speeding offences over time indicating that the cameras were becoming increasingly effective since their installation.

In conclusion, the offences recorded by the safety cameras provide a free source of data for generally tracking the changing effectiveness of the cameras over time. However, the lack of pre-installation data and the sometimes unknown periods of inactivity mean that the total actual effects of the safety cameras on offences cannot be known even for a group of sites. Individual sites with low numbers of offences provide little useful data.

4 Conclusions

Safety cameras are an effective means of reducing vehicle speeds and the frequency of crashes, and in particular injury crashes, at specific locations. The widespread use of safety cameras combined with other speed enforcement measures can be expected to have general safety benefits throughout the whole road system.

While there is no definitive best practice for choosing safety camera locations, there are a number of criteria that are frequently used and that make sense (see Section 3.1 for details):

- Locations with a high number of crashes (particularly injury crashes)
- Locations with a high proportion of speeding vehicles
- Locations with high traffic volumes
- Locations with large numbers of unprotected road users (pedestrians and bicyclists)

The applicability of each of these criteria varies by the type of safety camera being considered (see Section 3.2 for detailed consideration of each camera type).

As the placement of safety cameras becomes more widespread, there are additional criteria that come into play (see Section 3.3):

- Different camera types cover different areas of the road network so a mix of camera types has the advantage of giving the perception of wider coverage to drivers
- Deploying cameras widely throughout the road network also gives drivers the perception of wider coverage so they are more likely to moderate their driving generally

Evaluation of the effects of safety cameras on particular sites and as a whole can be attempted using a number of methodologies:

- Changes in crash numbers before and after installation
- Changes in vehicle speeds before and after installation
- Changes in offence detections from the time of installation onwards

There are limitations with each of these methodologies (see Section 3.4) such that evaluating the effectiveness of an individual safety camera is often not possible. By tracking many safety camera sites for a long period of time, the effect of the safety cameras can be examined but there will always be other factors that may explain any observed changes. A true experiment could be conducted to determine safety camera effects but it would involve deliberate non-treatment of good candidate sites for many years.

Random variation in the evaluation measures also means that a proportion of sites would be expected to appear worse after the installation of safety cameras even if the cameras are actually having a universal positive effect. This effect is exacerbated for sites with low numbers of crashes and offences. This means that there is no definitive method for detecting non-performing sites and relocating them. Since the major cost of an installation is the support infrastructure, decommissioning a site should really only be considered where changes in the environment would require major new infrastructure or where other treatments have been installed that prevent speeding behaviour.

Regular analysis of the crash and offence data for all safety camera sites as a group can give some indication of the safety benefits. As more sites are put into operation and current sites have been around for a longer time, the degree of certainty of any effects can be increased. However, the fundamental issues with attributing any observed changes to the safety cameras will remain and need to be explained along with any analysis. Likewise, when reporting individual site effects, the role of random variations needs to be clearly explained.

This study gives a reasonable set of principles for selecting safety camera sites and evaluating their effectiveness. However, the detailed processes for South Australia will depend on what data is available, the resources and funding that can be applied, and political and other considerations.

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