School Zone Speed Study in Nevada

Nevada Department of
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Office of Traffic Safety

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List of Acronyms

AADT	: Annual Average Daily Traffic
ADA	: Americans with Disabilities Act
AE	: Automated Enforcement
ASE	: Automated Speed Enforcement
AWZSE	: Automated Work Zone Speed Enforcement
CMF	: Crash Modification Factor
DSDS	: Dynamic Speed Display Signs
DOT	: Department of Transportation
FHWA	: Federal Highway Administration
GHSA	: Governors Highway Safety Association
IIHS	: Insurance Institute for Highway Safety
LiDAR	: Light Detection and Ranging
NCMD	: National Child Mortality Database
OEM	: Original Equipment Manufacturer
PCU	: Portable Camera Unit
PET	: Post Encroachment Time
SMD	: Speed Monitoring Display
SRTS	: Safe Route to School
SSC	: Speed Safety Camera
SSM	: Safety Surrogate Measure
TTC	: Time to Collision

Executive Summary

Speeding remains a leading cause of traffic fatalities, as evidenced across various crash datasets. In Nevada, the number of speed-related fatal crashes has shown a concerning upward trend, increasing from 89 in 2019 to 103 in 2020, and further to 112 in 2021. The implications of this trend extend to vulnerable road users, particularly in school zones, where speeding poses an increased risk to children. According to the Washoe County School District Police Department, over the past five school years (2019-2024), at least one-third of traffic citations issued annually were due to drivers exceeding speed limits within school zones.

To gain insight into current speed issues in school zones and potential countermeasures, the research team at University of Nevada, Reno conducted a comprehensive school zone traffic speed study. Specifically, the study had two primary objectives: (1) to assess speed compliance and the distribution of vehicle speeds within selected school zones across Nevada and (2) to conduct an extensive review of school zone speed management strategies, particularly those employing automated enforcement techniques. The team leveraged advanced data collection methods, including Light Detection and Ranging (LiDAR) technology and high-resolution vehicle telemetric data, allowing for an in-depth analysis of speed behaviors in these zones.

Study data sets were gathered from 15 school zones in both Southern and Northern Nevada, covering a range of school types, roadway network layouts, and traffic conditions. The analysis revealed that compliance with the posted speed limits during school zone speed control hours was alarmingly low, with only about 34% of drivers adhering to the speed limits based on LiDAR data and a compliance rate of 24% observed through vehicle telemetric data. At each of the study sites, the 85th percentile speed, a standard measure indicating the speed at or below which 85% of drivers travel, exceeded the reduced speed limit during school zone speed control, suggesting that speeding occurrences are prevalent across all study sites.

In addition to the field data analysis, the study included a thorough literature review of domestic and international speed management approaches. This review highlighted the effectiveness of safe speed cameras (SSCs) in reducing speeding on special roadway segments, such as school zones. SSCs, which automate speed monitoring and violation enforcement, have proven successful in a large number of cases, showing significant reductions in both the speeding occurrences and speed-related crashes. The implementation of SSCs with adequate management in Nevada school zones could potentially serve as a proactive and effective measure to enhance traffic safety.

In conclusion, this study underscores a critical need for improved speed management strategies in Nevada's school zones, with a substantial portion of drivers exceeding safe speed limits which were discovered through field data collection and assessment. The study provides a comprehensive review of potential solutions, such as SSCs, that could offer an effective and sustainable approach to reducing speed-related risks and protecting vulnerable road users.

Section 1. Introduction

According to the latest National Highway Transportation Safety Administration (NHTSA) data, in 2022, there were 12,151 fatalities in speeding-related crashes, which account for 29 percent of total traffic fatalities (NHTSA, July 2024). In Nevada, the Department of Transportation's Speed Management Action Plan studied traffic data over a five-year period from 2015-2019. During this period there were 454 speed-related fatal crashes which accounted for 31% of the state's total. Additionally, speed-related fatal crashes in Nevada rose from 89 in 2019 to 103 in 2020 and reached 112 in 2021. Furthermore, the Washoe County School District Police Department's report shows that, in the past five school years (SY) 2019-2024, almost every year at least one-third of the traffic citations have been issued for drivers speeding in a school zone. In School Year (SY) 2023-24 alone, 44% of the tickets issued were for speeding in a school zone, up significantly by 20% from SY 2022-23. To add more context to school zone speeding, a study by the Traffic Safety Commission, based on field observations at 118 schools, revealed that overall driver speeding behavior is significantly frequent, with nearly three of every four drivers exceeding the posted speed limit (TSA, 2023). In addition, the latest NHTSA's factsheet notes that a review of school-transportation-related traffic crashes from 2013 to 2022 shows that there were 1.5 times more fatalities among pedestrians (169) than occupants of school transportation vehicles (111) (NHTSA, Aug., 2024). Furthermore, according to the latest National Child Mortality Database (NCMD), traumatic injuries as a result of a vehicle collision are the leading cause of child death in the United States (NCMD Programme, 2023). All the above facts underline the significance of speed management, especially across school zones. The US Department of Transportation's (USDOT) National Roadway Safety Strategy (NRSS) lists safer speeds as one of its objectives and its action steps include, "*Prevent speeding by studying and piloting the equitable application of enforcement strategies, including automated enforcement*."

This study's aim is twofold: 1) Assess vehicle speeds' distribution and speed limit compliance status at selected school zones in Nevada using advanced data sources (e.g., Light Detection and Ranging [LiDAR], and high-resolution vehicle telemetric data), and 2) Conduct and synthesize a comprehensive information review associated with school zone speed management strategies/practices featuring automated enforcement. As illustrated in Figure **1.1**, a total of five task-by-task approaches were proposed to meet the study aims.

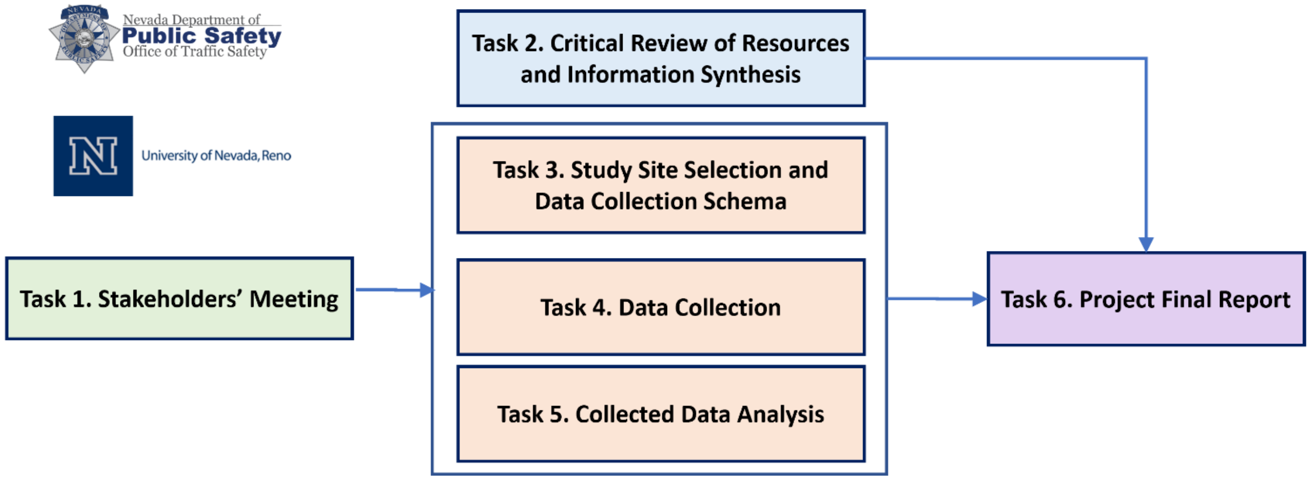


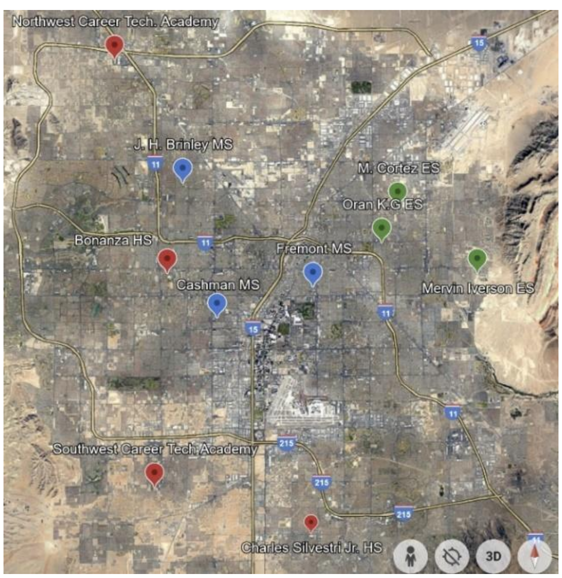
Figure **1.1.** Overall Study Process

The study findings will help gain further insights into the extent of drivers' school zone speed compliance status, and ultimately assist in developing a more informed, data-driven decision for major stakeholders.

Section 2. Study Site and Data Collection Schema

2.1 Study Site Selection Process

In selecting the study sites, several factors were considered. These include the mix of different school levels (e.g., elementary vs middle vs high school), school adjacent roadway features (e.g., roadway lane number, speed limit, traffic volume), school zone control type (e.g., flasher, dynamic speed flasher), land use context (e.g., urban, rural), and neighbor's socioeconomic context/equity (e.g., Title 1). These factors were identified and reviewed with various stakeholders over several meetings with study team. For the Southern Nevada sites, initially 25 study site candidates were suggested by stakeholders during the study kick off meeting in April 2024. After in-depth review of all the above factors, the final ten (10) sites were selected for field data collection in this study. In addition, to provide a broader and further insight into school zone speed status in Northern Nevada, a total of five (5) study sites were selected from Washoe County School district. For the corresponding sites, he selection was based on the previous LiDAR data availability and a balanced mix of school types (e.g., elementary vs middle vs high school). Figures **2.1** and **2.2** present the distribution of the final 15 study sites while Table **2.1** illustrates key features of each site.



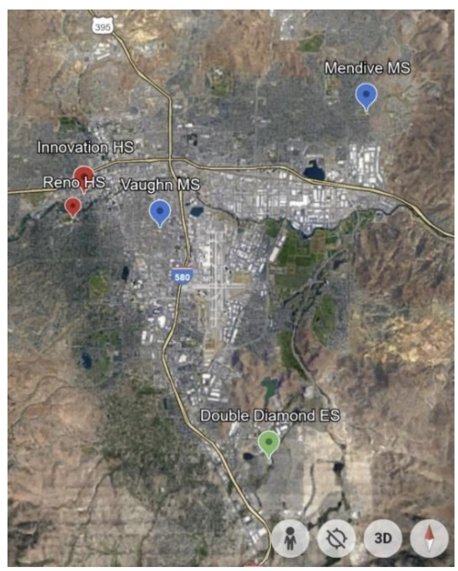


Figure **2.1**. Southern NV Study Sites Figure **2.2**. Northern NV Study Sites

: High School (: Middle School (MS)

: Elementary School (ES)

Table **2.1**. Study Site Description

Study Sites	School Name	Land Use	Roadway (through lane number/direction)	LiDAR Data Collection Sites	Speed Limit		School Zone Control Features
				Marked "x"	During Non-School Zone Speed Control Period	During School Zone Speed Control Period	
Southern NV	Bonanza HS	Urban	S. Torrey Pines Dr. (2)	x	35	15	Flashers, during AM/PM intervals
			Del Rey Ave. (1)		25	15	Static Signs, during AM/PM intervals
			Redwood St. (1)		25	15	Static Signs, during AM/PM intervals
	Cashman MS	Urban	W. Desert Inn Rd. (2)	x	45	15	Flashers, during AM/PM intervals
			Cameron St. (1)		25	15	Static Signs, during AM/PM intervals
			S Warnock Rd. (1)		25	15	Static Signs, during AM/PM intervals
	Charles Silvestri Jr HS	Urban	E. Silverado Ranch Blvd. (2)	x	45	15	Dynamic Flashers, during AM/PM intervals
			Jack Leavitt St. (1)		25	15	Static Signs, during AM/PM intervals
	J. H. Brinley MS	Suburban	W. Smoke Ranch Rd. (2)	x	35	15	Flashers, during AM/PM intervals
			Maverick St. (1)		25	15	Static Signs, during AM/PM intervals
	Fremont MS	Urban	E. St. Louis Ave. (1)	x	30	15	Flashers, during AM/PM intervals
	M. Cortez ES	Urban	E. Tonopah Ave. (1)	x	25	15	Flashers, during AM/PM intervals
			N. Lamb Blvd. (3)		45	15	Static Signs, during AM/PM intervals
	Northwest Career S	Suburban	W. Tropical Pkwy. (2)	x	30	15	Flashers, during AM/PM intervals
	Mervin Iverson ES	Suburban	American Beauty Ave. (1)	x	25	15	Flashers, during AM/PM intervals
			S. Hollywood Blvd. (2)		35	15	Static Signs, during AM/PM intervals
	Oran K.G ES	Urban	E. Bonanza Rd. (3)	x	35	15	Flashers, during AM/PM intervals
			N. Honolulu St. (1)		25	15	Static Signs, during AM/PM intervals
	Southwest Career S	Suburban	S. Rainbow Blvd. (2)	x	45	25	Flashers, during AM/PM intervals
			W. Shelbourne Ave. (1)		25	15	Flashers, during AM/PM intervals
Northern NV	Innovation HS	Urban	W. 2nd St. (2)	x	30	15	Flashers, during the whole school period
	Mendive MS	Urban	Vista Blvd. (2)	x	40	25	Flashers, during the whole school period
			Whitewood Dr. (1)		25	15	Flashers, during the whole school period
			Del Rosa Way (1)		25	15	Flashers, during the whole school period
	Reno HS	Urban	Booth St. (1)	x	25	15	Static Signs, during AM/PM intervals
			Foster Dr. (1)		25	15	Flashers, during the whole school period
	Vaughn MS	Urban	Vassar St. (1)	x	25	15	Flashers, during the whole school period
			Bresson Dr. (1)		25	15	Static Signs, during the whole school period
	Double Diamond ES	Urban	S. Meadows Pwky (2)	x	35	15	Static Signs, during the whole school period

2.2 Data Sources

In this study, two data sources, 1) roadside Light Detection and Ranging (LiDAR data) and 2) High Resolution Vehicle telemetric data, were explored. Each data source offers unique information that would complement each other and hence provide further understanding of vehicle speeds.

2.2.1 Roadside LiDAR Data

Considered as a microscopic data provider, LiDAR sensor presents a wealth of informative data. This includes detailed trajectories (i.e., 10 Hz equivalent to 0.1 tracking rate) of vehicles, pedestrians and other transportation modes such as micromobility (e.g., bicycles, scooters). Each trajectory's speed and count can be estimated. While the detailed information gathering is feasible, the collected information pieces are limited to the LiDAR detection range (600 ft). In the field, usually the LiDAR sensor is placed 10-12 feet high on a signal, streetlight, or utility pole and LiDAR sensor is connected to a portable cabinet. Figure **2.3** presents a typical roadside LiDAR field deployment. **Appendix A** presents detailed LiDAR field installation process and sensor location at each study site.

Figure **2.3**. Roadside LiDAR Deployment Schema

2.2.2. High-Resolution Vehicle Telemetric Data

Vehicle telematics probe data was first used enterprise-wide in fleet management in the early 2000s. Though it has been increasingly applied since 2010, vehicle telemetric probe data, particularly original equipment manufacturer (OEM) data, has recently become an emerging data source for traffic safety and operational studies. Advancements in GPS tracking technology and telematics are continuing to evolve with paradigm shifts in how transportation agencies collect transportation data, improved efficiencies in data collection and dissemination, and minimized costs for prevailing usage (SCAG, 2022). There are three major strengths of vehicle telemetric probe data:

- **High-resolution waypoints of complete vehicle movements with direct measurements**: Vehicle telemetric data is directly collected from in-vehicle sensors, portraying vehicle movements with high temporal and spatial granularities. Such high temporal and spatial granularities (e.g., less than 3 seconds per point and a geographic precision of under 10 feet more than 95% of the time, allowing for accurate per-street or even per-lane vehicle localization.) As the waypoints are continuous within a large-scale network, information, such as trip timing and trip mileage, can provide insights into large-scale traffic management and impact measurement. In addition, the speed information provided by telemetric probe data is directly obtained from the vehicle in addition to those measured by the roadside or in-roadway sensors.
- **Large Sampling through Timely and On-demand Data Acquisition without Infrastructure-based Detection**: Current OEM telemetric probe data providers report a data penetration rate of around 3% of total road traffic across the U.S., sufficient for measuring traffic performance without the need for additional traffic sensors. Research has shown that traffic operations can be effectively studied using trajectory data with a penetration rate of about 1% (Waddell *et al.*, 2020). In addition, OEM telemetric probe data providers commonly offer customizable data acquisition options and nearly real-time data delivery, effectively complementing missing data when the repair of monitoring stations is infeasible.
- **Crowd-sourced data collection**: The data collection of vehicle telemetric data is infrastructure agnostic, and therefore can be nearly ubiquitous across the roadway network, facilitating studies that focus on underrepresented areas and transportation system users.

OEM telemetric probe data is of significant interest now because of rapidly increasing data penetration. A study shows that the current penetration of Wejo telemetric data in Indiana can be more than 5% of the total traffic (Sakhare *et al.*, 2022). The European initiative “eCall” mandates OEMs to integrate cellular radios into all new cars beginning in 2018 (EU, 2015). Global market estimates indicate that the number of vehicles with telematics embedded will rise to 339.3 million worldwide by 2024 and that by 2030, about 95% of new vehicles sold will be equipped with vehicle telematics (Berg Insight AB, 2021).

In this research, a 10-day data set of OEM telemetric probe data is employed, including 5 days of school days and 5 days within the spring break back in 2023. The OEM data provider reports their data penetration rate can be 3%-5% across the U.S., including the region of the study. Research has shown that problematic arterial operations can be identified using trajectory data of a penetration rate of about 1% (Waddell *et al.*, 2020). Figure **2.4** presents a raw data sample while Figure **2.5** illustrates sample of trajectory waypoints over a broader school zone area captured using this dataset.

dataPointId	journeyId	capturedTimestamp	latitude	longitude	Zipcode	regionCod	speed	heading	wejoVehic	expectedC	ignitionSt	make	model	year	bodyClass	fuelTypeP	fuelTypeS	wejoBody	wejoPo
b9b6c0ce-bfc1-4749-b8	ed358a0607a75356e7	2023-03-06 09:32:10-08:00	36.19189	-115.08	89115	NV	30.02	177.8	7.27E+18	1	MID_JOURNEY								
28b8d3b7-a326-4984-9	2d38e03886c330b209	2023-03-06 09:50:29-08:00	36.19222	-115.08	89115	NV	37.22	178	1.51E+18	3	MID_JOURNEY								
3e44e43d-c5ca-4b08-b	37819421fc88c93411	2023-03-06 09:21:11-08:00	36.19329	-115.08	89115	NV	42.94	358	4.78E+18	3	MID_JOURNEY								
d8768ad5-0d56-4372-b	2d38e03886c330b209	2023-03-06 09:50:38-08:00	36.19095	-115.08	89115	NV	34.36	176	1.51E+18	3	MID_JOUR	CHEVROLE	Equinox	2019	Sport Utili	Gasoline		SUV	ICE
2f9fc7c4-a590-41e0-b2	b3c8d3b4218a4ea1b	2023-03-06 09:08:56-08:00	36.19054	-115.08	89115	NV	39.36	358	4.94E+18	3	MID_JOURNEY								
b9b6c0ce-bfc1-4749-b8	ed358a0607a75356e7	2023-03-06 09:32:23-08:00	36.19036	-115.08	89115	NV	32.61	178.1	7.27E+18	1	MID_JOURNEY								
3926e6b0-65c6-4ef0-90	8b46ff5c7e491f81edf	2023-03-06 09:05:04-08:00	36.19308	-115.08	89115	NV	41.51	357	-3.81E+18	3	MID_JOURNEY								
b9b6c0ce-bfc1-4749-b8	ed358a0607a75356e7	2023-03-06 09:32:08-08:00	36.19213	-115.08	89115	NV	30.42	178.6	7.27E+18	1	MID_JOURNEY								
48f5aa78-51ac-47b8-al	37ef353047de3f45545	2023-03-06 09:45:03-08:00	36.19222	-115.08	89115	NV	38.65	358	5.84E+18	3	MID_JOUR	CADILLAC	SRX	2015	Sport Utili	Gasoline		SUV	ICE
e4b66ddb-7093-4337-9	bb3f3c6813041f6527	2023-03-06 09:44:21-08:00	36.18996	-115.08	89115	NV	35.78	178	-6.81E+18	3	MID_JOURNEY								
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b4abb4a3-9d07-4702-a	3fab2287035466e48d	2023-03-06 09:02:39-08:00	36.18933	-115.08	89115	NV	35.07	175	1.48E+18	3	MID_JOURNEY								
012cc95c-b1cb-4949-b	451a43437c6a9c6f84	2023-03-06 09:33:05-08:00	36.19385	-115.08	89115	NV	44.38	177	1.19E+18	3	MID_JOURNEY								
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0e5dfa35-4974-458f-81	4765e85e2a49115e62	2023-03-06 09:27:10-08:00	36.19378	-115.08	89115	NV	40.08	178	3.71E+18	3	MID_JOURNEY								
81510763-7306-4e1d-b8	3835536e11c833d887	2023-03-06 09:49:15-08:00	36.1898	-115.08	89115	NV	35.07	358	2.69E+18	3	MID_JOUR	CHEVROLE	Sonic	2020	Hatchbac	Gasoline		Hatchbac	ICE
b9b6c0ce-bfc1-4749-b8	ed358a0607a75356e7	2023-03-06 09:31:52-08:00	36.19417	-115.08	89115	NV	31.62	178.3	7.27E+18	1	MID_JOURNEY								
ab70f65c-cb6c-4a0d-a	4765e85e2a49115e62	2023-03-06 09:27:31-08:00	36.19024	-115.08	89115	NV	40.08	178	3.71E+18	3	MID_JOURNEY								
76f37ac1-f688-4402-9e	36c1cc186508a0a45e	2023-03-06 09:49:23-08:00	36.1927	-115.08	89115	NV	44.38	358	-9.17E+18	3	MID_JOURNEY								
660a9887-37e8-4882-bf	dd18235f043116cfb1	2023-03-06 09:43:02-08:00	36.19435	-115.08	89115	NV	36.51	177	-9.01E+18	3	MID_JOURNEY								
8d87ecfe-2afe-4cad-aa	c7a7951f5d69f4ee16	2023-03-06 09:50:46-08:00	36.18976	-115.08	89115	NV	39.36	177	-6.33E+18	3	MID_JOURNEY								
ff923a9e-8c22-4ead-9d	a9d5f7f8490ef7e84f0	2023-03-06 09:34:01-08:00	36.19373	-115.08	89115	NV	46.53	176	-6.22E+18	3	MID_JOURNEY								
c81bdc5e-182d-4780-b	c7a7951f5d69f4ee16	2023-03-06 09:50:49-08:00	36.18928	-115.08	89115	NV	39.36	178	-6.33E+18	3	MID_JOURNEY								
9ca7ed11-0a2b-426b-a	c2ca96f911858ae85f	2023-03-06 09:06:33-08:00	36.19152	-115.08	89115	NV	42.23	358	1.87E+18	3	MID_JOURNEY								
7327698e-37cc-4a74-80	f3c1aa4a262a270e07	2023-03-06 09:20:29-08:00	36.19167	-115.08	89115	NV	37.22	178	4.94E+18	3	MID_JOURNEY								

Figure **2.4**. Waypoint Data Sample

Figure **2.5.** Sample Trajectory of Waypoints

A summary of each data source feature is presented in Table **2.2**.

Table **2.2**. Data Source Description

	Roadside LiDAR Data	High-resolution Vehicle Telemetric Data
Spatial Coverage	600 ft	Entire roadway network including major and minor roadways surrounding the school zone
Temporal Coverage	Southern NV Sites: May 2024, 72 hours Northern NV Sites: April/May 2023, 96 hours except Mendive MS (48 hours)	March 6th- 20th, 2023
Resolution level	10 Hertz (Every 0.1 seconds)	0.3 Hertz (every 3 seconds)
Penetration Rate / Vehicle Coverage Rate	100 %	3-5%

2.3 Performance Metrics

This study aims to fully capture vehicles speed distribution during school zone period and non-school zone periods to gain in-depth understanding of speed associated safety and risk levels. In this context, the following metrics will be reviewed to assess drivers driving behavior within the selected school zone sites.

- Speed Limit Compliance rate: This metric represents the number and percentage of observed vehicles traveling below or at speed limit within the study sites. With the two different data sources and corresponding features, notably the different spatial coverage, the following logic was applied to define compliance rate for each case:
    - LiDAR data-based compliance rate: Vehicle speeds used for compliance rate measures are extracted from the LiDAR trajectory data through lane-based detection zones placed within the school zone (passed the school zone flasher/sign) and away from traffic controls that will interrupt traffic flow; therefore, free-flow school zone speeds of all through vehicles at that point are extracted and the compliance rate calculated. This exact location varies based on the site and their traffic controls.
    - High resolution vehicle telemetric data-based compliance rate: The compliance rate, derived from high-resolution vehicle telemetric data, is calculated based on the continuous behavior of each vehicle's trajectory as it traverses the entire school zone. For instance, compliance is defined by a vehicle maintaining a speed below 15 mph throughout the school zone during the designated speed control period, where the posted speed limit is 15 mph. This method of identifying compliance is more stringent than assessments using LiDAR data with a broader spatial coverage.
- Speed Categorization: Depending on the observed speed and its range of over the posted speed limit, a total of three different speed categories are reviewed. These three categories include:
    - Speed Limit < Observed speed ≤ Speed Limit + 10 mph
    - Speed Limit + 10 mph < Observed speed ≤ Speed Limit + 20 mph
    - Observed speed > Speed Limit + 20 mph
- 85th percentile speed: 85th percentile speed is a statistical measurement that denotes the speed at or below which 85% of vehicles travel on a road. In transportation engineering, this value is considered

as a safe and reasonable speed, and is often used to set speed limits. In this study, 85th percentile speed is estimated to understand better how drivers are driving in relation to the established speed limit. As shown in Figure **2.6**, comparison between the field observed 85th percentile speed to the posted speed limit provides useful information regarding the driver's speed limit compliance status and effectiveness of the speed limit.

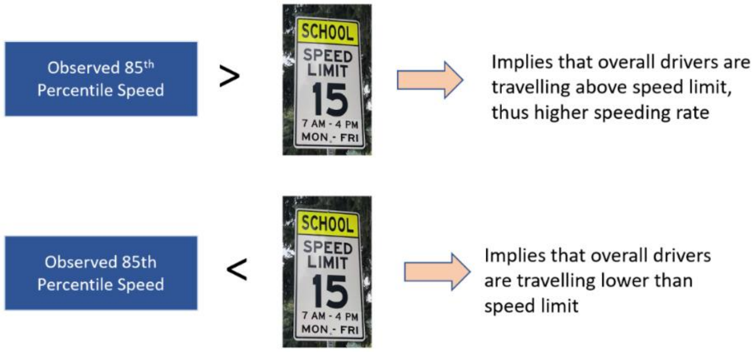


Figure **2.6.** 85th Percentile Speed and Posted Speed Limit

- Maximum Speed: In addition to the speed compliance rate, the observed maximum speeds during school zone period and non-school zone period are reviewed. As shown in Figure **2.7**, the extent of speed impact on injury levels significantly differs. Hence, in order to gather a full aspect of school zone speed impact on safety, it is essential to capture the observed maximum speed, especially even at sites with a high-speed compliance rate. Furthermore, as illustrated in Figure **2.8**, studies show that the degree of driver's yielding to crossing pedestrian is highly related to the vehicle driving speeds. Therefore, understanding field observed maximum speeds especially during the school zone speed enforced period is critical in assessing school zone safety.

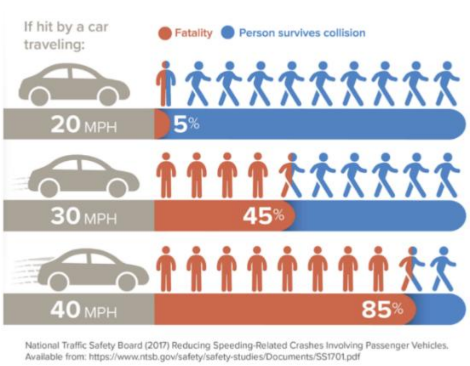


Figure **2.7**. Speed Impact on Injury Levels

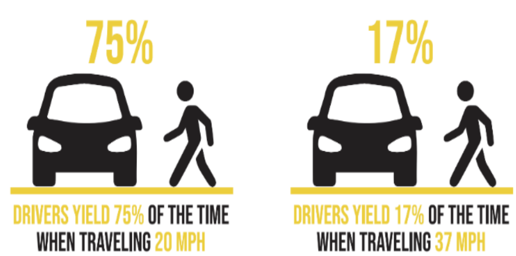


Figure **2.8**. Driving Speed and Yielding Status

- Spatial Speed Distribution: It is common to observe drivers changing vehicle speed over the course of the roadway. Therefore, it is important to review how vehicle speeds change over different points along the roadway within the school zone. This information will also provide insights on effectiveness of school zone sign/flasher along the school zone roadway.
- Temporal Speed distribution: The 85th percentile and average speed information over time of the day will be examined. This information will provide an overview of how the vehicle speeds vary along the time of the day, especially presenting speed pattern differences during school zone period and non-school zone period.
- Conflicts based on post-encroachment time (PET): In traffic safety field, various surrogate safety measures (SSM) are reviewed to estimate overall safety level. Potential Conflicts, also known as Near Misses, between vehicle to vehicle, vehicle-to-pedestrian, and vehicle to micromobility (e.g., bicyclists, scooters) are estimated based extracted interactions for which two road users' trajectories cross each other within a certain time difference, post-encroachment time (PET). Figure **2.9.** presents a sample field observed conflict distribution. Further description of conflicts and PET are presented in **Appendix A**.

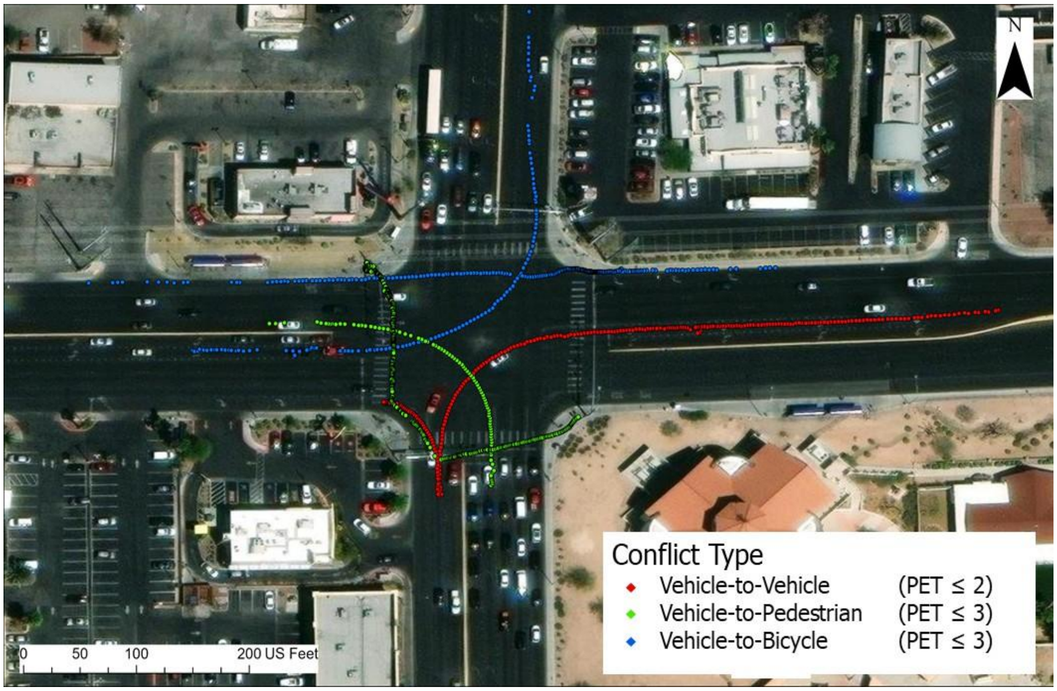


Figure **2.9**. Example of Various Conflict Distribution

Section 3. Data Analysis and Findings

This section describes the identified performance metrics (Section 2) based on field collected roadside LiDAR data and high-resolution vehicle telemetric data. In general, two contrasting time periods (i.e., school zone period vs non-school zone period). For study sites, where applicable, school zone period was divided into AM and PM periods. These sites include all ten (10) Southern sites and one Northern site, Mendive MS. The school zone period of the remaining four (4) Northern sites correspond to school operation time without any break in the middle.

3.1 Roadside LiDAR Data

For the compliance rate analysis, speeds obtained at midblock locations within the school zone were assessed. These locations are adjacent to the school itself, and anywhere from 100-400 ft away from the flasher depending on the site. It should be noted that the LiDAR data is collected along the roadway segment presented in Table **2.1** in previous section. An overall summary of all sites' average speed compliance rate is presented in Table **3.1.** As presented in Table **3.1**, an average of 35.1 and 31.6% of compliance rates are observed for Southern NV sites and Northern NV sites respectively. For the Northern NV sites, note that due to the different school zone period setting systems, separate AM and PM compliance rates only reflect for the Mendive MS site while average represents all five (5) Northern NV sites.

Table **3.1**. Summary of Average Speed Compliance Rate for All Sites

Average Speed Compliance Rate (%)		Southern NV Sites	Northern NV Sites
School Zone Period	AM	36.2	58.53 *
	PM	34.1	52.57 *
	Total	35.1	31.6 **
Non-School Zone Period	Total	50.7	46.2

*: Only for Mendive MS
**: for all 5 Northern study sites

Detailed summary of compliance and speed categorization status is presented in Tables **3.2** and **3.3** for Southern and Northern sites.

Table **3.2**. Observed Compliance and Speed Categorization during School Zone Period

Study Site	Roadway	Rate (Observations point)			
		Compliance	1-10 mph Over	11 – 20 mph Over	21 mph + Over
Southern Study Sites					
Bonanza HS	S. Torrey Pines Dr	20.1 % (493)	57.9% (1422)	18.0% (441)	4.1% (100)
Cashman MS	W. Desert Inn Rd.	43.8% (3109)	52,6% (3729)	3,1% (217)	0.5% (36)
Charles Silvestri Jr HS *	E. Silverado Ranch Blvd.	31.1% (3178)	59.7% (6099)	8.1% (829)	1.1% (111)
J. H. Brinley MS	W. Smoke Ranch Rd.	29.2% (1154)	53.5% (2113)	14.8% (586)	2.5% (97)
Fremont MS	E. St. Louis Ave.	12.1% (530)	63.0% (2767)	22.5% (990)	2.4% (105)
M. Cortez ES	E. Tonopah Ave.	53.5% (702)	33.0% (432)	12.3% (161)	1.2% (16)
Mervin Iverson ES	W. Tropical Pkwy.	24.3% (253)	34.1% (356)	37.9% (395)	3.7% (39)
Northwest Career S	American Beauty Ave.	33.5% (1342)	60.8% (2437)	5.0% (202)	0.7% (29)
Oran K.G ES	E. Bonanza Rd.	41.3% (6553)	54.4% (8626)	3.3% (526)	0.9% (149)
Southwest Career S	S. Rainbow Blvd.	62.1% (1889)	31.6% (961)	5.8% (175)	0.6% (18)
Northern Study Sites					
Double Diamond ES	S. Meadows Pwky.	37.8% (8154)	59.1% (12756)	2.7% (575)	0.5% (101)
Innovation HS	W. 2nd St.	25.3% (1914)	61.4% (4643)	12.4% (936)	1.0% (75)
Mendive MS *	Vista Blvd.	56.0% (2265)	42.1% (1702)	1.8% (71)	0.1% (6)
Reno HS	Booth St.	27.3% (1787)	58.3% (3815)	13.6% (890)	0.7% (49)
Vaughn MS	Vassar St.	11.4% (1042)	75.9% (6968)	12.6% (1156)	0.1% (9)

*: Collected over 48 hours

Table **3.3**. Observed Compliance and Speed Categorization during Non-School Zone Period

Study Site	Roadway	Rate (Observations point)			
		Compliance	1-10 mph Over	11 – 20 mph Over	21 mph + Over
Southern Study Sites					
Bonanza HS	S. Torrey Pines Dr	49.3% (11002)	45.3% (10118)	5.1%% (1132)	0.3% (61)
Cashman MS	W. Desert Inn Rd.	89.6% (100171)	9.9% (11039)	0.5% (528)	0.04% (42)
Charles Silvestri Jr HS *	E. Silverado Ranch Blvd.	67.2% (47854)	30.5% (21756)	2.1% (1502)	0.1% (103)
J. H. Brinley MS	W. Smoke Ranch Rd.	40.4% (13976)	53.5% (18531)	5.8% (2010)	0.3% (103)
Fremont MS	E .St. Louis Ave.	38.5% (5301)	55.6% (7657)	5.6% (766)	0.3% (41)
M. Cortez ES	E. Tonopah Ave.	68.7% (3369)	28.6% (1402)	2.5% (123)	0.2% (11)
Mervin Iverson ES	W. Tropical Pkwy.	42.9% (1331)	47.3% (1466)	9.2% (284)	0.6% (18)
Northwest Career S	American Beauty Ave.	20.7% (7974)	62.3% (23993)	16.2% (6231)	0.8% (309)
Oran K.G ES	E. Bonanza Rd.	40.4% (30683)	50.5% (38392)	8.5% (6468)	0.6% (491)
Southwest Career S	S. Rainbow Blvd.	49.8% (36553)	45.4% (33318)	4.6% (3375)	0.3% (214)
Northern Study Sites					
Double Diamond ES	S. Meadows Pwky.	51.2% (16704)	42.8% (13952)	5.7% (1874)	0.3% (86)
Innovation HS	W. 2nd St.	68.2% (4904)	30.4% (2187)	1.3% (92)	0.1% (7)
Mendive MS *	Vista Blvd.	38.8% (24266)	54.6% (34161)	6.3% (3969)	0.3% (203)
Reno HS	Booth St.	26.6% (1437)	66.1% (3574)	7.0% (377)	0.4% (20)
Vaughn MS	Vassar St.	46.4% (4133)	51.4% (4580)	2.1% (186)	0.1% (9)

*: Collected over 48 hours

To capture a comprehensive and better understanding of each study site's speed features, it is essential to review speed statistics, especially the 85th percentile and maximum speed in addition to average speed values. Tables **3.4** and **3.5** describe the observed speed statistics including the 85th percentile speed that is critical in assessing vehicle driving speeds in relation to the posted speed limit.

Table **3.4**. Speed related statistics during School Zone Period

	Roadway	Speed Statistics (mph) Speed Limit	85th Percentile Speed	Average Speed	Maximum Speed
Southern Study Sites					
Bonanza HS	S. Torrey Pines Dr	15	27.45	20.38	51
Cashman MS	W. Desert Inn Rd.	15	19.82	15.76	47
Charles Silvestri Jr HS *	E. Silverado Ranch Blvd.	15	37.52	26.66	62.17
J. H. Brinley MS	W. Smoke Ranch Rd.	15	25.98	19.03	53.84
Fremont MS	E .St. Louis Ave.	15	27.67	21.3	54.29
M. Cortez ES	E. Tonopah Ave.	15	24.38	14.88	49.65
Mervin Iverson ES	W. Tropical Pkwy.	15	30.45	21.25	50.58
Northwest Career S	American Beauty Ave.	15	20.79	17.03	48.53
Oran K.G ES	E. Bonanza Rd.	15	20.19	16.19	51.14
Southwest Career S	S. Rainbow Blvd.	25	29.56	22.76	56.54
Northern Study Sites					
Double Diamond ES	S. Meadows Pwky.	15	19.59	16.12	50.92
Innovation HS	W. 2nd St.	15	24.32	18.55	55.32
Mendive MS	Vista Blvd.	25	28.35	23.66	52.74
Reno HS	Booth St.	15	24.74	18.49	**72.16**
Vaughn MS	Vassar St.	15	24.6	20.18	38.42

Table **3.5**. Speed related statistics during Non-School Zone Period

	Roadway	Speed Statistics (mph) Speed Limit	85th Percentile Speed	Average Speed	Maximum Speed
Southern Study Sites					
Bonanza HS	S. Torrey Pines Dr	35	41.25	34.96	86.2
Cashman MS	W. Desert Inn Rd.	45	43.52	34.41	87.68
Charles Silvestri Jr HS *	E. Silverado Ranch Blvd.	45	48.40	41.93	86.83
J. H. Brinley MS	W. Smoke Ranch Rd.	35	41.75	36,11	74.35
Fremont MS	E .St. Louis Ave.	30	36.78	31.42	73.21
M. Cortez ES	E. Tonopah Ave.	25	28.93	22.5	54.06
Mervin Iverson ES	W. Tropical Pkwy.	25	33.36	23.7	65.51
Northwest Career S	American Beauty Ave.	30	40.52	34.57	79.97
Oran K.G ES	E. Bonanza Rd.	35	43.00	35.82	**93.54**
Southwest Career S	S. Rainbow Blvd.	45	50.93	45.00	**95.13**
Northern Study Sites					
Double Diamond ES	S. Meadows Pwky.	35	42	31.27	86.63
Innovation HS	W. 2nd St.	30	32.65	27.49	62.81
Mendive MS	Vista Blvd.	40	47.42	38.71	**94.58**
Reno HS	Booth St.	25	33.04	28.03	57.11
Vaughn MS	Vassar St.	25	2o.61	25.42	52.45

It should be noted that, at every study site, even during designated school zone periods, the observed maximum speeds were alarmingly high, often exceeding the school zone speed limit by more than three times.

The following paragraphs present key informative figures and table at Bonanza High School where the speed compliance rate during the school zone period show approximately 20.1 % value. Full description of all reviewed sites is included as **Appendix A**.

Figure **3.1** presents an example of spatial speed distribution at Bonanza High School. As clearly shown, all speed statistics converge closely to the posted speed limit as vehicle approaches near to the flasher location (0 ft location) and continue to slow down past 150 ft away from the flasher location.

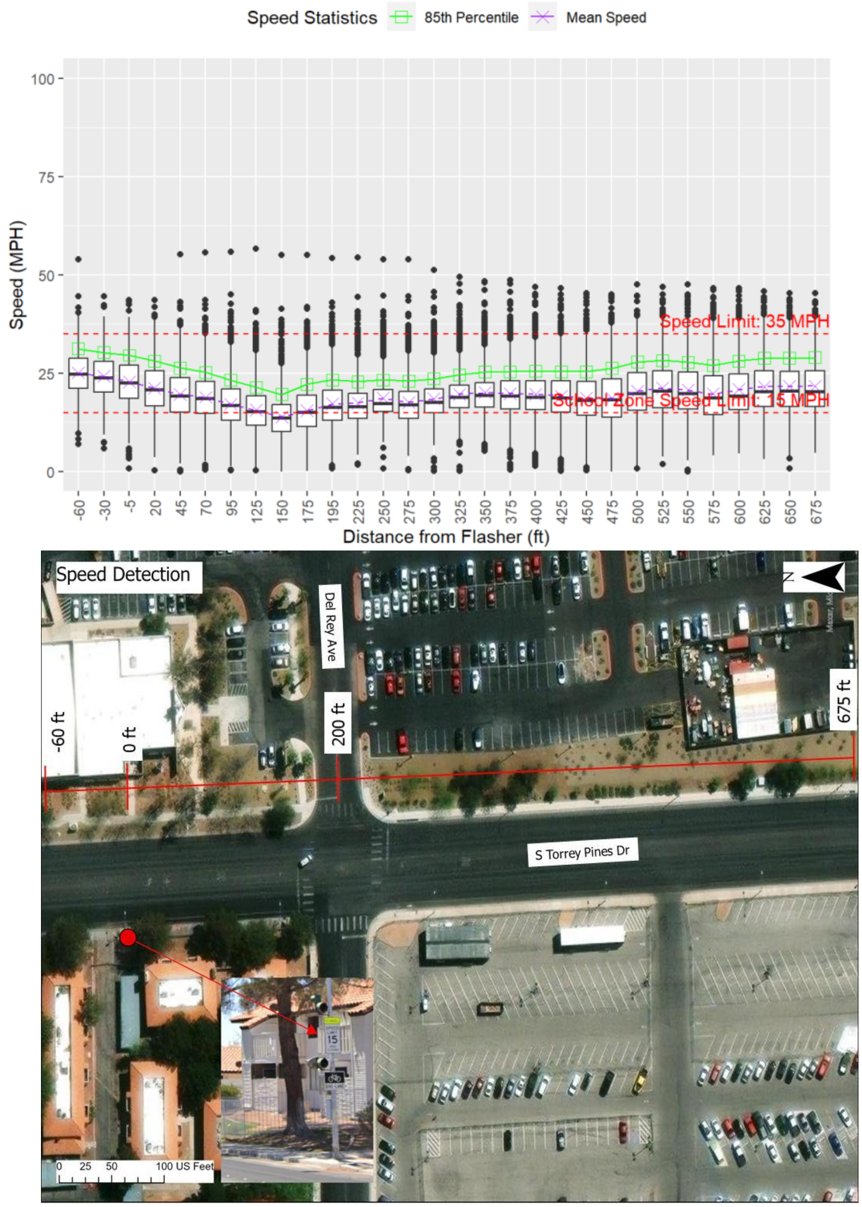


Figure **3.1**. Example of Spatial Speed Distribution at Bonanza HS

In Figure **3.2**, vehicle speeds distribution over time of the day is presented. While it is obvious speeds during school zone period are dropping, the 85th percentile values during these periods show way above 20 mph. Especially during the PM school zone period, the 85th percentile speed is close to 30 mph, which is over 15 mph than the posted speed limit and posing potential safety risk concerns. The high speeds distribution (over posted speed limit) is also illustrated in Figure **3.3**.

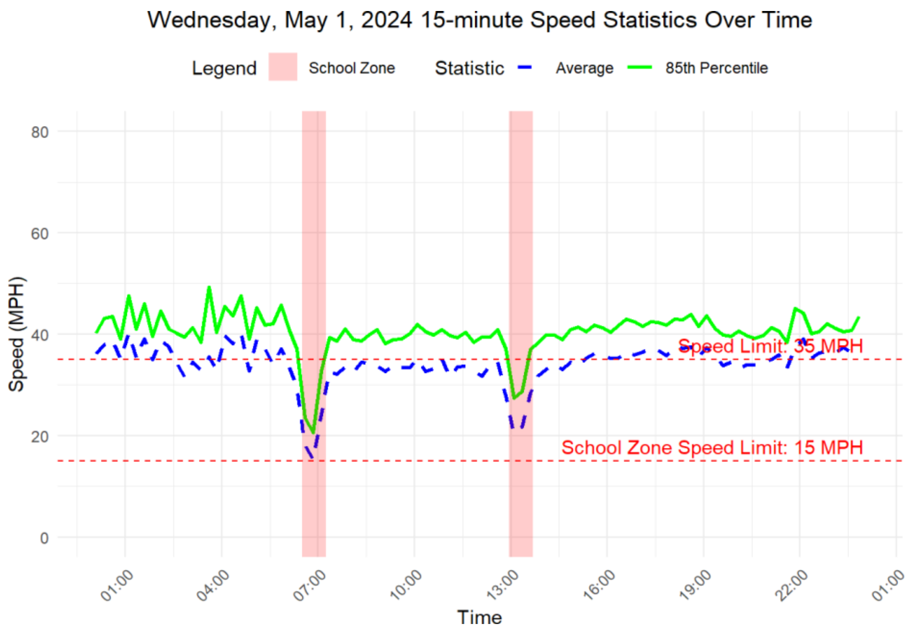


Figure **3.2**. Example of Temporal Speed Distribution at Bonanza HS

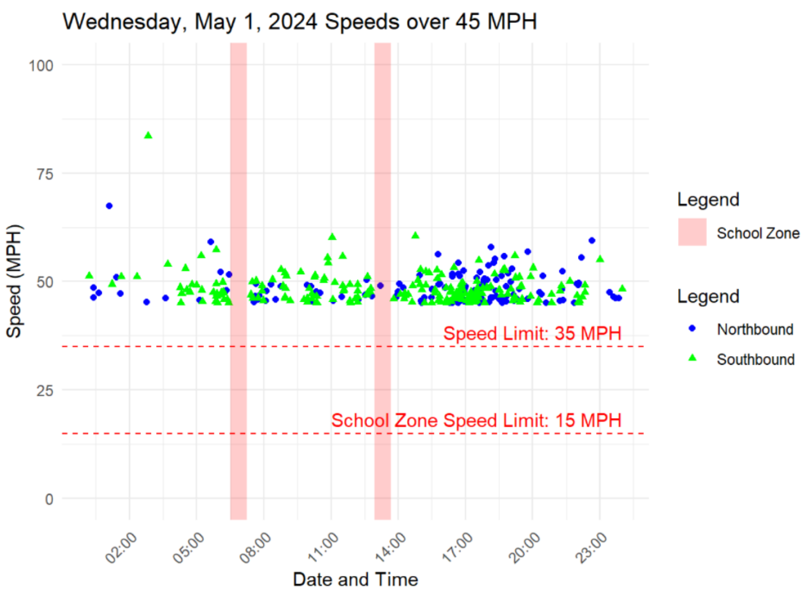


Figure **3.3**. Example of Speed Distribution over posted Speed Limit at Bonanza HS

Another essential information is pedestrian crossing behavior. Figure **3.4** presents pedestrian trajectories during the school zone period. Observations show that while many pedestrian crossings are within the crosswalk, mid-block crossings are still observed during the school zone period (Table **3.6**). All this information about each site can be found in each detailed report included in **Appendix A**. Furthermore, the conflict based on the PET as defined in Section 3 is also reviewed to further assess overall safety level of the school zone study site. As presented in Figure **3.5**, different types of conflicts were observed at each site.

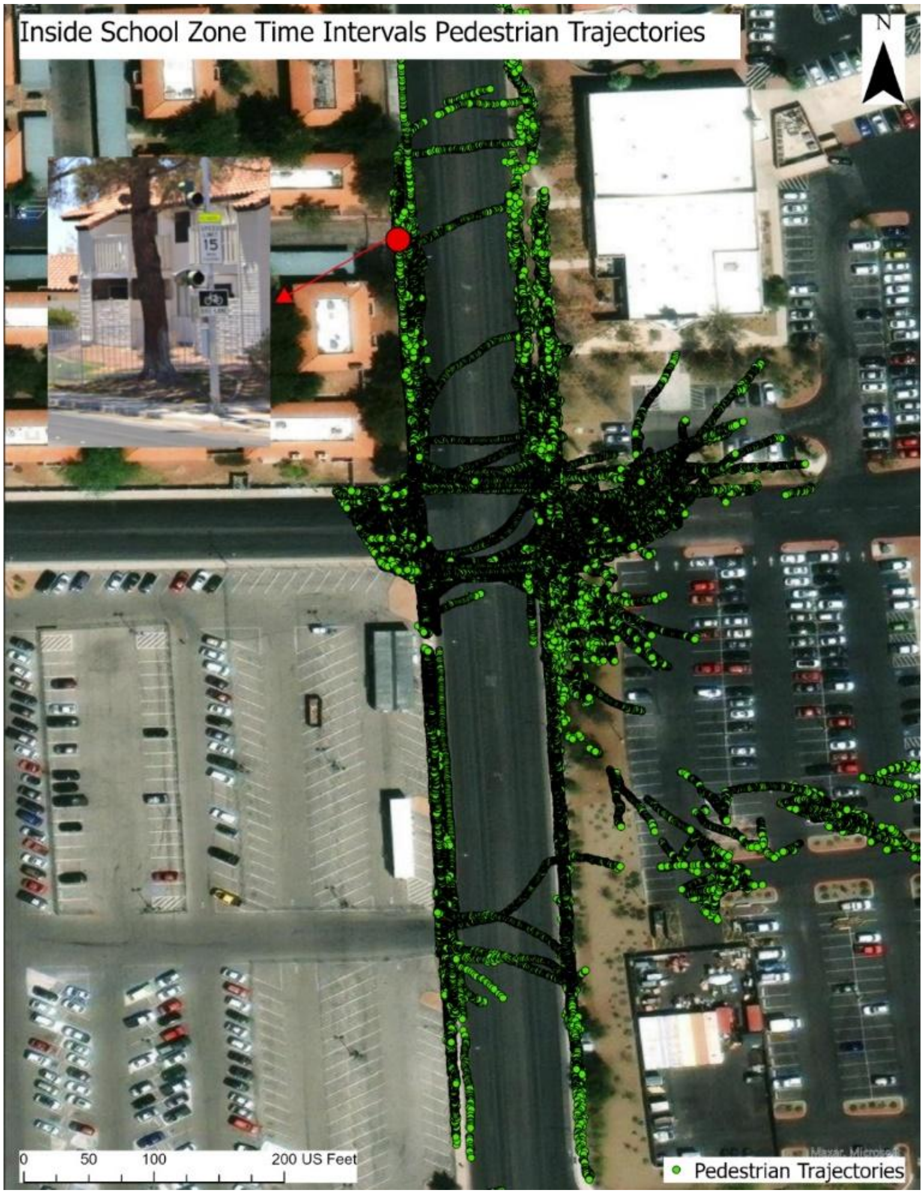


Figure **3.4**. Sample of Pedestrian Trajectories

Table **3.6**. Pedestrian Crossing Counts during School Zone Time Intervals (S. Torrey Pines Dr.)

Interval	Crosswalk	Midblock
Wednesday AM	27	1
Thursday AM	29	1
Friday AM	27	1
Wednesday PM	70	3
Thursday PM	60	1
Friday PM	69	1

Figure **3.5**. Sample of Conflict Types

3.2 High Resolution Vehicle Telemetric Data

In the compliance rate analysis utilizing high-resolution vehicle telemetric data, vehicle speeds throughout the school zones are systematically analyzed. Compliance rates are categorized based on trajectories that: 1) maintain speeds at or below the designated school zone limits; 2) have waypoints with speeds exceeding the limits by less than 10 mph; 3) include waypoints with speeds exceeding the limits by more than 10 mph but less than 20 mph; and 4) contain waypoints with speeds exceeding the limits by more than 0 mph.

It is important to note that high-resolution vehicle telemetric data represents a sampled data set, with a penetration rate of 3-5% in Nevada. The data points are collected at 3-second intervals. This research utilized a 15-day data set from March 6-20, 2023 (Refer to Table **2.1** for data range); however, the week of March 13-17, 2023 coincided with spring break for 10 schools in Southern Nevada. Consequently, speed observations for school zone speed control cases were extracted from only 5 operational days. Non-school zone speed control cases were also analyzed from these same 5 days. Compared to LiDAR data, the high-resolution vehicle telemetric data analysis encompasses a broader scope, including minor streets with school zones at the study sites. Additionally, the compliance rate definition differs from that used in the LiDAR data analysis, with the telemetric data approach being generally less restrictive. As a result, compliance rates derived from high-resolution telemetric data tend to be lower in most cases. Table **3.7** presents an overall summary of all sites' speed compliance rates during school zone control periods. Compliance rates of 35.1 and 31.6% are observed for Southern NV sites and Northern NV sites, respectively. For the Northern NV sites, note that due to the different setting systems of school zone speed control period, separate AM and PM compliance rates only reflect the Mendive MS site, while the average represents all five (5) Northern NV sites.

Table **3.7**. Summary of Speed Compliance Rates for All Sites Using Vehicle Telemetric Data

<table>
<tr><th colspan="2">Average Speed Compliance Rate (%)</th><th>Southern NV Sites</th><th>Northern NV Sites</th></tr>
<tr><td rowspan="3">School Zone Speed Control Period</td><td>AM</td><td>26.76%</td><td>17.71% *</td></tr>
<tr><td>PM</td><td>24%</td><td>23.24% *</td></tr>
<tr><td>Total</td><td>24.74%</td><td>16.73% **</td></tr>
<tr><td>Non-School Zone Speed Control Period</td><td>Total</td><td>41.45%</td><td>40.31%</td></tr>
</table>

*: Only for Mendive MS
**: for all 5 Northern study sites

Tables **3.8** and **3.9** present detailed summaries of compliance and speed categorization status for Southern and Northern sites.

Table **3.8**. Observed Compliance and Speed Categorization during School Zone Speed Control Period

Study Sites	School Name	Roadway	School Zone Speed Distribution Rates			
			Compliance	1-10 mph Over	11 – 20 mph Over	21 mph + Over
Southern NV	Bonanza HS	**S. Torrey Pines Dr.**	**14.38%**	**43.79%**	**33.33%**	**8.5%**
		Del Rey Ave.	*45.92%*	*47.96%*	*6.12%*	*0%*
		Redwood St.	*29.17%*	*32.29%*	*34.38%*	*4.17%*
	Cashman MS	**W. Desert Inn Rd.**	**14.84%**	**66.89%**	**15.75%**	**2.51%**
		Cameron St.	*0%*	*80%*	*20%*	*0%*
		S Warnock Rd.	*16.67%*	*61.11%*	*22.22%*	*0%*
	Charles Silvestri Jr HS	**E. Silverado Ranch Blvd.**	**13.99%**	**26.19%**	**32.64%**	**27.18%**
		Jack Leavitt St.	*9.89%*	*44.39%*	*42.51%*	*3.21%*
	J. H. Brinley MS	**W. Smoke Ranch Rd.**	**16.37%**	**55.56%**	**11.11%**	**16.96%**
		Maverick St.	*31.88%*	*49.28%*	*17.39%*	*1.45%*
	Fremont MS	**E. St. Louis Ave.**	**4.17%**	**22.4%**	**64.58%**	**8.85%**
	M. Cortez ES	**E. Tonopah Ave.**	**48.89%**	**35.56%**	**13.33%**	**2.22%**
		N. Lamb Blvd.	*6.32%*	*59.17%*	*24.4%*	*10.11%*
	Northwest Career S	**W. Tropical Pkwy.**	**19.85%**	**75.06%**	**4.07%**	**1.02%**
	Mervin Iverson ES	**American Beauty Ave.**	**31.17%**	**22.08%**	**44.16%**	**2.6%**
		S. Hollywood Blvd.	*8.07%*	*49.3%*	*30.73%*	*11.91%*
	Oran K.G ES	**E. Bonanza Rd.**	**21.87%**	**58.18%**	**8.66%**	**11.29%**
		N. Honolulu St.	*51.85%*	*37.96%*	*10.19%*	*0%*
	Southwest Career S	**S. Rainbow Blvd.**	**56.77%**	**40.98%**	**2.26%**	**0%**
		W. Shelbourne Ave.	*48.76%*	*47.35%*	*3.89%*	*0%*
Northern NV	Innovation HS	**W. 2nd St.**	**16.71%**	**71.03%**	**11.7%**	**0.56%**
	Mendive MS	**Vista Blvd.**	**12.38%**	**72.15%**	**12.48%**	**3%**
		Whitewood Dr.	*27.55%*	*55.61%*	*16.84%*	*0%*
		Del Rosa Way	*19.2%*	*77.6%*	*3.2%*	*0%*
	Reno HS	**Booth St.**	**14.78%**	**67.3%**	**17.92%**	**0%**
		Foster Dr.	*14.16%*	*69.45%*	*15.87%*	*0.51%*
	Vaughn MS	**Vassar St.**	**6.83%**	**76.24%**	**16.3%**	**0.62%**
		Bresson Dr.	*44.44%*	*51.85%*	*3.7%*	*0%*
	Double Diamond ES	**S. Meadows Pwky.**	**1.39%**	**54.57%**	**40.34%**	**3.71%**

Table **3.9**. Observed Compliance and Speed Categorization during Non-School Zone Speed Control Period

Study Sites	School Name	Roadway	Non-School Zone Speed Distribution Rates			
			Compliance	1-10 mph Over	11 – 20 mph Over	21 mph + Over
Southern NV	Bonanza HS	**S. Torrey Pines Dr.**	**35.87%**	**56.42%**	**7.62%**	**0.09%**
		Del Rey Ave.	*37%*	*51.98%*	*9.69%*	*1.32%*
		Redwood St.	*19.83%*	*49.14%*	*28.45%*	*2.59%*
	Cashman MS	**W. Desert Inn Rd.**	**92.49%**	**6.98%**	**0.53%**	**0%**
		Cameron St.	*22.62%*	*60.71%*	*16.67%*	*0%*
		S Warnock Rd.	*50.83%*	*44.17%*	*5%*	*0%*
	Charles Silvestri Jr HS	**E. Silverado Ranch Blvd.**	**67.64%**	**31.4%**	**0.95%**	**0%**
		Jack Leavitt St.	*23.89%*	*58.41%*	*17.7%*	*0%*
	J. H. Brinley MS	**W. Smoke Ranch Rd.**	**21.19%**	**63.15%**	**15.32%**	**0.35%**
		Maverick St.	*56.31%*	*37.86%*	*5.83%*	*0%*
	Fremont MS	**E. St. Louis Ave.**	**62.13%**	**36.09%**	**1.78%**	**0%**
	M. Cortez ES	**E. Tonopah Ave.**	**47.29%**	**50.39%**	**2.33%**	**0%**
		N. Lamb Blvd.	*79.13%*	*20.43%*	*0.38%*	*0.06%*
	Northwest Career S	**W. Tropical Pkwy.**	**8.24%**	**56.13%**	**34.27%**	**1.37%**
	Mervin Iverson ES	**American Beauty Ave.**	**23%**	**68%**	**9%**	**0%**
		S. Hollywood Blvd.	*16.85%*	*65.02%*	*17.41%*	*0.72%*
	Oran K.G ES	**E. Bonanza Rd.**	**32.06%**	**58.33%**	**9.6%**	**0%**
		N. Honolulu St.	*56.31%*	*37.86%*	*5.83%*	*0%*
	Southwest Career S	**S. Rainbow Blvd.**	**56.39%**	**39.42%**	**4.01%**	**0.18%**
		W. Shelbourne Ave.	*19.92%*	*41.87%*	*36.18%*	*2.03%*
Northern NV	Innovation HS	**W. 2nd St.**	**78.95%**	**21.05%**	**0%**	**0%**
	Mendive MS	**Vista Blvd.**	**21.68%**	**69.4%**	**8.67%**	**0.25%**
		Whitewood Dr.	*56.59%*	*40.42%*	*2.99%*	*0%*
		Del Rosa Way	*38.12%*	*57.43%*	*4.46%*	*0%*
	Reno HS	**Booth St.**	**23.46%**	**65.43%**	**10.49%**	**0.62%**
		Foster Dr.	*21.35%*	*68.91%*	*9.55%*	*0.19%*
	Vaughn MS	**Vassar St.**	**22.7%**	**68.25%**	**8.89%**	**0.16%**
		Bresson Dr.	*75%*	*20.83%*	*4.17%*	*0%*
	Double Diamond ES	**S. Meadows Pkwy.**	**24.94%**	**66.57%**	**8.33%**	**0.16%**

To capture a comprehensive and better understanding of each study site's speed features, it is essential to review speed statistics, especially the 85th percentile and maximum speed in addition to average speed values. Tables **3.10** and **3.11** describe the observed speed statistics including the 85th percentile speed that is critical in assessing vehicle driving speeds in relation to the posted speed limit.

Table **3.10**. Speed-related Statistics during School Zone Speed Control Period

Study Sites	School Name	Roadway	Speed Statistics (mph)			
			Speed Limit	85th Percentile Speed	Average Speed	Maximum Speed
Southern NV	Bonanza HS	**S. Torrey Pines Dr.**	**15**	**25.91**	**18.49**	**44.94**
		Del Rey Ave.	*15*	*14.32*	*8.29*	*30.06*
		Redwood St.	*15*	*23.62*	*15.4*	*40.08*
	Cashman MS	**W. Desert Inn Rd.**	**15**	**20.75**	**16.53**	**43.66**
		Cameron St.	*15*	*22.87*	*14.49*	*32.21*
		S Warnock Rd.	*15*	*27.91*	*17.32*	*35.78*
	Charles Silvestri Jr HS	**E. Silverado Ranch Blvd.**	**15**	**31.49**	**22.85**	**52.25**
		Jack Leavitt St.	*15*	*17.17*	*10.41*	*39.57*
	J. H. Brinley MS	**W. Smoke Ranch Rd.**	**15**	**26.73**	**19.15**	**47.96**
		Maverick St.	*15*	*17.44*	*10.22*	*29.35*
	Fremont MS	**E. St. Louis Ave.**	**15**	**29.35**	**22.98**	**46.53**
	M. Cortez ES	**E. Tonopah Ave.**	**15**	**22.19**	**13.32**	**36.79**
		N. Lamb Blvd.	*15*	*19.44*	*27.2*	*55.12*
	Northwest Career S	**W. Tropical Pkwy.**	**15**	**21.47**	**16.72**	**45.81**
	Mervin Iverson ES	**American Beauty Ave.**	**15**	**27.91**	**17.8**	**46.53**
		S. Hollywood Blvd.	*15*	*33.64*	*14.32*	*56.54*
	Oran K.G ES	**E. Bonanza Rd.**	**15**	**21.47**	**15.77**	**53.68**
		N. Honolulu St.	*15*	*19.32*	*13.23*	*30.06*
	Southwest Career S	**S. Rainbow Blvd.**	**25**	**24.33**	**12.11**	**40.36**
		W. Shelbourne Ave.	*15*	*16.11*	*8.98*	*32.93*
Northern NV	Innovation HS	**W. 2nd St.**	**15**	**27.91**	**19.29**	**39.36**
	Mendive MS	**Vista Blvd.**	**25**	**45.09**	**33.29**	**62.27**
		Whitewood Dr.	*15*	*14.32*	*8.29*	*30.06*
		Del Rosa Way	*15*	*24.33*	*16.23*	*37.93*
	Reno HS	**Booth St.**	**15**	**32.4**	**24.79**	**45.81**
		Foster Dr.	*15*	*24.33*	*15.32*	*37.93*
	Vaughn MS	**Vassar St.**	**15**	**22.19**	**17.2**	**40.56**
		Bresson Dr.	*15*	*17.17*	*11.02*	*26.48*
	Double Diamond ES	**S. Meadows Pwky.**	**15**	**21.47**	**16.52**	**47.96**

Table **3.11**. Speed-related Statistics during Non-School Zone Speed Control Period

Study Sites	School Name	Roadway	Speed Statistics (mph)			
			Speed Limit	85^{th} Percentile Speed	Average Speed	Maximum Speed
Southern NV	Bonanza HS	**S. Torrey Pines Dr.**	**35**	**39.57**	**32.41**	**57.27**
		Del Rey Ave.	*25*	*30.42*	*20.86*	*48.67*
		Redwood St.	*25*	*35.07*	*24.13*	*52.25*
	Cashman MS	**W. Desert Inn Rd.**	**45**	**43.94**	**38.32**	**68.63**
		Cameron St.	*25*	*30.24*	*23.34*	*40.8*
		S Warnock Rd.	*25*	*28.24*	*22.95*	*36.51*
	Charles Silvestri Jr HS	**E. Silverado Ranch Blvd.**	**45**	**47.24**	**41.91**	**69.79**
		Jack Leavitt St.	*25*	*35.07*	*28.88*	*49.91*
	J. H. Brinley MS	**W. Smoke Ranch Rd.**	**35**	**42.94**	**35.89**	**60.84**
		Maverick St.	*25*	*27.2*	*18.36*	*41.2*
	Fremont MS	**E. St. Louis Ave.**	**30**	**29.35**	**22.89**	**48.67**
	M. Cortez ES	**E. Tonopah Ave.**	**25**	**28.63**	**20.5**	**39.37**
		N. Lamb Blvd.	*45*	*44.38*	*35.36*	*73.37*
	Northwest Career S	**W. Tropical Pkwy.**	**30**	**42.23**	**35.67**	**57.66**
	Mervin Iverson ES	**American Beauty Ave.**	**25**	**30.78**	**25.85**	**41.51**
		S. Hollywood Blvd.	*35*	*45.09*	*35.93*	*63.7*
	Oran K.G ES	**E. Bonanza Rd.**	**35**	**42.23**	**34.11**	**60.45**
		N. Honolulu St.	*25*	*30.06*	*21.72*	*38.65*
	Southwest Career S	**S. Rainbow Blvd.**	**45**	**50.31**	**40.58**	**66.01**
		W. Shelbourne Ave.	*25*	*37.22*	*28.88*	*52.25*
Northern NV	Innovation HS	**W. 2nd St.**	**30**	**27.91**	**23**	**36.79**
	Mendive MS	**Vista Blvd.**	**40**	**38.54**	**46.53**	**99.42**
		Whitewood Dr.	*25*	*26.48*	*18.51*	*38.65*
		Del Rosa Way	*25*	*19.11*	*27.91*	*39.97*
	Reno HS	**Booth St.**	**25**	**32.4**	**24.79**	**45.53**
		Foster Dr.	*25*	*30.78*	*25.85*	*41.51*
	Vaughn MS	**Vassar St.**	**25**	**31.49**	**26.72**	**47.24**
		Bresson Dr.	*25*	*24.33*	*17.23*	*41.95*
	Double Diamond ES	**S. Meadows Pkwy.**	**35**	**38.65**	**29.51**	**56.54**

Similar to the results derived from LiDAR data, maximum speeds within all studied school zones were significantly exceeded, even during the designated school zone speed control periods. However, the extent of speed violations was less than those captured by LiDAR data. This discrepancy may be attributed to the nature of high-resolution vehicle telemetric data, which records speed directly from in-vehicle sensors and aggregates instantaneous speed variations every 3 seconds, potentially smoothing out extreme speed fluctuations.

When comparing the compliance rates between LiDAR and high-resolution vehicle telemetric data, the most significant difference was observed at Double Diamond Elementary School. The compliance rate derived from telemetric data was substantially lower than that recorded by LiDAR. This school zone, located on South Meadows Parkway, spans a relatively long distance, as illustrated in Figure **3.6**.

Figure **3.6**. Westbound Trajectory Waypoints within the School Zone on South Meadows Parkway

In the LiDAR study area, compliance rates are higher, as indicated by a significant proportion of green dots in the observations. However, there is a noticeable increase in speeding maneuvers both upstream and downstream of the school zone. Since the compliance rate is based on trajectories traversing the entire school zone, this pattern leads to a significant deterioration in overall compliance. Figure **3.7** exhibits speed distribution along the school zone in detail. Callout 7 presents the lowest speed, which occurs near the intersection.

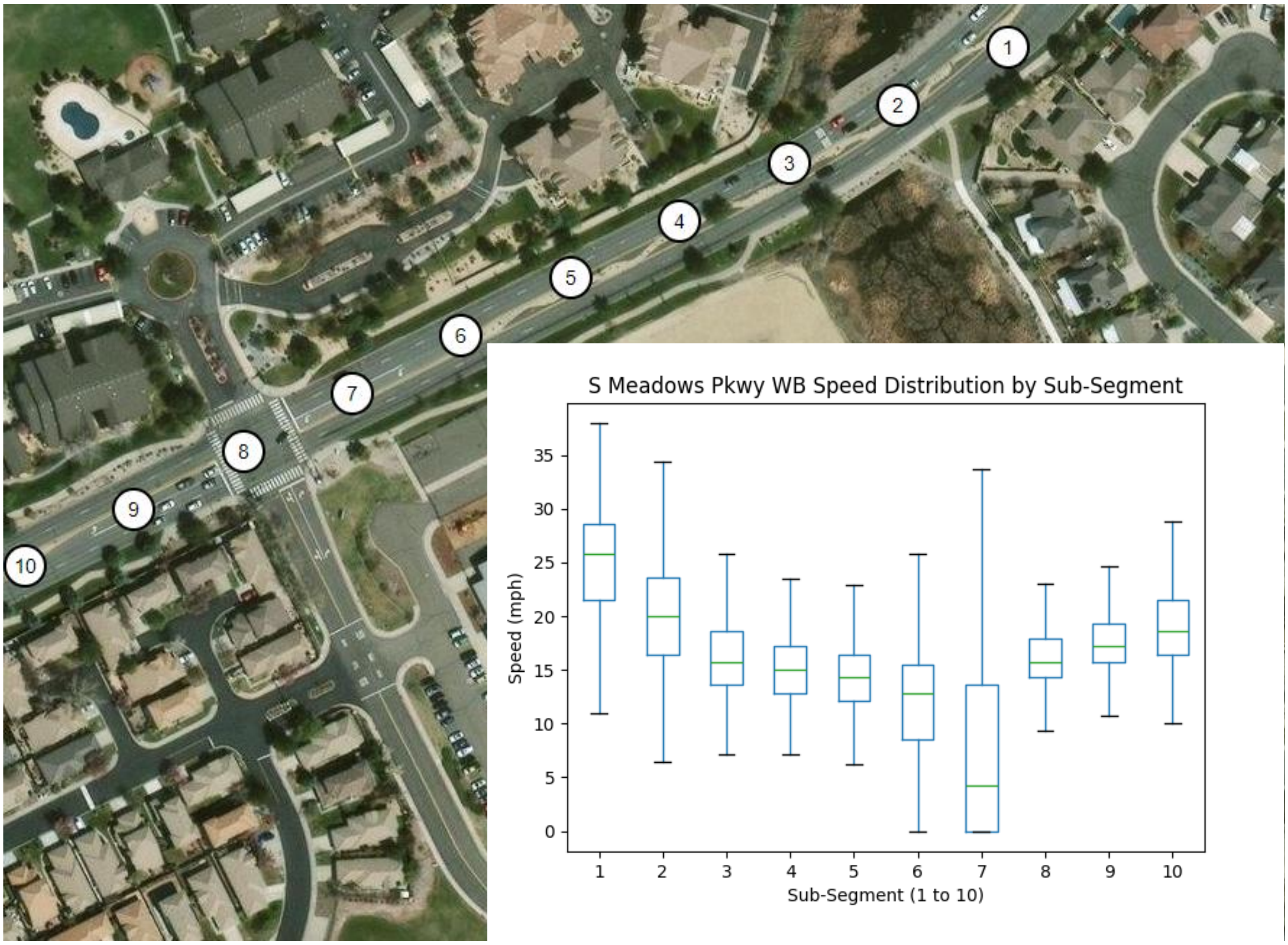


Figure **3.7**. Speed Distribution of Westbound Trajectories within the School Zone

In addition, high-resolution vehicle telemetric data allows for assessment and monitoring for minor roads which are often not covered by conventional data collection efforts. Figure **3.8** shows an example of Warnock Road near Cashman Middle School

Figure **3.8**. Southbound Trajectory Waypoints on Warnock Road during School Zone Speed Control Period

A complete and detailed information of all performance metrics obtained using high resolution vehicle telemetric data, of each site is included in **Appendix B.**

Section 4. Critical Information Synthesis

With this study's aim on reviewing speed features across school zones to enhance overall school safety, this section is organized into two major parts: Section 4.1 summarizes the overall approaches in addressing school zone speed and Section 4.2 focusing on the automated speed control strategy.

4.1 General Approaches to Managing School Zone Speed

Speed management in school zones is crucial for ensuring the safety of students and road users, including pedestrians, due to the high pedestrian volume during peak commuting times on school days. According to the latest National Child Mortality Database (NCMD), traumatic injuries as a result of a vehicle collision are the leading cause of child death in the United States (NCMD Programme, 2023). Research also revealed that school-age children are at higher risk of auto-pedestrian collisions (APCs) on school days (Morrison et al., 2022). In the United States, various strategies are employed to enhance school safety, especially with the launch of the Safe Routes to School Program in every 50 states and the District of Columbia. In this study, the Three Es (Engineering, Enforcement, and Education)" approach will be reviewed: (1) Engineering improvement that primarily includes the following: i) Improve infrastructure, including modifying the geometric design such as speed bumps and humps, roundabouts, enhanced crosswalks, and added lanes. ii) Add informative signals, such as pedestrian beacons, dynamic messages, and vehicle real-time speed displays. (2) Enforcement that covers approaches of implementing speed enforcement through automated methods (e.g., red-light safety cameras, speed safety cameras, school bus stop-arm cameras, etc.), and manual enforcement (e.g., police officer presence). (3) Education: Enhance safety awareness through education. These efforts can work separately or in combination to create a safer environment around schools, protecting vulnerable populations from traffic hazards. The following section will introduce these commonly used approaches for managing speed in school zones.

4.1.1 Engineering

Engineering efforts encompass improvements of 1) infrastructure design, such as speed bumps, roundabouts, enhanced crosswalks, and added lanes; 2) traffic control elements, such as traffic signals, road signs or markings to control speed and provide advance notice to drivers (e.g., pedestrian beacons, dynamic messages, vehicle real-time speed displays). This approach is widely used due to its cost-effectiveness and minimum privacy concerns. Table **4.1** presents some examples of engineering approaches to mitigating school zone speed.

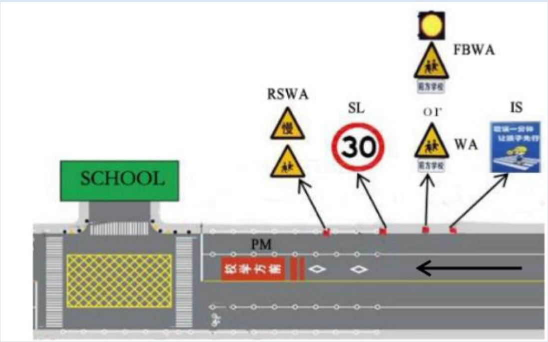
Table **4.1.** Engineering Efforts

Project Managing or Research Conducting Agency and State Reference Source(s)	Effort and Results
Phoenix City Council, Arizona Reference: (Thomas E. Callow, 2002)	In 2002, the city implemented solar-powered driver feedback monitors operating from 7 am to 5 pm on school days. A staggered median safety island replaced one crosswalk, and pedestrian warning signs instructed students to "Use Caution When Entering the Street." A talking pushbutton for a walkway entrance of the school has a gated entrance that is closed outside of arrival and dismissal times.  A Staggered Crosswalk Was Installed for The Program During these periods, it was found that the 85th percentile speeds were 29 mph, which was 6 mph less than the posted speed limit. There was only a singular pedestrian collision six months after the project was completed. It was also noted that significantly fewer pedestrians crossed at unmarked locations and used more caution when crossing. Motorists were also observed to be more willing to stop for pedestrians.

San Francisco, California **Reference: (Jose, 2015)**	In 2012, around Marshall Elementary School, the San Francisco Municipal Transportation Agency created "Home Zones" to focus on improving traffic calming measures.  Minna-Natoma Home Zone Project Area Speed humps, edge lines, raised crosswalks, painted markings, and accessible platforms were installed. The study found to reduce average vehicle speeds below 20 mph. The perception of pedestrian safety in relation to vehicles stopping or yielding improved. Pedestrian volumes had an increase of about 20% on average. There was a significant increase in motor vehicle volumes during the study.
Mississippi Department of Transportation, Mississippi **Reference: (Strawderman et al., 2013)**	In 2013, the Mississippi DOT conducted a study to determine the impact of school zone sign density as a means for DOT guidelines regarding school zone signage placement. It was revealed that vehicle speeds on 2-lane roads and in low sign saturation school zones were the points where the vehicle speeds were the highest. The speeds were most effectively reduced at points where there were four-lane roads with a high saturation of signs.
Washoe County, Nevada **Reference: (Hardy, 2024)**	The American Rescue Plan Act granted $40,000 to the Washoe County School District and the City of Reno to install light beacons at several school zones. It was recorded that for the 2023-2024 school year, there were 13 student-involved crashes, all of which involved students' routes home from school and 6 in the school zone itself.
New York City, New York **Reference: (DiMaggio et al., 2014)**	In 2005, New York City was granted $10.2 million to implement a Safe Routes to School (SRTS) program. The proposed changes included 124 schools receiving road narrowing, new traffic and pedestrian signals, timed crossings, speed bumps, speed boards, high-visibility crosswalks, and new parking regulations. There was a successful decline in school-travel-related pediatric pedestrian injury risk with the intervention of SRTS. Between 2001 and 2010, there were 140,835 pedestrian crashes in New York City, of which 4,021 injuries involved school-aged pedestrians injured during school travel hours. By comparing census tracts with completed SRTS improvements to non-STRA census tracts, there was an overall 44% risk reduction in pedestrian versus auto collisions.
Pitt County,	The Eastern Carolina Injury Prevention Program (ECIPP) conducted a citation study alongside

North Carolina **Reference: (Sarah Worth O'Brien & Carrie L. Simpson, 2012)**	a speed study to determine the effectiveness of "Your Speed" signs surrounding the school.  "School Speed Limit" Sign Assembly Incorporating "Your Speed" Sign The 85th percentile speeds of drivers above the speed limit decreased by at least 10.6% following the installation of "Your Speed" signage. Long-term compliance with "Your Speed" signs did not diminish after drivers became more accustomed to its presence. However, outside of school hours, when the "Your Speed" signs were non-operational, drivers were observed to generally drive at the same speeds that were recorded before the signs were installed.
Montgomery County Department of Transportation, Maryland **Reference: (Montgomery County Department of Transportation, 2020)**	MCDOT's Safe Routes to School team works to improve infrastructure within ½ mile radius around schools in Montgomery County so that students walking to and from school are safe. The team improves physical and operational infrastructure around schools, so that speed and other potential conflicts with motor vehicles can be reduced. This includes installing crosswalks, ADA ramps, high-intensity activated crosswalk (HAWK) signals, pedestrian countdown signals, bike racks, and more.  An Island Was Installed North of Whetstone Elementary School
Texas Transportation Institute, Texas Reference: **(Ullman & Rose, 2005)**	In 2005, a study evaluated dynamic speed display signs (DSDS) installations in various permanent locations, including school speed zones, transition speed zones, sharp horizontal curves, and approaches to signalized intersections on high-speed roadways.

	Example of Permanently Installed Self-contained DSDS Units Researchers measured vehicle speeds before the installation, one week after, and four months post-installation to assess both initial and sustained effects of the DSDS. The findings showed that DSDSs reduced average speeds significantly in school zones by up to 9 mph, while reductions in other areas were less pronounced, averaging 5 mph or less. The study concluded that DSDSs are particularly effective in reducing the speeds of higher-speed vehicles and can maintain their effectiveness over time under appropriate site conditions.
Texas Department of Transportation, Texas **Reference: (Texas Transportation Institute, 2004)**	A research effort analyzed the speed data before and after rear-facing school speed limit beacons were installed in the field. Results show that a flashing beacon at the end of the school zone is a potentially effective means of improving drivers' compliance with school zone speed limits. The percentage of vehicles exceeding 35 mph was significantly reduced by approximately 25–30%. Rear-Facing Beacon Installation
Brigham Young University, Utah **Reference: (Ash & Saito, 2012)**	In 2010, speed monitoring displays (SMDs) were installed in four reduced-speed school zones in Utah to evaluate the effectiveness of these dynamic signs in improving speed compliance. Safety and efficiency vary by location, and SMDs can reduce speed and increase drivers' speed compliance without any negative impact on-site safety.
City of Bellevue, Washington Reference:	The Elementary School Crosswalk Enhancement Program was incorporated into five locations based on the pedestrian density surrounding the schools. The project costs about $15,000 per school and is funded by the DOT for Bellevue and the Bellevue Parent-Teacher-Student Association.

(City of Bellevue, 2012)	Measures were taken to improve the infrastructure for pedestrians by raising the crosswalks, extending the curbs, and adding bollards and traffic circles. The city also implemented educational measures, which were shown as safety tip plaques on the bollards and brochures for safe walking practices. The average vehicle speed was reduced by 3 mph, and parents/residents of the area received highly positive feedback about the improvements. The only disadvantage found was the limitation of bicycle lanes due to the curb extensions.
Beijing University of Technology, China **Reference: (Xiaohua Zhao et al., 2016)**	In 2016, a study tested multiple design alternatives, including Flashing Beacons, School Crossing Ahead Warning Assemblies, Reduce Speed and School Crossing Warning Assemblies, and School Crossing Ahead Pavement Markings.  Placement for Six Types of Signs and Markings The results indicated that the Flashing Beacon and School Crossing Ahead Warning Assembly, the Reduce Speed and School Crossing Warning Assembly, and the School Crossing Ahead Pavement Markings were most effective for school zones adjacent to major multilane roadways characterized by high traffic volume and the presence of pedestrian crossing signals. For school zones on minor two-lane roadways with lower traffic volume and without pedestrian signals, the School Crossing Ahead Pavement Markings were recommended.
University of Calgary, Canada **Reference: (Tay, 2009)**	In 2009, a study investigated speed compliance in school and playground zones. The study found that mean speed and non-compliance rates were lower in school zones with chain-link fencing than without fencing.
Swiss Federal Roads Office (FEDRO), Switzerland **Reference: (Lindenmann, 2005).**	In 2005, a research effort focused on residential districts and neighborhood streets where reduced speed limits, combined with structural traffic calming measures (e.g., speed bumps and road narrowing) were implemented. The study revealed a significant reduction in accident frequency and severity, with a 15% overall decrease in accidents and a 27% decline in accident severity. These findings supported the rapid and extensive implementation of 30 km/h zones across Swiss municipalities.
City of Gwacheon and Ajou University, South Korea **(Lee et al., 2006a)**	In 2006, researchers conducted a study on speed-monitoring displays (SMDs) to evaluate their effectiveness in reducing vehicle speeds in school zones in South Korea. In the short term, vehicle speeds decreased by an average of 17.5% (8.2 km/h) upon drivers recognizing the presence of an SMD, with consistent reductions observed throughout the day. The 85th percentile speed also dropped from 54.3 km/h to 46.3 km/h. Over the long term, the effectiveness slightly diminished but remained significant, with a

	12.4% (5.8 km/h) average speed reduction and a further decrease in the 85th percentile speed to 45.0 km/h. The installation of SMDs resulted in a substantial reduction in the number of speeding vehicles, indicating a lasting positive impact on driver behavior and enhanced traffic safety in school zones.

4.1.2 Enforcement

On-site speed enforcement by law enforcement personnel is the predominant form of speed enforcement across the United States. Radar or laser speed detection devices held by hand or mounted on petrol vehicles are used to monitor vehicle speed, and then speeding drivers are pulled over manually. In September 2023, the Green Bay police department (GBPD) deployed officers to patrol six school zones for speed enforcement. There were 72 written warnings and 59 speed citations, mostly in school zones, during the enforcement week (Green Bay Police Department, 2023). In January 2024, the Reno police department focused on designated pedestrian safety zones in downtown Reno and school zones to enforce pedestrian safety. During that time, the police department issued 120 traffic tickets, 39 warnings, and three arrests (Timko, 2024). Although police presence in school zones is perceived as an effective measure, it requires significant resources (e.g., police workforce). A recent study in Nevada, though limited to the northern Nevada sites, indicated that law enforcement personnel presence may not significantly reduce driver speeds as anticipated, especially once law enforcement personnel departs, given the considerable effort involved (Vargo, 2024).

Automated enforcement (AE) uses cameras to capture images of drivers committing traffic violations. Fully automated systems capture the license plate information of offenders and send citations to the registered owners. More advanced systems allow citations to be sent directly to the individual driver. According to the categorization provided by the Governors Highway Safety Association (GHSA), the common types of AE include red-light safety cameras, speed safety cameras, and school bus stop-arm cameras as exhibited in Figure **4.1**. (DeWeese, 2023).

Figure **4.1.** Automated Enforcement Technologies (DeWeese, 2023)

Red-light safety cameras

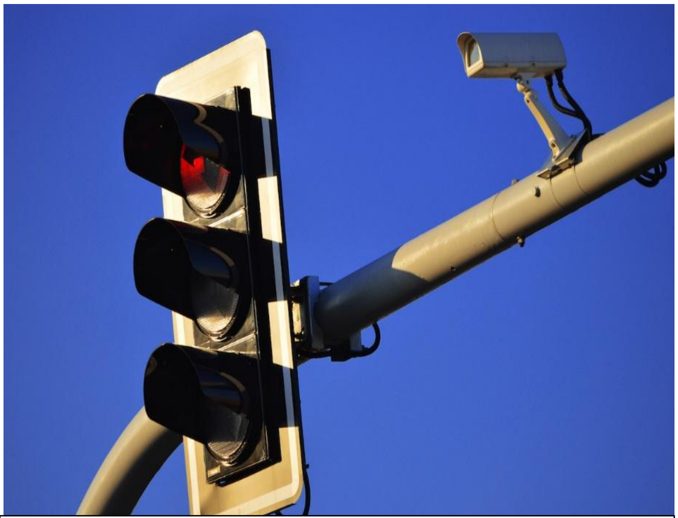


Figure **4.2.** Red-light Safety Camera (Lee Cossell,

Red-light safety cameras (Figure **4.2**.) capture photographs of vehicles that enter intersections after the traffic light has turned red. These cameras are integrated with the traffic signals and equipped with sensors that monitor traffic flow, thus capable of detecting and capturing images of vehicles that enter the intersection after the traffic signal has turned red, providing evidence for issuing citations. Photos are then reviewed by police officers, the camera vendor, and law enforcement officials before issuing a citation. Currently, twenty-two states and the District of Columbia enacted laws permitting red-light camera use, while eight states have passed laws prohibiting red-light cameras (World Population Review, 2024).

Speed safety cameras

Figure **4.3**. Speed Safety Camera in Georgia (WGXA News, 2023)

Speed Safety Cameras (SSCs, Figure **4.3**.), also known as Automated Speed Enforcement (ASE), are advanced systems that use cameras and speed measurement technologies to detect and photograph vehicles that exceed the speed limit. They operate in conjunction with various approaches, such as engineering solutions, educational campaigns, and conventional law enforcement methods. The primary goal of SSCs is to influence driver conduct, discourage speeding, and enhance overall road safety. The legislation status and exemplary successful practices of SSCs will be discussed in detail in the following Section 4.2.

School bus stop-arm cameras

School bus stop-arm cameras are mounted to protect students as they board and disembark. These cameras activate when the bus's stop arm extends, capturing high-resolution images and videos of vehicles illegally passing the stopped bus. This technology provides clear evidence of violations that can be used to identify and penalize speeding drivers. In October 2020, Carroll County Public Schools (CCPS) in Maryland equipped 311 school buses with *BusPatrol*'s stop-arm cameras, which effectively capture violations of school bus-stopping laws, recording incidents. The camera deployment has led to a substantial reduction in stop-arm violations, improving safety for the district's 23,500 daily student bus riders (Spree, 2021). Up to 2023, There are 24 states with laws allowing for stop-arm cameras, but only about a dozen have actually implemented them (Gray, 2023).

Figure **4.4**. School Bus Arm Camera (Spree, 2021)

In the context of this study, speed safety camera (SSC) is the technology that is promising for mitigating the rising concerns in relation to speeding in school zones in Nevada. For consistency and clarity, the terms **Automated Enforcement (AE)**, **Automated Speed Enforcement (ASE)**, and **Safe Speed Cameras (SSCs)** will be used interchangeably throughout the remainder of this report.

While following paragraphs provide detailed contents of various automated enforcement technologies, it should be noted that in this school zone study, specifically, the AE, Automated Speed Enforcement (ASE), and SSCs can be considered interchangeably.

4.1.3 Education

Education has a crucial role in enhancing traffic safety. Programs that educate drivers, pedestrians, and cyclists about safe practices (e.g., safe crossing) can significantly reduce risks and promote safety. These educational efforts include public awareness campaigns, school-based safety programs, and community workshops, all aimed at informing individuals about the importance of following traffic rules and adopting safe behaviors on the roads. Table **4.2** illustrates sample Education efforts in enhancing school safety.

Table **4.2**. Educational Efforts

Project Managing or Research Conducting Agency and State Reference Source(s)	Effort and Result
Los Angeles School District, California **Reference: (Arbogast et al., 2014)**	In 2011, the Los Angeles Unified School District tested students with a randomly divided split between using a unique interactive video game about pedestrian safety and a traditional didactic session about pedestrian safety. Before and after the study, the students were tested on a simulated street set called Street Smarts to observe appropriate pedestrian behavior. While the student's decision-making behavior improved comparably with both methods, students who played the video game more frequently exhibited appropriate behavior for exiting a parked car, signaling to a car backing up, and signaling to a stopped car.
Montgomery County, Maryland **Reference: (Dunckel et al., 2014)**	In 2007, as part of the Pedestrian Safety Initiative Program, students were challenged to think about pedestrian safety through a stakeholder group comprised of parents, teachers, and students, which helped to develop strategies, messages, and activities. The school also hosted assemblies, overhead announcements, and bracelet handouts to encourage the students to be more invested in their own pedestrian safety.

Detroit Public School System, Michigan **Reference: (Timothy J. Gates et al., 2010)**	The Detroit Public School System conducted initial training that involved written pre and post-tests, as well as before-and-after observations of street-crossing behavior among students in Grades 2-7 at five public schools in Detroit. Then, 7 to 12 months after the initial training was completed, students were retrained to refresh on the safety topics discussed initially. The study measured the effectiveness of training based on two measures of effectiveness 1) the child pedestrian violation rate and 2) the percentage of correct test responses. The study saw an overall decrease of 35.4% in violation rates and a 40% increase in test scores. The study recommends that students be retrained annually for pedestrian safety within elementary and middle schools.

4.1.4 Summary

Engineering, Enforcement, and Education are the "Three Es" critical for enhancing safety in school zones.

- The engineering method offers direct and immediate improvements to school zone safety through physical infrastructure. Basic methods like well-marked crosswalks, adequate signage, and flashing lights provide clear visual cues that alert drivers to the presence of a school zone and encourage slower speeds. Traditionally, school zones are equipped with those basic roadway markings and traffic signs to notify drivers they have entered a school zone. In some cases, more advanced methods are considered based on the specific situation and environment due to higher costs and require careful consideration and planning, such as raised crosswalks, medians, platforms, and added lanes. The engineering method is the most popular and widely applied approach with cost-effectiveness. However, the concentration of intensive information in one place can sometimes distract drivers, and it does not work for those who intentionally speed despite being aware of the school zone. In such cases, enforcement tends to be more effective than engineering methods.

- Traditional enforcement, like police patrols, offers immediate consequences for non-compliance. Drivers slow down when they perceive the presence of police to avoid high penalties in school zones. However, one police officer can only pull over one vehicle at a time, which reduces its overall effectiveness when multiple vehicles are speeding simultaneously. Additionally, the limited number of officers available for patrol means that coverage is often insufficient, leading drivers to perceive a low risk of being caught. Automated enforcement significantly enhances the effectiveness of traffic law enforcement by integrating the strengths of both engineering and enforcement. Despite initial legislative challenges, there has been a growing acceptance of automated enforcement methods across the country in recent years. This trend is reflected in the expanding application of SSCs. The following section will delve into the legislative history and current deployment of SSCs.

- Education focuses on teaching pedestrians, bicyclists, and drivers about safe practices to change their attitudes and behaviors over time, laying the groundwork for long-term safety improvement. However, it needs to be applied in conjunction with proper engineering and enforcement methods, as drivers and pedestrians need clear cues and infrastructure to stay alert and keep safe. Additionally, the effectiveness of education can be limited if not regularly reinforced and may not immediately influence those who are already negligent or unaware of school zone safety protocols.

4.2. Speed Safety Camera (SSC)

Speed Safety Camera (SSCs), previously known as Speed Camera Enforcement or Automated Speed Enforcement (ASE), is recognized as the five-star method among the Federal Highway Administration's (FHWA) 28 proven safety countermeasures (FHWA, 2024). "*We're losing far too many of our friends and loved ones to preventable traffic crashes*," said Jonathan Adkins, chief executive of the Governors Highway Safety Association (GHSA). "*Safety cameras can help change that. The data and research clearly show that automated enforcement reduces the dangerous driving behaviors that needlessly kill people every day*" (Mohn, 2023). In addition, according to the Crash Modification Factor (CMF) Clearinghouse, the CMF of Automated Speed Camera Enforcement Cameras shows an average of 0.868 value, which indicates approximately 13.2% crash reduction can be expected with the implementation of such countermeasures (CMF *Clearinghouse*, 2024). The above facts underline the importance and effectiveness of SSCs in addressing speed concerns. This section illustrates the latest legislative status of speed camera implementation across the U.S. and representative studies highlighting the effectiveness of SSC applications in various cases, such as work zones and speed zones.

4.2.1 Overview of State Law

In 2021, the U.S. Congress passed the Infrastructure Investment and Jobs Act (IIJA), which granted states the ability to use NHTSA grant funding for AE specifically to address speeding and red-light running in school and work zones only (*National* Archives, 2023). Under this legislation, states are permitted to use funding provided through the State and Community Highway Safety Grant Programs (DeWeese, 2023). As of 2023 (Figure 5), speed safety cameras were in operation in 211 U.S. communities across 20 states and the District of Columbia (*Insurance Institute for Highway Safety (IIHS)*, 2023). This is a significant increase from the first two communities to implement speed safety cameras in Peoria, AZ, and Paradise Valley, AZ, in 1987 (*Insurance Institute for Highway Safety (IIHS)*, 2023). Figures **4.5** and **4.6** provide visual representations of the current legislation status of speed cameras and red-light cameras for each state in the U.S. Hawaii and Alaska are not included in the figure. The map highlights the following:

- 5 states legally permit the use of SSCs.
- 16 states, along with the District of Columbia and Rhode Island, permit both speed cameras and red-light cameras.
- 23 states do not legislate their use.
- 4 states permit red-light cameras only.

On October 13, 2023, California passed Assembly Bill No. 645, granting state and local government entities the authority to install and operate speed cameras in designated high-risk areas. These areas include school zones, work zones, and regions with a high incidence of speed-related accidents. California is the latest state to approve the use of speed cameras. The use permissions across the U.S. are listed in Table **4.3**. It should be noted that California, Utah, and Missouri are listed as permitted in Table **4.3** but shown as not permitted in Figure **4.6** due to different updated times and definitions from various sources. In Table **4.3**, these three states are listed as permitted under specific restrictions.

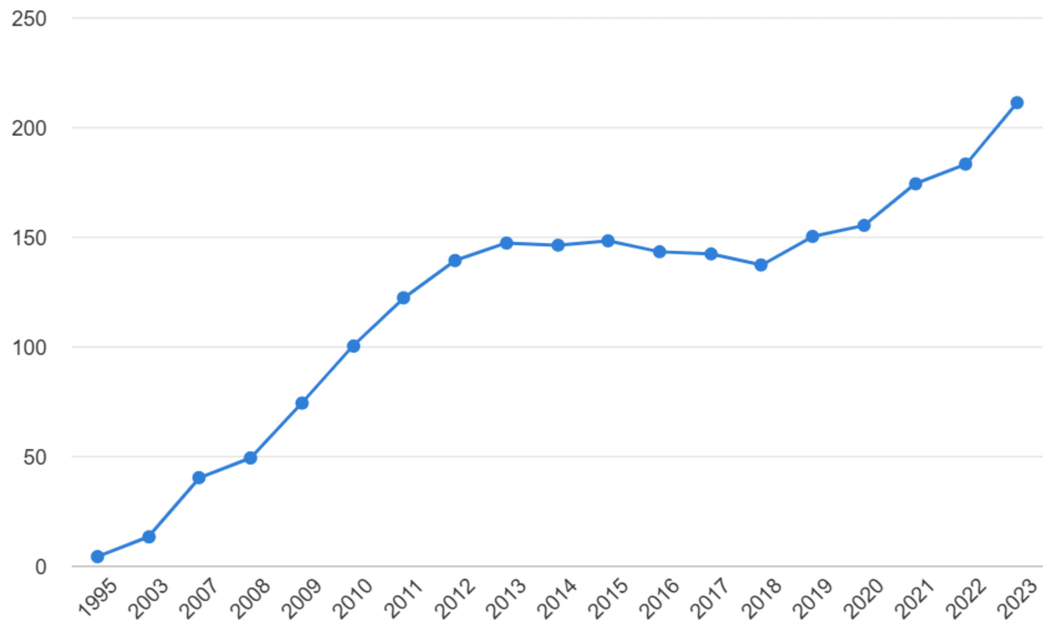


Figure **4.5**. Trends in the Number of U.S. Communities with Speed Safety Cameras(Insurance Institute for Highway Safety (IIHS), 2024)

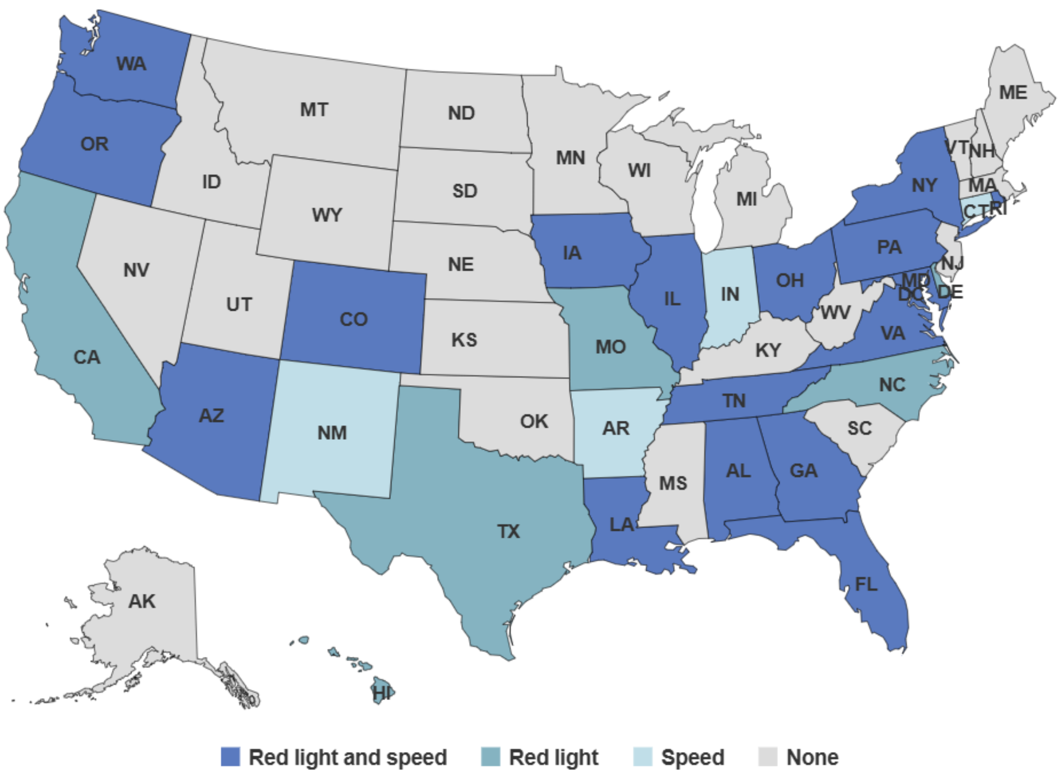


Figure **4.6**. States where Speed and Red-light cameras Are Used (Insurance Institute for Highway Safety (IIHS), 2024)

Table **4.3**. State that Legally Permit to Use SSCs (FindLaw, 2024; Insurance Institute for Highway Safety (IIHS), 2024)

State	Where are cameras permitted?
Alabama (AL)	Alabama permits speed cameras within specific jurisdictions, such as Center Point and Midfield.
Arizona (AZ)	Arizona permits the use of cameras to enforce speed and red lights as long as the use complies with Arizona state standards.
Arkansas (AR)	Arkansas permits speed cameras in limited circumstances: school zones, railroad crossings, and highway work zones when a police officer is present. Arkansas permits speed cameras in limited circumstances: school zones, railroad crossings, and highway work zones when a police officer is present.
California (CA)	School zones, safety corridors, and known speed contest or exhibition streets within specified jurisdictions
Colorado (CO)	Colorado law permits red light and speed enforcement cameras in limited circumstances.
Connecticut (CT)	Work zones on highways with posted speed limits of 45 mph or greater, school zones, pedestrian safety zones, and DOT-approved locations
Delaware (DE)	Work zones and residential districts
District of Columbia (DC)	Citywide
Florida (FL)	School zones
Georgia (GA)	School zones
Illinois (IL)	Construction or maintenance speed zone, in a safety zone (within 1/8th of a mile of a school or a park district used for recreational purposes) in municipalities with a population of 1,000,000 or more inhabitants
Indiana (IN)	Highway work sites when workers are present
Iowa (IA)	Specified jurisdictions
Louisiana (LA)	Specified jurisdictions
Maryland (MD)	Specified jurisdiction; highway work zones
Missouri (MO)	Specified jurisdictions
New Mexico (NM)	Specified jurisdictions
New York (NY)	Specified jurisdictions and work zones
Ohio (OH)	Statewide
Oregon (OR)	Statewide
Pennsylvania (PA)	Philadelphia; active work zones; no more than 5 Philadelphia school zones

Rhode Island (RI)	School zones, Monday through Friday, between 7:00 a.m. and 6:00 p.m. from August 15 through June
Tennessee (TN)	On school zone and on any S-curve that inhibits a driver's full vision through the bend
Utah (UT)	School zones and areas that have a posted speed limit of 30 mph or less
Virginia (VA)	School crossing zones, highway work zones and high-risk intersection segments
Washington (WA)	Hospital, public park, and school speed zones; school walk zones; roadway and state highway work zones when workers are present; specified state highways within city limits; limited high crash risk locations

4.2.2 Overview of SSC Practices

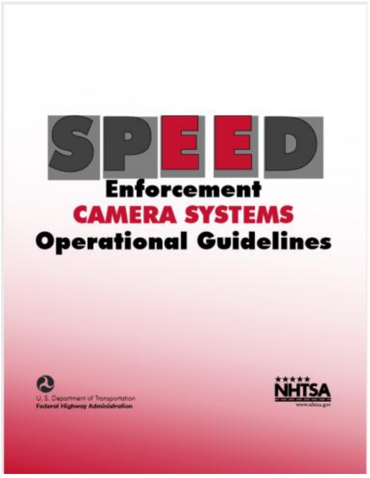
In 1987, the Paradise Valley Police Department in Arizona became the first agency in the Nation to utilize SSCs. After SSCs were deployed, the town realized a 42 percent decrease in collisions. The deployment of photo enforcement has continued to rise through time, with 49 communities using SSCs in 2008 (FHWA, 2024b), as illustrated in Figure **4.5**. In 2021, FHWA listed SSC as one of the Proven Safety Countermeasures (FHWA, 2024a). In 2022, USDOT National Roadway Safety Strategy 2022 (NRSS) called out to enable safer speeds by promoting SSCs as a Proven Safety Countermeasure and piloting automated or other enforcement strategies focused on speeding designed to ensure their equitable application (United States Department of Transportation, 2022). Up till 2023, the use of SSCs is not new anymore, operating in 211 U.S. communities and 20 (*Insurance Institute for Highway Safety (IIHS)*, 2023).

Federal Level

With the fast expansion of SSC in recent years, there has been a substantial increase in the number of communities that use SSC as a part of their speed management and traffic law enforcement strategy. To assist practitioners in considering and regulating its use, federal government agencies have published a series of guidelines that instruct the crucial components of an SSC program, including planning and startup, field operations, violation processing, and adjudication.

- In 2008, FHWA and NHTSA jointly published the ***Speed Enforcement Camera Systems Operational Guidelines***. These guidelines were developed based on lessons learned from previous programs, and they also provide a high-level overview of the technologies available at that time (Speed Enforcement Camera Systems Operational Guidelines 2008, 2008).

- As an update to the 2008 guide, in 2023, the ***Speed Safety Camera Program Planning and Operations Guide*** (the SSC Guide) was published. The update adds new information on program practices, technologies, speed-over-distance or point-to-point (P2P) enforcement, and case study examples from jurisdictions using SSC (Speed Safety Camera Program Planning and Operations Guide 2023, 2023).
- In 2023, the Governors Highway Safety Association (GHSA) published ***Automated Enforcement in a New Era*** that examines traffic safety cameras. The report discusses the benefits of traffic safety cameras that detect speeding, red-light running and school bus stop-arm violations and makes recommendations to states and traffic safety partners considering implementing or expanding the use of this proven technology (DeWeese, 2023)
- SSC is also one of the 28 FHWA's Proven Safety Countermeasures, with proven effectiveness of 54% of all types of crash reduction along urban arterials (FHWA, 2024a).



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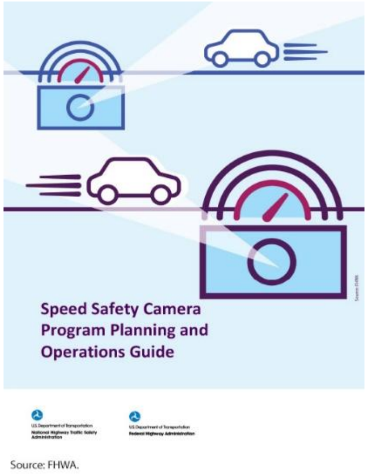

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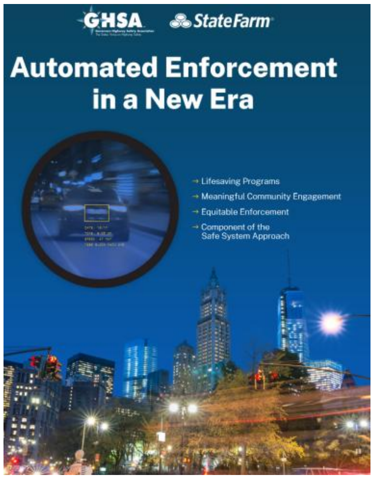

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Figure **4.7a.** Speed Enforcement Camera Systems Operational Guidelines 2008, FHWA
Figure **4.7b**. Speed Enforcement Camera Systems Operational Guidelines 2023, FHWA
Figure **4.7c.** Automated Enforcement in a New Era, GHSA

State Level

SSCs are widely used in more than 20 states and well documented as an effective and sustainable technology for reducing speeds and crashes, significantly improving public safety.

Table **4.4**. State Level Efforts

State Reference Source(s)	Organization	Effort and Outcome
Illinois **Reference: (Illinois Department of Transportation, 2011)**	Illinois Department of Transportation (IDOT)	In 2004, Illinois enacted the Automated Traffic Control Systems in Highway Construction or Maintenance Zones Act, which authorized the use of speed-radar photo enforcement (SPE) in highway work zones.  Speed-radar Photo Enforcement Vehicle SPE was pilot tested in two work zones in Illinois: one on Interstate 64 in the summer of 2006 and another on Interstate 55 in the summer of 2007. SPE effectively reduced vehicle speeds in these work zones by 3 to 8 mph. In almost all scenarios, SPE brought average speeds significantly below the 55-mph speed limit. The percentage of speeding free-flowing cars decreased from 93%, 40%, and 30% to 45%, 8%, and 4% across three data groups. Similarly, the percentage of speeding heavy vehicles dropped from 69%, 17%, and 6% to 15%, 4%, and 1% in the same data groups.
Indiana **Reference: (Indiana Office of Court Services, 2023)**	Indiana Department of Transportation (INDOT)	In February 2023, the House Committee of Roads and Transportation discussed HB 1015, which would implement a worksite speed control pilot program. As a part of the program, the Indiana Department of Transportation would collaborate with state police and a third-party vendor to implement the program. Violations would be issued as an initial warning and then increasing civil penalties for anyone going more than 10 mph over the speed limit. However, INDOT is restricted to placing no more than 4 worksites worth of cameras in a calendar year
New Jersey **Reference: (Janice, 2005)**	New Jersey Institute of Technology (NJIT)	The use of public safety officers, citizen speed watch programs, speed trailers, and automated enforcement to encourage compliance with speed limits" can lead to a 5% speed deduction for vehicles driving from 42 to 39 mph on the study site.

Oregon **References: (Mark Joerger, 2010), (Oregon Department of Transportation, 2023)**	Oregon Department of Transportation (ODOT)	In 2010, the impact of photo radar speed enforcement on traffic speed through an active highway work zone was examined. The result found that 48.7% of vehicles would exceed the posted speed limit of 45 mph during non-enforcement periods. When the photo radar was active, there were only 23.7% of vehicles exceeding the speed limit. In 2022, photo radar was implemented in the I-5 work zone for the Medford Viaduct & Barnett Road Overpass Project due to frequent near-miss incidents. ODOT aims to enhance safety for both work zone personnel and the traveling public by exploring new tools and expanding the use of existing ones, such as mobile photo radar.
Pennsylvania **Reference: (Pennsylvania Department of Transportation, 2024)**	Pennsylvania Department of Transportation (PennDOT)	In 2023, the program aims to enhance safety by reducing speeding in work zones on selected PennDOT-operated and all Commission-operated highways. It deploys portable automated speed enforcement systems to monitor and enforce excessive speeding (11+ MPH over the limit) in active work zones. Comparing work zone crashes in 2023 to the pre-pandemic and pre-Automated Work Zone Speed Enforcement (AWZSE) year of 2019, there were 460 fewer crashes in 2022 than in 2019, reflecting a reduction of about 26%. This reduction contrasts sharply with the national trend of increasing work zone crashes from the pre-pandemic period to the present.  Speed Camera Enforcement Warning
Washington **Reference:** **(Washington Traffic Safety Commission, 2010)**	Washington Traffic Safety Commission (WTSC)	In 2009, Washington State Legislature passed a budget proviso for two automated speed enforcement pilot projects in Seattle and Tacoma. Initial project outcomes for Seattle sites demonstrated a reduction in average speed and a decrease in the percentage of vehicles triggering the camera (i.e., violations). Although speed data was unavailable for the Tacoma site, the number of speeding infractions issued dropped.

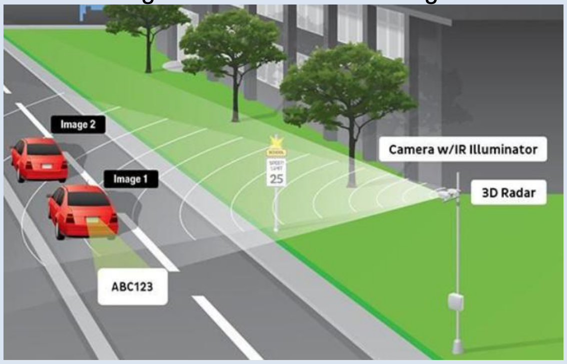
		 Fixed Automated Speed Enforcement Camera Location

Metropolitan Level

In addition to state-level efforts, many local agencies, including school districts, have demonstrated effective use of SSCs. Table **4.5** presents some examples of these efforts.

Table **4.5**. Local effort and outcome

State Reference Source(s)	Organization	Effort and Outcome
Washington D.C, District of Columbia **Reference: (Richard A. Retting & Charles M. Farmer, 2003)**	Washington Metropolitan Police Department	In 2001, Washington D.C. implemented speed cameras in seven random sites out of 60 targeted enforcement zones for approximately 6 months. The Washington Metro Police Department conducted a speed camera program using 5 unmarked camera-equipped police cars, whose operators are specially certified in radar operation. Results of the study concluded that mean speeds in these zones decreased by 14%, which includes that the proportion of vehicles exceeding the speed limit by 10 mph or more decreased by 82%.
Miami-Dade County, Florida **Reference: (Chris Hush, 2024)**	Miami-Dade commissioners	Miami-Dade County approved a plan that will allow 206 school zones to have speed camera enforcement used. The program will begin in 2024 with preparation requirements involving traffic studies at each location and educational program implementation. The cameras will cite drivers who exceed 11 mph over the posted speed limit in a school zone. Drivers who are cited will receive a $100 violation fee after the warning period, but they will not receive any points on their driving record or car insurance.

		 Speed camera warning sign
Atlanta, Georgia **Reference: (Propel ATL, 2022)**	Atlanta Board of Education	As awareness grows about the potential harm of relying on speed cameras, a shift in perspective is underway. Speed cameras are not a catchall solution. Instead, the primary focus should be on safe street design, addressing the root causes of speeding behavior. Atlanta Public Schools shares data from its speed camera program transparently, in order to provide accountability, prevent racial profiling associated with police enforcement, and inform street design.
Atlanta, Georgia **References: (Propel ATL, 2022), (Propel ATL, 2023)**	City of Atlanta	In 2023, Speed cameras went live in ten Atlanta Public School (APS) zones. The program is conducted by Atlanta Public Schools in partnership with the City of Atlanta. Drivers who exceed the speed limit in these zones by 10 mph or more while the sign's beacons are flashing will receive a ticket.  SSCs Illustration Employed by Atlanta Public Schools As awareness grows about the potential harm of relying on speed cameras, a shift in perspective is underway. Speed cameras are not a catchall solution. Instead, the primary focus should be on safe street design, addressing the root causes of speeding behavior. Atlanta Public Schools shares data from its speed camera program transparently in order to provide accountability, prevent racial profiling associated with police enforcement, and inform street design

Bibb County, Georgia **Reference: (WGXA News, 2023)**	Bibb County	In 2023, Bibb County made plans to implement six new speed enforcement camera zones along with six that already exist within the county. These cameras enforce the speed limit from an hour before school sessions to an hour after school sessions. The zones have flashing lights to indicate reduced speeds. The cameras enforce reduced speed also during the regular speed times in the middle of the school day. A driver who is recorded for speeds over 10 mph over the posted speed limit receives a fine of $100 for the first time, and $150 for each subsequent violation. The money that is collected from the violations is redirected toward local law enforcement and public safety initiatives. It is important to note that the citations do not show up on the driver's record and are not reported to their insurance policies.
University Park, Maryland **Reference: (Town of University Park, 2021)**	Town of University Park	The Mayor and Common Council of the Town of University Park have authorized the use of speed monitoring systems in designated school zones and within one-half mile of the University Park Elementary School. The Town of University Park will start operations of its speed monitoring systems with a 30-day warning period that began on Thursday, August 12, 2021. The location of the first-speed monitoring systems will be on East-West Highway and Adelphi Road.
New York City, New York **References: (New York City DOT, 2022), (FHWA, 2024c)**	City of New York	From 2014 to 2015, New York City began to use a Speed Camera Program that uses the same radar and laser technology relied upon by law enforcement. The cameras are only allowed to be enforced in locations including 13,230 feet of a school, on a street abutting a school building, entrance, or exit, and within an hour or a half hour before and after school hours as well as during school activities. Limitations include most injury crashes that occur not directly in school zones, simply adjacent or nearby; however, the cameras are only allowed to be placed in school zones. It has also been found that 84% of fatal and serious injury crashes occur at times other than school days around school hours. In 2014 and 2015, the daily rate of speeding violations declined by over 60 percent, from 104 in the first month to 35 in the camera's 18th month.

		 Installation of A SSC Fixed units reduced speeding in school zones by up to 63% during school hours in New York.
Portland, Oregon **Reference: (Freedman et al., 2006)**	City of Portland	In 2005, SSC vans were deployed into school zones from March to May, executing rotational SSC vans at 5 demonstration school zones and 5 control school zones. Traffic speeds and volumes were measured at least 24 hours before the start of the school zone, during the presence of SSC, and after the SSC ended. The study observed that 85th percentile speeds were typically reduced by 5 mph after the SSC demonstration began. The proportion of traffic that exceeded the speed limit by more than 10 mph was reduced by about two-thirds when ASE was present, and by about one-quarter when ASE was not present".  ASE equipment

		 School zone traffic signs
Portland, Oregon **Reference: (City of Portland, 2023)**	City of Portland	In 2015, the State authorized Portland to pilot speed safety cameras 2021, State granted Portland permanent use of speed safety cameras Between 2016-2018, Portland installed eight speed-safety cameras in fixed locations along four high crash corridors. Since installing them, speeding has dropped 71% and top-end speeding has dropped 94%.  Speed-safety camera warning sign with a 30-mph speed limit sign and a driver feedback sign posted on SE Division Street east of 148th Avenue
Rhode Island **Reference: (Socarras, 2023)**	City of Providence	By September 2019, the City of Providence installed 15 Portable Camera Units (PCUs) that are used to enforce speed from 7 am to 6 pm Monday through Friday. The cameras are placed based on the number of violations issued and areas that have problematic speeds and traffic concerns. For the cameras placed in new locations, which consist of 6 PCUs, warnings were issued to violators for 30 days following actual violations after the warning period. Additionally, signage was increased for the areas with photo-enforced speed limits. The range of speed that incites a violation is 11 mph

		over the speed limit. The external PCU vendor reviews the violation for accuracy, then it is mailed to the offender who must pay $50. The operation of speed-enforcing cameras resumed again in September 2023.
Fairfax County, Virginia **Reference: (County of Fairfax, 2024)**	Police Department and Fairfax County Public Schools	In 2024, the Speed Camera Pilot Program was implemented in selected school zones and work zones to change the behavior of drivers and make roads safer. Speed cameras are expected to improve the safety of roads by protecting pedestrians and slowing down motorists, especially around congested and vulnerable locations.
Prince William County, Virginia **Reference: (Kiser, 2024)**	Prince William County Department of Transportation	The Prince William County Department of Transportation will install an Automated Traffic Enforcement Pilot Program in 2024 in 4 school zones. The program plans to expand the location in the coming months. The cameras will begin with a 30-day warning period, then, a $100 fine will be issued to drivers who exceed the speed limit.
Suffolk, Virginia **Reference: (Andy Fox, 2023; City of Suffolk, 2023)**	City of Suffolk	Suffolk City implemented SSCs in various school zones and construction zones around the city. Citizens are fined $100 for a violation of the school zone speed limits.  SSCs Employed in Suffolk The first round of SSCs was installed on Route 460 and 58. The cameras had a warning sign a distance ahead of the camera that displayed “Special Photo Enforced.” After the SSCs were installed, the study found that from June 15 to July 15, confirming a 36% drop from the initial number of warnings that were issued.

Prince William County, Virginia **Reference: (Prince William County, 2024)**	Prince William County Department of Transportation	2024, the Automated Traffic Enforcement Pilot Program will begin rolling out in several school zones across the county during the month of February. The goal of the program is to improve the overall safety and well-being of residents and others by implementing strategies and measures to reduce the number of severe injuries and fatalities on county roads. The pilot program will begin with a 30-day warning period at each location. During this time, drivers speeding in active school zones will receive warnings instead of fines. Following the warning period, drivers who continue to speed in these zones will be fined $100. These citations will not affect driving records, demerit points, or insurance premiums.
Edmonds, Washington **Reference: (City of Edmonds, 2024)**	City of Edmonds, Washington	In May 2023, the Edmonds City Council approved the School Zone Camera Enforcement Program as part of this initiative, and work began to install the equipment to achieve full implementation. The Automated School Zone Speed Enforcement Project will help Edmonds PD address multiple complaints and concerns received by concerned parents and residents who live and work near the schools.
Seatle, Washington **References: (City of Seattle, 2013; Rebecca L. Sanders, 2019)**	City of Seattle	In 2012, Seattle implemented fixed automated speed cameras in four school zones. The cameras have flashing beacon operations during the arriving and leaving times of the schools, which is when the cameras capture speeding. Since the program began, there has been a 64% decrease in traffic violations per camera. The average speeds have decreased by 4%. The rate of individuals who re-offend after receiving and paying for a citation is only 10%.
Washington **Reference: (City of Lake Forest Park, 2023)**	City of Lake Forest Park	The City of Lake Forest Park began its first photo enforcement program in 2009, with the goal of increasing school zone pedestrian safety and reducing collisions on SR 522. Two school zones with two cameras each are active for two hours surrounding the starts and ends of school days, including half days and early release days. In 2023, the school zone cameras issued a total of 14,739 violations, with only one collision for the entire year. There has been a decrease in collisions at the intersection of Bothell Way and NE 165th by more than 39% since installing the camera system. Nearly 80% of the drivers cited for a photo enforcement ticket live outside of the City of Lake Forest Park. And 91% of all violators who receive a ticket and pay it do not get another violation.

International Cases

Similar to the U.S., school zone speed management is one of the core safety concerns across the world. Table **4.5** illustrates application examples of automated speed enforcement cameras to address speed safety issues.

Table **4.5**. International effort and outcome

Country Reference Source(s)	Research Title/Topic	Effort and Outcome
Canada **Reference: (Ward Vanlaar et al., 2011)**	Evaluation of the Winnipeg Photo Enforcement Safety Program	In 2009, mobile photo radar enforcement was deployed to monitor vehicle speeds at two locations near schools. The two schools had speed limits of 60 kph and 50 kph, in which the speed data for these locations was compared before versus during and after the intervention. The study was challenged in that there were gaps in the period of collection due to issues with the monitoring device, therefore it is unknown how the driver's behavior was affected during these periods. The study did find there was a significant decrease in speeding violations at the experimental site and a significant increase at the control sites. Data for the winter conditions found that there was generally an increase in violations, whereas, during the summer, the speeding violations remained constant.
South Korea **Reference: (Lee et al., 2006b)**	Effectiveness of Speed-Monitoring Displays in Speed Reduction in School Zones	Two field studies were conducted to evaluate the short-term and long-term effectiveness of speed-monitoring displays (SMDs) for reducing speeds in school zones. In the short-term study, results indicated that vehicle speeds began to decrease when drivers noticed the SMD, with an average speed reduction of about 17.5% at the SMD location. In the long-term study, the average speed reduction at the SMD location was slightly lower, at 12.4%. The number of speeding vehicles significantly decreased after the installation of SMD. Additionally, the 85th percentile speed dropped from 54.3 km/h to 46.3 km/h in the short-term study and further to 45.0 km/h in the long-term study.
Australia **Reference: (Champness et al., 2005)**	Time and Distance Halo Effects of an Overtly Deployed Mobile Speed Camera	Electronic data loggers monitored vehicle speeds as they passed over induction loops embedded in the road surface. These loops were placed at 500-meter intervals over a 3.5-kilometer stretch of a 100-kph high-capacity road. Vehicle speeds recorded by the loggers were then compared to baseline data at each loop and overall. Results indicated a significant reduction in speeds, with mean speeds dropping by 6 kph and the 85th percentile speeds decreasing by 7 kph.

		Additionally, the proportion of vehicles exceeding the speed limit declined sharply from 53% to 16% in the vicinity of the active speed camera.
Malaysia **Reference: (Rohani et al., 2014)**	The Effect of Speed Camera Warning Sign on Vehicle Speed in School Zones	Two school zones in Parit Raja were chosen for case studies: Seri Sabak Uni School and Pintas Puding School. Speed camera warning signs were installed on both sides of the road at each location, positioned 200 meters from the school entrances. While the installation of speed camera warning signs was intended to encourage drivers to adhere to the speed limits, this study found that drivers largely ignored the speed regulations.
Sweden **Reference: (Vadeby & Howard, 2024)**	Spot speed cameras in a series - Effects on speed and traffic safety	This study evaluated the impact of speed camera systems on mean speeds, speed compliance, and the number of fatalities and serious injuries. Spanning 20 years of data, the study utilized a before-and-after analysis at 361 speed measurement locations and applied an Empirical Bayes before-and-after analysis with controls for crash outcomes on 202 road sections. Results indicated a mean speed reduction of 3.5 km/h across all vehicles and road sections, with decreases of 7.9 km/h at camera locations and 3.0 km/h between cameras. These effects were sustained over the long term. Speed compliance improved by 16 percentage points overall, with increases of 42 percentage points at camera locations and 13 percentage points between cameras. The presence of speed cameras led to an average 38.6% reduction in fatalities, and although there was a suggestion of a decrease in serious injuries, this was not statistically significant. On roads where the speed limit was lowered from 90 to 80 km/h in conjunction with the installation of speed cameras, mean speeds were further reduced by an additional 3.6 km/h compared to roads with an unchanged limit of 90 km/h.

Notable Research

Table **4.6** presents sample research activities associated with the evaluation of speed enforcement cameras.

Table **4.6**. Academic Research

Research Title	Result and conclusion
An Evaluation of the Safety Affects of Speed Enforcement	An analysis of collision data from January 2000 to December 2003 estimated a 12% reduction in total collisions due to automated speed enforcement cameras. The study concludes that the speed camera program implemented by the Charlotte DOT

Cameras **(Christopher M. Cunningham et al., 2005)**	has been effective, and similar programs should be considered by other agencies facing speed-related issues.
Effectiveness of a fixed speed camera traffic enforcement system in a developing country **(Shaaban et al., 2023)**	This study assesses the impact of fixed-speed cameras on driver compliance in Qatar. Traffic volumes and speed data were gathered from automated traffic counts (ATCs) at 89 sites across 20 road corridors during off-peak hours. Average vehicle speeds and the proportion of drivers exceeding the speed limit were analyzed to gauge compliance with posted speed limits. Results showed that as the posted speed limit increased, the percentage of speeding drivers decreased. Fixed speed cameras reduced average travel speeds by 7% to 15% at the camera locations. However, even with speed cameras, the percentage of speeding drivers ranged between 4% and 18%. The study concluded that installing fixed-speed cameras should be prioritized on lower-speed roads.
Evaluating the Effectiveness of Speed Cameras on Philadelphia's Roosevelt Boulevard **(Erick Guerra et al., 2024)**	In 2020, the study focused on the effectiveness of speed cameras in reducing crashes, injuries, and fatalities on Roosevelt Boulevard in Philadelphia, PA. It was found that the installation of speed cameras significantly decreased crashes, injuries, and fatalities on the treated sections of Roosevelt Boulevard compared to similar roadways. The reductions in traffic incidents were on the high end of what is typically reported in academic literature, with total crashes, traffic injuries, fatalities, and pedestrian injuries all showing statistically significant decreases. The study concluded that speed cameras were highly effective in improving road safety and recommended extending and expanding the automated speed enforcement pilot program in Philadelphia.
Impact of automated photo enforcement of vehicle speed in school zones: Interrupted Time Series Analysis **(Quistberg et al., 2019)**	This study measured the impact of automated photo speed enforcement in school zones on motorist speed and speeding violation rates during school travel. Automated enforcement cameras, active during school commuting hours, were installed around 4 elementary schools in Seattle, WA in 2012. Motorist speed violation rates decreased by nearly half in the citation period compared to the warning period. The hourly maximum violation speed and mean hourly speeds decreased to 2.1 MPH and 1.1 MPH, respectively. The impact of automated enforcement was sustained during the second year of implementation.
Safety Impact of Automated Speed Camera Enforcement: Empirical Findings Based on Chicago's Speed Cameras **(Tilahun, 2023)**	This paper reviewed the effectiveness of automated speed cameras and examined considerations shaping the public debate on their use in the United States. Using data from Chicago, Illinois, and the empirical Bayes approach, the study evaluated the impact of speed cameras on reducing injury crashes and fatalities. Between 2015 and 2017, there was an estimated 12% reduction in fatal and injury crashes at treated locations, with a 15% decline in fatality and severe injury crashes. Some treated sites did not achieve the expected safety benefits. Nevertheless, the paper offers recommendations for improving the efficacy of speed cameras.

Speed Safety Cameras (SSC) Transportation Research Synthesis **(Minnesota Department of Transportation, 2023)**	In 2023, MnDOT conducted research to review the impact SSCs. Among the studies that reported both overall crashes and serious or fatal crashes, all concluded that SSCs led to the greatest reductions in serious injury and fatal crashes. No increase in crash rates or other adverse safety effects were reported. These findings align 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.

4.2.3 Summary

Through reviewing the deployment of SSC, it is evident that SSCs are being increasingly adopted in the United States and worldwide. As illustrated in Figure **4.5**, starting from 1995, there has been a constant increase in its application, with a significant acceleration beginning in 2018. To date, SSC has proven through practices to be a significantly effective approach, providing continuous, reliable, and efficient monitoring of school zones with manageable and sustainable investment. Furthermore, in general, studies and scholarly articles researched, both domestic and international, presented overall positive effects in reducing safety risks after the implementation of SSCs.

SSCs can offer the benefits as follows:

- **Leveraging Limited Resources**: SSCs can operate continuously without requiring law enforcement officers to be present, maximizing the limited law enforcement resources and allowing for societal benefits and safety enhancement as officers could focus on other critical tasks.
- **Consistent and Reliable Monitoring**: SSCs provide constant, unbiased monitoring of traffic conditions, improving compliance levels as drivers become aware that enforcement is seamlessly active.
- **Deterrent Effect**: According to established studies, results suggest that the presence of SSCs significantly deters potential violators, as drivers are more likely to adhere to traffic regulations, enhancing overall traffic safety on roads.

Despite their proven effectiveness in controlling speed and enhancing safety, approximately half of the

U.S. states have not yet legalized their use. The primary challenge in implementing SSCs lies in navigating legal restrictions, including potential constitutional challenges, the necessity for enabling legislation, and specific evidentiary requirements. However, with over 20 states and 211 communities already incorporated SSCs into daily use, there are ample opportunities for other states to learn from extensive experiences from state, local, international, and research parties who used SSCs. In addition, the latest ***Speed Enforcement Camera Systems Operational Guidelines*** published in 2023 by FHWA also provide comprehensive and practical assistance for transportation agencies to implement and manage SSC programs.

Section 5. Conclusion

Using two emerging data sources, an in-depth review of vehicle speeds across fifteen school zone sites in Northern and Southern Nevada is thoroughly performed. These study sites include four elementary schools, five middle schools, and six high school sites. Study findings show that:

- Based on field collected LiDAR data assessment, approximately 34% of the compliance rate is observed during the school zone period, while approximately 58% is the prevalent compliance rate during the non-school zone periods.
- Using high-resolution vehicle telemetric data, approximately 24.74% of the compliance rate is observed during the school zone speed control period, while approximately the compliance rate is about 41.45% during the non-school zone speed control periods.
- All study sites show that the field observed 85th percentile speed is higher than the posted speed limit during both school zone and non-school zone periods. This fact implies that drivers' speeding behavior is prevalent across all study sites.
- Despite the low rate of vehicle speeds over 20 mph than the posted speed limit, an average value of 1.3% and 0.3% during school zone and non-school zone periods, respectively, significantly high field observed maximum speed (e.g., 60 mph during school zone period and 90 mph during the non-school zone period) presents critical safety concerns.
- An in-depth analysis of pedestrian trajectories shows that some sites have high mid crossing volumes during the school zone periods. This observation implies the need for closer review and potential enhancement of current infrastructure design (e.g., location of crosswalk) to address these frequent mid crossings.
- The presence of conflicts between various transportation modes (e.g., vehicle to pedestrian, vehicle to bicyclist) at specific sites (e.g., Bonanza HS, M. Cortez ES) presents serious potential crash risks. Hence, it is recommended that these sites be revisited for an in-depth review of infrastructure design and signal timing elements.
- Safe Speed Camera (SSC) is highlighted as one of the FHWA's proven safety countermeasures for speed management. Several states (e.g., NY, WA, GA) also demonstrated the effectiveness of SSC in school zones for speed reduction during the school zone periods. Furthermore, the practice of re-

investing the collected fines of speeding back to the communities for safety enhancement (e.g., infrastructure redesign/modification, funding safety culture education) has been progressively shifted and helps change the public's negative impression of SSCs more towards a proactive and positive safety enhancement tool. Hence, SSC might be a potential solution to address observed speeding issues in NV school zones. Given these encouraging outcomes, SSCs could serve as a promising approach to addressing the ongoing challenge of speeding in Nevada's school zones. By incorporating SSCs, Nevada has the opportunity not only to strengthen compliance with school zone speed limits but also to advance a community-centered, system-based approach to road safety. This approach would help create safer roads and a healthier living environment, prioritizing the well-being of children and other vulnerable road users within our communities.

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