

Reducing School Bus Stop-Arm Violations in Texas

Pilot Test Results for the Application and Effectiveness of Digital Video
Technology in Identifying School Bus Stop-Arm Violations

Contract No. 588EGIA235



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INTRODUCTION

The Texas Transportation Institute (TTI) conducted this project to address the growing problem of school bus stop-arm violations in Texas. The goals of the project were to 1) document the magnitude of the statewide problem of stop-arm violations and recommend methods for continued monitoring of the issue; (2) evaluate and test the application and effectiveness of a mobile digital video camera monitoring system in identifying violators of the State stop-arm law and determine potential for statewide deployment of this technology and 3) identify potential strategies to reduce stop-arm violations in Texas. This report presents the methods, results, and conclusions of the project.

BACKGROUND

Approximately 35,000 public school buses transport over 1.4 million Texas children every day (Texas Department of Public Safety (DPS). School buses are one of the safest forms of transportation accounting for less than 0.5 percent of Texas roadway crashes (DPS, 2001) but children must take care when boarding or leaving the bus. According to the National Highway Traffic Safety Administration (NHTSA), children are at greatest risk when they are getting on or off the school bus. Most of the children killed in bus-related crashes are pedestrians, five to seven years old. Nearly one-third of the deaths occur in the 10-foot area surrounding the school bus because of passing motorists who ignore the flashing red warning lights and disregard a bus' deployed stop-arm (NHTSA, 2006).



Figure 1. Children Exiting a Stopped School Bus

Statewide, school bus crash statistics indicate that injury-producing crashes directly or indirectly involving a school bus have increased from 701 in 1991 to 951 crashes in 2001, an increase of 36 percent, according to the most recent available data¹ (DPS, 2001). During the same period, nine school-aged children were killed while loading or unloading the school bus. An average of 20 student pedestrian injuries occurred each year (DPS, 2001).

The potential for injury or death caused by motorists passing a stopped school bus with its red lights flashing and stop-arm extended is extremely high. All states have laws making the passing of a stopped school bus illegal (commonly called a “stop-arm” violation). These laws require that traffic in both directions stop on undivided highways, but state laws vary on the requirements to stop on a divided highway. All states, however, require motorists traveling behind the bus to stop on divided highways.

The penalty for a stop-arm violation also varies among states. In some states, the penalty for the first offense can be a large fine and / or a mandatory license suspension. In Texas, violators can be fined up to \$1,000 for the first offense. A second conviction under the statute is a state jail felony. The requirements for motorists to stop for school buses and the penalties for not complying with the law are contained in Transportation Code Section 545.066 of the Texas Statutes, which states:

§ 545.066. PASSING A SCHOOL BUS;OFFENSE.

(a) An operator on a highway, when approaching from either direction a school bus stopped on the highway to receive or discharge a student: (1) shall stop before reaching the school bus when the bus is operating a visual signal as required by Section 547.701; and (2) may not proceed until: (A) the school bus resumes motion; (B) the operator is signaled by the bus driver to proceed; or (C) the visual signal is no longer actuated. (b) An operator on a highway having separate roadways is not required to stop: (1) for a school bus that is on a different roadway; or (2) if on a controlled-access highway, for a school bus that is stopped: (A) in a loading zone that is a part of or adjacent to the highway; and (B) where pedestrians are not permitted to cross the roadway. (c) An offense under this section is a misdemeanor punishable by a fine of not less than \$200 or more than \$1,000, except that the offense is: (1) a Class A misdemeanor if the person causes serious bodily injury to another; or (2) a state jail felony if the person has been previously convicted under Subdivision (1).

A previous NHTSA survey on speeding and other unsafe driving behaviors found that respondents felt that passing a stopped school bus was more dangerous than any other unsafe driving behavior including racing another driver, driving through a stop sign or red light,

¹In 2007, the TxDOT Traffic Operations Division assumed responsibilities for the collection and analysis of Texas traffic crash data. Data for 2002-2007 will become available for analysis in late 2008.

crossing railroad tracks with red lights flashing, passing in a no-passing zone, and speeding (NHTSA, 1998). Then why do motorists choose to ignore the law?

One explanation is that some drivers are just not well informed about the requirements of the law. One survey found that motorists were unaware of their responsibilities under the law and /or the specific requirements of the law (CUTR, 1997). A survey of Texas motorists revealed motorists' confusion about the law regarding stopping for school buses on multilane facilities (Brackett et al., 1984). Some motorists just chose to ignore the law because they are in a hurry or they do not think that they will get caught. Increasingly, distraction is a key factor in failing to follow the stop-arm law. Many drivers simply do not see the stopped school bus until it is too late.

For school bus drivers, this problem is not new. Drivers have long complained about motorists illegally passing their school bus, but proving that a violation occurred can be challenging. In many states, including Texas, a law enforcement officer must witness the violation in order to write a traffic citation. Motorists can contest the citation and courts can reduce the charge, throw out cases entirely, or dismiss the case due to insufficient evidence (i.e., vehicle make and color and license plate number). Texas DPS statistics show that the number of stop-arm violation convictions is declining (see Table 1).

**Table 1. Stop Arm Violation Convictions,
Texas, 2001-2006**

Year	# of Convictions
2000	1,451
2001	1,427
2002	1,432
2003	1,493
2004	1,491
2005	1,343
2006	831

Source: Texas Department of Public Safety, 2007

Building a comprehensive stop-arm compliance program addressing the safety concerns caused by illegal passing of school buses requires elements of enforcement, engineering, education, technology and policy/legislative changes.

Enforcement activities increase compliance with laws governing the passing of school buses (NHTSA, 2000). Routine and selective enforcement activities can be effective for areas or routes with high concentrations of stop-arm violations or “hot spots” and usually involve officers

patrolling intersections and streets during morning and afternoon school hours or riding on a particular school bus. If an officer riding on the bus witnesses a violation, they forward the offender's information to a second waiting patrol officer who issues the citation. These activities are typically short term and may involve the local media to bring heightened awareness of the stop-arm violation problem and potential dangers of violating the law to the community. Selective Traffic Enforcement Programs (sTEP) implemented in waves (education/publicity-enforcement-publicity) have also been effective in several communities to bring awareness of the issue and help reduce the number of illegal passings.

Engineering measures employ vehicle, design, construction, and signage to prevent motorists from passing stopped school buses (NHTSA, 2002). Some districts have explored ways to enhance the visibility of school buses such as installing flashing headlamps or strobe lights and / or installing additional stop arms as a means to inform drivers of their responsibility to stop. Some districts have made changes to routes to minimize dangerous crossing situations (NHTSA, 2002; Griffin and Davies, 1995).

Public information and education (PI&E) activities are important to increase motorists' awareness of the consequences of breaking the law and penalties if they disobey the law. Additionally, outreach to other professionals such as the media, school bus drivers, law enforcement, and prosecutors heightens awareness among the different groups needed to effectively reduce stop-arm violations in their communities.

The use of technology is also an important tool in identifying stop-arm violators for targeted educational efforts and to provide information to law enforcement for the issuance of citations. To identify stop arm violators, several school districts have installed stop-arm cameras outside of the bus or in front of the driver on the dashboard facing outwards through the windshield. Cameras are positioned to capture information about the vehicle passing the bus including the make, model, color, and license plate number. Some systems record information about the location, date, and time of the incident - all required evidence for the issuance of stop-arm citations and convictions.

Many of these systems utilized the industry standard at the time – VHS analog recording – a technology that had largely been used for in-bus surveillance purposes. Two factors largely prevented the widespread use of these systems: high costs and the issue of legality (e.g. the use of the recorded image to prosecute violators in the courts). Since that time, technology improvements have resulted in computer-based digital video systems equipped with high resolution cameras, improved accessibility, and significantly lower costs. The availability and

performance of these systems in reducing stop-arm violations and improving school bus safety is still relatively unknown.

Recently, school districts have explored the use high resolution cameras to photograph license plates. In 2008, the New York Association for Pupil Transportation (NYAPT) conducted a pilot study with the Syracuse City School District to track the number of motorists who illegally pass stopped school buses using ELSAG North American digital cameras mounted above bus drivers' windows to photograph license plates (Cuthbert, 2008). During the six week pilot period, the cameras captured 68 incidents of motorists illegally passing stopped school buses - an average of two per day. The use of this technology provided the NYAPT with an opportunity to educate the community about the dangers of illegal passing.

The use of this technology to address areas or routes with a high incidence of stop-arm violations is also gaining momentum. The Christiansburg Police Department in Virginia is working with the Center for Truck and Bus Safety at the Virginia Tech Transportation Institute (VTTI) to develop an automated video-based camera system that will record license-plate information from illegally passing vehicles (VTTI press release, 2008).

Legislation in support of the use of such technology has been introduced in several states and school districts are examining the benefits of these technologies in reducing the number of violations and as an opportunity for public education about the consequences of violating the law. House Bill 1843, introduced during the 80th Texas Legislative session, would allow school districts to install video monitoring systems to capture images of vehicles that pass the bus when the stop-arm is deployed; change the stop-arm offense to a civil penalty; and allow school districts to prosecute an illegal passing offense providing that the recorded image clearly shows the vehicle, license plate, and the time the offense allegedly occurred. The proposed legislation was not enacted into law.

Given the advances in technologies over recent years, further studies are needed to examine how effective these systems are in identifying stop-arm violations and their potential to enhance school bus safety through the reduction of stop-arm violations. This study involves conducting a pilot test to determine how effective a mobile digital video camera system is in identifying school bus stop-arm violators and the potential application of the system in reducing the incidence of stop-arm violations. The results of this pilot study will provide valuable information to school districts about the availability and potential applications of this technology.

This report presents the results of the first statewide stop-arm violation survey; the field evaluation to test the potential application and use of school bus stop-arm cameras; and concludes with recommended strategies to reduce stop-arm violations in Texas.

SCHOOL BUS STOP-ARM VIOLATION SURVEY

One of the goals of this project was to document the magnitude of the statewide problem of stop-arm violations and recommend methods for continued monitoring of the issue. This section describes these activities.

School bus drivers are increasingly reporting more and more heart-stopping near misses involving motorists passing their school buses while stopped with red lights flashing and stop-arm extended. Education and awareness is a major component of nearly every traffic safety program. However, many people are just not aware of how often this serious and potentially life threatening situation occurs. In the mid-1990's several states conducted surveys to determine the actual extent of illegal passing. The problem was worse than they had imagined (NHTSA, 2002):

- The School Transportation Management Section of the Florida Department of Education conducted a study in 1995 through the University of South Florida. On one day in May of that year, 10,590 vehicles illegally passed stopped school buses in 58 of Florida's 67 school districts. Since approximately 11,150 school buses participated in the survey, this meant an average of almost one illegal passing per school bus that day. A follow-up 2000 study found an increase to 10,719 recorded passings during a typical school day.
- A one-day study was conducted in September 1996 in 119 of the 131 school divisions in the State of Virginia. On that day, 3,394 Virginia motorists illegally passed a stopped school bus. Multiplying the results by a 180-day school year brings the total number of illegal passings to over 600,000 a year. Of the 3,394 total in September 1996, 187 were right-side passes, on the side of the bus students use to enter and exit.
- In 1996, the Illinois Department of Transportation's Division of Traffic Safety conducted a probability-based sample survey of 250 school buses to estimate the total number of stop-arm violations in the state. Drivers of 250 buses were asked to record stop-arm violations during a 41-school day time period. The survey was completed and returned by 135 drivers who reported 3,450 violations.

The stop-arm violation problem is not unique to Texas. Taking the lead from the Florida study, the North Carolina pupil transportation community gathered baseline data in April, 1997. Of 117 school districts in North Carolina, 114 participated in a one day stop arm violation count. This yielded a result of 2,636 stop arm violations reported by drivers on April 15, 1997.

DATA COLLECTION

Data collection is an important component in monitoring successes of traffic safety programs. The collection of baseline data establishes a benchmark for assessing any future traffic safety efforts directed toward reducing stop-arm violations.

In 2006, the Texas DPS School Transportation Unit conducted the first annual statewide survey of school bus violations. The survey was distributed to the 1,254 public and charter school districts with instructions for school bus drivers to participate in the survey on November 8, 2006 (see Appendix A). Bus drivers were asked to observe the vehicles that illegally passed school bus while stopped with the red loading lights activated on this date and record information about the vehicle, bus, and roadway on the survey form. Drivers were reminded that their primary concern was student safety and to exercise extreme care when completing the survey form.

A total of 761 or 61% of the school districts participated in the one day survey. The participating districts operated 24,580 school buses covering 27,258 routes across the state. Completed surveys were returned to the DPS and data entry conducted by the DPS staff.



Figure 2. DPS employee prepares to enter survey data

RESULTS

TTI obtained an electronic file containing the data extracted from the survey from DPS. Data were entered by school district which is the unit of analysis. Data were analyzed and results are discussed next.

Baseline Data

School districts reported that a total of 12,850 stop-arm violations occurred on November 8, 2006 (see Table 2). Of the 761 districts and charter schools, a total of 481 (63%) reported that drivers observed at least 1 stop arm violation during the day.

Analysis of the stop-arm violation data reveal no particular pattern regarding time of day in which the violation occurred as 47% of the illegal passings happened during the morning hours (6am-10am) while 53% occurred in the afternoon (2pm-6pm).

The majority (58%) of violations occurred while the motorist was traveling in the opposite direction (coming toward) the stopped school bus. In more than one-third of the violations (38%) the motorists was traveling in the same direction as the stopped school bus.

Most motorists were observed passing the left side of the bus (80%). Surprisingly, 11% passed the stopped school bus on the right side. Due to data limitations; however, it is not possible to determine if the right-side violation occurred in a right-turn lane adjacent to the stopped school bus.

Table 2 shows that just over one half (53%) of all reported stop-arm violations occurred on two-lane roadways. In addition, 13% of all stop-arm violations happened on four-lane roadways with a median. This finding supports earlier studies citing motorists' confusion about stopping requirements on roadways with medians (Griffin & Davies, 1995; CUTR, 1997).

**Table 2. Summary Statistics for
School Bus Stop Arm Violations**

	Frequency	Percent
Total passes reported	12,850	
Total districts surveyed	1,254	
Total surveys returned	761	60.7
Districts reporting at least 1 passing	481	63.2
Districts with no reported passings	280	36.8
Time of Day Passing Occurred		
AM	6031	46.9
Midday	1	0.01
PM	6818	53.1
Vehicle Passed From		
Opposing	7443	57.9
Same	4901	38.1
Not Reported	506	3.9
Side of Bus Illegal Passing Occurred		
Left	10,230	79.6
Right	1,456	11.3
Not Reported	1,164	9.1
Type of Roadway		
2-lanes	6,802	52.9
3-lane	840	6.5
4-lane, no median	1,238	9.6
4-lane, median	1,707	13.3
5+ lanes	954	7.4
Not reported	1,309	1.0

Source: Survey of Texas School Districts on School Bus Stop Arm violations conducted by the Texas Department of Public Safety on November 8, 2006.

Stop-Arm Violations Per Bus

The number of reported violations per bus was calculated for each school district and charter school reporting at least one illegal passing and ranked. Table 3 shows that the highest rate of violations per bus (7.8) occurred at the Girls and Boys Preparatory Academy in Houston, Texas followed by George Gervin Academy in San Antonio, Texas (7.33). (Note that these schools have very few buses). Red Oak Independent School District (ISD) in Ellis County reported 3.5 violations per bus while Amarillo ISD in Potter County reported 3.4 violations per bus. This information is useful for identifying locations to direct future countermeasure efforts.

Table 3. Top 10 School District / Charter School By Stop Arm Violations Per Bus

Ranking	School District/Charter School (County)	# of Buses	Stop Arm Violations	Violations per Bus
1	Girls & Boys Preparatory Academy (Harris)	5	39	7.8
2	George Gervin Academy (Bexar)	3	22	7.3
3	Red Oak ISD (Ellis)	4	14	3.5
4	Amarillo ISD (Potter)	84	284	3.4
5	Leggett ISD (Polk)	3	10	3.3
6	Garrison ISD (Nacogdoches)	9	28	3.1
7	Zion Lutheran (Dallas)	1	2	2.0
8	Ysleta ISD (El Paso)	199	355	1.8
9	Alamo Heights ISD (Bexar)	23	41	1.8
10	Leakey ISD (Real)	6	10	1.7

Source: Survey of Texas School Districts on School Bus Stop-Arm Violations conducted by the Texas Department of Public Safety on November 8, 2006.

Table 4 ranks school districts and charter schools by the total number of reported stop-arm violations. The highest number of stop-arm violations was reported by Northside ISD (Bexar County) with 870 violations, followed by 787 violations reported by Aldine ISD (Harris) and 427 violations reported by Dallas ISD (Dallas).

Table 4. Top 10 School District / Charter School By Number of Reported Stop-Arm Violations

Ranking	School District/Charter School (County)	# of Routes	# of buses	Stop Arm Violations	Violations per Bus
1	Northside ISD (Bexar)	1,250	680	870	1.3
2	Aldine ISD (Harris)	536	675	787	1.2
3	Dallas ISD (Dallas)	742	842	427	0.5
4	Ysleta ISD (El Paso)	137	199	355	1.8
5	Cypress-Fairbanks ISD (Harris)	643	819	319	0.4
6	United ISD (Webb)	204	183	286	1.6
7	Amarillo ISD (Potter)	65	84	284	3.4
8	Pasadena ISD (Harris)	189	253	271	1.1
9	Fort Worth ISD (Tarrant)	1,483	804	259	0.3
10	Corpus Christi ISD (Nueces)	133	230	233	1.0

Source: Survey of Texas School Districts on School Bus Stop-Arm Violations conducted by the Texas Department of Public Safety on November 8, 2006.

STATEWIDE ESTIMATES OF STOP-ARM VIOLATIONS

Survey results show that almost 13,000 stop-arm violations were recorded on November 8, 2006 by 761 of the 1,254 participating public school districts and charter schools (61%). Statewide estimates can be determined two ways: by calculating the estimated number of daily violations and the number of violations per calendar school year (180 days). To determine statewide estimates of daily stop-arm violations based on the survey sample, the total number of reported stop-arm violations (12,850) is divided by the total number of buses in the sample (27,258) resulting in 0.47 stop-arm violations per bus. The estimated number of school buses operating in the State on any given day is 35,000 (DPS). Multiplying 35,000 times 0.47 provides a statewide estimate of 16,450 illegal passings occurring each day in Texas. If this number is multiplied by the number of school days in a typical school year (180), then an estimated 2.96 million stop-arm violations will occur during a typical school year in Texas.

These estimates translate into a significant risk for our children. Continued monitoring of the occurrence of stop-arm violations on an annual basis will provide the State and local communities with the 1) knowledge of where these violations are occurring so that PI&E, enforcement, and other countermeasures can be effectively targeted; and 2) ability to compare changes in the incidence of stop-arm violations over time in communities that receive targeted countermeasures to reduce stop-arm violations to determine effectiveness.

The survey conducted by the DPS establishes a baseline from which to start. Future statewide surveys of stop-arm violations should follow the standardized procedures established during this initial survey such as using the same survey instrument and conducting the survey on the same day (November 8). The use of standardized methods allows for improved data reliability and greater external validity by allowing year to year comparisons under similar conditions.

FIELD EVALUATION

TTI conducted a field evaluation on the potential application and use of school bus stop-arm cameras to assist school districts in addressing stop-arm violations. The evaluation included selecting a digital video monitoring system for testing; developing a field test protocol; implementing the testing protocol; and evaluating the results. This section describes these activities.

DIGITAL VIDEO BUS CAMERA SYSTEM SELECTION

Most camera monitoring systems on the market are used for school bus surveillance to improve the driver's field of vision and monitor behavior and activity of people both inside and outside the bus (Bryant, 2006). As Figure 3 shows, cameras can be used to monitor children's behavior while boarding and exiting the bus and while riding on the bus. Video monitoring also provides a means to assess a bus driver's skills and safety risk and detect stop-arm violations around the bus. As a result, several systems have been adapted for use outside the school bus to record stop-arm violations.

TTI conducted a review of mobile digital video camera systems and contacted several vendor representatives to discuss the potential of their system to capture information on vehicles that illegally pass stopped school buses.



Figure 3. Images from surveillance video recorded by school bus monitoring system

Selection Criteria

Several criteria were considered in the selection of the mobile digital video camera system for pilot testing. System cost was a major factor as the project budget allocated up to \$5,000 for purchasing two systems. Other system features considered included recording channels, video resolution, storage medium; and hard disk capacity of the digital video recording (DVR) unit; network interface; date and time stamp capability; available camera lenses; and system add-ons such as a global positioning system (GPS) capable of recording vehicle speed and location, and the ability to record driver inputs such as stop-arm use, speed, turning and warning lights, and brakes.

System costs varied from \$2,500 to \$6,000 per unit depending largely on the selected quantity and quality of digital cameras and the storage capacity of the hard drive. Table 5 compares system features of mobile digital video monitoring systems reviewed and considered for the pilot test.

Based on these criteria, the *Seon Explorer™ Mobile Surveillance* 4-channel DVR system was obtained for pilot testing. The system was equipped with four cameras (12mm), one lock box, one DVR unit, one 60 gigabyte (GB) hard drive and installation instructions and hardware (see Figure 4). Seon also provided a bus warning light and stop arm wiring harness hookup, and a GPS unit. Two complete systems were obtained for the pilot test.



Figure 4. SEON Explorer™ Mobile DVR System

Table 5. Mobile Digital Video Monitoring Systems Reviewed

Feature	Seon Explorer Package	Seon Trooper Package	Honeywell Case Study Equipment	Safety Vision Route recorder 5Cmobile DVR
Recording Channels	4 video, 2 audio	9 video, 2 audio	Configuration dependent	5 channels
Video Resolution	up to 720 x 480	720 x 480 (record/playback)	6640 X 480	720 X 480
Compression	MPEG4	M-JPEG	M-JPEG	Wavelet
Quality	adjustable	adjustable	NA	NA
Recording Rate	30 fps per camera	60 fps per camera	40 fps aggregate	30 fps per camera
Storage Medium	Dual swappable 2.5" or 3.5" hard drive	Dual swappable 3.5" or 2.5" hard drive	hard non-removable drive	removable hard drive
Disk Capacity	40 - 750 GB	160 - 600 GB	up to 80 GB	80 GB
Removable Memory	hard drive, USB drive	hard drive, USB drive	NA	NA
Network Interface	Ethernet port (TCP/IP)	LAN (TCP/IP)	LAN	NA
Playback Rate	1/32 to 600x	1/32 to 600x	NA	NA
Search Function	segment, alarm or date/time	event or internal timer	time date	NA
User Interface	front panel, on screen display	front panel, on screen display	on screen display computer connection	laptop computer, computer connection
Time Stamp	real time	real time	real time	real time
Battery Backup	Time and programmed information	Time and programmed information	NA	NA
Delay	on/off up to 60 minutes	on/off up to 60 minutes	on /off up to 255 minutes	NA
GPS	optional	optional	optional	optional
Operating Temperature	(- 4)°F to 122°F	High and low temperature protection with heater	standby (- 40)°F to 150°F / recording 41°F to 131°F	(- 40)°F to 149°F
Weight	DVR 7 lbs, DVR lock box 9 lbs	DVR 7 lbs, DVR lock box 9 lbs	4.85 lbs	9.5 lbs
Available lenses (mm)	2.9, 3.6, 6.0, 8.0, 12.0, 16.0	2.9, 3.6, 6.0, 8.0, 12.0, 16.0	3.6, 6.0, 8.0, 12.0	multiple camera options
Cost Range*	\$2,500-\$4,000	\$2,500 - \$4,000	\$3,000-\$6,000	2,500 - \$5,000
Web location	www.seon.com/	www.seon.com/	www.honeywellvideo.com/	www.safetyvision.com/

Notes: NA= no information available

* System costs vary from \$2,500 to \$6,000 depending on the number of cameras, lens length, and size of hard disk.

FIELD TEST PROTOCOL

This section describes the protocol for conducting the field test to determine the application and effectiveness of a mobile digital video camera system in identifying motorists who illegally pass school buses with stop arms extended. System applications under review in the pilot test include the:

- 1) quality of the image recorded by digital camera
- 2) ability to identify detailed vehicle characteristics (make, model, color, etc) from digital image
- 3) ability to identify vehicle license plate number from digital image
- 4) ability to identify driver characteristics from digital image
- 5) ability of the system to record a stop-arm violation incident
- 6) ability of the system to record stop-arm violations in multiple lanes and in multiple directions
- 7) ability of the system to record stop-arm violations under varying lighting conditions
- 8) ability of the system to record stop-arm violations under varying weather conditions
- 9) ease of system use for bus drivers
- 10) ease of system use for other transportation employees
- 11) ability of system software to interface with recorded video
- 12) ease of system software use

The overall goal of the pilot test was to determine if the mobile digital video camera system is an effective means of capturing information on vehicles that violate school bus stop-arm laws.

Methods

Participants

Bryan/College Station, Texas was selected as the pilot test location based on prior interest in the project, in addition to their proximity and access to TTI. In March, 2008, Mr. Hector Silva was hired as the new College Station Independent School District (CSISD) transportation director. Mr. Silva agreed to participate in the pilot test and was instrumental in organizing and hosting the local project kick-off meeting and facilitating all aspects of the pilot test. The CSISD

Transportation Services operates about 70 school buses over 53 routes, the majority of which are urban.

Bus Route Selection

Bus routes with the highest number of driver reported stop-arm violations were considered for participation in the pilot test. Based on vehicle availability and accessibility, CSISD identified Bus 77 to participate in the pilot study. Bus 86 was identified as a back up for participation.

Bus Camera Installation

TTI coordinated with the CSISD bus maintenance technicians to schedule a day and time for installing the Seon Explorer™ on Bus 77. The date of installation was April 9, 2008. The CSISD mechanic installed all necessary electrical equipment while a TTI technician installed the cameras, DVR unit and lockbox. Because of size and required ease of access, the lock box and DVR unit were installed on the dashboard (see Figure 5).

A total of four digital cameras were mounted on the outside of Bus 77 (see Figures 6 and 7). Camera 1 and Camera 2 were mounted on the outside driver's side of the bus. Camera 1 was adjusted to record video of vehicles that pass the front of the bus. Camera 2 was aimed to view vehicles driving in the opposing lanes of traffic.

Camera 3 was mounted on the inside of the bus facing forward to view activity from the front bus window and record any vehicles that might pass on the right side of the bus. Camera 4 was mounted facing forward on the passenger side of the bus to record the bus door opening and closing. A red "panic" button was also installed on the driver's side dash board for the driver to push if a stop-arm violation was observed. This action marks the event for easier locating and allows for quick searches. The system was set up to automatically start recording at the beginning and end of the AM and PM bus routes.



Figure 5. Lock box and DVR unit installed on bus dashboard



Figure 6. Digital cameras installed on drivers' side of Bus 77



Figure 7. Digital cameras installed on passenger side of Bus 77

Post Installation Modifications

After installation, the system operated for one day and TTI reviewed the video for image quality and recording angles. Cameras were adjusted to better view and potentially record vehicle license plate information of opposing traffic lanes. The camera resolution was also changed to record at a higher resolution. Finally, timers were set to record at specific times of the days between the hours of 6:30 am to 8:30 am and 2:30 pm to 5:30 pm.

FIELD TEST IMPLEMENTATION

Data collection took place from April 9th through May 30, 2008. It was estimated that the 60 GB system hard drive could store approximately 5 days of AM and PM video recordings. Because the test system included two hard drives, a schedule was established to exchange the hard drives weekly (see Table 6). Hard drive #1 was retrieved after the first week of data collection and then archived while hard drive #2 recorded for the week. Hard drive #1 was returned to the system the following week. This process repeated throughout the 7 week data collection period. A total of 209 hours of video was recorded during this period.

Table 6. Hard Drive Exchange Schedule

Date	Hard Drive	Function
21-Apr-08	1	Install
	2	Archive
28-Apr-08	1	Archive
	2	Install
5-May-08	1	Install
	2	Archive
12-May-08	1	Archive
	2	Install
19-May-08	1	Install
	2	Archive
26-May-08	1	Archive
	2	Install

Special Circumstances

During the data collection period, Bus 77 experienced mechanical problems and was taken out of service for engine repairs. TTI discussed removing the installed video system from Bus 77 and re-installing the system on the designated alternate bus. But repairs were scheduled to be completed within one week so the system remained on the bus. After it became apparent that the bus repairs would take more time than anticipated, the second system obtained from

Seon was installed on the alternate Bus 86. Bus 77 returned to service shortly after the second installation was complete, and for a short period of time (1 week), both video monitoring systems were in use.

Data Storage

Each DVR unit was connected to a laptop PC pre-installed with Seon HD Reader™ software for viewing and archiving the recorded video. The archival process involved identifying a specific time period to archive, such as the AM route on a Thursday. This video was archived and saved with a file name denoting the camera, date, and time period (AM or PM). Video segments were saved to an external 500 GB hard drive as MPEG and EDR files for later review. Instructions for video archiving are contained in Appendix B.

FIELD TEST RESULTS

Data Extraction

Reducing the recorded video to usable information was very labor intensive. The process required that a person (hereafter referred to as “reviewer”) watch 209 hours of video captured during the data collection stage and record information about each stop-arm violation in a data entry spreadsheet. Separate data entry spreadsheets were created to reduce information from videos recorded by the 4-camera and 3-camera configured systems used in the pilot study (see Figures 8 and 9).

4 – Camera Configured System

For the 4-camera configured system, video was archived as a MPEG file for viewing in Windows Media Player. Using this file format required that each camera video be viewed independently. To start, the reviewer watched the Camera 4 video and recorded the bus door open and close time. This information was necessary to identify time frames for review on Cameras 1, 2, and 3 to identify possible stop-arm violators. Any stop-arm violations that occurred on the right side of the bus were also noted and recorded from the Camera 4 video.

Next, the reviewer watched the Camera 1 video. During this step, the reviewer forwarded the video to the “door open” time and played the video in real time to determine if any vehicles passed through the video frames between the time the door was open until the door closed. This

step was repeated for each “door open” and “door close” time noted during the Camera 4 video review. Vehicles identified during this step represented “possible” stop-arm violators.

To determine if the vehicle actually passed the extended stop arm and committed a stop-arm violation, the reviewer had to view the Camera 2 video. The same process was used to identify the location on the video when the suspected violation occurred. The reviewer forwarded to the location on the video and watched in real time to determine if the vehicle noted in Camera 1 was also seen in Camera 2. This step was necessary because Camera 1 faced toward the front of the bus and Camera 2 faced toward the rear of the bus creating a “blind spot” in the recording area around the stop-arm (see Figure 8). If a violator was viewed on Camera 2 between the “door open” and “door close” time frame, then a stop-arm violation was recorded. The “blind spot” issue was resolved with the 3-camera configured system. This extraction process was repeated each day that the Seon system recorded both AM and PM videos and the video was successfully archived.

3 – Camera Configured System

In the 3-camera configured system, Camera 1 remained in the same place while Camera 2 was moved below the stop arm facing perpendicular to the bus (see Figure 9). Camera 3 was removed and Camera 4 remained in the same place to monitor any potential passings on the right side of the school bus and also to record when the door opened and closed. This configuration corrected the blind spot and allowed for the reviewer to see when a vehicle crossed the plane of the stop arm.

Video for the 3-camera configured system was archived as an .EDR file which allowed the reviewer to watch all three camera videos simultaneously. Although this file type was easier to reduce, the reviewer still had to watch the majority of the video in real time which made the data extraction process very time consuming.

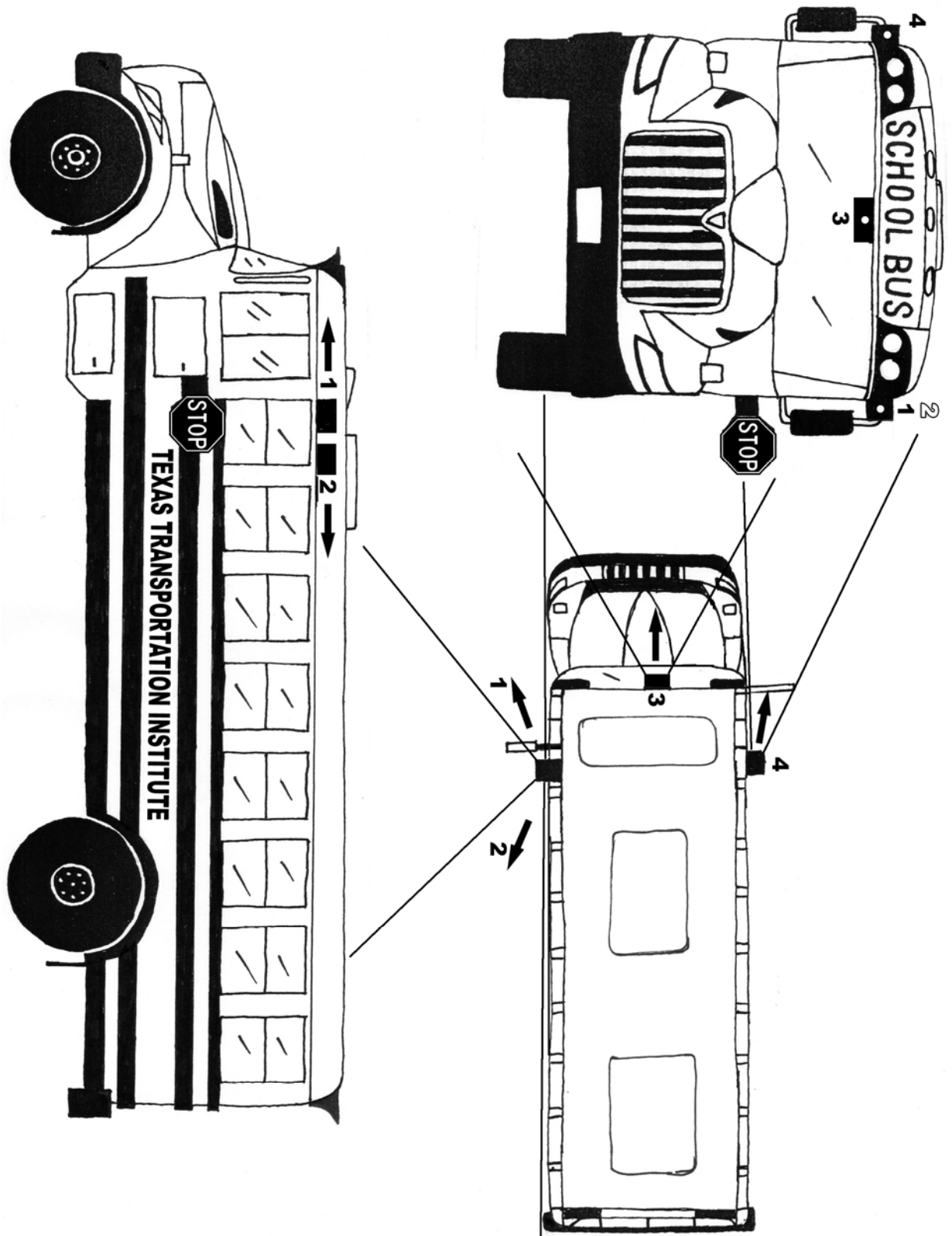


Figure 8. 4-Camera Configuration System and Range of View

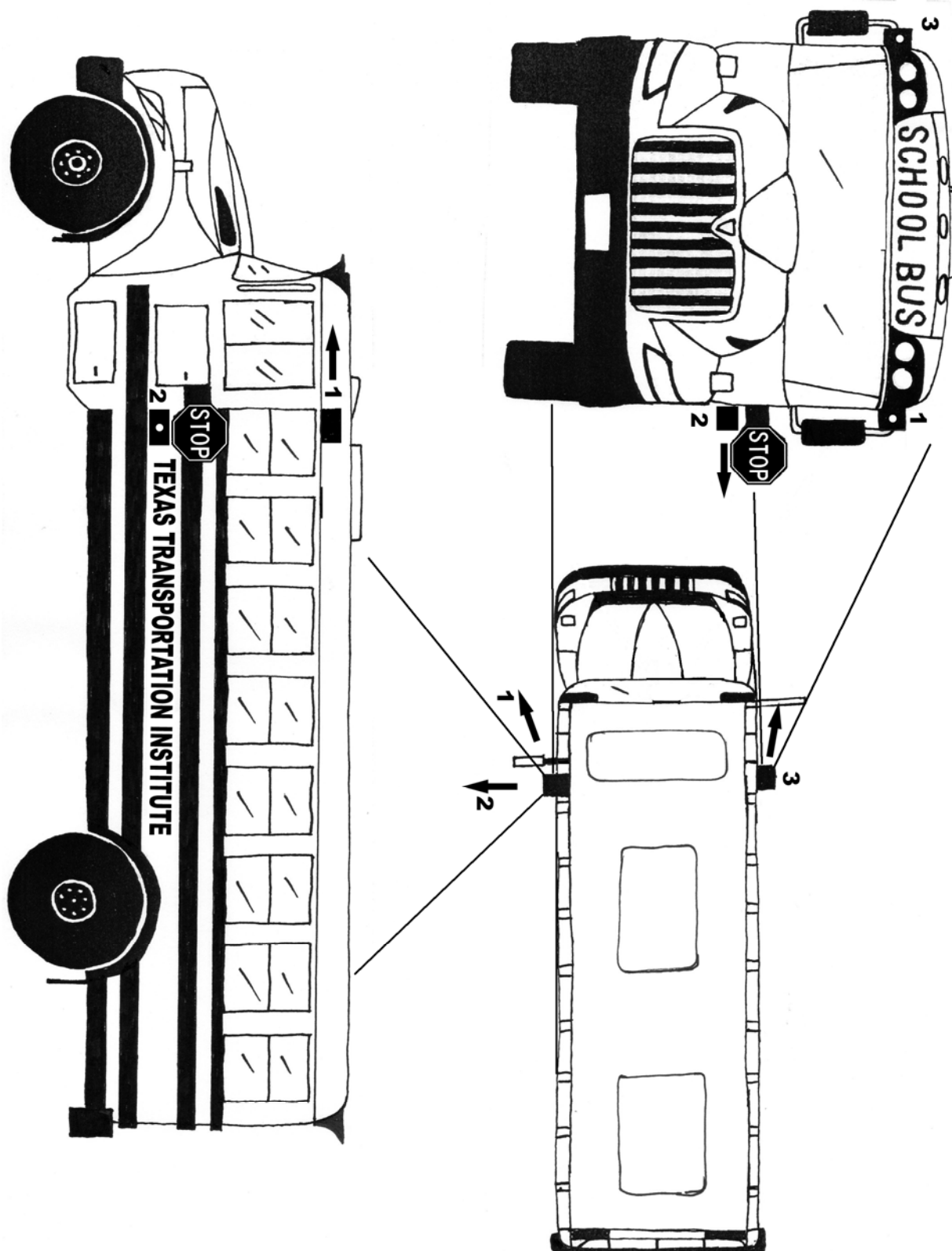


Figure 9. 3-Camera Configuration System and Range of View

Data Results

Over the 4-week data collection period, Bus 77 recorded for 31 days and captured a total of 26 stop-arm violations, an average of 0.84 violations per day. The 3-camera system on Bus 86 was operational for 7 days and recorded 7 violations, an average of 1 violation per day.

If the same method to estimate daily stop-arm violations statewide is applied to the pilot test data, an estimated 50 illegal passings occur each day in the College Station ISD (0.84 multiplied by 60 buses). If this number is multiplied by the number of school days in a typical school year (180), then an estimated 9,072 stop-arm violations will occur during a typical school year in College Station, Texas.

More than one half of all violations occurred during the morning routes (54%). Most stop-arm violations occurred on 4-lane roadways with a center turn lane (14 violations) and 4-lane roadways with a median (10 violations). The majority of passings occurred while the motorist was traveling in the opposite direction (coming toward) the stopped school bus. Vehicle make and model were easily identifiable from the video. The majority of violations were committed by cars (21 violations) followed by light trucks or vans (10 violations).

Out of the 33 recorded violations, only one license plate number was readable. In the test system, camera lenses were 12 mm and capable of reading license plate numbers from approximately 15 to 20 feet. The position of the cameras (high on the bus) also made it difficult to read license plate numbers. To adequately read vehicle license plate numbers would require cameras positioned toward multiple lanes and capable of reading license plate numbers from longer distances. This finding warrants further investigation and testing to determine cameras capable of capturing license plate numbers from the vehicles in multiple lanes and to determine the appropriate size and position of such cameras.

Ease of System Use for Bus Drivers

A bus driver's primary concern is the safety of the children on the school bus and a mobile digital video camera system should not interfere with those duties. The DVR unit tested successfully met the criteria as it automatically activated when the school bus was started, recorded only a preset length of time, and turned off automatically when the school bus was turned off. This feature helped the bus driver as they were not distracted by turning the DVR on and off when they exited the bus or temporarily parked.

The DVR unit was hard wired to the bus ignition circuit and received power only when the bus engine was running. An internal voltmeter allowed the unit to monitor the voltage being pulled from the bus circuitry. If the voltage to the DVR dropped below 12 volts the system would automatically shut down. This is a helpful feature in that the DVR unit can operate independently of the bus driver. It also prevents the DVR unit from draining the battery when the bus is not operating or is parked.

The DVR also had an internal timer which recorded only between the hours of 6:30 am to 8:30 am and 2:30 pm and 5:00 pm. This feature was helpful in that the bus driver did not have to manually start the recording, thus the system did not add to the driver workload.

The Seon system was also equipped with a red panic button. This feature allowed the bus driver to press the button if they observed a vehicle illegally passing the stopped school bus. This action imprinted a “time stamp” on the recorded video which made it easier to locate the violation when reducing the data. According to the bus driver, the system presence and the panic button allowed for the driver to focus on the driving task and provided some level of comfort in knowing that the system was there to monitor illegal passings and, thus, improve the safety of the children.

Ease of System Use for Other Transportation Employees

A mobile digital video camera system should be easy to use. Feedback from TTI staff and school district employees indicated that the Seon system met this criteria. Installation of the camera system was not difficult but did require knowledge of the school bus electrical system. Minimal tools were needed to install the system and included a screw driver, power drill, socket set and wire crimpers.

The DVR unit was equipped with a lock box secured by screws and the hard drive within the unit was locked into place to keep from disconnecting during normal bus operations. Two keys were needed to remove the hard drive from the DVR. One key unlocked the outer box housing the DVR unit and another key unlocked the hard drive located within the DVR. Removal of the hard drive from the DVR unit was simple and could be performed by school district employees with minimal instruction and no special training.

Ability of System Software to Interface with Recorded Video

A proprietary hard drive reader program was needed to view and archive the recorded video. The program allows for the video segments to be archived as MPEG or .EDR file. An

.EDR file extension is Seon's system file and allows for playback in the quad split screen view as shown in Figure 10. MPEG file format allowed for viewing video segments in Windows Media Player. However, each camera video had to be archived as a separate file, thus preventing the quad split screen viewing. This feature would require that school district personnel be trained to use the hard drive reader program.

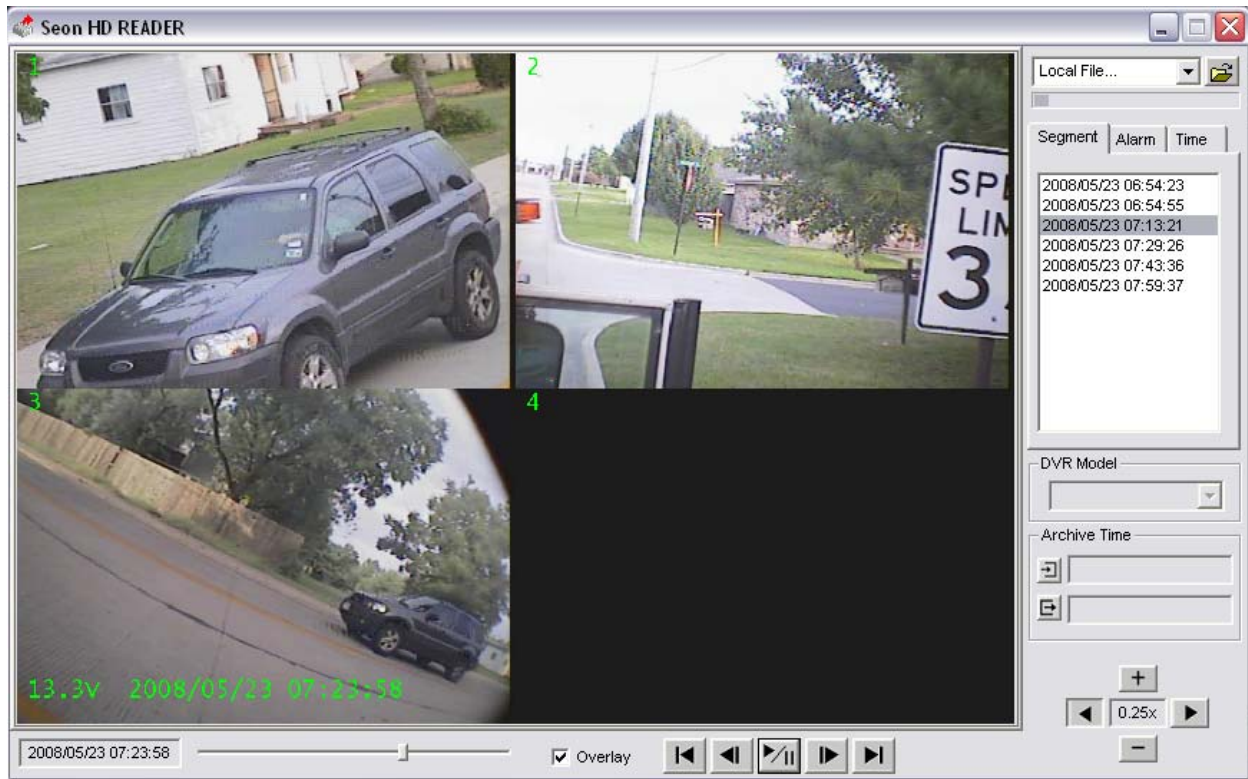


Figure 10. Quad Split Screen View of Recorded Video

Another issue is the size of the hard drive space required to store the archived video segments. One day of video (morning and afternoon) required 2.3 GB of storage space as an .EDR file and 11.5 GB of storage space a MPEG file (MPEG files included a total of eight video files while the .EDR format included two video files). The DVR hard drive is capable of storing 60 GB of video (or about 1 week of recording) and would require a large amount of hard disk space for subsequent storage of the archived files. .

Ease of System Software Use

Reducing the video requires that a person view the footage either before or after the archival process. For the pilot test, Bus 77 was archived as MPEG files while video from Bus 86 was archived as .EDR files. As discussed previously, videos saved as MPEG files required watching camera files in a particular sequence to identify the number of stop-arm violations which proved to be a very lengthy and time consuming process.

For video saved as .EDR files, a person must view the file through the Seon hard drive reader program. This program requires some exploring to understand its full potential as many features are buried under multiple pull down tabs or right clicks of the mouse button. Menus are not clearly defined and features are not easily accessible.

Another challenge using the hard drive reader program is that it lacks the ability to quickly search or locate specific time segments within the video. As with any computer program, the program takes some time to master and gain proficiency. However, a person with some computer experience should be able to learn how to archive and view videos within a minimal amount of time.

Summary

The technology advancements of digital video cameras and recording units have yielded systems capable of capturing information about vehicles that illegally pass stopped school buses with their stop arms extended. This pilot test evaluated several system applications of the SEON Explorer™ Mobile DVR System for use in identifying stop-arm violations (see summary in Table 7).

Overall, the Seon system performed well and was capable of recording high quality video to monitor the incidence of stop-arm violations. The system cameras performed well in recording high quality color images of vehicles that passed stopped school buses with their stop-arms extended easily identifying information about the vehicle such as make, model, color, and direction of travel. However, the camera lenses (on system tested) were not adequate to read vehicle license plate numbers. This information is essential if school districts and communities wish to use this technology to identify the driver of the vehicle committing the stop-arm violation for targeted PI&E and enforcement efforts.

Table 7. Summary Evaluation of Mobile Video Camera System

Feature Evaluated	Results/Comments
quality of the image recorded by digital camera	Good.
ability to identify detailed vehicle characteristics (make, model, color, etc) from digital image	Good. Identified vehicle characteristics clearly
ability to identify vehicle license plate number from digital image	Could only identify 1 license plate. Image was not clear enough most of the time to identify tag number.
ability to identify driver characteristics from digital image	Could not identify driver characteristics from image.
ability of the system to record a stop-arm violation incident	Good. Was able to identify all cases of stop arm violations during the test period.
ability of the system to record stop-arm violations in multiple lanes and in multiple directions	Good. Cameras were capable of adjustments to allow for multiple lanes of viewing and recording.
ability of the system to record stop-arm violations under varying lighting conditions	Feature not tested as all recordings occurred during daylight hours.
ability of the system to record stop-arm violations under varying weather conditions	Feature not tested as all recordings occurred during good weather conditions.
ease of system use for bus drivers	Good. Did not detract from driving tasks.
ease of system use for other transportation employees	Good. Very limited instruction needed.
ability of system software to interface with recorded video	Good. Need proprietary software.
ease of system software use	Requires time for video review, some difficulty in learning program, training needed, lacks ability for quick searches.

Based on the pilot test results, the minimum recommendations for selecting a digital video camera system to monitor stop arm violations should include:

- The ability to capture the time and date of the violation
- A minimum of 4 channels to maintain a field of view around the bus
- One camera facing forward
- One camera facing backward
- One camera viewing the plane of the stop arm (viewing perpendicular to the direction of travel for the school bus)
- One camera monitoring the opening and closing of the school bus door
- A camera lens capable of reading license plate numbers across multiple lanes of traffic including a center turn lane
- Ability to record to a removable hard drive
- Hard drive storage space with a minimum of 60 GB or larger capacity to record multiple days of footage

RECOMMENDATIONS

The following recommendations are based on the study outcomes.

- Review Texas Crash data as they become available to examine trends since 2001.
- Continue to monitor the incidence of stop-arm violations and changes by conducting annual stop-arm survey.
- Develop a comprehensive program to reduce the statewide incidence of stop-arm violations through the emphasis of awareness and education of the public.
- Utilize survey data to evaluate engineering, enforcement, and education components of a stop-arm violation program.
- Educate school bus drivers on the subject of stop-arm violations and develop training materials such as brochures, and an instructional video on how to correctly identify stop arm violators.
- Develop pamphlets targeted at the public to educate them about stop-arm violations and the consequences of violating the law.
- Conduct further testing to evaluate technologies and / or cameras capable of capturing license plate information from vehicles that illegally pass stopped school buses so that drivers can be identified.

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APPENDIX A:

SCHOOL BUS ILLEGAL PASSING SURVEY FORM

SCHOOL BUS ILLEGAL PASSING SURVEY FORM

DEAR SCHOOL BUS DRIVER: The Texas Department of Public Safety School Transportation Unit is conducting an annual study to obtain information about vehicles that illegally pass your stopped school bus while you are loading and unloading students. **THE 2006-2007 SURVEY WILL BE CONDUCTED ON NOVEMBER 8, 2006.** Please observe the vehicles that illegally pass your school bus **while it is stopped with the Red Loading Lights activated** on this date and put an **X** in the appropriate blank on the form that best fits the illegal passing. Each row on the form represents one (1) vehicle that illegally passes your stopped school bus. There are six spaces provided for your convenience. Additional sheets may be used, as necessary. **REMEMBER: Please take extreme caution when completing the form – YOUR MAIN RESPONSIBILITY IS THE SAFETY OF YOUR STUDENTS.** Time permitting, please complete as much information as possible. Should you have questions, call SCHOOL TRANSPORTATION 254.759.7111. THANK YOU FOR YOUR COOPERATION.



School District Name: _____
 Driver Name: _____
 Bus Number: _____ Route Number: _____
 AM _____ MID _____ PM _____
 Date: _____

TIME OF PASS	# OF STUDENTS AT BUS STOP	VEHICLE PASSED FROM THE:	PASSED ON WHICH SIDE OF THE BUS	TYPE OF VEHICLE	TYPE OF ROADWAY
1. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____
2. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____
3. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____
4. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____
5. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____
6. A.M. _____ P.M. _____	1 TO 5 _____ 6 TO 10 _____ 11 OR MORE _____	FRONT (opposite way) _____ REAR (going same way) _____	LEFT (driver side) _____ RIGHT (door side) _____	CAR _____ LIGHT TRUCK / VAN _____ HEAVY TRUCK _____	2 LANES _____ 3 LANES _____ 4 LANES, NO MEDIAN _____ 4 LANES, W/ MEDIAN _____ OVER 4 LANES _____

Please Report only violations that meet the following criteria:

- (1) BUS IS COMPLETELY STOPPED
 - (2) RED LIGHTS ARE FLASHING AND STOP SIGN (if equipped) IS EXTENDED
 - (3) VEHICLE PASSES BY THE RIGHT SIDE OR LEFT SIDE OF THE BUS WHILE STOP IS BEING MADE.
- This data collection form should be completed by each bus driver on the day of the illegal passing count and should be turned in **EVEN IF THERE ARE NO VIOLATIONS TO REPORT**. Bus Driver, after p.m. route, please return completed form to transportation director (or designee) who will collect all forms and return to TX DPS no later than November 17, 2006. Should you have questions, please call SCHOOL TRANSPORTATION 254.759.7111.

SCHOOL BUS ILLEGAL PASSING SURVEY

DEAR SCHOOL SUPERINTENDENT / TRANSPORTATION DIRECTOR:

The Texas Department of Public Safety School Transportation Unit is conducting an annual study to obtain information about vehicles that illegally pass stopped school buses while loading and unloading students. **THE 2006-2007 SURVEY WILL BE CONDUCTED ON NOVEMBER 8, 2006.** Please instruct your drivers to observe the vehicles that illegally pass their school bus ***while it is stopped with the Red Loading Lights activated*** on this date and put an **X** in the appropriate blank on the form that best fits the illegal passing. Each row on the form represents one (1) vehicle that illegally passes the stopped school bus. There are six spaces provided for your drivers convenience. Additional sheets may be used, as necessary. Instructions are on the survey at the top and bottom of the form. **REMINDER TO DRIVERS to please take extreme caution when completing the form – THEIR MAIN RESPONSIBILITY IS THE SAFETY OF THEIR STUDENTS.** Time permitting, please have them complete as much information as possible on the attached form.

Please copy the form as necessary and distribute to all drivers with instructions to complete and return to you on November 8, 2006. Please complete and attach this cover sheet and return with all forms to the address below no later than November 17, 2006.

Please **print** all information below.

School District: _____

Superintendent: _____

Transportation Director: _____

Person completing this form: _____

Contact phone number: _____

Email address: _____

Total number of routes for your district: _____ Total number of buses: _____

My district bus routes are mostly: Rural _____ City _____

Complete and return this form with all surveys no later than **November 17, 2006** to the following:

School Transportation
Texas Department of Public Safety
1617 East Crest Drive
Waco, TX 76705-1598

Thank you for your cooperation. Should you have questions please call CHARLEY KENNINGTON OR PAM McCURDY, 254.759.7111 or email charley.kennington@txdps.state.tx.us or pam.mccurdy@txdps.state.tx.us

APPENDIX B:

DATA REDUCTION ARCHIVING INSTRUCTIONS

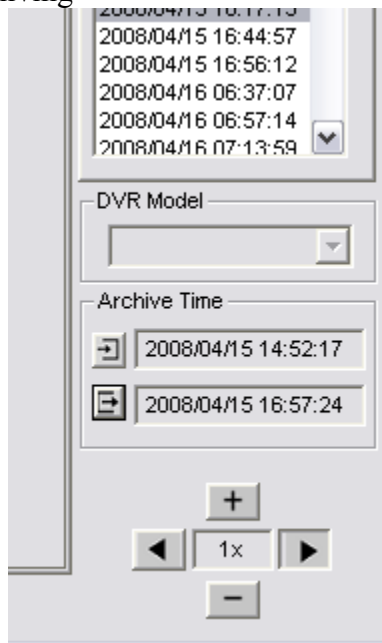
Archiving Instructions for School Bus Cameras

Set up:

1. Insert Seon Hard Drive in Seon Hard Drive Read.
2. Plug in power cord to outlet. Do not turn on.
3. Plug USB cord in to computer.
4. Turn on Hard Drive Reader.
5. Open Seon Hard Drive Read program

Archiving Instructions

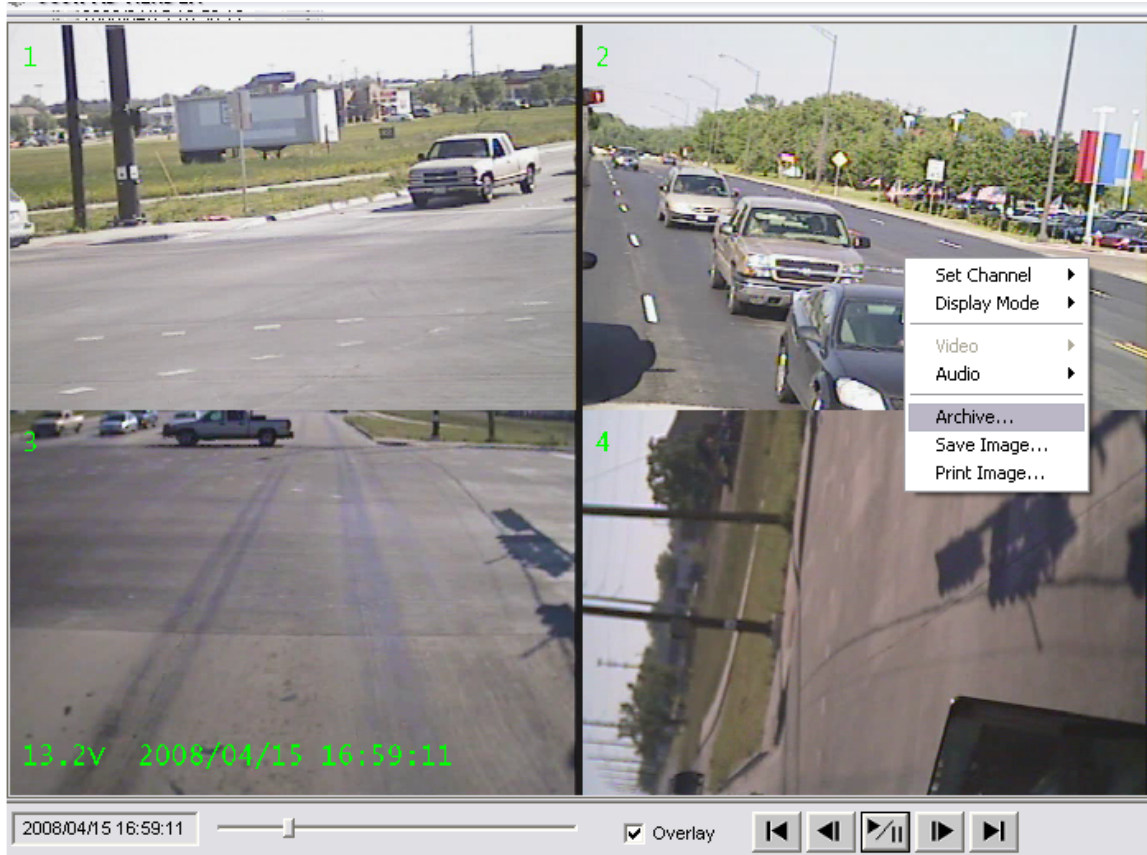
1. Select time frame for archiving



2. Click the top button to indicate when you want to start archiving. For example the picture shows the start time of 2008/04/15 14:52:17. That is April 15, 2008 at 2:52 PM.
3. Click the bottom button to indicate when you want to stop archiving. For example the picture shows the start time of 2008/04/15 16:57:24. That is April 15, 2008 at 4:57 PM.
4. Once that is done, right click on the camera you wish to archive. The camera order is 1,2,3,4 going top left, top right, bottom left, bottom right.

1	2
3	4

5. After right clicking on the camera select archive from the drop down menu.



6. After selecting archive name the video file Cam # date am/pm. This would be Cam 2 4_15_2008 PM.
7. Click Ok.
8. You will need to select the video compression style next. You will pick MPEG 4 V3.
9. Click Ok.
10. After this you will see a pop up box that will display the progress of the archiving. The longer the video the larger the video file and the longer it will take to archive the video.
11. Archive all 4 videos before turning off Reader or shutting down the program.