

RESEARCH BRIEF

An Overview of Automated Enforcement Systems and Their Potential for Improving Pedestrian and Bicyclist Safety



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Introduction

The following paper summarizes the impacts of speeding and red-light running on pedestrians and bicyclists; describes automated speeding and red-light enforcement systems; reviews safety effectiveness evidence for these systems; and highlights resources that provide agencies information on complementary speed management approaches and guidance on developing automated enforcement programs based on safety principles and good practices.

Safety Consequences of Red-Light Running & Speeding

The costs of speeding and running red-lights are substantial. These actions not only endanger the motorist and the passengers in their car, but also other motorists, bicyclists, and pedestrians. Injuries and deaths caused by speeding and running red-lights negatively impact the physical and emotional health of individuals, families, and communities. They also result in major economic cost to society through loss of life, property damage, emergency response services, and law enforcement services.

Between 2010 and 2014, red-light running was, on average, involved in 706 fatalities per year. This represented 28% of annual fatalities at signalized intersections. During the same time period, on average, 37 red-light running-related fatalities per year involved a pedestrian or bicyclist (FHWA, 2017a). In 2015, the latest year for which data are available, 771 people were killed and 137,000 more were injured in crashes involving a driver that ran a red-light (IIHS, n.d.). The 2016 Traffic Safety Culture Index by AAA found 93% of drivers consider it unacceptable to drive through a red-light when they could have stopped safely, yet 36% admit to having run a red-light in the last 30 days (AAA Foundation for Traffic Safety, 2017). Finally, according to the National Safety Council's estimate of the average economic cost per death

in fatal motor vehicle crashes, the economic cost of red-light running fatalities in 2015 was \$1.2 billion (NSC, 2017).

Speeding is linked to an even greater number of traffic crashes and fatalities. Data from the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) shows speeding was associated with 30% of total traffic deaths for the ten year period of 2006 to 2015 (NHTSA, 2017a). At least one driver was speeding in 27% of all fatal crashes in 2016 and 10,111 lives were lost in these crashes (NHTSA, 2017b). Many more were seriously injured. Based on cost estimates from the National Safety Council and adjusting for inflation, the economic cost of speeding-related fatalities in 2017 totaled \$16.2 billion (NSC, 2017). Furthermore, research by the National Transportation Safety Board (NTSB) indicates speeding is under-identified as a factor in fatal crashes (NTSB, 2017).

Impact on Pedestrians & Bicyclists

Data on the total number of bicyclist and pedestrian injuries and deaths as a result of traffic crashes reveals persistent problems. In 2016, 840 bicyclists and 5,987 pedestrians in the United States were killed in traffic crashes. In 2015, the most recent year for which data are available, an estimated 45,000 more bicyclists and 70,000 pedestrians were injured (NHTSA, 2017b). This means, on average, a pedestrian was killed nearly every 1.5 hours. These pedestrian and bicycle fatalities accounted for 18% of the 37,461 traffic fatalities in 2016 (NHTSA, 2017b).

According to NHTSA's Federal Analysis Reporting System (FARS) data, in 2016, speeding was involved in 427 pedestrian and 56 bicyclist fatalities (NHTSA, n.d.). While these are the best estimates available, they are dependent on police officers' judgment after the event of a crash, and may not fully capture all levels of speeding. There are also wide state-by-state variations in how speeding is reported in crashes. For example, 14 states do not even report whether a vehicle was estimated to 'exceed speed limits' in a crash, and

Figure 1. Expected decrease in fatal crashes based on reduced operating speeds

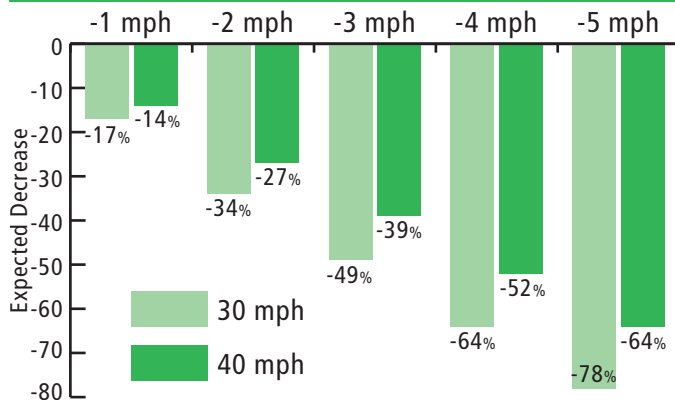
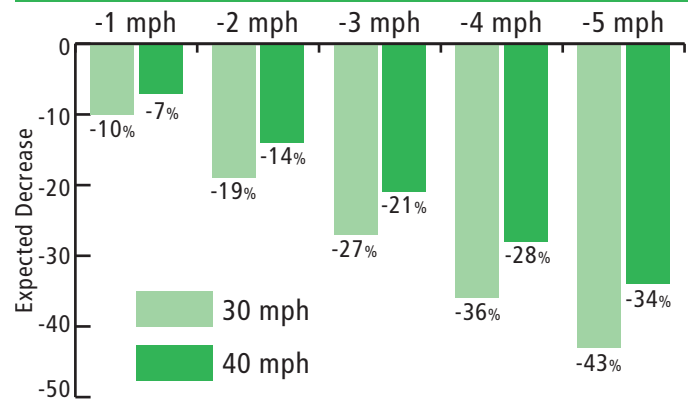


Figure 2. Expected decrease in injury crashes based on reduced operating speeds



Figures 1 and 2 were developed based on Table 3E-2 "Crash Modification Factors for Changes in Average Operating Speed" from the Highway Safety Manual, 1st Edition. The figures show how small reductions of 1 or 2 mph in average motor vehicle speed, especially at lower initial speeds, can significantly improve safety by reducing crash rates by the estimated percent (AASHTO, 2010). Crash effects are also expressed as crash modification factors (CMFs) or multipliers of baseline crashes. So, a crash reduction factor (CRF) of 17% or 0.17 would be a CMF of 0.83 (or $1 - 0.17$).

may rely mostly on subjective judgments such as 'too fast for conditions' (NTSB 2017).

Increased vehicle speed itself, regardless of the speed limit or speeding designation, has also been documented by research to have serious consequences when a pedestrian is involved. A number of researchers have studied the relationship between impact speed and pedestrian injury severity (Kröyer, Jonsson, & Várhelyi, 2013; Rosén & Sander, 2009; Tefft, 2012, and other earlier studies). Pedestrians and bicyclists are particularly vulnerable to speeding and to incrementally higher speeds in general. Research on the relationship of speed and crash severity at speeds under 30 mph shows an increase of 1 or 2 mph in vehicle impact speed results in significantly higher risk of severe injury and fatality for pedestrians (Kroyer et al. 2013).

Research conducted for the first edition of the Highway Safety Manual supports this general finding based on analyses of data for all crash types. A one mph reduction in average operating speed on a road section was estimated to result in a 17% decrease in fatal crashes, and a 10% decrease in injury crashes of all types based on an initial average operating speed of 30 mph (AASHTO, 2010 - see Figures 1 and 2).

Traffic speed is also important to perceptions of safety, and the level of stress a pedestrian or bicyclist may encounter on a given street. Pedestrians and bicyclists may feel comfortable on streets that carry a lot of traffic at low speeds, but can become discouraged if the traffic is travelling at higher speeds (Mekuria, Furth, & Nixon, 2012). Automated enforcement systems, together with engineering measures and education, can assist in making roads safer and more appealing for pedestrian and bicycle use.

In 2016, 26% of pedestrian fatalities and 37% of bicyclist fatalities occurred at all types of intersections (NHTSA, n.d.). Unfortunately, it is difficult to acquire precise data on the number of pedestrian and bicyclist injuries and deaths that involve red-light running. However, in 2014, the latest year for which data were available, more than 60% of people killed in red-light running crashes were road users other than the driver running the red-light – this includes passengers, occupants of other vehicles, pedestrians, and bicyclists (IIHS, 2016). Additionally, research shows red-light runners are more likely to also be speeders (Eccles, Fielder, Persaud, Lyon, & Hansen, 2012).

Reducing the number of traffic crashes caused by speeding and running red-lights is vital to diminish

the negative impacts of unlawful behavior and thus increase roadway safety for all road users, including pedestrians and bicyclists. Providing widespread, around-the-clock traffic enforcement through use of officers alone is challenging due to reduced staffing levels, increasing amounts of travel, and conflicting enforcement priorities (NTSB). Communities are seeking ways to enhance the presence and effectiveness of traffic law enforcement to complement other safety programs to reduce crashes and injuries. Use of automated enforcement systems is one way to consistently and objectively enforce established traffic laws and deter dangerous driver behaviors at locations and times where traditional enforcement may be difficult to implement or insufficient (Farmer 2017; FHWA & NHTSA, 2008).

Automated Enforcement Systems: Definition and History

An automated enforcement system uses an electronic camera to enforce traffic laws by assisting with detection of infractions and providing photo documentation of the vehicle or driver violating the traffic law. Two of the most common types of automated enforcement systems are red-light cameras and automated speed enforcement cameras.

Red-Light Cameras (RLC)

Red-light cameras take photographs of vehicles entering intersections after the traffic signal has turned red. In most instances, offenses are detected by sensors in the pavement, which are tied to a timing system that connects the traffic signal and pole-mounted camera. The camera photographs the vehicle, license plate, and/or driver, usually when the vehicle enters the intersection on red as well as while the vehicle is in the intersection (Eccles et al., 2012). Photos are reviewed by local jurisdiction officials such as police officers, or by both the camera vendor and local jurisdiction officials. The vehicle owner

of record or driver may then receive a citation. RLCs are used throughout the world, though most comprehensively in Australia, Canada, Europe, Singapore, and the United States (Eccles et al., 2012). They have been in place in the United States since 1993, and are estimated to be in use in over 400 communities (Goodwin, Thomas, Kirley, O'Brien, & Hill, 2015; IIHS, 2017).

Automated Speed Enforcement Cameras (ASE)

Automated speed enforcement cameras generally use photo radar technology to monitor and/or enforce posted speed limits (Eccles et al., 2012). ASE systems include:

- **fixed cameras**, which continually monitor traffic speeds without an operator;
- **semi-fixed cameras**, with cameras that are rotated between housings resulting in housings with active cameras and 'dummy housings' without cameras;
- **mobile camera operations**, most often deployed in vehicles with or without enforcement agents present; and
- **average speed enforcement systems** that measure average speed between two check points on a roadway.

ASE may also be combined with RLCs when used at intersections. In all ASE systems, a computer-controlled camera takes a photograph of the vehicle and license plate when the vehicle exceeds the enforcement threshold – a set number of miles above the posted speed limit. The camera records the time, date, location and speed as well. For states that require driver liability, legible photographs of the driver are also necessary. The citation is then mailed to the owner of the vehicle, who may be required to pay a fine or identify the offending driver. ASE technology has been utilized in the U.S. since 1986, and is in use in 142 communities (NTSB, 2017; IIHS, 2017).

Safety Impact of Automated Enforcement Systems

A 2007 NHTSA study titled *Automated Enforcement: A Compendium of Worldwide Evaluations of Results* produced a compendium of evaluation studies of automated enforcement systems worldwide. Critically reviewing studies through 2005, the researchers evaluated the safety impact of these systems (Decina, Thomas, Srinivasan, & Staplin, 2007). Narrowing the results to studies that evaluated effects on crashes, seven studies of RLCs and 13 ASE studies were reviewed. In general, the review found RLCs and ASE led to substantial reductions in crashes resulting in injuries.

Regarding RLCs, the compendium concluded RLCs reduce crash severity at intersections with high rates of red-light running. Yet the studies suggest that while RLC implementations led to a decrease in red-light running violations and a 25% decrease in right-angle crashes at red-light intersections, there was on average a 15% increase in lower-severity rear-end crashes, which somewhat offset the angle crash reductions (Decina et al. citing Eccles Lyon and Griffith 2005). An economic analysis incorporating crash severity found, however, a net benefit of the RLC systems due to an overall decrease in crash severity. Furthermore, benefits were greater at locations with a high ratio of right-angle to rear-end crashes; with a higher proportion of entering average daily traffic (ADT) on the major road; with shorter cycle lengths and green timing phase periods; and with one or more left-turn phases (Decina et al., 2007).

All 13 reviewed studies on automated speed enforcement reported statistically significant reductions in crashes following the introduction of automated speed enforcement. The most robust evaluations reviewed were of fixed, conspicuous camera enforcement programs used to treat specific high crash spots or lengths of roadway, ranging in length from 0.31 mi (500 m) to 3.2 m (5.2 km). A follow-up article to the compendium using evidence from the best-controlled evaluation

studies, concluded the best estimate of injury crash reductions from these studies is in the range of 20-25% for fixed camera ASE programs (Thomas, Srinivasan, Decina, & Staplin, 2008).

Covert, or unmarked and inconspicuous mobile enforcement programs were used in Australia and Canada to increase the general deterrent effect by increasing the perception that speed enforcement may be encountered anywhere. Review of these types of implementations, which may be relevant for pedestrian and bicyclist safety throughout developed areas, also provided evidence of crash reductions in the range of 20 – 25% system-wide. However, these results are based on only two studies (Thomas et al., 2008).

Studies of conspicuous (marked and well-publicized) mobile enforcement programs at select corridors yielded more variable effect estimates possibly due in part to treatment differences and partly due to study differences, but all the studies reviewed by Decina et al. (which were conducted from 2000 – 2005) estimated crash reductions.

One study reviewed by Decina et al. estimated a reduction in crashes that injured pedestrians, but this finding should be considered with caution. Still, around half of all the crash-based ASE evaluations reviewed by Decina et al. also documented speed reductions that provide supporting evidence for crash effects and potential safety benefits to pedestrians (Decina et al., 2007). (The other studies did not measure operating speeds.)

Studies and articles released after the completion of NHTSA's compendium generally support the results of its reviews of the safety impacts of automated enforcement systems. A 2010 well-controlled study on red-light running in Iowa, found RLCs were effective in reducing total crashes, as well as red-light running crashes. Interestingly, this study found rear-end crashes did not increase at intersections with RLCs (Hallmark, Orellana, McDonald, Fitzsimmons, & Matulac, 2010). Observational data of driver behavior at intersections with combined red-light and

speed cameras found that warning signs on the intersection approach reduced the likelihood of rear-end collisions (Polders et al., 2015).

Considering citywide roadway safety, a 2011 report concluded the decline of fatal red-light running crashes was greater for cities with red-light camera enforcement programs than for cities without programs (35% vs. 14%) (Hu, McCartt, & Teoh, 2011). Additionally, the report showed the rate of fatal red-light running crashes during 2004-2008 for cities with camera programs was 24% lower than what would have been expected without cameras. Researchers have also studied the safety impacts of ending RLC programs. A 2017 study by Hu and Cicchino, analyzed crashes at signalized intersections in large U.S. cities that terminated RLC programs compared to similar cities with continuously operating RLC programs. The report determined cities with ongoing RLC programs had significantly lower annual rates of both fatal red-light running crashes and fatal crashes at signalized intersections; 21% and 14% respectively.

There have also been several studies and articles on ASE since the compendium. A 2008 study of speed cameras found that cameras significantly reduced the mean speed of vehicles and led to an 88% decrease in the odds of vehicles travelling 11 mph or more above the 65 mph speed limit (Retting, Kyrychenko, & McCartt, 2008). A 2010 report by Moon and Hummer on ASE cameras deployed in Charlotte, NC during the years 2004-2006, found a significant reduction in collisions on the corridors with cameras in place. These reduction trends continued for some time after when the cameras were removed, suggesting an effect due to publicity of the camera enforcement, though collisions slowly returned to pre-deployment levels.

Other studies show ASE can improve safety on highways and in work zones. An evaluation of the use of fixed camera systems to enforce speed limits on an Arizona freeway documented significant crash and speeding reductions (Shin, Washington, & van Schalkwyk, 2009). Finally, a

2011 concluded ASE reduced the speed of cars and trucks by three to eight mph in work zones (Tobias, 2011).

ASE has been proven to be effective on lower-speed streets too. A well-controlled study analyzing the effect of mobile ASE at midblock locations on urban arterials with speed limits of 50 km/h (~ 31 mph) in Edmonton, Alberta, Canada, linked ASE to significant reductions for all crash types and crash severity levels. The largest reductions were estimated for severe crashes – a 20% decrease (Li, El-Basyouny, & Kim, 2015). The report also found greater reductions at locations with comparatively more enforcement hours per year and continuous enforcement year-to-year. A study using similar data from Edmonton, but focusing on rotation schedules for mobile ASE, found that shorter (1 hour vs. 2 hours), but more frequent enforcement intervals at the enforcement locations resulted in 75 fewer speed-related crashes per month, on average. Based on the finding, the researchers suggest increasing coverage by reducing the time period of individual enforcement operations, while increasing the frequency of coverage (Li, El-Basyouny, Kim, & Gargoum, 2016).

The Montgomery County, Maryland, ASE program is restricted to school zones and streets with speed limits of 35 mph and lower. Using a before-and-after with comparison group, Hu and McCartt (2016) concluded Montgomery County's ASE program, which was also well-publicized, significantly decreased the likelihood of a fatal or incapacitating crash on these types of ASE-eligible roads by 19%. This program further implemented and evaluated a corridor-focused enforcement approach by rotating semi-fixed cameras to provide enforcement along corridor segments rather than a single point on the corridor. The rotation of locations along a corridor further decreased likelihood of a fatal or incapacitating collision by 30% (Hu & McCartt, 2016).

Although the corridor approach in Montgomery County, Maryland, discourages speeding at multiple enforcement points along a roadway, it is

different from average speed enforcement (speed-over-distance). Average speed enforcement implementations discourages speeding along an entire roadway segment because it records average speed between cameras located at the beginning and end of the enforcement segment. At the time of this review, average speed enforcement technology does not yet seem to be deployed in the U.S., and there are currently no operational guidelines from FHWA (NTSB, 2017). Research shows average speed enforcement can reduce the proportion of speeding vehicles and the 85th percentile speed of free flowing traffic on roadways (Goodwin et al., 2015; Soole, Watson, & Fleiter, 2013). This finding is important because speed-over-distance may be perceived as a 'fairer' approach to enforcement and may reduce the tendency noted in some studies of drivers slowing at and speeding up after passing localized enforcement zones (Thomas et al., 2007). This finding may also be important since many communities set speed limits based on the 85th percentile of free flow traffic. However, using the 85th percentile in this way is not mandatory, nor does it prioritize safety as it can encourage ever-increasing speed limits (Goodwin et al., 2015).

Studies of combined red-light and speed cameras are limited. Using proper controls, a study of combined red-light and speed cameras in Edmonton, Canada, found significant reductions to total crashes (25%), angle crashes (33%), and rear-end crashes (11%) (Contini & El-Basyouny, 2016).

In response to these studies, a number of agencies and organizations recognize the potential of automated enforcement systems to reduce traffic crashes and fatalities. Among these are: FHWA, NHTSA, NTSB, the National Association of City Transportation Officials (NACTO), the CDC, the American Association of State Highway and Transportation Officials (AASHTO) Board, AASHTO's Standing Committee on Highway Traffic Safety (SCOHTS), and the International Association of Chiefs of Police (IACP) (Eccles et al., 2012; NTSB, 2017). There is not yet much evidence, and

effectiveness of automated enforcement systems on pedestrian and bicyclist safety is difficult to determine due to the relatively low frequency of pedestrian collisions, especially at specific locations, and a frequent lack of pedestrian count data. Regardless, the information presented on the consequences of red-light running and speeding suggest reductions to these unlawful behaviors may improve the actual and perceived safety of pedestrians and bicyclists.

Enhancing Effectiveness of Automated Enforcement

Several guides exist to help communities implement automated enforcement systems. NHTSA, FHWA, the Federal Motor Carrier Safety Administration (FMCSA), and the National Cooperative Highway Research Program (NCHRP) have developed comprehensive guides (Eccles et al., 2012; FHWA & NHTSA, 2005; FHWA & NHTSA, 2008). These guides methodically describe the process of developing automated enforcement programs, including planning, program startup, operations, adjudication and evaluation. They include best practices and case studies, which can be used by cities to start or improve their use of automated enforcement systems. They also note that, in combination with public education and enforcement provided by automated enforcement systems (as a supplement to officer enforcement), additional roadway design countermeasures are the most effective way to minimize crashes from red-light running and speeding. NTSB recently released a report that provides recommendations for updating some of these federal guides (NTSB, 2017).

Combining automated enforcement systems with traffic calming measures has been proven to be most effective. In Portland, a study of ASE conducted in 2005 in school zones around the city found that speed reduction was greatest when ASE was combined with the use of a flashing beacon indicating the speed limit and fines for speeding in the school zone. This combination

resulted in an effect on speed reduction twice that of ASE alone. This same study found the effects of ASE on speed reduction were sustained for, at minimum, a full month at the demonstration sites following camera removal (Freedman et al., 2006).

An information brief titled Engineering Countermeasures to Reduce Red-Light Running developed by FHWA suggests the following engineering improvements to counter red-light running: increase the size of traffic signal lamps from 8 to 12 inches; add additional signal heads; implement an all-red clearance interval of 1-3 seconds; install advanced warning signs/flashing lights; adjust the approach speed; add a green phase extension for cars in the dilemma zone; remove on-street parking and unwarranted traffic signals; install advanced traffic signals; and time yellow lights appropriately (FHWA, 2009).

Each of these engineering countermeasures should (likely) be considered and employed on a site by site basis, with the intent of increasing overall safety and reducing crashes. For example, regarding the timing of yellow lights, Insurance Institute for Highway Safety (IIHS) researchers suggest that cities increase the length of the yellow phase incrementally and let the RLC document the results (Retting, Feguson, & Farmer, 2008). This allows the city to determine the optimal time a light should remain yellow at each intersection to maximize the safety effects of the automated enforcement systems.

To increase program effectiveness, another strategy is to rotate RLCs between multiple intersections to maximize efficiency with a limited amount of camera systems. A study conducted in 2010 found, however, that having RLCs fixed at the most problematic intersections was more effective than rotating cameras between different locations (Tay & DeBarros, 2011). The study argues that risk-taking drivers will choose not to obey the law if they are uncertain about enforcement; thus having consistent enforcement at the most problematic intersections is the best or more effective approach to maximize safety. Some jurisdictions have also developed a grace

Primary Resources for Automated Enforcement Programs

- [*Red-Light Camera Systems Operational Guidelines*](#) (2005) – FHWA & NHTSA
- [*Speed Enforcement Camera Systems Operational Guidelines*](#) (2008) – FHWA & NHTSA
- [*Automated Enforcement for Speeding and Red Light Running*](#) (2012) – NCHRP
- [*Countermeasures That Work, 8th Edition*](#) (2015) – NHTSA
- [*Reducing Speeding-Related Crashes Involving Passenger Vehicles*](#) (2017) – NTSB

time of 0.1 or more seconds before the camera begins taking photos. This can reduce the number of citations issued and decrease the number of citations contested in court, as well as increase public acceptance of the system (Eccles et al., 2012; Farmer, 2017).

For ASE, the document Speed Enforcement Camera Systems Operational Guidelines, developed by NHTSA, FHWA, and FMCSA, offers a number of engineering countermeasures to aid the effectiveness of ASE programs. FHWA's Speed Management Toolkit also details appropriate countermeasures with speed and crash reduction evidence (Thomas, Srinivasan, Worth, Parker, & Miller, 2015). Measures mentioned by these resources include: speed-lowering geometric designs such as roundabouts at intersections; lane number reductions (road diets); traffic-calming devices such as speed tables and humps for lower-speed roads; pavement resurfacing/friction treatments; and setting appropriate speed limits (FHWA & NHTSA, 2008; Thomas et al., 2015). In addition, publicity of enforcement programs is also considered an effective way to enhance deterrent effects of enforcement and increase effectiveness (Goodwin et al. 2015).

Strategies to enhance effectiveness of camera-based speed enforcement are also mentioned in guidance documents. Speed Enforcement Camera Systems Operational Guidelines (FHWA & NHTSA) again suggests that cameras can be rotated among a greater number of “housings” for a semi-fixed system allowing cities to deter speeding at a greater number of locations despite a limited number of cameras. If “dummy housings” are set up, these guides suggest cities should still focus principally on high risk roads and zones. A policy review found cameras placed in low-risk environments can lead to public skepticism regarding the motive for their use (Willis, 2006). Additionally, many cities consider the enforcement threshold or speed tolerance, which is the difference between the posted speed limit and the speed at which tickets are issued. Typical ranges for enforcement thresholds are 4-11 mph over the posted speed limit, subject to location and whether or not it is in a school or work zone (Eccles et al., 2012). Research from Australia and Finland shows that lowering enforcement thresholds in a well-publicized manner can increase potential for reduced speeds (Goodwin et al., 2015). However, some jurisdictions may want to begin programs with a higher threshold to reassure the community the program is taking a reasoned approach. The area of citation thresholds may warrant additional investigation. At least, program operators may share evidence that citation thresholds are clearly within detection tolerances of the measurement equipment.

Potential Challenges to Automated Enforcement Programs

Issues surrounding automated enforcement can present challenges to developing and implementing effective programs. Many of these challenges may be addressed by public education and outreach, and by modifying or carefully establishing program components. More and more, highway safety stakeholders are also

looking to lessons learned from the public health community for communicating effectively about injury prevention and the reasons for traffic safety programs and measures.

According to US DOT, communication with residents should always emphasize the proven benefits of automated enforcement with safety as the first and foremost reason for implementing such a system (FHWA & NHTSA, 2008). Marketing automated enforcement as a safety tool is most effective when such systems are evaluated for effectiveness and used to complement other roadway safety initiatives. Additionally, the CDC recommends framing injury prevention programs in terms of allowing people to fully live out their lives, free of disabling injury and communicating this message consistently (NCIP & CDC, 2010).

Legal Issues

Some of the main Constitutional challenges raised by critics involve due process, equal protection, the fourth amendment, the “takings clause” of 5th amendment, and privacy (Lynn et al., 1992). Yet, each time the issue of constitutionality has been raised, the courts have upheld the legality of automated enforcement systems (FHWA & NHTSA, 2008). Courts have, however, found issue with certain operational aspects of ordinances.

The legal requirements for automated enforcement are discussed in the Red-Light Camera Systems Operational Guidelines, Speed Enforcement Camera Systems Operational Guidelines, and the 2008 NCHRP Report. Although automated speed enforcement programs have, in the past, been implemented in communities without state level enabling legislation, these programs have been more vulnerable to legal challenges, which often contributed to their demise (Rodier, Saheen, & Cavanaugh, 2007). Communities should address legal requirements and necessary resources early on. For example, to protect against evidentiary challenges, jurisdictions may establish time frames for mailing citations to violators, procedures for extracting image data from cameras, and standards for processing and storing photo

Figure 3. States using speed and/or red-light cameras (Source: Insurance Institute for Highway Safety, www.iihs.org, November 2017)

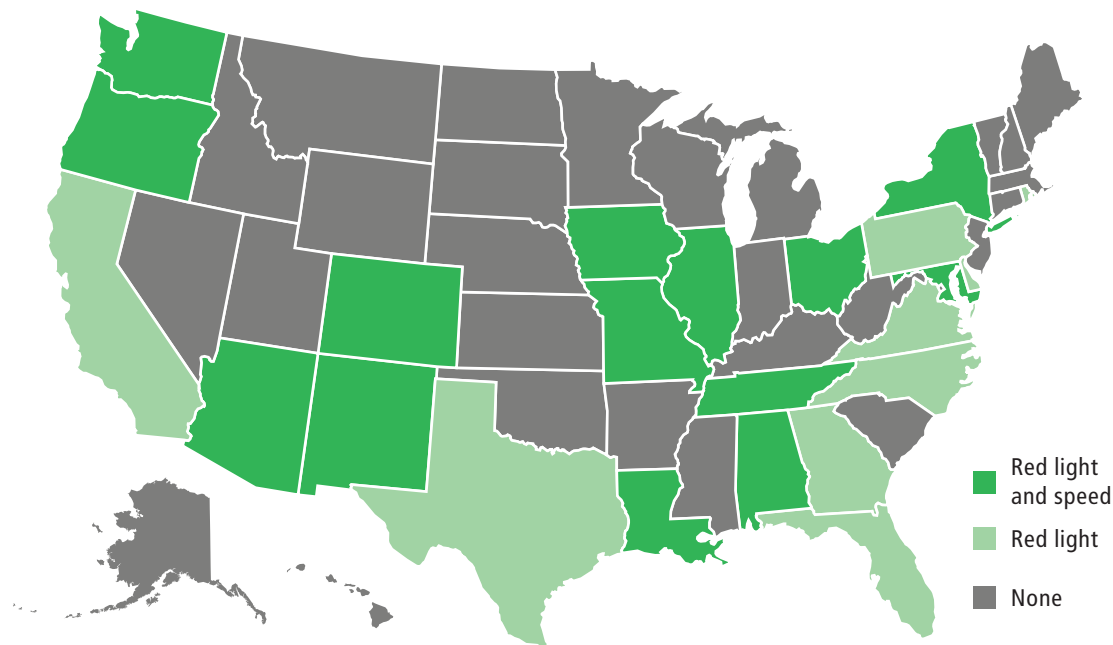


Figure 3 displays which states allow each system, and the Insurance Institute for Highway Safety website provides more information on specific details and the laws in individual cities (IIHS, 2017).

evidence (Lynn et al., 1992). Without these safeguards, a jurisdiction will be at risk of having the system challenged in court. A study by the city of Toronto (2016) estimated implementation of a new mobile speed enforcement program would require six months for legal review of the program and one to two years to expand court services.

Public Opinion

Opponents also often express the belief that automated enforcement systems are used primarily to generate revenue, the cameras are faulty, speeding is not a pressing issue, or some prefer direct officer contact (Eccles et al., 2012; NTSB, 2017; Farmer, 2017). In general, public opinion surveys show more support for red-light cameras than for ASE (Goodwin et al., 2015; Cicchino, Wells, & McCartt, 2014). Additionally, support for automated enforcement tends to increase after a program is in operation (Cicchino et al., 2014; NTSB, 2017). A recent national survey by the AAA Foundation for Traffic Safety (2017) found 55% of respondents supported RLCs on residential streets and the same percent supported RLCs in urban areas. For ASE, the AAA survey found 58% support for using ASE with a 10 mph enforcement

threshold in school zones, but slightly less support for using ASE with a 10 mph enforcement threshold on residential streets (43%) and in urban areas (42%) (AAA Foundation for Traffic Safety, 2017).

To foster positive public opinion, communities may benefit from taking time to consider how people perceive road safety and initiating a dialogue about injury prevention using such materials as *Adding Power to Our Voices: a framing guide for communicating about injury* (NHIP & CDC, 2010). In terms of program elements, communities may consider first implementing and evaluating an automated enforcement pilot program. Areas such as school zones and work zones may be good candidates for pilot programs as children and road workers are viewed as especially vulnerable to traffic injury (Goodwin et al., 2015; NTSB, 2017). Vendor contracts and fee structures should also be addressed to prioritize public safety and be clearly conveyed to the public for a transparent program (Eccles et al., 2012; Madsen & Baxandall, 2011). FHWA recommends against paying vendors on a per citation basis (Goodwin et al., 2015). In some communities, fines associated with automated enforcement are lower than fines issued by

enforcement officers for the equivalent violation (City and County of San Francisco, 2015). Evidence suggests that the certainty of penalties may be more important for deterrence than the amount of the penalty (Goodwin et al., 2015). NCHRP recommends any revenue generated in excess of operating costs be spent on additional roadway safety initiatives (Eccles et al., 2012).

Some citizens do not understand the connection between speed and crash severity. Effective communications are key, however traditional means of providing information may not always be effective. An interactive survey of residents in Minnesota found that after providing all interview participants with information about the safety effects of speed and ASE, the people who switched to having a more favorable opinion of ASE responded very positively to the safety information while people who remained unfavorable to ASE continued to express inaccurate opinions about the relationship between speed and safety (Peterson, Douma, & Morris, 2017). While research shows education campaigns can improve effectiveness of automated enforcement systems as well as public opinion of such systems, educational campaigns are not guaranteed to positively influence opinion (NTSB, 2017; Peterson et al., 2017).

Education campaigns may be used to explain how automated enforcement works and why such a program is worthwhile to a community in terms of saving lives and preventing serious injuries (FHWA & NHTSA, 2005; FHWA & NHTSA, 2008; NCIP & CDC, 2010). Guides also suggest that information about a community's automated enforcement program should be easy to find and include answers to frequently asked questions, what safeguards in place to ensure only those who are in clear violation receive citations, and how to make an appeal, if there is a mistake. For RLCs, education about proper response to yellow lights is also necessary, as legal codes differ between states. Furthermore, program partners can be crucial to education efforts – findings from an interactive survey of residents in Minnesota

suggest information about ASE may be more effective from an independent, non-governmental body (Peterson et al., 2017).

Discussion

Speeding and red-light running continue to have a detrimental impact on individual lives and society as a whole. Currently few studies have explored the impact of automated enforcement as it relates to pedestrian and bicycle safety directly, likely due to data constraints. However, the reduction of vehicle speeds and crash severity that have been documented to result from ASE and RLCs is expected to create a safer environment for vulnerable road users.

Research shows automated enforcement can be an effective tool for improving roadway safety, especially when combined with other countermeasures. Automated enforcement systems are tools to compliment engineering, traditional enforcement, and educational and public information improvements to help enforce traffic speeds when these other measures alone are insufficient. When legally allowed, revenue generated from automated enforcement programs may be used to enhance these other types of safety programs. Engineering improvements such as roundabouts, road diets, and traffic calming treatments play a significant role in lowering the number of speeding-related crashes, as well as creating permanent reductions in speed that require less (but still some) support from enforcement. Similarly, engineering improvements to signalized intersections can enhance safety and reduce the need for supplemental enforcement. Educating the public and other key stakeholders can foster public support and help improve program effectiveness and acceptance. Involving each department or jurisdictional entity with a role in traffic safety and planning is necessary to build the cooperation and collaboration, while maintaining a focus on safety. Automated enforcement complements a comprehensive approach to addressing issues of traffic safety, and, evidence suggests, contributes to a decrease in the number of crashes, serious injuries, and fatalities.

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Since its inception in 1999, the Pedestrian and Bicycle Information Center's (<http://www.pedbikeinfo.org>) mission has been to improve the quality of life in communities through the increase of safe walking and bicycling as a viable means of transportation and physical activity. The Center is maintained by the University of North Carolina Highway Safety Research Center with funding from the U.S. Department of Transportation.



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