U.S. Department of Transportation
Federal Highway Administration

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Model Evaluation Plan for Work Zone Speed Safety Cameras

INTRODUCTION

Highway construction and maintenance efforts can create a high-risk environment for highway workers. Operating agencies provide a safe workspace for the highway workers and ensure that drivers can navigate the work zone in a safe and efficient manner. There are many proven and documented countermeasures that could improve safety for all users through a work zone. These countermeasures incorporate speed management, including speed enforcement. However, speed enforcement is labor intensive and can be difficult or even hazardous to law enforcement officials given the physical constraints of a work zone.

Speed safety cameras (SSCs) are recognized as one of the 28 proven safety countermeasures by the Federal Highway Administration (FHWA) and are named as a National Highway Traffic Safety Administration (NHTSA) 5-star countermeasure. SSCs are highly effective in reducing fatalities and serious injuries on the Nation's highways.[1] Specifically, implementation of SSCs in work zones can reduce severe crashes while also minimizing risks for workers, reducing speeding, and smoothing traffic flow. SSCs detect speeding vehicles and capture photographic and video evidence of the vehicles that violate a set speed threshold using speed measurement devices.

Using speed measurement devices such as SSCs may raise concerns about privacy, lack of presence of law enforcement, and perceived revenue generation. Therefore, agencies should document all aspects of SSC implementation and evaluate its effectiveness in achieving the safety goals of the effort. The FHWA and NHTSA *Speed Safety Camera Program Planning and Operations Guide*,[2] published in 2023, identifies program evaluation and monitoring as one of the 6 key steps for deploying SSCs to determine if safety goals are being met and to identify possible changes to improve effectiveness and public perception. This documentation includes a comprehensive evaluation plan, which captures the resulting outcomes.

An evaluation of SSCs includes both quantitative and qualitative measures and would provide an agency with invaluable material to share within the agency, with the traveling public, or with others. In some States, SSC evaluation metrics may be required, either within the operating agency or by State legislation that authorizes the use of SSCs.

This document provides foundational materials that agencies may use as a starting point when developing a plan and conducting an evaluation of work zone SSCs. Specifically, this document presents considerations for data collection and analysis with the understanding that the goals, available data, and nature of work zone SSCs are likely to vary for every agency.

EVALUATION PLAN AND ASSOCIATED METRICS

An SSC evaluation plan provides a structure for examining the SSC program's progress toward achieving the program goals. Regular and frequent monitoring of certain performance aspects of the program confirms program reliability (i.e., that the system is functioning appropriately). There are several key components of an evaluation plan, including:

[1] *Proven Safety Countermeasures: Speed Safety Cameras*, FHWA, 2023. https://highways.dot.gov/safety/proven-safety-countermeasures/speed-safety-cameras.

[2] *Speed Safety Camera Program Planning and Operations Guide*, FHWA, January 2023. https://highways.dot.gov/sites/fhwa.dot.gov/files/Speed Safety Camera Program Planning and Operations Guide 2023.pdf.

- The program monitoring needs and performance measures.
- The elements of the program to be evaluated (e.g., safety effects, speed effects, equity effects, operations outputs, public opinion, enforcement outcomes).
- A data collection and analysis plan.
- The reporting methods for the dissemination of the findings.[3]

Legislation may dictate some aspects of the plan, such as the performance measures. All aspects of the SSC deployment need to be well documented for the elements to be evaluated and the subsequent data collection and analysis plan, including such information as:

- The costs to implement the system, including procurement and installation costs, as well as costs to operate the system.
- Dates, times, and locations where the systems are deployed.
- Details about the work zone (e.g., road classification, historical traffic volumes, type of work zone, presence of workers, presence of channelization).
- Details about other work zones with similar conditions to be used for comparison purposes (e.g., same approximate locations, same approximate times, same presence or absence of work activity and proximity to that activity).

The elements to be evaluated determine which metric (or metrics) will be used to evaluate the system performance. Metrics can be quantitative or qualitative and may vary based on deployment type. Several factors, such as the location of the deployment (e.g., rural versus urban), ease with which to collect data, or ease of access to data (e.g., law enforcement-issued citations) will form the basis of which consideration to use for the evaluation. Such factors should be taken into consideration before deployment so that the best metric is used in each case.

Table 1 summarizes the types of metrics that can be used to evaluate the SSC program. These metrics are described below in more detail. While not specifically listed in this table, additional data sources describing work zone characteristics where SSCs are deployed and the SSC deployment dates, times, and locations are also needed to support a robust evaluation; data about other work zones with similar conditions may also be desired for comparison purposes.

Table 1. Data and analyses to evaluate work zone speed safety camera (SSC) effectiveness.

System Goals	Data Source	Possible Measures
Reduced Vehicle Speeds	Speed	- Changes in speed: • Within the work zone where an SSC is deployed. • Upstream and downstream from the same work zone. - Relative changes in speed for different work zone conditions (road classification, channelization, etc.) where an SSC is deployed. - Changes in speed variance at the work zone where an SSC is deployed. - Continued changes in speed after implementation (i.e., the halo effect). - Changes in speed at work zones without an SSC and systemwide.
	Citations	- Number of citations issued. - Changes in the number of citations issued. - Changes in speed for which citations are issued (e.g., are fewer citations issued for >20 mph over the speed limit?). - Disposition results of issued citations.
	Costs	Number of citations issued.
	Opinions and Surveys*	- Number of citations issued. - Changes in the number of citations issued. - Changes in speed for which citations are issued (e.g., are fewer citations issued for >20 mph over the speed limit?). - Disposition results of issued citations.

[3] Ibid (*Speed Safety Camera Program Planning and Operations Guide*).

System Goals	Data Source	Possible Measures
Reduced Crashes – Traveling Public	Crashes	- Fatal crashes in work zones with an SSC - Injury crashes in work zones with an SSC - Total crashes in work zones with an SSC - Crashes by type in work zones with an SSC - Speeding-related crashes in work zones with an SSC - Crashes systemwide, including possible migration
	Documented "Near Misses"	"Near miss" incidents as measured by video analytics or other potential sources
	Costs	Number of citations issued
	Opinions and Surveys*	- Public perception of SSC program - Worker perception of SSC program - Staff (i.e., those responsible for SSC implementation) perception of SSC program
Reduced Crashes – Workers	Crashes	Work zone crashes involving workers
	Documented "Near Misses"	"Near miss" incidents between workers and vehicles as measured by video analytics or other potential sources
	Costs	Benefit-cost analysis with respect to worker safety
	Opinions and Surveys*	Perception of improved safety when work zone SSCs are present
Improved Mobility	Speed	- Changes in speed at the work zone with an SSC - Changes in speed variance at the work zone with an SSC - Changes in speed and speed variance systemwide
	Throughput	- Changes in throughput (vehicles/hour) - Changes in traffic flow (e.g., reduction in hard braking, stop-and-go traffic)
	Costs	Benefit-cost analysis with respect to mobility
	Opinions and Surveys*	- Public perception of SSC program - Worker perception of SSC program - Staff (i.e., those responsible for SSC implementation) perception of SSC program
Equity	Citations	Representation of different demographics across citations
	Surveys*	Public perception of SSC with respect to equity

*Denotes a qualitative data source

Quantitative Metrics

As mentioned earlier, the authorizing legislation in some States may mandate which metrics are reported to the legislature (e.g., crash or speed statistics), whereas other States may state that a report is required or make no mention of reporting at all. These factors should be taken into consideration before deciding which of the following metrics to use in the evaluation. Four primary quantitative metrics for evaluating the effectiveness of a work zone SSC program are described in this section: speed data, crash data, citation data, and cost data.

Speed Data. Perhaps the most direct measure of SSC effectiveness is change in travel speeds through a work zone. These changes include absolute changes in speed as well as changes in speed variance—i.e., the difference in operating speeds among vehicles traveling on a roadway. Such changes can be reported in terms of the following:

- Changes in average speed or 85th-percentile speed when an SSC is present versus when it is not present.
- Changes in percentage of drivers exceeding the posted speed limit or target thresholds (SSC presence versus no SSC presence).
- Changes in speed variance (SSC presence versus no SSC presence).

To better understand SSC effects, compare speeds when an SSC is present at a work zone to similar conditions (i.e., same approximate locations, same approximate times, same presence or absence of work activity, and proximity to that activity) when an SSC is not present. If the SSC is a permanent installation for the duration of the work zone, compare changes in speed from upstream of the work zone to those passing through the work zone to similar work zones where an SSC is not deployed. However, such a comparison must also recognize that other differences between the two work zones may also contribute to any differences in observed speed behavior. Similarly, for a thorough analysis, document the posted speed limits in and around the work zone, including the normal posted speed limit and any advisory or enforceable work zone speed limits.

SSC impacts at a single work zone can be measured by comparing speeds at the work zone prior to SSC deployment to speeds during SSC deployment. The measurement should include speeds upstream, within, and downstream of the work zone. As described in the following section, document the halo effect, a phenomenon that will affect speeds after SSC deployment. Therefore, in the cases where SSC effects will be measured as a single work zone, comparing speeds after SSC implementation may be problematic due to these potential halo effects.

Temporal and spatial halo effects of SSC deployment may interest us if data are available. Typically, halo effects have been measured in terms of the distance downstream of the SSC where speeds remained reduced, or the time after the SSC has left the work zone that speeds remained reduced. In most cases, halo effects have diminished quickly (i.e., speeds returned to what they were prior to the presence of an SSC a very short distance downstream and very quickly after the SSC has been removed from the work zone). However, enforcement theory suggests that deploying frequently at the same location may eventually have a sustained speed-reducing effect as repeat motorists develop an expectation of enforcement presence at the location. Related to halo effects, speed and crash migration to other locations is another phenomenon that can arise systemwide. These spillover effects can be positive or negative, so agencies should consider assessing speed and crash characteristics over the broader roadway network surrounding SSC installations.

SSC deployments constantly collect speed data as part of their function. Consequently, these data can be used in the evaluations to determine the range of speeds of passing vehicles and how frequently the speeds violate a set speed threshold. However, measuring speed upstream and downstream from the installation is more difficult, as well as at sites used for comparative analyses. For these other sections, it would be necessary to turn to other sources. All agencies make use of speed data to support a wide range of operations strategies, so it is quite possible that speed data needed for an SSC evaluation are available "in house." Such data could be from internal systems, such as a deployed queue warning system or similar means of speed monitoring. Speed data may also be available from external sources that an agency purchased (e.g., from the Regional Integrated Transportation Information System, INRIX®, or other sources). In addition, for some deployments it may be beneficial to access the National Performance Management Research Data Set (NPMRDS) as a source of speed data.

The NPMRDS serves as a national database of probe-vehicle-based speed and travel time data (https://ops.fhwa.dot.gov/publications/fhwahop20028/index.htm). The spatial resolution is defined by traffic message channel (TMC) location codes, which represent a unique, directional roadway segment that is about half a mile to a mile long in urban and suburban areas and could be as long as 5 to 10 miles in rural areas. In rural SSC deployments, given the length of TMC segments, this dataset may not be useful.

Related to speed data are other mobility metrics, such as volume and throughput, which can be used to assess increases in mobility. For safety purposes and reducing speeding along with other mobility benefits, agencies typically implement SSCs. Again, agencies frequently collect such data to support many operations strategies and data may be readily available.

Crash Data. Changes in speeds are used as the most direct measure of work zone SSC effectiveness, but the ultimate objective of a work zone SSC program is to reduce or eliminate fatal and serious injury crashes. This objective aims to reduce both crash frequency and severity, which means detailed crash data are needed for an effective evaluation. It is extremely challenging to determine the effects of SSCs (or any safety countermeasure) in work zones. The combination of geometric constraints of the roadway through the work zone, the type and time of work activities performed, and the temporary traffic control involved to implement the geometric constraints and accommodate the work activities all confound to influence crash risks, making each work zone unique.

SSC deployments in work zones may achieve two types of crash reductions:

- A localized reduction in crash risk, relative to what the crash risk would have been during that time and at that location if an SSC had not been deployed.
- An overall programmatic reduction across all work zones (both those where an SSC has been deployed and where it has not) may occur in a State or region due to increased driver situational awareness and expectancy of SSC presence in work zones relative to what would have occurred if the SSC program did not exist.

Several reasons, including lack of work zone exposure data nationally, inconsistent documentation of work zone-related crashes in crash reports, and a lack of a comprehensive set of high-quality crash modification factors of key work zone elements make estimating programmatic effects of a work zone SSC program challenging. Without such data and models, developing solid work zone crash prediction models in one or more jurisdictions without an SSC program would be difficult. These results could be compared to model results in regions that have an SSC program in place. Presumably the lack of consistent data will be resolved over time as agencies adopt the Work Zone Data Exchange (WZDx) or Connected Work Zone Standard, the Model Minimum Uniform Crash Criteria, and similar means of data capture.[4, 5, 6]

If the project duration is sufficient to provide conditions with and without SSC presence for comparison, it might be possible to estimate localized effects of SSC deployments on a project-by-project basis. Aggregating these comparisons across multiple projects could provide an overall estimate. The SSC deployment methods used determine the extent to which such an analysis is possible. If the work zone is in place for an adequate period of time before the SSC deployment, it is possible to evaluate a semipermanent deployment that remains at the work zone location continuously using a simple before-during analysis of crashes. Of course, if the SSC deployment is installed at the same time the work zone is implemented, then this type of comparison cannot be made. Instead, comparing crash experiences at an SSC work zone to those at a comparable work zone without SSC would be necessary. The quality of that comparison would depend on how closely the characteristics of the work zone without SSC match the SSC-work zone characteristics. Furthermore, this type of analysis would focus only on the localized effect of the SSC deployment.

Work zone SSC programs that use mobile technology and are moved from location to location create additional challenges for those assessing their effectiveness in reducing crashes. Both the localized effect of SSC deployments as well as any programmatic effects of an SSC program within a State or region will depend on deployment frequency, which is a function of the amount of equipment and staffing allocated to the program. Past research has indicated that mobile SSC deployments have very limited temporal or spatial halo effects, suggesting that the localized effect on crashes is also likely to be limited. It is possible that advance notification requirements (e.g., signing upstream of an SSC) may be partially responsible for the quick decay of enforcement effect, compared to traditional enforcement efforts without advance notification that experience a somewhat longer halo effect. An earlier study concluded that the halo effect of traditional enforcement can be extended somewhat by repeated days of enforcement presence at a location, but again without advance notification of such presence. In summary, evaluating the effect of mobile SSC deployments requires focusing specifically on days when an SSC is present, comparing crash experiences on those days with days when an SSC is not present.

Across all SSC deployments—fixed or mobile—the key to being able to estimate the effect of work zone SSCs upon crashes revolves around the need to have a large dataset of SSC and non-SSC comparable days (most likely across multiple work zones), as well as a number of crashes large enough to analyze. Unfortunately, accurate work zone data (especially work activity) is still difficult to obtain, although agencies' recent efforts to improve the accuracy and availability of work zone event data may reduce those difficulties in the future. Similarly, and perhaps fortunately, work zone crashes are rare events. Consequently, sample size is small, which limits the ability to conduct a statistically significant crash analysis. However, assuming accurate work zone data do become available at some point in the future, crash frequency modeling techniques could be used to determine the extent to which SSC presence influences crashes, given other work zone attributes in the model such as roadway geometrics through the work zone or annual average daily traffic.

[4] FHWA "Work Zone Data Exchange" (accessed April 2024): https://ops.fhwa.dot.gov/wz/wzdx/index.htm.

[5] Institute of Transportation Engineers "Connected Work Zone Implementation Guidance Standardization" (accessed May 2024): https://www.ite.org/technical-resources/standards/cwz/.

[6] NHTSA "Model Minimum Uniform Crash Criteria" (accessed April 2024): https://www.nhtsa.gov/traffic-records/model-minimum-uniform-crash-criteria.

Citation Data. Citation data are used to assess the effectiveness of SSC use in work zones. These data encompass the number of citations issued over a given time period, changes in the number of citations issued over multiple time periods, changes in the speeds for which citations are issued, and disposition results of those citations (paid, contested, dismissed, etc.). The financial outcomes of those citations are also useful data, as they can be compared to the financial cost of using SSCs (see Cost Data section). Equity impact using the citation data may also be measured by examining violators based on local versus transient travelers.

Cost Data. The costs of a work zone SSC program are another commonly used metric to assess program performance. The most frequent use of cost data is to compare them to the benefits of the program. Therefore, it is important to capture both in-kind contributions as well as program outlays, including procurement, installation, and operational costs. Incorporating savings attributed to speed and crash reductions, increased mobility, and fines collected into cost-benefit analyses is possible. For example, these cost-benefit analyses can be informed by monetizing values of crash reductions, such as those covered in the Evaluation Approach and Results section. Care should be taken with respect to cost-benefit analyses as there could be negative perceptions associated with an implementation that is perceived as a revenue generator for the agency. It may be more valuable to the agency to focus on the societal benefits of speed and crash reductions and improved mobility.

Other Quantitative Data. Other metrics that should be considered for evaluation include collecting demographic data and tracking system maintenance and calibration, staff training, and other elements to monitor program fidelity. Demographic data can be used to ensure the system is equitable and not issuing a disproportionate number of citations or fines on any demographic, to include low-income communities.

Qualitative Metrics

A qualitative evaluation consists of nonnumerical metrics, such as opinions, surveys, and collation of complaints and unsolicited comments. Ideally, agencies should measure public acceptance prior to SSC installation, at program startup, and periodically during operations to identify any changes in acceptance, which underscores the importance of considering system evaluation at the very beginning of the implementation of an SSC program. Surveys implemented before system deployment can provide a baseline for comparison and evaluation.

Opinion data are used in some instances to evaluate work zone SSC program effectiveness. Agency and contractor staff, as well as the motoring public, can gather perceptions of changes in driver behavior. Public opinions regarding the potential improvement in safety may also be collected and reported. Collecting qualitative data such as opinions through surveys can be complicated as they are more subjective than quantitative data. For this reason, care must be taken when formulating the questions to be used to evaluate opinions to avoid biasing the responses (in either a positive or negative way). Some of the types of elements that can be measured through surveys include the following:

- Awareness of the program's existence.
- Awareness of companion marketing and media campaign.
- Sources of information (i.e., how respondents learned about the program).
- Awareness of program features and operational aspects.
- Presence of incorrect beliefs (i.e., misconceptions) of SSC features and operations.
- Perceptions of the purpose of SSCs.
- Perceived appropriateness of site selection and amount of enforcement.
- General attitudes toward safety, speeding, and enforcement.
- Perceived likelihood of self or others being cited.
- Perceptions of changes in own driving behavior corresponding to SSC deployment.
- Perceptions of changes in behaviors of other drivers.
- Perceptions of equitable implementation of the SSC program.
- Level of support for the SSC program.
- Perceptions of others' support for the SSC program.
- Awareness of effects of SSCs on road safety.
- Desired changes to SSC program.[7]

[7] *Speed Safety Camera Program Planning and Operations Guide*, FHWA, January 2023. https://highways.dot.gov/sites/fhwa.dot.gov/files/Speed Safety Camera Program Planning and Operations Guide 2023.pdf.

Summary on Metrics

To be most effective, with-and-without comparisons should be made under the same operating conditions at each location where speeds are compared. For example, if an SSC is deployed where a short-term lane closure is required to allow work activities to occur, it is beneficial if the non-SSC deployment data were collected under identical conditions, as other research shows that both work activity and lane closures affect travel speeds. Tracking the percentage of vehicles exceeding the posted speed limit and the citation threshold speed over time is also useful as another speed-related metric.

As noted previously, reducing work zone crashes is the primary goal of a work zone SSC program. Estimating the effect of a work zone SSC program upon crashes is desirable but challenging, especially for the mobile camera-based systems that most agencies use. Identifying work zones that were in place prior to the implementation of the SSC program and that were targeted for frequent SSC deployments for several months after the program was initiated is an effective approach that was done in the Delaware pilot test. Other methods are also possible but will require more specific data regarding conditions present on a nearly continuous basis (e.g., when and where work activities occur, when and where short-term or long-term lane closures were installed). Adopting the WZDx specification and technology to improve the accuracy of work zone event data would be highly beneficial in attempting to conduct a more rigorous and detailed crash analysis.

EVALUATION APPROACH AND RESULTS

Once the type of evaluation and measures to be analyzed has been decided, the following basic steps identified by the FHWA and NHTSA *Speed Safety Camera Program Planning and Operations Guide*[8] will help agencies use those data effectively:

1. Identify and gather crash, speed, and other data for relevant phases for SSC treatment and comparison sites.
2. Compile with other relevant data about sites and comparison sites (roadway variables and volume data by year). If changes are made to the roadway, these changes may also need to be factored into the analysis by year of implementation.
3. Evaluate those data in comparison to the data before installation and, if possible, in comparison to similar sites without SSC installations.
4. Determine if the SSC has impacted speed-related crashes at the site by lowering crash frequency, frequency of severe crashes, or speeding-related crashes, proportion of severe crashes, or other measures as previously identified.
5. Shift enforcement efforts to other sites if they become higher priorities based on crash and speed data.
6. Continue to monitor crash data at enforced sites.[9]

At least 12 States have deployed or are in the process of deploying SSCs in work zones. The means by which each agency has evaluated the implementation has varied, which provides a rich set of materials for others. Regarding the work zone SSC effects on speed, studies to date strongly indicate a significant presence effect, typically resulting in 5 mph or more reductions in average speeds in the vicinity of the SSC deployment. For example, in 2024, Pennsylvania Department of Transportation (DOT) and the Pennsylvania Turnpike Commission reported that over the first 5 years of Pennsylvania's work zone SSC pilot program operations, there was a 38-percent reduction in speeding in work zones (1 mph or more over the speed limit), a 47-percent reduction in excessive speeding in work zones (11 mph or more over the speed limit), and work zone crashes declined by up to 50 percent when a speed enforcement vehicle was present.[10] Similarly, Connecticut DOT reported that speeding decreased at two work zones by 17 to 18 percent.[11] With respect to crash reductions, Arkansas DOT saw a 28-percent decrease in total work zone crashes after SSCs were deployed.[12]

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[8] Ibid (SSC Program Planning and Operations Guide)

[9] Ibid (SSC Program Planning and Operations Guide)

[10] *2023 Annual Report Automated Work Zone Speed Enforcement, Pennsylvania Department of Transportation, 2024.* https://workzonecameras.penndot.gov/wp-content/uploads/2023/04/2023PennDOT-AWZSE-Report_033023.pdf.

[11] *CTDOT Automated Work Zone Speed Control Pilot: Legislative Report, 2024.* https://portal.ct.gov/dot/programs/know-the-zone?language=en_US.

[12] Arkansas SB 481, 2023. Accessed March 2024: https://www.arkleg.state.ar.us/Bills/Detail?id=sb481&ddBienniumSession=2023%2F2023R.

CONCLUSIONS

Studies have shown that public opinion has been favorable toward work zone SSCs, but that does not mean there will not be pushback from the community. Work zone SSC implementation is in the public eye, which means it is essential to execute the implementation effectively. A solid evaluation, starting with a well-thought-out and executed evaluation plan, is a critical aspect of the implementation. The results of the evaluation will be useful both internally for agency staff and vendors, law enforcement, and elected officials to identify possible improvements or changes to the program and externally to inform the traveling public. One way to ensure success of the evaluation is to work with individuals who are knowledgeable about evaluation methods. Another important factor is documentation of specific locations of each deployment. Finally, in all cases, going into the work zone SSC deployment with the plan to evaluate the system will go far to ensure success.

FOR MORE INFORMATION

The FHWA and NHTSA Speed Safety Camera Program Planning and Operations Guide
https://highways.dot.gov/sites/fhwa.dot.gov/files/Speed%20Safety%20Camera%20Program%20Planning%20and%20Operations%20Guide%202023.pdf.

NHTSA Countermeasures That Work: Speed Safety Camera Enforcement
https://www.nhtsa.gov/book/countermeasures-that-work/speeding-and-speed-management/countermeasures.

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