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SPEED SAFETY CAMERAS (SSC)

Prepared by SEH

The effort for this Transportation Research Synthesis (TRS) is to provide a summary of current research on the effectiveness of Speed Safety Cameras (SSC), also referred to as Automated Speed Enforcement (ASE), for reducing vehicle speeds and the severity and frequency of crashes. This was investigated generally and specifically for school zones and work zones.

The purpose of this TRS is to serve as a synthesis of pertinent completed research to be used for further study and evaluation by MnDOT. This TRS does not represent the conclusions of either the authors or MnDOT.

Image Source: FHWA

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16. Abstract (Limit: 250 words)

Since the mid-1990s, the use of Speed Safety Cameras (SSCs), also referred to as Automated Speed Enforcement (ASE), as a speed reduction countermeasure has been growing across the US. Minnesota does not currently permit SSCs by law, but recent interest from community leaders has led to the reconsideration of the use of SSCs on Minnesota roadways. The purpose of this TRS is to review relevant research regarding the impact of SSCs as a standalone countermeasure to: reduce and manage speeds, to reduce the severity and frequency of crashes, and to understand spillover or other unintended consequences. Just over 150 communities and 20 states within the US are currently using SSC systems. Of the 13 methodologically sound SSC studies and four literature reviews that evaluated the effects of SSCs on driver speeds, all found some level of speed reductions for mean, threshold, and/or 85th percentile speeds. Of the eight SSC studies and six literature reviews that conducted multi-year crash history analysis before and after the implementation of SSC programs, all found reductions in the number of fatal and severe crashes. Of the studies that reported both overall crashes as well as serious and fatal crashes, all concluded that SSCs resulted in the greatest reductions for serious injury and fatal crashes. No increase in crash rates or other adverse safety effects were reported. Results are consistent with other literature reviews published from 2005 to 2010. The research indicates that SSCs are an effective countermeasure for reducing speeds, crash frequency and crash severity.

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Technical Advisory Panel

Chelsea Moore-Ritchie, Sr. Transportation Planner
SEH

Dave Cowan, Safe Routes to School Coordinator
MnDOT

Derek Leuer, State Traffic Safety Engineer
MnDOT

Heather Kienitz, Consultant Project Manager/Sr. Traffic Engineer II
SEH

Jason Radde, Sr. Engineer
MnDOT

Ken Johnson, Assistant State Traffic Engineer
MnDOT

Leif Halverson, Project Coordinator
MnDOT

Mark Wagner, OTE Project Manager
MnDOT

Michelle Moser, State Work Zone Engineer
MnDOT

Nathan Drews, OTE Safety Section
MnDOT

Tom Sohrweide, Sr. Traffic Engineer II
SEH

EXECUTIVE SUMMARY

Since the mid-1990s, the use of Speed Safety Cameras (SSCs) as a speed reduction countermeasure has been growing across the US. Concurrently, there have been a flurry of legal challenges brought against the use of SSCs since most states lack legislation explicitly enabling their use. Despite this barrier, 20 states successfully implemented SSC programs or pilots, and growing research is becoming available regarding their effectiveness and best practices for implementation. Minnesota does not currently permit SSCs by law, but recent increases in operating speeds, related traffic fatalities and deadly traffic stops have led community leaders to reassess the effectiveness and use of SSCs on Minnesota roadways.

The purpose of this TRS is to review relevant research regarding the effectiveness of SSCs as a countermeasure to reduce speeds and improve safety.

Research Objectives

To explore the following questions related to Speed Safety Cameras:

1. Are SSCs effective for reducing and managing speeds where deployed?
2. Can SSCs reduce the severity and frequency of crashes where deployed?
3. Are there known spillover or other unintended consequences for implementing SSCs?

Research for this document will not cover implementation best practices as this is not included in the scope. However, a list of additional resources for program implementation will be provided within this document.

Summary of Findings

Trends in SSC usage

Just over 150 communities and 20 states within the US are currently using SSC systems at the statewide, district or zone (i.e. school zones and work zones) level. Fines and program administration varies with most programs using administrative citations for speed violations that do not get reported on driving records.

Speed Reduction

Of the 13 methodologically sound SSC studies and four literature reviews that evaluated the effects of SSCs on driver speeds, all found some level of speed reductions for mean, threshold and/or 85th percentile speeds. Many studies measured to the level of statistical significance with a 95% confidence level. The research indicates that SSCs are an effective countermeasure for reducing motorist speeds.

- **Mean speed:** Most studies cited a 10-14% reduction on lower speed limit roadways and 5-10% reduction on higher speed limit roadways consistent with the literature review by Wilson et al. in 2010 which found a 1-15% reduction in mean speeds for SSC programs.
- **Threshold speeding** (Typically > 10 mph over speed limit)**:** Lower speed limit roadways cited 60-82% reductions in threshold speeds (except Seattle which used a 5 mph threshold and cited a

50% reduction) and higher speed limit roadways cited anywhere from 23.7% to 88% reductions in threshold speed with the use of SSC programs. This larger range in effectiveness for the ability of SSCs to reduce threshold speeds on high-speed roadways indicated that there may be more variables influencing speeding activity on high-speed roadways.

- **School Zones:** Based on the three US studies that evaluated the use of SSCs in school zones, a 50-60% reduction in threshold speeding appears reasonable as well as a 2-5 mph reduction in mean speeds, with an added speed reduction benefit when flashers were used in combination with cameras.
- **Spillover/Unintended Consequences:** Spillover effects for speed reduction were mixed for both location based and temporal spillover. No unintended consequences were found related to SSC programs impact on speed.

Crash Reduction

Of the eight SSC studies and six literature reviews that conducted multi-year crash history analysis before and after the implementation of SSC programs, all found reductions in the number of fatal and severe crashes. Of the studies that reported both overall crashes as well as serious and fatal crashes, all concluded that SSCs resulted in the greatest reductions for serious injury and fatal crashes. One study out of Scottsdale, AZ found a reduction in overall crashes, except for rear-end crash types. No increase in crash rates or other adverse safety effects were reported. Results are consistent with other literature reviews published from 2005 to 2010.

- **Overall Crashes:** Results varied by study with a range of 10-54% reduction in overall crashes.
- **Injury crashes:** Results varied by study with a range of 10-54% reduction in injury crashes.
- **Severe Injury and Fatal Crashes:** Results varied by study with a range 19-56% for serious injury and fatal crashes.

BACKGROUND

In some form, automated speed enforcement has been applied in the US as early as 1910[1]. The technology used in modern day automated speed enforcement (also referred to as Speed Safety Cameras (SSC)), however, is relatively new. Speed safety cameras detect speeding through a speed measurement device and capture photographic or video evidence of the vehicles violating a set speed threshold[2]. The type of SSCs, speed thresholds at which a violation occurs, and policies and regulations vary from state to state. According to the 2022 MnDOT Work Zone Speed Management Study, 19 states and the District of Columbia currently permit the use of SSCs either in pilot or permanent form throughout the US.[3] The following section provides background information into the diversity of SSC and how they are used.

Types

SSCs are deployed in three ways: as fixed units, point-to-point (P2P) units, or mobile units. Fixed units are a single, stationary camera that targets one location. P2P units capture the average speed over a certain distance with the use of multiple cameras and can be deployed as permanent installations or temporary installations for places such as work zones. Mobile units are generally mounted on a vehicle or trailer[4]. Figure 1 below describes suitable circumstances for SSC deployment.[1]

In 2021, the Federal Highway Administration (FHWA) added SSCs as a Proven Safety Countermeasure, marking it as an effective strategy for reducing highway fatalities and serious injuries on the nation's highways[5]. According to FHWA research[6], fixed units are most suited to long term problems on multilane facilities where the sight distance for enforcement is limited. P2P units are effective in most

Table of selection considerations for SSC deployment.

Considerations for Selection	Fixed	P2P	Mobile
Problems are long-term and site-specific.	X	X	
Problems are network-wide, and shift based on enforcement efforts.			X
Speeds at enforcement site vary largely from downstream sites.		X	X
Overt enforcement is legally required.	X	X	X
Sight distance for the enforcement unit is limited.	X	X	
Enforcement sites are multilane facilities.	X	X	

Figure 1 - Selection considerations for SSC deployment (Source: FHWA-SA-21-070)

[1] Savage, M. Automated Traffic Enforcement, National Convergence of State Legislatures, 2004. http://www.ncsl.org/programs/transportation/0700trnrv.htm. Accessed April 2005.
[2] FHWA-SA-21-070 - https://safety.fhwa.dot.gov/provencountermeasures/speed-safety-cameras.cfm
[3] MnDOT Work Zone Speed Management Study 2022
[4] FHWA-SA-21-070 - https://safety.fhwa.dot.gov/provencountermeasures/speed-safety-cameras.cfm
[5] FHWA Memorandum. Promoting and Implementing the Updated Proven Safety Countermeasures. Office of Safety Technologies. October 27, 2021
[6] FHWA-SA-21-070. (2021). Proven safety countermeasures, Speed Safety Cameras. US Department of Transportation, Washington DC. https://safety.fhwa.dot.gov/provencountermeasures/pdf/PSC_New_Speed Camera_508.pdf

situations except when problems are network-wide. In those circumstances, mobile units function best.

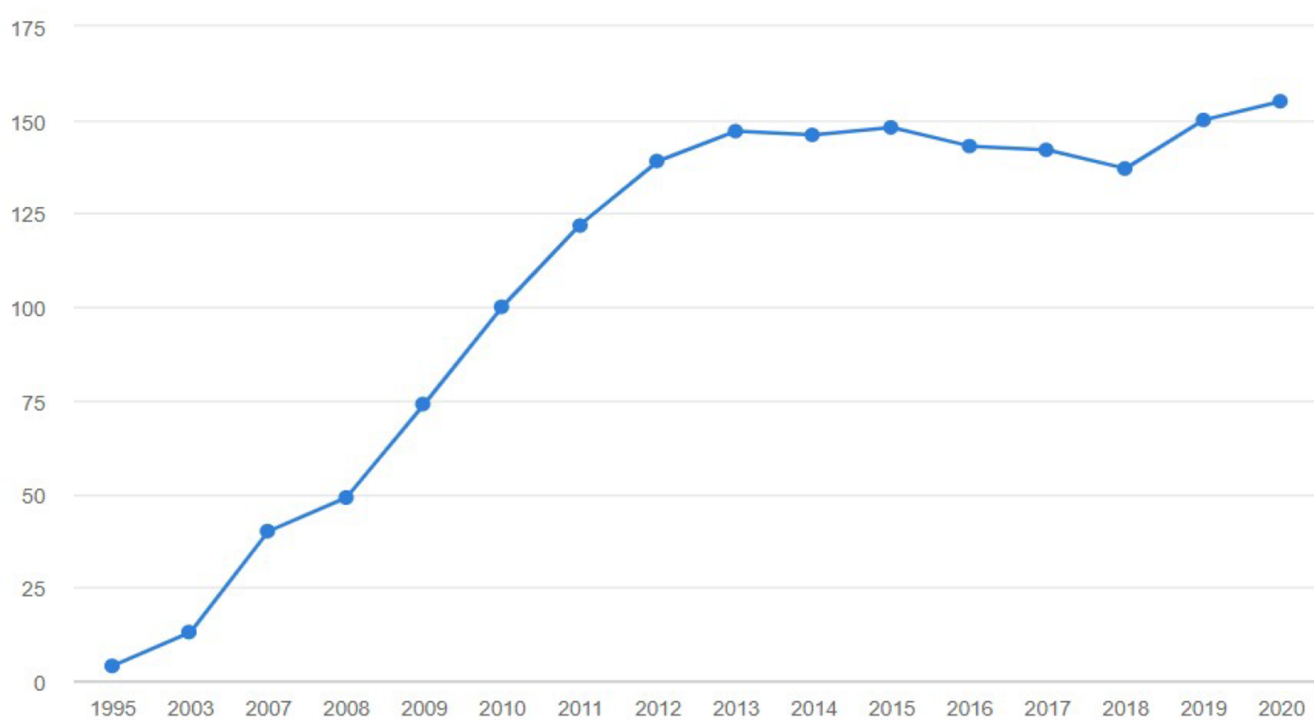
Threshold Speeds

A threshold speed is generally considered a speed at which a violation or citation is issued. Threshold speeds are typically set by state legislatures or Departments of Public Safety. In most cases, the threshold speed is reached when motorist speeds are greater than 10 mph above the posted speed limit. However, the threshold speed may be as low as 5 mph over the posted speed limit on a lower speed roadway. For example, in Portland, Oregon the threshold speed is greater than 45 mph in a 40 mph work zone, and in Seattle, Washington school zones the threshold speed is any speed greater than 25 mph in a 20 mph school zone.

Programs by State

Figure 2 shows the usage of SSCs in US communities from 1995 to 2020. According to the data from the Insurance Institute for Highway Safety (IIHS), usage grew from a few US communities in 1995 to approximately 150 in 2013. From 2013 to 2019, the number of US communities using SSCs plateaued and even slightly decreased, likely amid growing legal challenges. In 2019 usage once again began to increase with just over 150 communities across the country having documented speed safety camera programs as of 2020.

Figure 2. Trends in the number of U.S. communities with speed cameras from 1995 to 2020 (Source: IIHS Website)



The MnDOT Work Zone Speed Management Study, published in 2022, summarized the different speed safety programs throughout the US. Of the 20 states identified as having SSC programs, only 4 use SSCs at the statewide level. The majority of programs are/were located in specified jurisdictions, or for special speed zones such as work zones or school zones. Only three out of the 20 states are still in the pilot phase (Connecticut, Delaware and Pennsylvania) while the other 17 states have permanent programs.

Fines vary by state as well as whether or not violations end up on a driving record (criminal vs. administrative citations). Fines range from $50 at the low end to $375 at the high end, with most under $100. In 17 of the 20 states, citations do not affect the driving record, with the exception of Arizona and Oregon which do impact driving records and Alabama which can, but generally does not. Figure 3 provides the full list of SSC programs as published in the MnDOT Work Zone Speed Management Study.

Figure 3 - Speed Safety Camera Programs, 2022

(Source: MnDOT Work Zone Speed Management Study)

State	Pilot/ Permanent	Location	Fine value	Violation on Driving Record
Alabama	Permanent	Specified Jurisdictions	\$60 - \$100	Generally not
Arizona	Permanent	Statewide; not on State Highways	Mirrors traditional penalty amounts	Yes
Colorado	Permanent	Work Zones, School Zones, Neighborhoods, Adjacent to Parks	\$40+	No
Connecticut	Pilot	Work Zones	\$75 - \$150	No
Delaware	Pilot	Work Zones	\$74.50	No
D.C.	Permanent	District-wide	Varies	No
Georgia	Permanent	School Zones	\$75 - \$125 plus processing fees; issued when 11+ mph over Speed Limit	No
Illinois	Permanent	Work Zones when Workers are Present, School Zones, Adjacent to Parks, Large Cities	\$375 in Work Zones	No
Iowa	Permanent	Specified Jurisdictions	Varies; Fines Double in Work Zones	No
Louisiana	Permanent	Specified Jurisdictions	Varies	No
Maryland	Permanent	Specified Jurisdictions	\$40; issued when 12+ mph over Speed Limit	No
New Mexico	Permanent	Specified Jurisdictions; not on State Highways	\$100	No
New York	Permanent	Work Zones; Specified Jurisdictions	\$50 - \$100	No
Ohio	Permanent	Statewide, Except on Interstates Operated by Townships	Mirrors traditional penalty amounts	No
Oregon	Permanent	Statewide, including in Work Zones when Workers are Present	Mirrors traditional penalty amounts	Yes
Pennsylvania	Pilot	Work Zones when Workers are Present; Philadelphia	\$75 - \$150; issued when 11+ mph over Speed Limit	No
Rhode Island	Permanent	School Zones	\$50 - \$95	No
Tennessee	Permanent	Statewide	\$50	No
Virginia	Permanent	Work Zones; School Zones	Not to Exceed \$100; issued when 10+ mph over Speed Limit	No
Washington	Permanent	School Zones	Equal to a Parking Violation	No

SSCs in Minnesota

SSCs are currently not in use in the state of Minnesota. The 2012 report, "Identifying Issues Related to Deployment of Automatic Speed Enforcement in Minnesota[7]" by Frank Douma, cited the following legalities for the non-use of speed safety cameras in Minnesota.

To this day, bills continue to come before the State Legislature both against and in support of the use of speed safety cameras.

> In order for speed safety camera programs to be used in Minnesota, the legislature would need to amend the statute to:
>
> - indicate their approval of the use of speed safety camera evidence in court; and
> - create guidelines for how the reliability and accuracy of speed safety cameras can be established in court
>
> Generally, local authorities can only use "police officers" and "traffic-control signals" to regulate traffic. A statute would also need to be amended to include the use of SSCs.

Source: "Identifying Issues Related to Deployment of Automatic Speed Enforcement in Minnesota " by Frank Douma

MN Strategic Highway Safety Plan

According to the State's 2020-2024 Strategic Highway Safety Plan, speeding is a Core Focus Area for which SSCs are an identified strategy. The safety plan encourages the exploration of SSC effectiveness and use in other states and encourages the legislature to allow pilot programs in Minnesota, specifically within school zones.

Strategic Highway Safety Plan's Strategy 2 - Utilize Enforcement to Reduce Speeding (Years 1-2)

- *T2.2 Explore the potential for automated speed enforcement cameras in Minnesota by researching its effectiveness in states that have implemented it and any technical, legal, privacy, and equity barriers.*
- *T2.3 Encourage legislative changes to allow for a pilot project to test automated speed enforcement in school speed zones.*

These strategy recommendations became the basis for this report in order to better understand the effectiveness of speed safety cameras on speed reductions and safety.

[7] "Identifying Issues Related to Deployment of Automatic Speed Enforcement in Minnesota" - October 15, 2012 by Frank Douma

LITERATURE REVIEW

The following literature review summarizes available research related to effects of SSCs on driver speeds and crash reductions, as well as time and distance spillover effects. A total of 16 before-and-after studies and six literature reviews were found related to SSCs from 2003 to 2022. Of the 16 before-and-after studies, 14 evaluated the impacts of SSCs on driver speeds and eight evaluated multiyear crash data to understand the effects on safety. Of the six literature reviews, four evaluated SSCs with regard to driver speeds and all six reviewed studies related to crash reductions and SSCs. A complete research matrix including study methodology can be found in Appendix A.

Speed Reductions

From 2003 to 2022, 14 published before-and-after studies and four literature reviews were identified that evaluated the effects of SSCs on driver speeds. Thirteen of the 14 studies reported reductions in mean, threshold, and/or 85th percentile speeds with the use of SSCs, however the size of speed reduction varied by study. One study (Rohani et al. 2014) in Malaysia reported an increase in driver speeds, however, this study had a small sample size and no fine for violations, indicating an unreliable methodology. This study was thus excluded from the overall findings.

The remaining 13 studies that analyzed speed data before-and-after implementation of SSCs used some or all of the following speed characteristics to understand the effects of the SSCs on driver behavior.

Speed Characteristics

- Mean Speed
- Speeding (> posted speed limit)
- Threshold speed (speed at which a violation is/could be issued)
- 85th percentile speeds
- Speed Distributions

Summary of Existing Literature Reviews

The four literature reviews that evaluated driver speed changes after the implementation of SSCs were published in Transportation Research Board (TRB) and the Cochrane Collaboration (UK) between 2006 and 2010 and reviewed national and international studies.

A 2007 review by Rodier et al. analyzed 17 studies in the US, Canada and Europe for effects of automated speed enforcement programs or SSC on driver speeds. This study, published by the TRB, indicated approximately a 2- 15% reduction in speeds and an overall decline in vehicles exceeding the threshold speed limit. Similar results were found by Wilson et al. in 2010 with a 1-15% reduction in average speed range and 14-65% reduction in proportion of vehicles speeding. Wilson et al. also found multiple studies reporting 85th percentile speeds (Germany, New Zealand and Great Britain) all of which noted approximately a 5 mph decrease in 85th percentile speeds. Another study by Wilson (Wilson et al. 2006) found a 5-70% reduction in speeding vehicles and 50-65% reduction in vehicles traveling over 15 km/h (10 mph) over the speed limit.

An international review in 2008 by Thomas et al. looked at 13 studies on a variety of roadway and SSC types. The review found greater reductions at fixed camera installations and that p2p was the most effective at reducing the percentage of drivers at more than 15 mph above the speed limit.

Before-and-after Studies

Of the 13 before-and-after studies review for this research, six were conducted on lower speed limit roadways (35 mph or less) and seven were on higher speed limit roadways (40 mph or more). Of these studies, three analyzed SSC in school zones on lower speed roadways and two looked at work zones on higher speed roadways.

Lower Speed Limit Roadways (≤ 35 mph)

The five analyses of SSCs on lower speed limit roadways (20-35 mph speed limit) were all conducted in the US between 2003 and 2019. All studies used a >10 mph speeding threshold except Seattle, Washington which used a >5 mph threshold within a 20 mph school zone.

Non-School Zone

Two studies evaluated the use of SSCs on lower speed limit roadways, both within the Washington, DC area. The first, by Retting and Farmer in 2003, was an analysis of seven sites in DC and eight sites in Baltimore before and six months after the covert speed cameras (unmarked, camera equipped police vehicles) were in-use. The study found an overall decline in mean speeds by a statistically significant 14% and an 82% reduction in threshold speeds. In 2016, Hu & McCartt conducted a long term study of SSCs in Montgomery County, Maryland seven and a half years after the SSC program was implemented on 25-35 mph roadways. The speed data in Maryland showed a 10% reduction in mean speed and a 64% reduction in vehicles exceeding the threshold speed compared to 43% at control sites.

School Zones

Three studies evaluated the use of fixed SSCs in school zones within major metropolitan areas; Seattle, Washington (four elementary schools), Portland, Oregon (five neighborhood schools) and New York City (140 school speed zones). All three studies reported a sizable reduction in the rate of speed violations (exceeding threshold speeds) of around half to two-thirds.

Studies out of New York City (2014-2017 ASE Program Report) and Portland, Oregon (Freedman et al. 2006) used a >10 mph violation threshold in school zones, resulting approximately 60 and 66% reductions in speed violations, respectively. The study out of Seattle, Washington (Quistberg 2019) used a lower violation threshold of >5 mph, resulting in a slightly lower rate of threshold speeds reductions (~50%).

Figure 4 - "Photo Enforced" sign added to a 25 mph city speed limit sign in NYC
(Source: NYDOT 2014-207 ASE Program Report)

The Seattle and Portland studies also reported on change in mean speeds, with Seattle reporting a statistically significant 2 mph reduction in mean speeds and a 5 mph reduction in the mean reported in Portland school zones.

The Portland Study went a step further, reporting on 85th percentile speeds with and without flashing beacons. When SSCs were active, 85th percentile speeds at demonstration school zones were reduced by approximately 5 mph at sites without a flashing beacon. When the flashing beacons were used in combination with SSCs, 85th percentile speeds were reduced by approximately 8-9 mph, indicating a 3-4 mph benefit provided by the additional countermeasure.

Table 1. Effects of SSCs on driver speed on lower speed limit roadways (≤ 35 mph)

Source	Road speed(s)	Reduction in overall speeds/speeding	Reduction in Threshold Speeds	Reduction in 85th Percentile Speeds
Seattle, Washington (Quistberg 2019)	20 mph (School Zone Speed Limit)	Mean vehicle speed significantly decreased by 2 mph	Nearly 50% reduction in the rate of speeding violations (>25 mph)	Not provided
New York City, NY (2014-2017 ASE Program Report)	Not provided (School Zone)	Speeding during school hours at typical fixed camera locations drops 63 percent	The daily rate of violations (>10 mph) declined by over 60% , from 104 in the camera's first month to 35 in the camera's 18th month.	Not provided
Montgomery County, Maryland (Hu & McCartt 2016)	35 mph or less	10% reduction in mean speed	62% reduction in threshold violation (>10 mph).	Not provided
Portland, Oregon (Freedman et al. 2006)	20 mph (School Zone Speed Limit)	Mean speeds reduced by approximately 5 mph	Rate of threshold violators (>10 mph) was reduced by about two-thirds	Reduced by approximately 5 mph (without a flashing beacon) and 8-9 mph with flashing beacons
Washington, DC (Retting & Farmer 2003)	25-35 mph	Overall, mean speeds at Washington sites declined by a statistically significant 14%	The proportion of vehicles violating the speed threshold (>10 mph) declined 82%.	Not provided

Spillover Effects

A variety of speed spillover effects were reported on the lower speed limit roadways, ranging from location based (downstream and regional) to temporal (inactive periods and long-term sustainability).

For non-school zones, the two Maryland studies found a mix of regional spillover effects. The Washington, DC study (Retting and Farmer, 2003) saw no decline in traffic speeds at eight comparison sites, while Montgomery County (Hu & McCartt, 2016) saw a smaller but still notable reduction at locations not targeted by SSCs, suggesting a broader spillover effect.

The NYC program evaluation noted a trend of motorists accelerating almost immediately after passing the cameras. To combat this issue, the City is shifting to covert cameras to encourage compliance with the speed limit even outside school zones. The study also noted that speeding increases soon after the speed cameras are deactivated at the end of the school day.

The study out of Seattle reviewed speed data again after the second year of implementation and found that the speed reduction benefits were sustained.

Table 2. Spillover effects of SSCs on lower speed roadways (≤ 35 mph)

Source	Spillover effects and long-term findings
Seattle, Washington (Quistberg 2019)	• The impact of automated enforcement was sustained during the second year of implementation.
New York City, NY (2014-2017 ASE Program Report)	• Speeding at locations with speed cameras increases soon after the speed cameras are deactivated at the end of the school day. • Motorists tend to accelerate almost immediately after passing the speed camera. By not announcing locations, the City seeks to encourage compliance with the speed limit even outside of speed camera enforced school zones. • The rate of vehicles exceeding the speed limit by more than 11 mph during the hours that the cameras are deactivated is 146% higher than during the school hours when the cameras are active.
Montgomery County, Maryland (Hu & McCartt 2016)	• In Montgomery County, speeds were reduced by smaller amounts at locations not targeted by cameras, suggesting broader spillover effects.
Portland, Oregon (Freedman et al. 2006)	• The proportion of traffic that exceeded the speed limit by more than 10 mph was reduced by about one-quarter when ASE was not present. • The speed reduction effects observed at the demonstration school zones were still present one month after ASE operations ceased in May 2005.
Washington, DC (Retting & Farmer 2003)	• At eight comparison sites in nearby Baltimore, Maryland, where speed camera enforcement was not in place, no decline in traffic speeds was observed.

Higher speed limit roadways (≥ 40 mph)

Seven studies were published between 2005 and 2022 evaluating the effects of SSCs on roadways with speed limits of 40 mph. Of these, two studies involved SSC programs through work zones.

<u>Non-work zones</u>

In 2008 and 2009, evaluations of two pilot programs on high volume urban arterials were conducted in the US, one in Scottsdale, AZ and the other in Charlotte, NC. Speed data from the Scottsdale Program on the Loop 101 freeway was studied by both Retting et al. in 2008 and Shin et al. in 2009. Both studies found similar results for reductions in mean speeds with a 5-9% decrease on the 65 mph roadway. Shin et al. also noted a reduction in the standard deviation from 3.5 mph to 1.2 mph indicating a tightening of the speed distribution as shown in Figure 5.

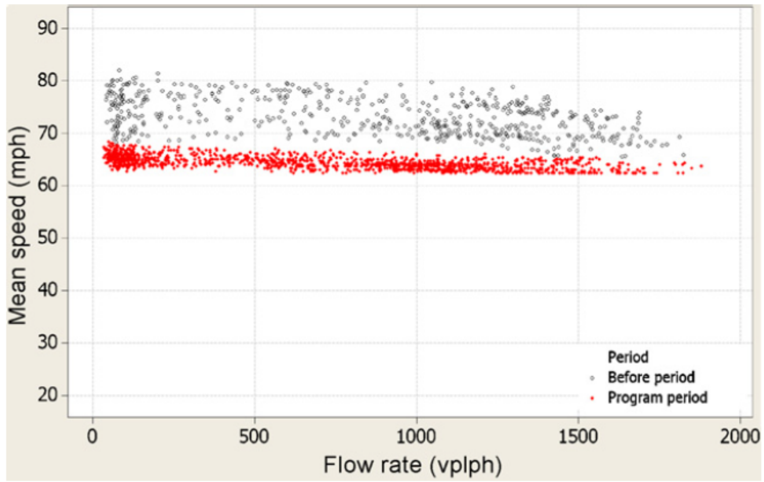


Figure 5 - Change in speed-flow relationship before and during SSC program periods on Loop 101 in Scottsdale, AZ (Shin et al. 2009)

The number of motorists exceeding the 75 mph threshold was found to be significantly reduced (95% confidence) in both studies, indicating SSC as an effective countermeasure for reducing speeding. Shin et al. noted that speeding detection frequencies (≥ 75 mph) were significantly affected by the period of observation and day of the week and as well as noting that speeding detection frequencies (speeds ≥ 76 mph) increased by a factor of 10.5 after the SSC was (temporarily) terminated.

The Charlotte, NC study (Cunningham et al. 2008) used a rigorous statistical analysis to evaluate speed data from three mobile units along 14 corridors over three time periods (one before and two after). Findings indicate that mean, median, and 85th percentile speeds all decreased after program implementation. Speeding in the before period was 1.55 times the percentage of speeding in the after1 period and 1.23 times the percentage of speeding in the after2 period at the treatment sites.

Two international studies, one in Australia (Champness et al. 2005) and Italy (Montella et al. 2015) also evaluated changes in speed after the implementation of SSCs, but with differences in methodology. The Australian study compared speed data at seven sites spaced 500 meters (1,640 feet) apart to evaluate speeds on sections of the roadway before and after the installed cameras to measure the time and distance halo effects of mobile overt speed cameras. Speeds on the roadway were 100 km/h (62 mph) at all data sites except the last section of testing which was 80 km/h (50 mph). The study found a significant reduction in mean and 85th percentile speeds [6 km/h (3.7 mph) and 7 km/h (4.3 mph) respectively] and the number of vehicles exceeding the speed limit fell from 53% to 16% immediately adjacent to the operational camera.

Montella et al. evaluated the use of point-to-point (P2P) speed enforcement systems, which calculated the average speed over a section. The study used an Empirical Bayes analysis of before-and-after speed data on the A56 urban motorway in Italy. Data included 133 days of speed collection over a four year period and found a 10% and 5% reduction in average speeds and a 14% and 8% reduction in 85th percentile speeds for light and heavy vehicles, respectively. They also found that the number of motorists exceeding the speed limit by 20 km/h (12.4 mph) was reduced by 84% for light and 77% for heavy vehicles.

Overall, the trends of a 5-10% reduction in mean speeds on high-speed roadways are consistent with the international literature review by Wilson et al. in 2010 which found a 1-15% reduction in mean speeds for SSC programs.

Work Zones

Two speed studies were identified that used SSCs through work zones on high speed roadways.

The first, a 2022 report by Pennsylvania DOT included both reduced speed and non-reduced speed work zones. The study analyzed 5,386 deployments and 644,009 citations over a two year period. Results show that the total percentage of speeding vehicles in SSC enforced work zones was reduced to 18-20% on average compared to 30-35% at the start of the program. Excessive speeding (>10 mph) was also reduced to 3%, down from 5-8% before the implementation of SSCs. Additional findings from the Pennsylvania study include the higher speeds for barrier protected work zones vs. unprotected work zones. Speed data show that throughout the life of the program, the percentage of vehicles over the speed limit and the percentage of vehicles excessively speeding have been more than double in barrier protected work zones compared to unprotected work zones.

The second work zone study looked at the use of SSCs in a work zone in Portland, Oregon between Nov 2008 and Oct 2009 (Joerger 2010). The two mile work zone was located within an industrial area on Yeon Ave, a four lane roadway with a continuous two-way left turn lane and a speed limit of 40 mph. Mean speed during non-enforcement was 44.2 MPH with an 85th percentile speed of 49.5 MPH. After the installation of SSCs, there was a 27.3% reduction in vehicles traveling faster than the 45 mph threshold. A flaw of the study was noted as sensors being unintentionally hidden from one direction (covert) and overt from the other direction. Given that the cameras were only visible for roughly half of drivers, the study concluded that a greater reduction in speeding would be expected with full visibility of SSCs.

Additional research and information on work zone speed safety cameras can be found in the 2022 MnDOT report titled Work Zone Speed Management Study.

Table 3. Effects of SSCs on driver speed on higher speed limit roadways (≥ 40 mph)

Source	Road speed(s)	Reduction in overall speeds/speeding	Reduction in Threshold Speeds	Reduction in 85th Percentile Speeds
2022 Report (Pennsylvania DOT)	Varies. 45 to 70 mph (Work Zone)	During the peak construction seasons, the total percentage of speeding vehicles in Automated Work Zone Speed Enforcement (AWZSE) enforced work zones has been reduced to 18-20% on average, reduced from 30-35% at the start of the program in 2020. Shorter work zones have better compliance.	Excessive speeding (11+ mph over the posted speed limit) has been reduced to 3%, down from 5-8% at the start of the program.	Not provided
Portland, Oregon (Joerger 2010)	40 mph (Work Zone)	A large reduction in speeding, was observed even though vehicles passing the traffic sensor from one direction had not yet seen the enforcement activity. A greater reduction in speeding would be expected if photo radar enforcement covered both directions of travel.	Average reduction in vehicles traveling faster than 45 mph was 23.7%	Mean and 85th percentile speeds during periods of non-enforcement remained quite stable throughout the study period, which emphasizes the impact of photo radar speed enforcement as a tool to reduce speeding in a work zone environment.
Scottsdale, AZ (Shin et al. 2009)	65 mph	• Reduced the average speed at the enforcement camera sites by about 9 mph on average. • Reduction in the standard deviation from 3.5 mph to 1.2 mph indicating a tightening of the speed distribution. • Reduction in the mean speed dependent on traffic flow.	• Sig. reductions in motorists exceeding 75 mph threshold • Threshold speeds are significantly affected by the period of observation as well as the day of the week. • Motorist exceeding threshold speeds increased by a factor of 10.5 after the SSCs	Not provided

			were (temporarily) terminated.	
Charlotte, NC (Cunningham et al. 2008)	Varies: high-volume, multilane, urban arterials	• Mean speeds significantly decreased by 0.82 mph and 0.67 mph during the after1 periods and after2 periods, respectively, compared with the before period. • Speeding in the before period was 1.55 times the percentage of speeding in the after1 period and 1.23 times the percentage of speeding in the after2 period at the treatment sites	Not provided	• Similar to mean speeds, 85th percentile speeds significantly decreased by 0.91 mph and 0.77 mph during after1 periods and after2 periods, compared with the before period.
Scottsdale, AZ (Retting et al. 2008)	65 mph	Scottsdale: 5 to 7 mph reduction in mean speed Glendale: 5 mph decline.	Study found an 88% decrease in threshold speeds	Not provided
Tangenziale di Napoli, Italy (Montella et al. 2015)	Varies (PAs)	10% reduction in average speeds of light vehicles and 5% reduction in mean speeds for heavy vehicles	The proportion of light and heavy vehicles exceeding the speed limits more than 20 km/h (12.4 mph) was reduced respectively by 84 and 77%.	• 14% reduction in 85th percentile speeds for light vehicles and 8% for heavy vehicles
Australia (Champness et al. 2005)	100 km/h (62 mph) Last section of testing was 80 km/h	Significant 6 km/h (3.7 mph) reduction in mean speed	The number of vehicles exceeding the speed limit fell from 53% to 16% immediately adjacent to the operational camera.	• 7 kph (4.2 mph) reduction in 85th percentile vehicle speeds

Spillover and Deactivation Effects:

A variety of speed spillover effects were reported on the high speed limit roadways, ranging from location based (downstream and regional) to temporal (inactive periods and long-term sustainability). Table 4 provides a summary of all reported speed spillover effects by study.

Upstream/downstream spillover:

> The Australian study by Champness et al. in 2005 specifically looked at effects upstream and downstream from the SSCs on a 100 km/h (62 mph) roadway (non-work zone). While the study found statistically significant reductions in the mean and 85th percentile speeds, they summarized that the effects had completely disappeared by 1,500 meters (0.9 miles) downstream and upstream halos were negligible. The study concluded that SSCs are most effective within a maximum range of one kilometer (0.6 miles) from locations with a history of high speed related crash risk. Shin et al. also analyzed downstream effects and found no evidence of speed reductions in the study corridor 40 miles away from the enforcement zone. Unlike Shin et al., Retting et al. did find a large reduction in speeding on the same Scottsdale corridor, 25 miles away from the installed cameras.

Regional spillover:

> Retting et al. reported that traffic speeds were fairly stable on urban freeways in Scottsdale that were not part of the study road, indicating no regional spillover effects.

Inactive time periods:

> The Pennsylvania and Portland studies both looked at impacts on roadway speeds through work zones when the cameras were inactive. In Pennsylvania, a small but measurable speed reduction was noted when cameras were not in effect compares to the Portland study which found that speed reductions did not persist beyond the departure of the SSC vans.

After removal:

> The studies from Portland (Joerger, 2010) Scottsdale (Retting et al. 2008), and Australia (Champness et al. 2005) all noted that speeds mostly or completely returned to pre-camera levels once the cameras were removed.

Table 4. Spillover effects of SSCs on higher speed limit roadways (≥ 40 mph)

Source	Spillover Effects
2022 Report (Pennsylvania DOT)	• Smaller (but measurable) speed reductions at times when AWZSE is not in effect in those zones
Portland, Oregon (Joerger 2010)	• The observed speeding reduction was temporary and did not persist beyond the departure of the photo radar enforcement van.
Scottsdale, AZ (Shin et al. 2009)	• Average speeds revealed no evidence of an effect at a similar site on the Loop 101 about 40 miles away from the enforcement zone.
Scottsdale, AZ (Retting et al. 2008)	• Speed cameras were associated with large reductions in speeding on the same highway, but 25 miles away from the camera installations. • Traffic speeds were fairly stable on urban freeways in Scottsdale that were not part of the study road. • After the removal of the SSCs, mean speeds returned to 69 mph, compared to 64 mph during the program enforcement period and 70 mph during the pre-program period. This indicates the there was a modest 1 mph decrease from the pre-program period, and that the removal of cameras did not result in higher mean speeds compared to pre-program speeds.
Australia (Champness et al. 2005)	• Speed reduction effects had completely disappeared by 1,500 meters (0.9 miles) downstream. • Upstream halos were negligible. • There was no time halo effect. • Speeds rebounded to pre-deployment speeds within 2 hours of camera removal. • Speed camera deployment will be most effective if it is within a maximum range of one kilometer (0.6 miles) from locations that have a history of high speed related crash risk.

Crash Reductions

Six literature reviews and eight before-and-after studies were identified that looked at changes in crash history before-and-after the implementation of SSCs pilot or permanent programs. Most studies analyzed the change in overall crashes and the reduction in severe injury and fatal crashes. A few studies looked at how the changes in safety affected people by mode.

Literature Reviews

Since 2006, six literature reviews were identified that summarize international and US studies on the effects of SSCs on crashes. All studies found reductions in overall crashes after the SSCs were installed, with the ranges of overall crash reductions varying from 5-72%. Results for reduction in injury and fatal crashes varied slightly less among the six studies with anywhere from 8-65% reduction in injury crashes and 11-71% reduction in fatalities. Thomas et al. in 2008 summarized that the best-controlled evaluation studies reported a 20-25% reduction in injury crashes, which appeared to be a "reasonable estimate of site-specific safety benefit from conspicuous, fixed-camera[s]." Table 5 below summarizes the literature review findings by study.

Table 5 - Summary of literature reviews for effects of SSCs on crash reductions

Source	Overall crash reduction	Reduction in injury and severe/serious/fatal crashes
Rodier et al. 2007, TRB (US Literature Review)	A number of studies that evaluate the safety effects of automated speed enforcement programs indicated a 9-50% reduction in crashes.	Many studies also find that the speed cameras were most effective at reducing more serious crashes involving injury and death.
Thomas et al. 2008, Highway Safety Research Center (International Literature Review)	Not provided	From the best-controlled evaluation studies, injury crash reductions in the range of 20- 25% appear to be a reasonable estimate of site-specific safety benefit from conspicuous, fixed-camera, automated speed enforcement programs.
Pilkington, Kinra 2005, British Medical Association (International Literature Review)	Reductions in outcomes across studies ranged from 5-69% for collisions.	Reductions in outcomes across studies ranged from 12- 65% for injuries, and 17-71% for deaths in the immediate vicinity of camera sites.
Decina et al. 2007, NHTSA (International Literature Review)	• Injury crash reductions of 20-25% for fixed speed cameras and 21-51% for mobile cameras. • Existing research indicates that automated enforcement systems can result in measurable safety improvements at high crash locations.	Based on statistical analysis, SSCs were estimated to result in up to a 50% reduction in fatal and serious crashes.

Wilson et al. 2006, Cochrane Collaboration (International Literature Review)	• Pre/post reductions ranged from 14-72% for all crashes.	• Pre/post reductions ranged from 8-46% for injury crashes, and 40-45% for crashes resulting in fatalities or serious injuries. • Compared with controls, the relative improvement in pre/post-crash numbers resulting in any type of injury ranged from 5- 36%.
Wilson et al. 2010, Cochrane Collaboration (International Literature Review)	The review found 8-49% reduction of crashes [in the vicinity of camera sites.]. Over wider areas, the review found reductions of 9-35% for all crashes.	The review found 8-50% reduction for injury crashes and 11-44% for crashes involving fatalities and serious injuries, in the vicinity of camera sites.

Before-and-after Studies

A total of eight before-and-after studies were identified that analyzed multi-year crash data to understand the effect of SSCs on safety. All studies were published after 2008, five of which focused on programs in the US, one in Canada and two in Italy. Of the US studies, one looked specifically at the use of SCCs in work zones and one looked at SSCs in school zones. All studies that reported on the findings found a reduction in overall crashes as well as a reduction in the number of injury, severe injury and fatal crashes. Results varied by study with a range of 10-54% reduction in overall crashes, 17-48% for injury crashes and 19-56% for serious injury and fatal crashes. Of the studies that reported on both overall crashes as well as serious and fatal crashes, all concluded that SSCs resulted in the greatest reductions for serious injury and fatal crashes. No increase in crash rates or other adverse effects were reported. The following provides a summary of the eight studies related to crash history. The research matrix in Appendix A provides additional information on methodology and results for each study.

Work Zone

In 2022, the Pennsylvania DOT published an analysis of crash data from the first full year of mobile SSC implementation (2020) in work zones on roadways with speed limits ranging from 45 to 75 mph. Findings from the study report a 19% reduction in work zone crashes (reduction of over 100 crashes) on Pennsylvania interstates, freeways, and expressways. Looking at pandemic related factors, work zone crashes were reduced by a greater percentage (19.2%) than traffic volume reductions from the pandemic (13.4%). A larger reduction (roughly 25%) was reported in the number of fatal crashes in work zones.

School Zones

One study in New York City (NYC) (2014-2017 ASE Program Report) evaluated the effect of SSCs on injury and fatal crashes within school zones. All school zones had speed limits of 35 mph or less. The NYC program looked at an average of yearly crash data before (2,870 total crashes) and after (2,442 total crashes) the installation of fixed speed cameras in school zones. Despite the fact that the City is prohibited from using speed cameras during the majority of the year, results from the study show a decline in the overall number of crashes (-15%), severe injury crashes (-17%) and fatalities (-55%). The SSCs had the same impact on injury reduction for pedestrians and motorists (both -17%), however, the benefit for bicyclists was less so with only a 7% reduction in the number of bicyclists injured. The lower crash reduction benefits for bicyclists compared to pedestrians and motorists is consistent with overall school speed zone trends (Li and Graham 2016, Grundy et al. 2009), indicating that this may not be specific to SSCs, but rather school speed zones in general. It is unclear if any other variables had an impact on the reduction of crashes within school zones other than the use of SSCs.

Figure 6 - NYC crash analysis before and after the installation of SSCs in school speed zones

BEFORE/AFTER CHANGE IN CRASHES AND INJURIES IN SCHOOL SPEED ZONES WITH SPEED CAMERAS
(Before: an average of the 3 years prior to installation
After: an average of the full years after installation until Dec 31, 2016)

	Before Period, Citywide	After Period, Citywide	Percent Change
CRASHES			
Total Crashes	2,870	2,442	-15%
Crashes w/ Injuries	2,182	1,873	-14%
INJURIES			
Motor Vehicle Occupant	2,610	2,165	-17%
Pedestrian	501	416	-17%
Cyclist	132	124	-7%
Total Injuries _	3,244	2,704	-17%
KILLED OR SEVERELY INJURED			
Fatalities	18	8	-55%
Severe Injuries	162	134	-17%

Lower speed limit roadways (≤ 35 mph) and school zones

A 2016 study by Hu and McCartt evaluated the effects of SSCs on safety on both lower speed limit roadways and school zones. They used a logistic regression model to evaluate the program's effect on fatal or incapacitating injuries from January 2004–December 2013. Included in the crash data were 19 residential streets with speed limits from 25 to 35 mph and school zones where speed safety data were collected. Findings from the study show a 19% reduction in the likelihood that a crash resulted in an incapacitating or fatal injury, and a cumulative reduction of 39% accounting for the camera program in its modified form, including both the law change[8] and the modified corridor approach.[9]

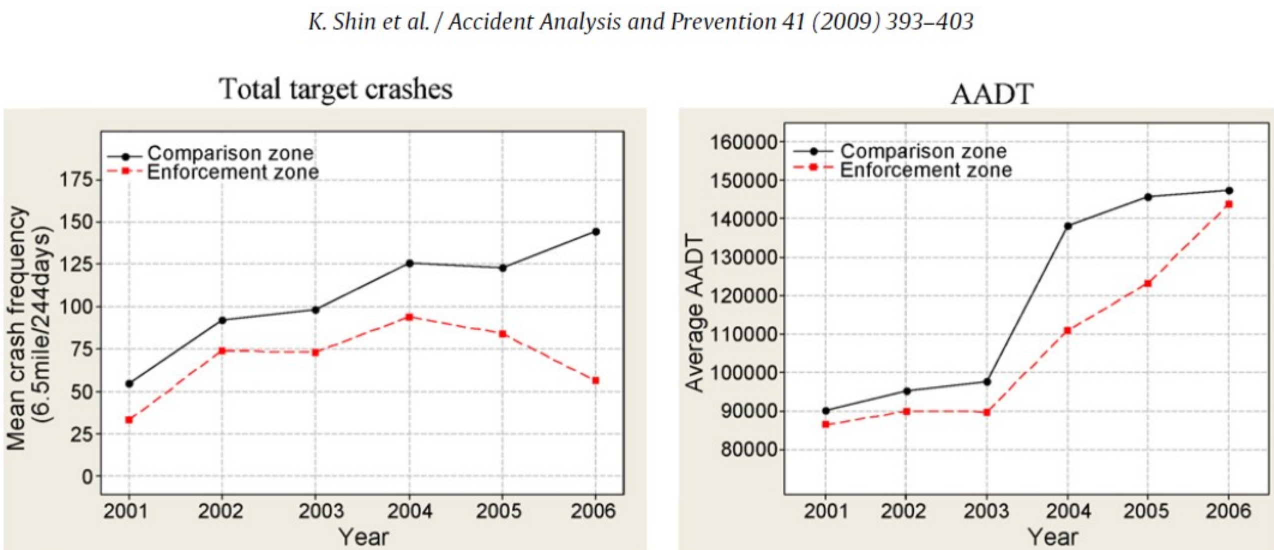
[8] Hu and McCartt 2016 - "To reflect changes in the state statute allowing the speed camera program, effective October 1, 2009, the speed threshold was changed to 12 mph above the speed limit, and school zone camera operations were restricted to 6 a.m.–8 p.m. on weekdays."
[9] Hu and McCartt 2016 – "In May 2012, some cameras began to be used in a roadway corridor approach in which cameras were periodically moved throughout the length of a roadway segment."

Higher Speed Limit Roadways (≥ 40 mph)

Five studies were identified and evaluated regarding the effects of SSCs on safety for higher speed limit arterials. Of the five studies conducted between 2008 and 2015, two were conducted in the US, one in Canada and two Italy.

The two US studies that evaluated SSC programs on urban arterials were located in Scottsdale, AZ (Shin et al. 2009) and Charlotte, NC (Cunningham et al. 2008) with crash data collected for the treatment sites between 2004 and 2006. The Scottsdale study used a before/after analysis with traffic flow correction and Empirical Bayes analysis to study crash outcomes over a 9-month demonstration project in 6.5 miles on Loop 101 from January 2006 through October 2006. The study concluded that fixed units can reduce crashes on urban principal arterials up to 54% for all crashes and 47% for injury crashes.

Figure 1 - Changes in total target crashes and AADT by year for comparison zone vs. enforcement zone in Scottsdale, AZ (Shin et al. 2009)



The second US study analyzed before-and-after crash data along five heavily enforced corridors in Charlotte, NC that implemented mobile SSCs. The data included just over one years' worth of collision data at 14 treatment sites. Results from the study suggest an average decrease in overall crashes of approximately 10%, with a decrease in reductions noted in the second year of the program and a higher level of reduction on more heavily enforced corridors.

In 2015, a robust evaluation of 93 enforced arterials in Edmonton, Canada was published by Li et al in the TRB. The study use the before-and-after Empirical Bayes method based on collision records, deployment information, traffic counts, and geometric road data. Results indicate that crash reductions were greatest along high-crash corridors and corridors with longer lengths of SSC deployment. The study also looked at the effects of continuous and discontinuous enforcement strategies on different arterials, and the analysis revealed that continuous enforcement achieved more reductions across all severities and types of collisions. Consistent with the other studies, the program in Edmonton had the highest reductions observed for severe collisions.

The final two studies on higher speed limit roadways were both conducted in Italy by Montella et al. between 2012 and 2015. The crash analyses of the A56 motorway in Tangenziale di Napoli (Montella et al. 2015) and the A1 motorway in Milan (Montella et al. 2012) included a total of 6 and 9 years of crash data and 559 and 1,922 crash counts, respectively. The A56 motorway study used the P2P camera system while the A1 motorway used the Safety Tutor System[10]. Both resulted in approximately 1/3 reduction in the total crashes after the SSCs were implemented. Additionally, the P2P system on the A56 motorway resulted in a 37% reduction in fatal and injury crashes while the Safety Tutor System resulted in a 55.6% decrease in severe crashes.

Based on the findings of this research, it was concluded that SSCs consistently show a positive effect in the reduction of overall crashes and serious and fatal crashes, regardless of roadway type. Additional analysis into the breakdown of crash data by mode may be required to further understand the extent to check SSCs can impact the safety of the most vulnerable users.

Table 6. Summary of effects of SSCs on crash reduction

Source	Road Speed Limit(s)	Overall crash reduction	Reduction in severe/serious/fatal
2022 Report (Pennsylvania DOT) **Work Zone**	Varies. 45 to 70 MPH	From 2019 to 2020, the first year the program was in operation, there was a 19% reduction in crashes in work zones. Reduction of over 100 crashes annually has occurred in 2020 in work zones on Pennsylvania interstates, freeways, and expressways.	Fatal crashes in Pennsylvania Work Zones continue their reduction from pre-AWZSE levels (roughly 25% reduction).
New York City, NY (2014-2017 ASE Program Report) **School Zone**	Not provided, (Generally 25 mph)	15% reduction in total crashes	Despite the fact that the City is prohibited from using speed cameras during the majority of the year, injuries at these locations have dropped 17 percent. • 55% fewer fatalities. • 14% reduction in injuries • 17% reduction in severe injuries

[10] The Safety Tutor System monitors the vehicles' average speed in all lanes over long sections of the motorway- generally 10 to 25 km in length - or using speed traps positioned at specific locations where accidents occur more frequently. https://www.infoviaggiando.it/code/14337/Safety-Tutor#:~:text=The%20Safety%20Tutor%20System%20allows,Traffic%20Police%20on%20the%20motorway.

Montgomery County, Maryland (Hu & McCartt 2016)	35 MPH or less	Not provided	• Speed cameras alone were associated with a 19% reduction in the likelihood that a crash resulted in an incapacitating or fatal injury. •The overall effect of the camera program in its modified form, including both the law change and the corridor approach, was a 39% reduction in the likelihood that a crash resulted in an incapacitating or fatal injury.
Scottsdale, AZ (Shin et al. 2009)	65 MPH	• The total number of target crashes decreased by 44–54%. • All crash types were reduced except rear-end crashes. It is concluded that the effect of the fixed-camera photo speed enforcement program (SEP) on rear-end crashes is uncertain. • Fixed units can reduce crashes on urban principal arterials up to 54% for all crashes and 47% for injury crashes. • The total estimated SEP benefits (looking at the costs of crashes only) range from an estimated $16.5M to $17.1M per year.	• The total number of injury crashes decreased by 28–48%, while the total number of property damage only crashes decreased by 46–56%.
Charlotte, NC (Cunningham et al. 2008)	Varies: high-volume, multilane, urban arterials	• The collision analysis seems to provide evidence that automated speed enforcement reduced collisions along treated corridors by around 10% on average. • The collision reductions were lower in the second year of program operation and were higher in corridors that were more heavily enforced.	N/A

Edmonton, Alberta, Canada (Li et al. 2015)	N/A, principal arterial	• The evaluation suggested that, in general, segments with a high collision number/ rate and longer deployment length achieved greater crash reductions. •The study also compared the safety effects of continuous and discontinuous enforcement strategies on different arterials, and the analysis revealed that continuous enforcement achieved more reductions across all severities and types of collisions.	• Consistent reductions in different collision severities • The reductions ranged from 14% to 20%, with the highest reductions observed for severe collisions.
Tangenziale di Napoli, Italy (Montella et al. 2015)	Varies, principal arterial	The system yielded a statistically significant 32% reduction in the total crashes. P2P speed enforcement involves the calculation of the average speed over a section.	P2P units can reduce crashes on urban expressways, freeways, and principal arterials up to 37% for fatal and injury crashes.
Milan-Naples, Italy (Montella et al. 2012)	N/A, principal arterial	31.2% reduction in the total crashes	• Reduction was 55.6% for severe crashes, 26.6% for non-severe crashes, 43.4% at curves, and 28.4% at tangents. However, the system's effectiveness decreased over time. • The greatest crash reductions were observed for severe crashes and crashes at curves.

Spillover /Long Term Effects:

A variety of crash spillover effects were reported on the high speed limit roadways, ranging from location based (downstream and regional) to temporal (long-term trends). Table 7 provides a summary of all reported crash spillover effects by study.

Upstream/Downstream and Regional:

> Location based spillover effects were mixed with Shin et al. in Scottsdale finding no significant reduction at comparison sites while Montella et al. in 2015 found statistically significant reductions in total crashes (21%) in parts of the Milan motorway that were not enforced (upstream and downstream). The study in Edmonton, Canada (Li et al. 2015) looked at adjacent, non-enforced segments and found mixed spillover results, likely due to environmental factors.

Long Term Trends:

> The study in Charlotte and the one in Tangenziale di Napoli both found that the effectiveness of the SSCs was reduced over time, possibly due to a reduction of the speed enforcement and to behavioral adaptation of drivers[11].

Table 7 - Crash spillover effects on higher speed limit roadways (≥ 40 mph)

Source	Spillover/Long Term Effects
Scottsdale, AZ (Shin et al. 2009)	Crash spillover effects were examined indirectly through the comparison site analysis. The study did not find statistically significant spillover crash effects.
Charlotte, NC (Cunningham et al. 2008)	The long-term effect of the countermeasure appears to indicate a slight decrease in the overall effect with the addition of collision data from 2005 (from a 12.0% to a 9% decrease); however, all indications are that the camera program was still reducing collision frequencies in 2005.
Edmonton, Alberta, Canada (Li et al. 2015)	For the enforced segments, only severe and speed-related collisions were significantly reduced, while for the unenforced segments, only the PDO collisions, total collisions, and speed-30 related PDO collisions were significantly reduced. One possible explanation is that the non-enforced approach had a better view of the covert mobile enforcement cameras that were intended to be covert, and slowed down prior to the zone, resulting in reduced property damage and total collisions.
Tangenziale di Napoli, Italy (Montella et al. 2015)	While the safety effectiveness of the system was statistically significant, effectiveness decreased over time. Crash reduction was 39.4% in the first semester after the system activation, while it was 18.7% in the fifth semester. This declining effect may be due to a reduction of the speed enforcement and to behavioral adaptation of drivers. Confirmation of the change of drivers' behavior over time is that for Italian Motorway A3 Naples–Salerno 1 year after the speed enforcement system activation, a significant speed increase was observed (30).

[11] Montella et al. 2015

Milan-Naples, Italy (Montella et al. 2012)	The system produced a statistically significant reduction of 21% in total crashes in the part of the motorway where it was not activated, thus generating a significant spillover effect.

ADDITIONAL RESOURCES

A variety of additional resources are available providing further studies and best practices for program implementation. The FHWA website on Speed Safety Cameras[12] provides the following consideration when implementing a SSC program.

FHWA Considerations (**FHWA-SA-21-070)**:

- Public trust is essential for any type of enforcement. With proper controls in place, SSCs can offer fair and equitable enforcement of speeding, regardless of driver age, race, gender, or socio-economic status. SSCs should be planned with community input and equity impacts in mind.
- Using both overt (i.e., highly visible) and covert (i.e., hidden) enforcement may encourage drivers to comply with limits everywhere, not only at sites they are aware are enforced.
- Agencies should conduct evaluations regularly to determine if SSCs are accomplishing safety goals and whether changes in strategy, scheduling, communications, or public engagement are necessary.
- Agencies should conduct a legal and policy review to determine if SSCs are authorized within a jurisdiction and how the authorization and other traffic laws will affect a SSC program.
- Agencies should develop an SSC program plan with consideration of the USDOT SSC guidelines for planning, public involvement, stakeholder coordination, implementation, maintenance, evaluation, etc.(Speed Enforcement Camera Systems Operational Guidelines. NHTSA, (2008).)

Table 8 provides additional resources, particularly related to program structure and implementation.

[12] https://safety.fhwa.dot.gov/provencountermeasures/speed-safety-cameras.cfm

Table 8. Additional resources on Speed Safety Camera Programs and Implementation

Publication	Summary/ Notable Information
FHWA - Speed Safety Camera Program Planning and Operations Guide (Thomas et al. 2021).	Not yet published
2021 FHWA Guidance Memo on Proven Safety Countermeasures	Memo adds SSC as a new Proven Safety Countermeasure.
2008 FHWA/NHTSA SEC Guidelines	Automated enforcement program and operational guides with information on identifying problems and setting up and maintaining an effective and transparent, community-supported enforcement program using speed or red light cameras.
System Analysis of Automated Speed Enforcement Implementation (Miller et al. 2016) NHTSA and FHWA	Evaluation of program administration
Proven Safety Counter Measures – Speed Safety Cameras (FHWA-SA-21-070)	Single page summary document
AASHTO Policy Resolution 2006-02	Resolution in support of Automated Traffic Law Enforcement
Automated Enforcement for Speeding and Red Light Running - NCHRP Report 729 (2012)	Guide for implementation
FHWA Case Study 5: Noteworthy Speed Management Practices	Implementation based findings. Results summarized in New York City, NY (2014-2017 ASE Program Report)
NCHRP Report 746 - Pedestrian Safety Relative to Traffic-Speed Management (2019)	Provided sources for case studies which were cited directly
Guide: Countermeasures That Work (Goodwin et al. 2015)	Provided sources for case studies which were cited directly
CDC Webpage for Automated-Speed-Camera Enforcement (04/15/2022)	Good background and literature review. Sources Cited directly.

CONCLUSION

The above research indicates that SSCs are an effective countermeasure for reducing motorist speeds and have been shown to reduce crashes.

While all reputable studies saw positive outcomes for speed reduction, the extent of speed reductions varied by study with the largest range in effectiveness occurring on high-speed roadways. This likely indicates that there may be more variables influencing the effectiveness of SSCs on speeding activity on high-speed roadways. SSCs were also found to be an effective speed reduction countermeasure within school zones based on available research, and that outcomes were greatest when combined with flashing beacons. Spillover effects for speed reduction were mixed, but no unintended consequences were found related to SSC program impacts on speed.

SSCs were also found to be an effective tool for reducing crashes, particularly for reducing severe injury and fatal crashes. No increase in crash rates or other adverse safety effects were reported. Results are consistent with other literature reviews published since 2005.

Additional variables such as differences in threshold speeds and program implementation best practices were not fully evaluated as part of this TRS. Recommended future research topics include:

- Impact of different SSC threshold speeds on speed reductions, in particular, for roadways of differing speed limit and character (i.e. a 6 mph threshold on lower speed roadways and 11 mph threshold on high speed roadways.)
- Best practices for program structure and implementation, including but not limited to:
    - Citation type (administrative vs. criminal)
    - Fine pricing and equity considerations
    - Implementation process for administrative fines and court process
    - System funding
    - Procurement of operating system or vendor contracting
    - Equity considerations for deployment
    - Masking and commercial driver research
    - Political implications and compliance with federal regulations

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Appendix A

MnDOT Speed Safety Cameras TRS
Research Matrix - 12/01/2022

Objective - To explore the following questions related to Speed Safety Cameras (Also known as Automated Speed Enforcement (ASE):
1. Are speed safety cameras effective for reducing and managing speeds where deployed?
2. Can speed safety camera reduce the severity and frequency of crashes where deployed?
3. Are there known spillover or other unintended consequences for implementing ASE?

	General Research Information			1. Key findings for effectiveness in reducing and managing speeds			2. Key findings for safety		3. Key findings for spillover effects
Studies	**Data Year**	**Topic**	**Road speed limit(s)**	**Reduction in mean speeds & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/ serious/ fatal**	**Spillover/Long Term Effects**
2022 Report (Pennsylvania DOT)	2020-2021	Work Zone	45 to 70 MPH	Yes	Yes		Yes	Yes	Smaller but measurable speed reductions at times when AWZSE is not in effect in those zones.
Seattle Washington, (Quistberg 2019)	2012-2015	School Zone	20MPH	Yes	Yes				Impact of SSCs was sustained during the second year
New York City, NY (2014-2017 ASE Program Report)	2014-2016	School Zones	Not provided	Yes	Yes		Yes	Yes	Notes trend of acceleration after passing the speed camera.
Montgomery County, Maryland (Hu & McCartt 2016)	2004-2013	General	35 MPH or less	Yes	Yes			Yes	Broader spillover effect findings.
Portland, Oregon (Joerger 2010)	2008-2009	Work Zone	40 MPH	Yes	Yes				Speeding reduction was temporary and limited to enforcement areas.
Scottsdale, AZ (Shin et al. 2009)	2006-2007	General/ PAs	65 MPH	Yes	Yes		Yes, except rear-end crashes	Yes	No evidence of an effect at a similar site 40 miles away. No statistically significant spillover crash effects.
Charlotte, NC (Cunningham et al. 2008)	2003-2005	General	High-volume, multilane	Yes	Yes	Yes	Yes	N/A	Slight decrease in the overall effect over time.
Montgomery County, Maryland (Retting et al. 2008)	2007	General / School Zones	35 MPH or less	Yes	Yes				Reductions in mean and threshold speeds at "spillover" sites.
Scottsdale, AZ (Retting et al. 2008)	2006	General/ PA	65 MPH	Yes	Yes				Large reductions in speeding on the same highway but 25 miles away from the camera installations.
Portland, Oregon (Freedman et al. 2006)	2005	School Zones	20 MPH 24 HR/Day	Yes	Yes	Yes			Reductions found when SSCs were not present.
Washington, DC (Retting & Farmer 2003)	2001	General	25-35 MPH	Yes	Yes				No decline in traffic speeds at comparison sites.
Edmonton, Alberta, Canada (Li et al. 2015)	2005-2012	General/PA	N/A				Yes	Yes	
Tangenziale di Napoli, Italy (Montella et al. 2015)	2009	General / PAs	Varies	Yes	Yes	Yes	Yes	Yes	Safety effectiveness decreased over time.
Milan-Naples, Italy (Montella et al. 2012)	2009-2011	General	N/A				Yes	Yes	Significant crash reductions at spillover sites.
Australia (Champness et al. 2005)		General	100 kph	Yes	Yes	Yes			Speed reduction disappeared by 1,500 meters downstream. Speeds rebounded within 2 hours of camera removal.
Malaysia* (Rohani et al. 2014)		School Zone	30 km/h	No, Speeds increased					When drivers figured out there was no fine for exceeding the speed limit, speeds appear to have increased.
Literature Reviews									
US Literature Review (Rodier et al. 2007)	Varies	General	Varies	Yes	Yes		Yes	Yes	
International Literature Review (Thomas et al. 2008)	2008	General	Varies		Yes			Yes	
International Literature Review (Pilkington, Kinra 2005)	1992 - 2003	General	Varies				Yes	Yes	Effectiveness of cameras up to three years or less after their introduction
International Literature Review (Decina et al. 2007)	2007	General	Varies				Yes	Yes	
International Literature Review (Wilson et al. 2006)	1984-2004	General	40-100 km/h	Yes	Yes	Yes	Yes	Yes	
International Literature Review (Wilson et al. 2010)		General		Yes	Yes	Yes	Yes	Yes	Trends were either maintained or improved with time.

*** Small sample size and no penalty for violation**

Appendix A

MnDOT Speed Safety Cameras TRS
Research Matrix - 12/01/2022

Objective - To explore the following questions related to Speed Safety Cameras (Also known as Automated Speed Enforcement (ASE):
1. Are speed safety cameras effective for reducing and managing speeds where deployed?
2. Can speed safety camera reduce the severity and frequency of crashes where deployed?
3. Are there known spillover or other unintended consequences for implementing ASE?

General Research Information						1. Key findings for effectiveness in reducing and managing speeds					2. Key findings for safety		3. Key findings for spillover effects
Source	**Source Type/ Publication**	**Data Year**	**Topic**	**Study Methodology**	**Sample Size**	**Road speed limit(s)**	**Violation/ Threshold Speed Definition**	**Reduction in overall speeds (mean) & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/serious/fatal**	**Spillover/Long Term Effects**
Case Studies													
2022 Report (Pennsylvania DOT)	US Case Study - DOT	2020-2021	Work Zone	Evaluation of portable automated speed enforcement systems to provide enforcement of excessive speeding (11+ MPH) in active work zones. • Evaluation of percent over speed limit and percent excessively speeding •Includes reduced speed and non-reduced speed work zones.	Speed Analysis: • 2 yrs (March 2020-Dec 2021) • 5,386 deployments • 644,009 citations Crash Analysis: • First calendar year of crash history in work zones and three years prior to implementation.	Varies. 45 to 70 MPH	• Excessive speeding • > 10 MPH when workers are present	• During the peak construction seasons, the total percentage of speeding vehicles in AWZSE enforced work zones has been reduced to 18-20% on average, reduced from 30-35% at the start of the program in 2020 • Shorter work zones have better compliance	Similarly, excessive speeding is AWZSE enforced work zones during the peak construction season has been reduced to 3%, down from 5-8% at the start of the program	N/A	From 2019 to 2020, the first year the program was in operation, there was a 19% reduction in crashes in work zones. Reduction of over 100 crashes annually has occurred in 2020 in work zones on Pennsylvania interstates, freeways, and expressways. • The crash data from 2020 indicates that work zone crashes reduced by a greater percentage (19.2%) than traffic volume reduced from the pandemic (13.4%).	Fatal crashes in Pennsylvania Work Zones continue their reduction from pre-AWZSE levels (roughly 25% reduction).	• Smaller (but measurable) speed reductions at times when AWZSE is not in effect in those zones
Seattle Washington, (Quistberg 2019)	US Case Study - Injury Prevention	2012-2015	School Zone	• Automated enforcement cameras (Fixed) active during school commuting hours • Schools selected based on high 85th percentile speeds • Compared speeds during citation period and 'warning' period prior to citation period • Multilevel mixed linear regression • 26,500 hours of vehicle speed data	• >2 yrs (Nov 2012-Jan 2015) • 4 elementary schools in Seattle, WA • Schools selected due to higher rates of speeding during school hours	20MPH	• Speed threshold = 26+ • high-speed violations > 35 MPH	The mean vehicle speed significantly decreased by 2 MPH during automated photo enforcement.	Nearly 50% reduction in the rate of speeding violations.	N/A	N/A	N/A	The impact of automated enforcement was sustained during the second year of implementation.
New York City, NY (2014-2017 ASE Program Report)	US Case Study - DOT	2014-2016	School Zones	Before-after evaluation of fixed speed cameras • 3 years of crash data prior to installation (prior to Dec 31, 2015) and one year after installation • 18 Months of speed data • The City can only use speed cameras for enforcement within school speed zones, which are defined by law as the street abutting the school building or property within 1,320 feet of the school. The law only allows the City to deter speeding with speed cameras (1) on school days during school hours, and one hour before and one hour after the school day; and (2) during student activities at the school and up to 30 minutes immediately before and up to 30 minutes immediately after such student activities.	• Crash data from 140 school speed zones with SSCs (out of 2,300 school speed zones) + 40 mobile units • Programs has used speed cameras at 875 school zone locations since program's inception	Not provided	> 10 MPH	• Speeding during school hours at typical fixed camera locations drops 63 percent	The daily rate of violations issued for excessive speeding in school speed zones at the typical camera has declined by over 60 percent, from 104 in the camera's first month to 35 in the camera's 18th month. Only 19 percent of plates were repeat violators	N/A	15% reduction in total crashes	Despite the fact that the City is prohibited from using speed cameras during the majority of the year, injuries at these locations have dropped 17 percent. • 55% fewer fatalities. • 14% reduction in injuries • 17% reduction in severe injuries In New York City 84 percent of fatal and serious injury crashes occur at times other than school hours on school days.	•Speeding at locations with speed cameras increases soon after the speed cameras are deactivated at the end of the school day. • Motorists tend to accelerate almost immediately after passing the speed camera. By not announcing locations, the City seeks to encourage compliance with the speed limit even outside of speed camera enforced school zones. • The rate of vehicles exceeding the speed limit by more than 11 MPH during the hours that the cameras are deactivated is 146% higher than during the school hours when the cameras are active.

General Research Information						1. Key findings for effectiveness in reducing and managing speeds					2. Key findings for safety		3. Key findings for spillover effects
Source	**Source Type/ Publication**	**Data Year**	**Topic**	**Study Methodology**	**Sample Size**	**Road speed limit(s)**	**Violation/ Threshold Speed Definition**	**Reduction in overall speeds (mean) & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/serious/fatal**	**Spillover/Long Term Effects**
Case Studies													
Montgomery County, Maryland (Hu & McCartt 2016)	US Case Study - TIP	2004-2013	General	• Used control sites in Arlington and Fairfax Counties (Virginia) • Citations issued for vehicles traveling at least 11 mph over speed limit until Oct 2009 when threshold increased to 12 mph • Logistic regression model to evaluate program's effect on fatal or incapacitating injuries • 19 residential streets in Montgomery County, Maryland • Streets with 25-35 mph speed limits January 2004–December 2013 • In May 2012, some cameras began to be used in a roadway corridor approach in which cameras were periodically moved throughout the length of a roadway segment. • Law Change: To reflect changes in the state statute allowing the speed camera program, effective October 1, 2009, the speed threshold was changed to 12 mph above the speed limit, and school zone camera operations were restricted to 6 a.m.–8 p.m. on weekdays.	Speed Data: 6 months prior to program through 7.5 yrs after Crash Data: January 2004-December 2013	35 MPH or less	10 MPH Threshold Speed 12MPH + Violation Speed	Speed cameras were associated with a 10% reduction in mean speed.	• 62% statistically significant reduction in the likelihood that a vehicle was traveling more than 10 mph above the speed limit at camera sites. • The percentage of vehicles exceeding the speed limit by more than 10 mph decreased by 64% compared to 39% and 43% at potential spillover sites and control sites, respectively.	N/A	Not provided	• Speed cameras alone were associated with a 19% reduction in the likelihood that a crash resulted in an incapacitating or fatal injury. •The overall effect of the camera program in its modified form, including both the law change and the corridor approach, was a 39% reduction in the likelihood that a crash resulted in an incapacitating or fatal injury.	• Scottsdale and Montgomery County, speeds were reduced by smaller amounts at locations not targeted by cameras, suggesting broader spillover effects. • On potential spillover roads in Montgomery County, the estimated combined effect of the speed cameras, law change, and corridor approach was a significant 27% reduction in the likelihood that a crash involved an incapacitating/fatal injury. The apparent spillover effect is consistent with the findings of the international evaluations of speed camera programs (Wilson et al. 2010).
Portland, Oregon (Joerger 2010)	US Case Study - DOT	2008-2009	Work Zone	• Before, during and after evaluation of ASE in work zone along Yeon Ave between Nov 2008-Oct 2009 • Used radar traffic sensors to collect volume, speed, classification, lane occupancy	• Total study Nov 2008-Oct 2009 • Photo radar enforcement March 2009-Sept 2009 • 2-mile work zone through industrial area on Yeon Ave (27,900 AADT, 4 lanes + Two-way left-turn lane)	40 MPH	45 MPH	A large reduction in speeding, was observed even though vehicles passing the traffic sensor from one direction had not yet seen the enforcement activity. A greater reduction in speeding would be expected if photo radar enforcement covered both directions of travel.	• Average reduction in vehicles traveling faster than 45 MPH was 23.7%	Mean and 85th percentile speeds during periods of non-enforcement remained quite stable throughout the study period, which emphasizes the impact of photo radar speed enforcement as a tool to reduce speeding in a work zone environment.	N/A	N/A	• The observed speeding reduction was temporary and did not persist beyond the departure of the photo radar enforcement van.
Scottsdale, AZ (Shin et al. 2009)	US Case Study - Accident Analysis & Prevention	2006-2007	General/ PAs	• Reviewed impact of speed enforcement program on speeding behavior during free flow conditions using generalized leased square estimation • Impact of SEP on crashes estimated using before/after analysis, BA analysis with traffic flow correction, and empirical Bayes before/after analysis • Scottsdale Loop 101 • ANOVA tests suggest that speeding detection frequencies are significantly affected by the period of observation as well as the day of the week	• 9 month demonstration program on 6.5 mile urban freeway segment • January 2006-October 2006	65 MPH	> 10 PMH	• Reduced the average speed at the enforcement camera sites by about 9mph on average. • Reduction in the standard deviation from 3.5 mph to 1.2 mph indicating a tightening of the speed distribution. • The reduction in the mean of speed is dependent on traffic flow: the reductions increased as traffic flow decreased due to the well-known relationship between speed and traffic flow.	• The activation of the SEP was an effective countermeasure for reducing speeding, resulting in significant reductions in the number of motorists exceeding 75mph • Speeding detection frequencies (≥ 75 MPH) are significantly affected by the period of observation as well as the day of the week. • Speeding detection frequencies (speeds ≥ 76 mph) increased by a factor of 10.5 after the SEP was (temporarily) terminated.	N/A	• The total number of target crashes decreased by 44–54%. • All crash types were reduced except rear-end crashes. It is concluded that the effect of the SEP on rear-end crashes is uncertain. • Fixed units can reduce crashes on urban principal arterials up to 54% for all crashes and 47% for injury crashes. • The total estimated SEP benefits (looking at the costs of crashes only) range from an estimated $16.5M to $17.1M per year.	• The total number of injury crashes decreased by 28–48%, while the total number of property damage only crashes decreased by 46–56%.	• Spillover effects, or general deterrence effects, were subjected to cursory examination in this study due to data and resource limitations. • Average speeds revealed no evidence of an effect at a similar site on the Loop 101 about 40 miles away from the enforcement zone. • Crash spillover effects were examined indirectly through the comparison site analysis. The study did not find statistically significant spillover crash effects.
Charlotte, NC (Cunningham et al. 2008)	US Case Study - TRB	2003-2005	General	• Collision and speed analyses were performed (before/after analysis) •Total collisions, data accounting for regression to the mean, and data for five heavily enforced corridors. • All reported collisions, rather than a subset of "speed-related collisions, • Speed data analyzed using the Proc Mixed procedure in SAS	•Three mobile units along 14 corridors in Charlotte, North Carolina Collision Analysis: • Aug 2004-Sept 2005 • 14 treatment corridors Speed Analysis: • 3 periods of data: Aug 2003 (before), Sept - Oct 2004 (just after "after1"), Sept-Oct 2005 ("after2")	Varies: high-volume, multilane, urban arterials	>10 MPH	• Mean speeds significantly decreased by 0.82 mph and 0.67 mph during the after1 periods and after2 periods, respectively, compared with the before period. • Speeding in the before period was 1.55 times the percentage of speeding in the after1 period and 1.23 times the percentage of speeding in the after2 period at the treatment sites	• The percentage of speeding in the before period was 1.55 times the percentage of speeding in the after1 period and 1.23 times the percentage of speeding in the after2 period at the treatment sites.	• Similar results to the mean speeds; 85th percentile speeds significantly decreased by 0.91 mph and 0.77 mph during after1 periods and after2 periods, compared with the before period.	• The collision analysis seems to provide evidence that automated speed enforcement reduced collisions along treated corridors by around 10% on average. • The collision reductions were lower in the second year of program operation and were higher in corridors that were more heavily enforced.	N/A	The long-term effect of the countermeasure appears to indicate a slight decrease in the overall effect with the addition of data from 2005 (from a 12.0% to a 9% decrease); however, all indications are that the camera program was still reducing collision frequencies in 2005.

General Research Information						1. Key findings for effectiveness in reducing and managing speeds					2. Key findings for safety		3. Key findings for spillover effects
Source	**Source Type/ Publication**	**Data Year**	**Topic**	**Study Methodology**	**Sample Size**	**Road speed limit(s)**	**Violation/ Threshold Speed Definition**	**Reduction in overall speeds (mean) & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/serious/fatal**	**Spillover/Long Term Effects**
Case Studies													
Montgomery County, Maryland (Retting et al. 2008)	US Case Study - TIP	2007	General / School Zones	• Speeds measured ~6 months before and 6 months after speed cameras and warning signs deployed • Telephone surveys • Weighted averages based on proportion of vehicles observed	• Speed camera program began May 2007 • cameras deployed on 5 randomly selected roads for evaluation. • 15 other locations had warning signs but no speed enforcement • 10 random sites had no warning signs nor speed cameras • 10 comparison sites randomly selected on residential streets	35 MPH or less	10+ mph	The decline in mean speeds ranged from 5% to 18%, and the average decline was 10%.	Traveling more than 10 mph above posted speed limits declined by about 70% at locations with both warning signs and speed camera enforcement.	N/A	N/A	N/A	• At the noncamera enforced "spillover" sites in Montgomery County, mean speeds declined by 2% and the proportion of vehicles exceeding speed limits by more than 10 mph declined by 16%, relative to the Virginia comparison sites. • The finding of speed reductions beyond targeted locations is evidence that highly visible automated enforcement can promote community-wide changes in driver behavior.
Scottsdale, AZ (Retting et al. 2008)	US Case Study - Accident Analysis and Prevention	2006	General/ PA	• 8-mile stretch on the Loop 101 freeway (150,000 AADT, 65 mph speed limit) • Fixed speed cameras • telephone surveys • multivariate logistic regression model used to understand effectiveness	• 3 study locations • 6 speed cameras, 3 in each direction with traffic warning signs • 9-month pilot program	65 MPH	> 10 mph	Scottsdale: 5 to 7 MPH reduction in mean speed Glendale: 5 mph decline.	Study found an 88% decrease in threshold speeds	N/A	N/A	N/A	• In addition to reducing speeding along the enforcement corridor, speed cameras were associated with large reductions in speeding on the same highway but 25 miles away from the camera installations. However, traffic speeds were fairly stable on urban freeways in Scottsdale that were not part of the study road. • Mean traffic speeds increased to 69 MPH after the camera enforcement was suspended for a 1 MPH decrease from baseline.
Portland, Oregon (Freedman et al. 2006)	US Case Study - NHTSA	2005	School Zones	• Before-and-after evaluation of a demonstration project at 5 school zones with documented speeding problems • 5 comparison sites without ASE	• 5 neighborhood schools in Portland • 2-month period • 2-lane minor arterials with parking all demonstration schools had flashing beacons	20 MPH 24 HR/Day	> 10 mph	Mean speeds at demonstration school zones were reduced by approximately 5 mph when ASE was present.	The proportion of traffic that exceeded the speed limit by more than 10 mph was reduced by about two-thirds when ASE was present.	• 85th percentile speeds at demonstration school zones were reduced by approximately 5 mph when ASE was present (without a flashing beacon). • 85th percentile speeds iat demonstration school zones were reduced by approximately 8-9 mph when ASE and flashing beacons were both present.	N/A	N/A	ASE still had an effect (although reduced to 1 to 2 mph) when ASE was not present. The proportion of traffic that exceeded the speed limit by more than 10 mph was reduced by about one-quarter when ASE was not present. The speed reduction effects observed at the demonstration school zones were still present one month after ASE operations ceased in May 2005.
Washington, DC (Retting & Farmer 2003)	US Case Study - TRB	2001	General	• Before and after evaluation of speed camera enforcement program in Washington DC and Maryland • 6 months at seven sites in DC and 8 sites in Baltimore. Unmarked vans. No marked cars nor uniformed officers. • Speed data collected 1 year before enforcement and 6 months after	• 60 targeted enforcement zones • Washington: 7 sample sites • Baltimore: 8 sample sites	25-35 MPH	> 10 mph	Overall, mean speeds at Washington sites declined by a statistically significant 14% compared with control sites.	The proportion of vehicles exceeding the speed limit by more than 10 mph declined 82%.	N/A	N/A	N/A	At eight comparison sites in nearby Baltimore, Maryland, where speed camera enforcement was not in place, no decline in traffic speeds was observed.
Edmonton, Alberta, Canada (Li et al. 2015)	Int. Case Study - TRB	2005-2012	General/ PA	• Before-and-after empirical Bayes method • Included information on collision records, deployment information, traffic counts, and geometric road data. • Covert mobile cameras	• 93 enforced arterial road segments were evaluated	N/A	N/A	N/A	N/A	N/A	• The evaluation suggested that, in general, segments with a high collision number/ rate and longer deployment length achieved greater crash reductions. •The study also compared the safety effects of continuous and discontinuous enforcement strategies on different arterials, and the analysis revealed that continuous enforcement achieved more reductions across all severities and types of collisions.	• significant reductions in all collision severities and types • The reductions ranged from 14% to 20%, with the highest reductions observed for severe collisions.	For the enforced segments, only severe and speed-related collisions were significantly reduced, while for the unenforced segments, only the PDO collisions, total collisions, and speed-30 related PDO collisions were significantly reduced. One possible explanation is that the non-enforced approach had a better view of the covert mobile enforcement cameras that were intended to be covert, and slowed down prior to the zone, resulting in reduced property damage and total collisions.

General Research Information						1. Key findings for effectiveness in reducing and managing speeds					2. Key findings for safety		3. Key findings for spillover effects
Source	**Source Type/ Publication**	**Data Year**	**Topic**	**Study Methodology**	**Sample Size**	**Road speed limit(s)**	**Violation/ Threshold Speed Definition**	**Reduction in overall speeds (mean) & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/serious/fatal**	**Spillover/Long Term Effects**
Case Studies													
Tangenziale di Napoli, Italy (Montella et al. 2015)	Int. Case Study - AAP	2009	General / PAs	• Point to point (P2P) speed enforcement system calculates average speed over a section • Empirical Bayes observational before/after study • Two steel gantries at section entrance and exit, with cameras in each lane. • Urban motorway A56 in Italy	**Speed Data:** • Four data collection periods spread out over two years (2009-2011): 12 days. 77 days, 21 days, 23 days. **Crash data:** • 2006 to 2011, with a before period of 3.08 years and an after period of 2.91 years. • Crash count for all treatment sites was 559 in the before period and 279 in the after period.	Varies	> 5, 10 and 20 km/h	• 10% reduction in average speeds of light vehicles • Effectiveness for heavy vehicles (weight > 3.5 ton) was lower than for light vehicles: 5 vs. 10% the reduction in the mean speed, and 8 vs. 14% the reduction in the 85th speed.	• The proportion of light and heavy vehicles exceeding the speed limits more than 20 km/h was reduced respectively by 84 and 77%.	• 14% reduction in 85th percentile speeds, 8% for heavy vehicles	The system yielded a statistically significant 32% reduction in the total crashes. Point-to-point speed enforcement involves the calculation of the average speed over a section.	P2P units can reduce crashes on urban expressways, freeways, and principal arterials up to 37% for fatal and injury crashes.	While the safety effectiveness of the system was statistically significant, effectiveness decreased over time. Crash reduction was 39.4% in the first semester after the system activation, while it was 18.7% in the fifth semester. This declining effect may be due to a reduction of the speed enforcement and to behavioral adaptation of drivers. Confirmation of the change of drivers' behavior over time is that for Italian Motorway A3 Naples–Salerno 1 year after the speed enforcement system activation, a significant speed increase was observed (30).
Milan-Naples, Italy (Montella et al. 2012)	Int. Case Study - TRB	2009-2011	General	• Evaluated the safety effectiveness of the Safety Tutor system installed on Italian Motorway A1 Milan–Naples in from 2001-2009. • An empirical Bayes observational before-and-after study was performed	• 79.88 km study area on the Italian Motorway A1 from Milan to Naples (Road E35). • Analysis period 2001-2009 • 6.5 yrs "before" study • 2.5 yrs "after" study • 1,922 crashes before • 477 crashes after	N/A	N/A	N/A	N/A	N/A	31.2% reduction in the total crashes	• Reduction was 55.6% for severe crashes, 26.6% for no severe crashes, 43.4% at curves, and 28.4% at tangents. However, the system's effectiveness decreased over time. • The greatest crash reductions were observed for severe crashes and crashes at curves.	The system produced a statistically significant reduction of 21% in total crashes in the part of the motorway where it was not activated, thus generating a significant spillover effect.
Australia (Champness et al. 2005)	Int. Case Study - Proceedings Road Safety Research	N/A	General	• GATSO wet film speed camera mounted on visible vehicle for 3 hours on Sept 14, 2004. • Measured time and distance halo effects of mobile overt speed cameras.	• Vehicle speed collected at 7 sites on the same road • Sites spaced 500 meters apart, two upstream from speed camera, one adjacent, and four downstream from speed camera • 100 km/h road	100 kph Last section of testing was 80 kph	110 kph ("Infringement" was used)	• Significant 6 kph reduction in mean speed	The number of vehicles exceeding the speed limit fell from 53% to 16% immediately adjacent to the operational camera.	• 7 kph reduction in 85th percentile vehicle speeds	N/A	N/A	• Speed reduction effects had completely disappeared by 1,500 meters downstream. • Upstream halos were negligible. • There was no time halo effect. • Speeds rebounded to pre-deployment speeds within 2 hours of camera removal. • Speed camera deployment will be most effective if it is within a maximum range of one kilometre from locations that have a history of high speed related crash risk.
Malaysia (Rohani et al. 2014)	Int. Case Study - Journal of Applied Sciences, Engineering and Tech.		School Zone	• Evaluation of speed camera warning signs at two elementary school zones in Parit Raja. • No fines for exceeding speed limit. • Speed camera warning signs installed in both directions • post-install data collected 1-month after date of installation	• Two elementary school zones in Parit Raja • Busy multi-lane arterials (2 lanes in each direction)	30 km/h		Speeds observed after the installation of speed camera warning signs were found to have significantly **increased.**	More than 50% of the Class 1, 2 and 3 vehicles were found to have been driven over 60 km/h.	N/A	N/A	N/A	When drivers figured out there was no fine for exceeding the speed limit speeds appear to have increased.
Literature Reviews													
US Literature Review: (Rodier et al. 2007)	TRB	Varies	General	Reviewed 17 studies in the US, Canada and Europe evaluating the safety effects of automated speed enforcement programs	Varies	Varies	Varies	A number of studies that evaluate the safety effects of automated speed enforcement programs were examined indicating approximately a 2 to 15 percent reduction in speed.	Studies show an overall decline in threshold speeds.	N/A	A number of studies that evaluate the safety effects of automated speed enforcement programs indicated a 9% - 50% reduction in crashes.	Many studies also find that the speed cameras were most effective at reducing more serious crashes involving injury and death.	
International Literature Review - Highway Safety Research Center (Thomas et al. 2008)	TRB	2008	General	Critical review of 13 international studies on a variety of roadway types.	Varies	Varies	Varies	N/A	•Greater reductions at fixed camera installations. • Speed -over-distance cameras were the most effective at reducing the percentage of drivers at more than 15 MPH above the limit.	N/A	N/A	On the basis of evidence from the best-controlled evaluation studies, injury crash reductions in the range of 20% to 25% appear to be a reasonable estimate of site-specific safety benefit from conspicuous, fixed-camera, automated speed enforcement programs.	Tables 2 and 3 give good summation of reviewed results.
International Literature Review (Pilkington, Kinra 2005)	British Medical Association (UK)	1992 - 2003	General	Review of 14 observational studies, most before/after studies without controls. • 6 studies assessed fixed cameras, 4 studied mobile cameras and studied the combination of fixed and mobile cameras	Varies	N/A	N/A	N/A	N/A	N/A	Reductions in outcomes across studies ranged from 5% to 69% for collisions.	Reductions in outcomes across studies ranged from 12% to 65% for injuries, and 17% to 71% for deaths in the immediate vicinity of camera sites.	All but one of the studies showed effectiveness of cameras up to three years or less after their introduction; one study showed sustained longer term effects (4.6 years after introduction).

General Research Information						1. Key findings for effectiveness in reducing and managing speeds					2. Key findings for safety		3. Key findings for spillover effects
Source	**Source Type/ Publication**	**Data Year**	**Topic**	**Study Methodology**	**Sample Size**	**Road speed limit(s)**	**Violation/ Threshold Speed Definition**	**Reduction in overall speeds (mean) & speeding (> posted speed)**	**Reduction in Threshold Speeds /Speeding Violations**	**Reduction in 85th Percentile Speeds**	**Overall crash reduction**	**Reduction in severe/serious/fatal**	**Spillover/Long Term Effects**
Case Studies													
International Literature Review (Decina et al. 2007)	NHTSA	2007	General	Review of 13 evaluation studies in the area of automated speed enforcement. • 4 studies evaluated local effects of fixed speed camera enforcement.	Varies	N/A	N/A	N/A	N/A	N/A	• Injury crash reductions of 20 to 25 percent for fixed speed cameras and 21 to 51 percent for mobile cameras. • Existing research indicates that automated enforcement systems can result in measurable safety improvements at high crash locations.	Significant and sizable crash reduction effects due to regression to the mean: up to half of observed fatal and serious crashes.	N/A
International Literature Review (Wilson et al. 2006)	Cochrane Collaboration (UK)	1984-2004	General	Review of 26 randomised controlled trials and controlled before-after studies that assessed the impact of speed enforcement detection devices on speeding, road crashes, injuries and deaths.	Varies	40-100 km/h	Varies	• Pre/post reduction in the proportion of speeding vehicles ranged across studies from 5% to 70% depending on the speed threshold set. • Compared with controls, the relative improvement was from 1% to 15% for average speed and from 14% to 65% for percent speeding.	• Pre/post reductions of 50% to 65% were reported in the proportion of speeding vehicles travelling >15 km/h over the speed limit.	• Speed enforcement study in Germany found 85th percentile speed drop from 42 to 37 km/hr for passenger vehicles • New Zealand nationwide before/after study saw reduction between 1.1%-1.6% for 85th percentile speeds at speed camera sites	• Pre/post reductions ranged from 14% to 72% for all crashes.	• Pre/post reductions ranged from 8% to 46% for injury crashes, and 40% to 45% for crashes resulting in fatalities or serious injuries. • Compared with controls, the relative improvement in pre/post crash numbers resulting in any type of injury ranged from 5% to 36%.	N/A
International Literature Review (Wilson et al. 2010)	Cochrane Collaboration (UK)		General	Review of 35 international studies	Varies		N/A	The relative reduction in average speed ranged from 1% to 15%.	The reduction in proportion of vehicles speeding ranged from 14% to 65%.	Many studies showed varying reduction in 85th percentile speeds, including: • Speed enforcement study in Germany found 85th percentile speed drop from 42 to 37 km/hr for passenger vehicles • New Zealand nationside study reduced by 4.3 km/hr on open roads cmopared to rest of county • Great Britain study showed reduction in 85th percentile speeds by 5.9 mph	The review found 8-49 percent reduction in crashes in the vicinity of camera sites. Over wider areas, the review found reductions of 9-35 percent for all crashes.	The review found 8-50 percent reduction for injury crashes and 11-44 percent for crashes involving fatalities and serious injuries, in the vicinity of camera sites. Over wider area, 17-58 percent for crashes involving fatalities and serious injuries.	Reviewed studies with longer duration showed that these trends were either maintained or improved with time.