

Preliminary Investigation

Caltrans Division of Research, Innovation and System Information

Work Zone Intrusion Alarms for Highway Workers



Requested by
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Executive Summary

Background

In an ongoing effort to improve worker safety, Caltrans is investigating innovative practices and technologies to protect construction and maintenance workers on California's highways. One situation identified for study is when an unauthorized vehicle enters the work zone. Since the work environment on the highway is often chaotic and noisy, it can be difficult for workers to spot an errant vehicle in time to take appropriate action.

These types of conflicts exist because traffic and roadwork are confined to the same space while highway construction repairs and improves existing roads. On a federal level in 2008, 80.5% of highway capital expenditures were allocated to: system rehabilitation (51.1%), expansion of existing roads (17.4%), and enhancement of those roads (12%). For system rehabilitation, that amounts to about \$40.4 billion (Scriba & Atkinson, 2014).

More than 20,000 workers are injured in work zones each year, with 12% of those due to traffic incidents. Challenges to work zone safety and mobility are further exacerbated by the growing issue of distracted driving.

Consequently, Caltrans has requested a Preliminary Investigation (PI) to investigate Work Zone Intrusion Alarms (WZIA) that give highway workers warning when an unauthorized vehicle has entered the work zone.

This PI focuses on what technologies are currently available, what are the features that enable application to enhance worker safety, and how the systems can improve worker safety in work zones. The scope of this investigation is as follows:

- Identify the benefits of using WZIA
- Identify the types of WZIA systems available
- Identify the manufacturers of the systems
- Perform a literature and internet review to identify and collect product information and reviews
- Summarize existing research on WZIA
- Make a recommendation of what WZIA products should be considered for further Caltrans review.

Summary of Findings

We present our findings in the topic areas summarized below.

Benefits of Using WZIA

The main benefit of using WZIAS is to reduce the risk of injury to exposed workers at a work zone site. These warning devices are best-suited when workers are in a temporary work zone which is also close to moving vehicles/traffic. It is assumed here that temporary work zones have minimal or no positive protection between them and the highway traffic.

As new technology continues to develop, WZIAs should continue to improve. Many of the studies discussed in this report have indicated that WZIAs need improvements in deployment protocols and performance reliability (Carlson, Fontaine, & Hawkins, 2000), (Krupa, 2010), (Novosel, 2014). Some of the more recent designs of WZIAs appear to have promising applicability for temporary work zones (Kochevar, 2014), (Teizer, Allread, Fullerton, & Hinze, 2010), (Virginia Technological University, 2015), (Astro Optics, ILLC, 2015).

Types of WZIA Systems Available

WZIAs are devices that are designed to sound an alarm when an errant vehicle enters the work area. Four types of WZIAs are available: microwave, infrared, pneumatic tube, and kinematic.

Microwave and infrared models are mounted on traffic drums or cones and use microwave signals or beams of infrared light to connect units. When a vehicle crosses into the work zone and interrupts the signal or beams, a high-pitched alarm is sounded near the workers. The pneumatic tube model is placed on the ground, with the tubes being laid perpendicular to traffic. When a vehicle drives into the area and over the tubes, the alarm sounds. The kinematic models are mounted on a traffic cone (or other similar hardware) and sound the alarm when the change in orientation angle of the cone indicates it has been tipped over. This system assumes an errant vehicle has knocked over the hardware and has entered the work area.

Manufacturers of Available WZIAs

The known manufacturers of commercially available WZIAs are listed below. The name of the associated WZIA device is also included along with a brief description of the hardware.

TAPCO (Traffic and Parking Control Co., Inc.)

Website: <http://www.tapconet.com>

Product Name: SonoBlaster

WZIA Type: Kinematic

Description: An impact-activated device attached to a traffic control device which produces a loud warning sound to alert workers when the device is struck by a vehicle.

Intellistrobe Safety Systems, LLC

Website: <http://flaggersafety.com/home.html>

Product Name: Intellistrobe W1-AG

WZIA Type: Microwave and Pneumatic

Description: This device is a stand-alone unit controlled electronically from a transmitter carried by an operator. It is used predominantly as an Auto Flagger Assistance Device

(AFAD), but optional safety equipment includes a pneumatic tube to alert the operator of lane intrusions.

Astro Optics, LLC

Website: <http://www.astrooptics.com/products/traffic-guard-worker-alert-system>

Product Name: Traffic Guard Worker Alert System

WZIA Type: Microwave and Pneumatic

Description: This device consists of a lightweight, easy-to-transport trip hose and sensor assembly that sends a signal to an alarm and flashing light up to 1000 feet away.

TraffiCalm Systems

Website: <http://trafficalm.com/>

Product Name: WrongWayAlert™

WZIA Type: Microwave

Description: This device is predominantly designed for wrong way driving detection. However, the radar detector for errant wrong way drivers and visual notification system have similar functionality to other WZIA systems. Consequently, this system could be adapted to a highway work zone condition.

Related Research, Resources, and Other Issues

- There are a number of studies available involving various types of WZIAS. In general, none of the studies are enthusiastic about the effectiveness of intrusion alarms' ability to improve the safety of workers on the highway.
- Some of the drawbacks identified in research studies are: insufficient equipment reliability, alarm systems being too quiet or directionally indecisive, and lack of objective method for estimating the reduction in risk experienced by workers when WZIAS are deployed. Since these alarms are specialized and pertain to a limited number of applications, it is difficult to assess whether or not risk is actually reduced.
- Some state departments of transportation (DOTs) are currently using or have had some experience with WZIAS. A query to DOTs was made for this PI inquiring about their experience with intrusion alarms. Those that have experience using intrusion alarms are Kansas, Maryland, Minnesota, Ohio, Oregon, Pennsylvania, and Washington. Those that do not use WZIAS include Illinois, Indiana, Michigan, Nebraska, Virginia, and Wisconsin. This information is based on an email sent out at the work start date of this preliminary investigation. The email was sent to American Association of State Highway and Transportation Officials (AASHTO) Maintenance Subcommittee members.
- Many WZIAS have been studied and developed as there is an identified need to reduce the risk posed by errant vehicles entering a work zone where conditions do not allow for the deployment of positive protection systems (e.g. a truck-mounted attenuator).

Researchers stressed the need to reduce the risk of intrusion since, when intrusion occurs into an active work zone, serious injury or death can occur.

Gaps in Findings

- Due to the fact that the definition of highway work zone incorporates a variety of physical situations (i.e. two-lane vs. multi-lane, short-term vs. long-term, moving or stationary, etc.) there are also a variety of reasons why warnings are used and needed. There is definite overlap between functionality and applications that causes confusion.
- Although there is agreement that reducing exposure of workers to dangerous situations increases worker safety, there does not seem to be any quantification as to how much risk has been reduced when intrusion alarms are utilized.
- A lack of evaluation methodology for WZIA effectiveness in previous research hindered the identification of benefits. There appears to be a minimum set of requirements on whether the use of an intrusion alarm would be considered such as being loud enough and not issuing false alarms.
- No previous cost-benefit analysis for WZIA usage was identified in this research.
- With respect to availability of hardware, there seems to be a lack of sources. It is possible the reason is due to lack of objective data indicating the cost-benefit value of deploying a WZIA system.

Next Steps

- Conceptually, WZIAS are supported by many state DOTs and organizations interested in improving work zone safety. In practice however, there does not appear to be one preferred device. It is recommended that further study be done into other state's WZIA deployments and identifying relevant lessons learned.
- The Traffic Guard Worker Alert System by Astro Optics, LLC, appears to have the most promise of currently available hardware. This product seems to have addressed some of the concerns and problems of other WZIAS. Field testing by Caltrans may indicate this WZIA increases the safety of work zone personnel in certain types of maintenance operations.
- Currently, there are few studies which quantify the overall safety improvement for work zone workers when WZIAS are employed. Further research on this would provide valuable data to support decisions on when and where to deploy the systems.
- Research should also be done on the frequency, type, and conditions of intrusions into work zones. A set of well-defined parameters describing the problem would be helpful to test the effectiveness of WZIAS or for development of new WZIA technology.

Detailed Findings

Benefits of Using Intrusion Alarm Systems

The main benefit of using a WZIA system is to reduce the risk of injury or death by providing advance warning to workers regarding errant vehicles entering the work zone. There appears to be no quantifiable method of determining the number of deaths or injuries that have been

avoided by using WZIAs, but there is general agreement that risk is reduced. Improving road workers safety through the use of technology is one component of improving highway safety.

Commercially Available Systems

SonoBlaster

Manufacturer: TAPCO (Traffic and Parking Control Co., Inc.)

Website: <http://www.tapconet.com>

The SonoBlaster is described by the National Work Zone Safety Information Clearinghouse as a dual alert (gives warning to both driver and construction worker) WZIA. It is an impact-activated device attached to a barricade, cone, drum, or other traffic control device that emits a loud warning sound to the workers when the traffic control device is struck (National Work Zone Safety Information Clearinghouse, 2016).

- An impact-activated safety device that warns roadway workers and errant vehicle drivers simultaneously.
- Mounts on typical work zone barricades, cones, drums, delineators, A-frames and other barriers.
- Upon impact of an errant vehicle, the SonoBlaster's built-in CO₂ powered horn blasts at 125 dB to signal workers that their work zone has been violated, giving them critical reaction time to move out of harm's way.

Sources who advocate for the SonoBlaster (Kochevar, 2014) indicate these advantages:

- Alerts both workers and drivers by emitting a 125 dB horn blast for 15 seconds from the device that was impacted by the errant driver
- The horn blast helps to pinpoint the source/direction of the errant vehicle
- The horn blasts are powered by CO₂ cartridges and need no dedicated electrical power
- Each unit operates independently
- The units are deployed in a similar manner as setting a traffic cone
- The units are light-weight, economical, and have a long-life.



Figure 1: Collection of SonoBlaster systems prior to testing in the field (Krupa 2012)

Intellistrobe W1-AG

Manufacturer: Intellistrobe Safety Systems, LLC

Website: <http://flaggersafety.com/home.html>

The Intellistrobe W1-AG Automated Flagger Assistance Device (AFAD) is available from Street Smart Rental, Inc. and is marketed under the Automated Flagger Systems product line:

Website: <https://www.streetSMARTrental.com/products/automated-flaggers-sales.html/>

The Street Smart Rental website describes this system as a highly visible, stand-alone unit controlled electronically from a transmitter carried by an operator located safely out of harm's way. It appears there are hardware limitations for poor line-of-sight conditions greater than 800 ft.

The Intellistrobe AFAD can be configured to act as a WZIA. The AFAD's optional Lane Intrusion Safety System component has an audible alarm and light system that is activated when a vehicle crosses over a pneumatic hose delineating the work area. The Modified Gate Arm allows visual confirmation for the controller. Note that the signal heads must be covered when the system is being used for lane intrusion only.

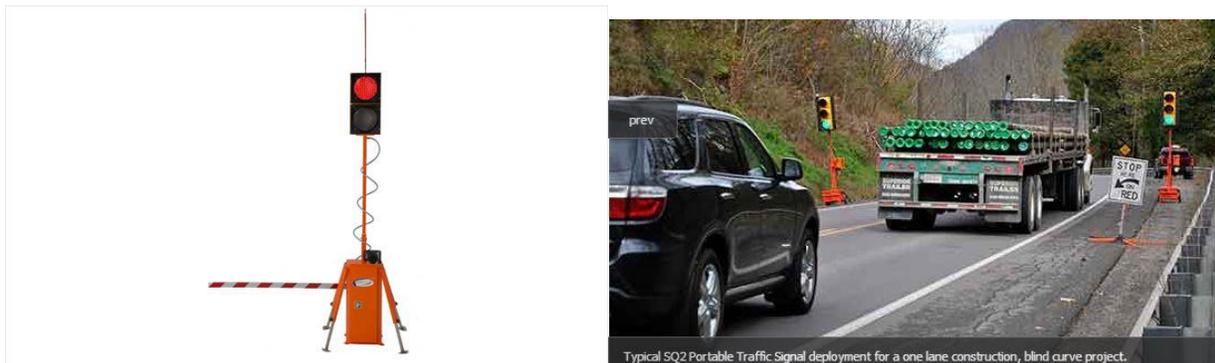


Figure 2: Pictures of the Intellistrobe as a single unit (left) also in an example in the field scenario (right)

WrongWayAlert™

Manufacturer: TrafficCalm Systems

Website: <http://trafficalm.com/wrongwayalert-wrong-way-warning-system/>

TrafficCalm advertises on its website the WrongWayAlert™ as an “Intrusion Warning System” but there are differences between this product’s intrusion warning and the other WZIAs discussed in this PI. The WrongWayAlert™ is designed to retrofit on existing roadway “Wrong Way” signage. This device raises driver awareness in wrong way driver situations, but also has the expanded capacity to simultaneously warn “right way” drivers that a wrong way vehicle is approaching. The hardware is typically deployed with the radar unit set up to detect errant vehicles entering a highway off-ramp from the wrong direction. When an errant vehicle is detected, a signal is sent to a receiver which triggers warning lights and potentially notifies first-responder personnel.

Although it is not known whether this system has been deployed as anything other than a wrong way detection system, it is speculated that the radar detectors and communication equipment might be utilized as a WZIA system monitoring a temporary work zone as opposed to a prescribed perimeter.

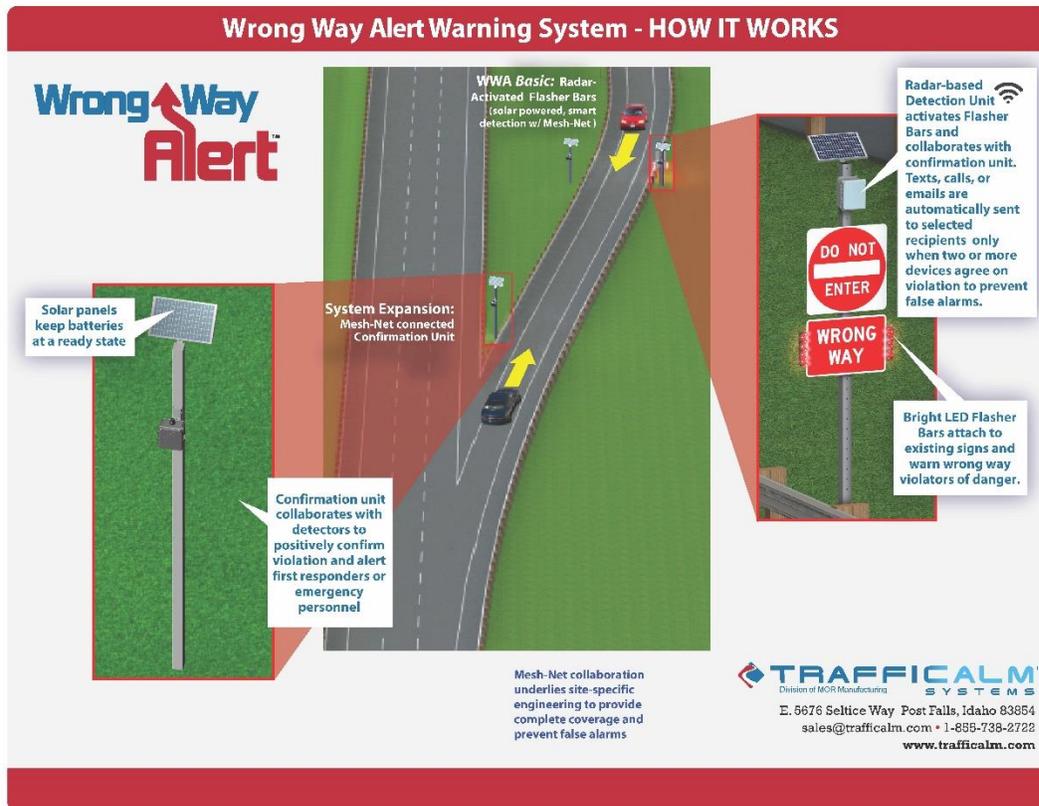


Figure 3: Schematic of how the WrongWayAlert system works (From: <http://trafficalm.com/wp-content/uploads/2016/01/Brochure-WWA-web-20151214.pdf>)

Traffic Guard Worker Alert System

Manufacturer: Astro Optics, LLC

Website: <http://www.astrooptics.com/products/traffic-guard-worker-alert-system>

The National Work Zone Safety Information Clearinghouse gives the following general description:

“The all new Traffic Guard Worker Alert System consists of a lightweight, easy-to-transport trip hose and sensor assembly that sends a signal to an alarm and flashing light up to 1000 feet away. The trip hose is placed ahead of or behind workers on the road, far enough away to provide ample warning in the event that an unauthorized vehicle crosses over the hose. The flashing light and alarm alert workers so they are able to quickly move out of the way of an oncoming vehicle. The faster the traffic is moving, the more distance there should be between the trip hose and work area.” (National Work Zone Safety Information Clearinghouse, 2016).

From the product information webpage, Astro Optics provides an excellent product description video of the Traffic Guard Warning System. Notes from the video:

(http://www.youtube.com/embed/WhNaA3mM_Fk?rel=0)

- The Traffic Guard is an audible/visual alarm system designed to protect workers from vehicular traffic.
- The system contains a standalone, lightweight trip hose with a transmitter and sensor to detect compression from vehicle/object contact. The standard length for the trip hose is 12 feet, but it can be purchased in different lengths.
- Another component is a portable Alarm Case with pulsing sound blast and flashing LED light signal. It can either rest on a surface or be attached to any metal surface via a heavy duty magnet.
- The third component of the system is a Personal Safety Device, which functions similarly to the portable Alarm Case, but is meant to be attached to a worker’s clothing. When there is loud ambient noise, the Personal Safety Device can notify the worker via vibration and/or through a head set.
- When a vehicle runs over the trip hose, it sets off all alarms.
- A green LED light shows the system is powered on and ready to operate. It is designed to be easily seen for visual verification that the system is up and running.
- The video recommends to step on the trip hose to test all the activated alarm devices.

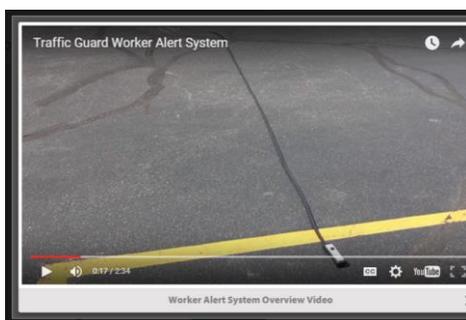


Figure 2: Picture of Traffic Guard trip line with attached sensor (From Astro Optics product video http://www.youtube.com/embed/WhNaA3mM_Fk?rel=0)



Figure 3: Portable Alarm System attached via a strong magnet to the side of a vehicle (From Astro Optics product video http://www.youtube.com/embed/WhNaA3mM_Fk?rel=0)



Figure 4: Traffic Guard Personal alarm device (From Astro Optics product video http://www.youtube.com/embed/WhNaA3mM_Fk?rel=0)

Known Current Usage in United States

The following information was obtained from the current online materials reviewed for this PI. Also, a brief email was sent out to the AASHTO Maintenance subcommittee members inquiring whether their DOT organizations currently use WZIAS in their highway maintenance operations (American Association of State Highway and Transportation Officials, 2015).

In summary, information is known on the following states pertaining to their use of WZIAS:

Table 1: List of states where information is known on their use of WZIAS

State	Do Not Use WZIAS	Use or Have Used WZIAS
Illinois	X	
Indiana	X	
Kansas		X
Maryland		X
Michigan	X	
Minnesota		X
Nebraska	X	

State	Do Not Use WZIAs	Use or Have Used WZIAs
Ohio		X
Oregon		X
Pennsylvania		X
Virginia	X	
Washington		X
Wisconsin	X	

The following states provided responses to the email inquiry:

Virginia

- AASHTO: Kevin Gregg, State Maintenance Administrator
- Response: No past or current experience with intrusion alarms
- Comment:
 - At this point we do not have any reason for not using warning systems, we just have not moved in that direction

Pennsylvania

- AASHTO: Matthew B. Briggs, Traffic Control Specialist Manager
- Response: Yes, they currently use Eastern Metal of Elmira Model HWZIA and 10-A. Yes, they find them useful.
- Comments:
 - Recently we have evaluated the use of new systems which can be placed closer to the actual work. These systems function similar to the currently used systems but use upgrade technology.
 - The new systems which are wireless and can provide each worker with an audible and vibratory notification with using supplemental devices on their ankle or hip. There are a couple products on the market. We are currently evaluating one of them, but have yet to receive any formal follow-ups
 - It does take additional time to set-up, but this is not a valid reason to not use them. These devices can be set-up once the temporary traffic control is set up and before the work actually begins. The alarms are loud, so residential usage needs to be accounted for during nighttime use, but again, this is not a reason not to use them.

Michigan

- AASHTO: Mark S. Geib, P.E., Engineer of Operations Field Services Division
- Response: No past or current experience with IA
- Comment:
 - The Michigan Department of Transportation has no experience with warning systems for highway maintenance workers.

Ohio

- AASHTO: Emily S. Willis, P.E, Ohio DOT, Office of Roadway Engineering
- Response: Limited experience with SonoBlaster
- Comments:
 - Ohio DOT has formally participated in an evaluation of SonoBlaster's back around 2008/2009. FHWA was the one doing a report on them and we were one of many states that participated. In a nutshell there were a bunch of issues...lots of false alarms, nearly impossible to tell if unit was still engaged without visiting each one up close, gaps in the system allowing unmonitored exposed areas, etc. Also, we did not find that they were very loud on a work site when they did go off.
 - The last time I reached out to FHWA asking if a final report had been prepared they told me no. They indicated that even after retooling the units after the interim report many of the same issues remained and that they were going to mark in their system that the interim report would serve as the final report (no final report would be prepared).

Illinois

- AASHTO: Timothy A. Armbrecht, P.E., S.E., Engineer of Maintenance Operations
- Response: No past or current experience with IA
- Comment:
 - In Illinois, we do not use them. I checked with a couple of our Operations Engineers, and one of them mentioned we tried one about +/-15 years ago for a short time. It may have simply been a trial. He thinks several of our districts tried them for a short time. He also believes it was effective but costly and took additional time to set up, which is probably why we didn't get past the trial phase. Since it was 15 years ago, a lot has changed, so our experience probably doesn't help you with today's technology advances.

Washington

- AASHTO: Kim Willoughby, P.E., Roadway Asset Manager WSDOT Maintenance Division
- Response: Yes, limited. See Comments below
- Comments:
 - Here at WSDOT, we have tested a number of different devices over the years, including the SonoBlaster that the FHWA was demonstrated back in 2009. Overall, the results weren't all that great as true work zone intrusion systems, they wouldn't give enough time for the workers to react if an intrusion into the work zone occurred or they weren't loud enough to attract attention.
 - That being said, we do still have some utilization of a system built for us by Zydax within one of our maintenance areas. The way this system works is it is set off by a worker (typically a flagger with a key fob) if something were to happen (WZ intrusion, hillside slide, etc.). This system is mainly used when the work zone is around a curve or where there is a larger potential for danger. It is not set up for every work zone.
 - In talking with the Maintenance Supervisor for that area, they have never had to set the alarm off because of an intrusion or problem, but it has been tested or set off accidentally and he stated that even the workers in the machine cabs could hear the alarm.

- We are also aware of a system by Oldcastle called AWARE and our work zone specialist Marty Weed will be checking with Oldcastle within the next month or so to see if that system is available.
- I just heard from another of our maintenance areas and they use the Robo-Flagger on just about every job. The team seems to like it, but they've never had to sound the alarm for an intrusion (they've tested it and set it off on accident and they say that everyone can hear it even around/in loud equipment).

Follow-up Notes

From the information obtained from Pennsylvania and Washington, two WZIA systems were noted. Some follow-up work was done to see if other manufacturers of WZIA systems could be obtained.

As indicated above, the state of Pennsylvania stated they use Eastern Metal USA- Sign of Elmira for their models HWZIA-300 and model 10A-M. Although this company advertises intrusion alarms, it is believed that the road work zone safety intrusion alarm pertains to a flagger assistance device. More detailed follow up would be necessary in order to determine if this were the case.

From the state of Washington, the Oldcastle Company (www.oldcastle.com) was mentioned as being the supplier of a new product line called AWARE. As of December 2015, the AWARE system was still undergoing trademark proceedings. There is no mention of this product on the Oldcastle website. The trademark information indicated that the AWARE system may have potential as a WZIA, but is not ready to be evaluated.

In conclusion, the information received from other state DOTs did not turn up any new leads for products or manufacturers. Their comments were very informative and should be looked at more closely if WZIA systems are evaluated in California.

Related Research and Resources

Related research found in this Preliminary Investigation pertaining to the application of WZIA systems is discussed in the following.

Creating Smarter Work Zones

Scriba, T., & Atkinson, J. (2014, March/April). *Publication Number: FHWA-HRT-14-003 . Issue No: Vol. 77 No. 5*. Retrieved from PUBLIC ROADS: Creating Smarter Work Zones.

This article from the Public Roads magazine advocates for using technology to create safer work zones in several applications. Although the authors do not identify specific WZIA products or usage methods, they do support that using WZIAs minimizes the risk posed by errant vehicles. This reduction in exposure seems to be a key point they are making.

This magazine provides good information on current technology and may be a good resource since, "the magazine covers advances and innovations in highway/traffic research and technology, critical national transportation issues, important activities and achievements of

FHWA and others in the highway community, specific FHWA program areas, and subjects of interest to highway industry professionals.” (<https://www.fhwa.dot.gov/publications/publicroads/>)

Evaluation of Innovative Traffic Safety Devices at Short-Term Work Zones

Wang, M.-H., Schrock, S., & Bai, Y. (2011). *K-TRAN: KU-09-5 Evaluation of Innovative Traffic Safety Devices at Short-Term Work Zones*. University of Kansas and Kansas Department of Transportation.

The objective of this study was to investigate and evaluate the usage and effectiveness of innovative traffic control devices that can be used in short-term work zones.

This study was conducted in three sections: a literature review of previously published research, a nationwide usage survey, and a field test for a selected device, which was a portable plastic rumble strip (PPRS).

This study discusses WZIAs and provides a good overall assessment of safety equipment at a work site. The authors do advocate the use of portable plastic rumble strips.

WZIA Effectiveness

Krupa, C. (2010). *NJ-2010-004 : Work Zone Intrusion Alarm Effectiveness*. New Jersey Department of Transportation.

This research tested the SonoBlaster to determine its effectiveness as a WZIA. In the end however, they decided the desirability of the hardware was not sufficient to complete the study.

From the paper <http://www.nj.gov/transportation/refdata/research/reports/NJ-2010-004.pdf>

“The New Jersey Department of Transportation (NJDOT) commissioned a study to evaluate how effective a work zone safety device known as the SonoBlaster® Work Zone Intrusion Alarm would be in protecting maintenance workers from injury caused by vehicles that breach the work zone, and how well it would be accepted by workers. The device is mounted on a traffic cone and when impacted by a vehicle, emits an alarm that provides advance warning to allow workers to react to avoid the intruding vehicle. The device also alerts the driver who may be drowsy or distracted, who can respond by braking or steering out of the work zone, or both actions. In a pilot test of the device, SonoBlaster® equipped traffic cones were used with standard cones to close a lane of traffic for maintenance work. Two impact simulations were performed resulting in sounding of the alarm, as no impacts occurred from traveling vehicles. The alarm’s sound volume and duration were satisfactory during normal traffic conditions for distances of at least 200 ft, including when ear protection was worn, but no conclusion could be made about hearing the alarm during jack hammer operations. Employees indicated that several set-up procedures were difficult. Moreover, in multiple instances the alarm fired when the control knob was in the locked, unarmed position. Additional field trials could not be scheduled. However, NJDOT believes that problems with quality control and reliability, combined with the cost of the alarm, raise doubts about the desirability of and benefits to be gained from deploying the device on NJDOT maintenance jobs.”

Strategies on Improving Worker Safety in Work Zones

Roadway Safety Consortium. (2011). Strategies on Improving Worker Safety in Work Zones. Retrieved from Work Zone Safety Clearinghouse.

This resource is a presentation on overall strategies pertaining to making a work zone environment safer for the workers and traveling public. It does discuss WZIAs as being a component in the list of strategies. This presentation recognizes that positive protection is not always available or possible to implement. Since work zones alongside highways are high-risk environments, they suggest WZIAs as being a viable option to reduce the risk of injury.

Valuable points made in the presentation:

Although this study did not go into great detail, it does support the concept that WZIAs help reduce the risk to workers and improve their safety while in the work zone. The study states that temporary work zones are extreme conditions and there is a lack of time to get out of harm's way. It suggests possible application when positive protection is not possible.

To be effective, WZIAs must be audible over ambient traffic (and operating equipment) noise. Devices which give off a large number of false alarms will deteriorate the sense of reliability and reduce credibility with workers.

This presentation indicated that early intrusion alarm systems used pneumatic hoses or infrared beams along the taper zones to trigger a warning. These turned out to be not very reliable and generated a lot of false alarms and are thus considered not commercially viable.

Common standalone systems use hardware mounted on work zone barricades, drums, cones, and delineators. They are triggered when a vehicle collides with them and they reach a critical tilting angle. These devices also suffer from operational limitations such as being too sensitive or having insufficiently loud siren volume.

The presentation did point out that some WZIAs can be manually operated by a designated spotter who sounds the alarm when observing dangerous conditions in or near the work zone.

Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones

Carlson, P., Fontaine, M., & Hawkins, G. (2000). Evaluation of Traffic Control Devices for Rural High-speed Maintenance Work Zones (FHWA/TX-00/1879-1). Austin, Texas: Texas Department of Transportation.

This report documents the first year activities of a two-year project in which various work zone traffic control devices, treatments, and practices were implemented and evaluated. The focus has been on work zones on rural, high-speed routes. Nine work zones have been studied. Many different types of advisory signage and visibility enhancing devices were studied and suggestions were given. With respect to evaluating WZIAs, they provided reasons why they did not consider evaluating this type of hardware in their study.

“Intrusion Alarm - These types of devices are market ready, but have demonstrated some difficulties, due to many different factors that affect their effectiveness. One of the most significant of these factors is the false alarm rate. A Texas Transportation Institute (TTI) study found these alarms require improved technology, increased reliability, and reduced setup effects before widespread implementation.” (Carlson, Fontaine, & Hawkins, 2000)

A noteworthy component of this report, however, is their write-up on what other state DOTs are using with respect to WZIAs. The following is taken directly from their report. Information found in the excerpt are from the authors or:

1. SHRP web site. <http://www.wsdot.wa.gov/fossc/OTA/SHRP/evals/>
2. Trout, N. and G. Ullman. Devices and Technology to Improve Flagger/Worker Safety. Research Report 2963-1F. Texas Transportation Institute, College Station, Texas, 1997
3. Federal Highway Administration web site. <http://ota.fhwa.dot.gov/roadsvr/CS115.htm>

Report discussion on state DOTs’ usage of WZIAs:

WZIAs are devices that sound an alarm when a vehicle enters the work area. Three types of WZIAs are available. Microwave and infrared models are mounted on drums or cones and use microwave signals or beams of infrared light to connect units. When a vehicle crosses into the work zone and interrupts the signal or beams, a high-pitched alarm is sounded near the workers. The pneumatic tube model is placed on the ground, with the tubes being laid perpendicular to traffic. When a vehicle drives into the area and over the tubes, the alarm sounds.

Microwave WZIAs. A typical Microwave WZIA features a transmitter mounted on one drum and a receiver and siren mounted on another drum up to 1,000 ft away.

Strobe lights can also be included in the system to alert workers under noisy conditions. Some units also feature a drone microwave unit that activates radar detectors within 2,300 ft. The drone radar can be used to detect vehicle speeds and activate the siren when a vehicle is found to be traveling over a preset threshold speed. Batteries for the radar intrusion alarms can be recharged using solar cells. The approximate cost of these units is \$4,000.

Other states have had difficulty in using the radar intrusion alarms. Reports have indicated that setup time is lengthy, strobe lights were not bright enough, sirens were not loud enough, and initial alignment of the unit was very difficult. A number of states also noted that false alarms were created by rain, dust, or drum movement.

Iowa tries to minimize the amount of time that crews are exposed to traffic, and the setup of the WZIAs would serve to extend the amount of time that a crew would need to do their job. The Iowa DOT rejected use of radar WZIAs due to their lengthy setup time. The Colorado DOT did not approve the use of the WZIAs because it felt that the sirens were not loud enough, the lights were not bright enough, and alignment of the units was too difficult. Alabama DOT also had difficulty keeping test units aligned. Its test devices then failed mechanically and had to be shipped backed to the manufacturer. Pennsylvania DOT noted that false alarms were so frequent that workers ignored the alarms. Washington DOT could not get its test unit to operate and noted that there was no troubleshooting guide to help workers determine what was malfunctioning.

Infrared WZIA. Infrared WZIAs are mounted on two cones. A transmitter cone is placed on the shoulder at the beginning of the taper, and a receiver/siren cone is placed diagonally at the opposite end of the detection zone. The alarm's 120 dB siren is supposed to provide 4-7 seconds of warning to workers. The infrared WZIAs met NCHRP crash-worthiness standards regarding fragmentation, vehicle damage, and work zone hazards. Strobe lights and solar rechargers are also available. The approximate cost of the Infrared WZIA is \$3,600.

States testing the infrared WZIA experienced a number of problems. Several states indicated that this unit was too sensitive, creating numerous false alarms. Due to the difficulty in aligning the beams, the infrared WZIAs can be used only for stationary operations. Also, it was noted that on hot days traffic cones become more flexible, causing the infrared beam to misalign, thereby triggering false alarms.

The Colorado DOT tested an infrared WZIA but found that the citizen's band (CB) frequency used by the alarm had too much interference, creating many false alarms. New York DOT recommended that the use of the infrared WZIAs be limited to sites where workers do not enter and exit the zone while the alarm is operational in order to reduce the number of false alarms.

Missouri rejected the system because it was too sensitive, and Iowa did not approve it due to alignment problems. Pennsylvania DOT tested the system, but chose not to use it since the agency could not get consistent results from the system. Washington DOT could not align its test units and noted the device did not perform as designed.

The Vermont DOT began testing two models of infrared WZIA shortly after two state highway agency employees were injured by an inattentive driver in a work zone. The first WZIA application was in early 1995 on a survey of a bridge deck. The workers reported that when vehicles tripped the alarm, the siren was more than loud enough to be heard over the noise of the generator and other equipment in the work zone. The WZIA has since been used at nearly a half-dozen work zones. The research team concluded that the alarm might be best-suited for projects that are a day long or shorter. However, even regular users reported having trouble installing it at job sites that lack shoulders wide enough for the placement of the alarm's components.

Pneumatic Tube Alarms. The pneumatic road tube WZIA system involves placing road tubes on the roadway perpendicular to the flow of traffic at the beginning of the work zone. The tubes are connected to a transmitter that activates a siren and a strobe light when vehicle drives over them. They can protect a distance of anywhere from 98 ft to 590 ft. The cost of a pneumatic road tube alarm is between \$880 and \$4,000 depending on the options desired.

States that have tested the pneumatic tube WZIA have encountered problems. Several states reported that the system does not give enough warning time for workers to respond and that the setup time is long. There were also questions about the durability of the system and its dependability. Pneumatic tubes are also easily punctured by heavy equipment and may require boosters after several hundred feet to ensure that air pressure is sufficient to activate a switch.

Safety Vest Incorporating Alarm

Virginia Technological University (2015). Researchers' Prototype Vest Offers a Warning System for Roadside Constriction workers, Rescue Personnel. Retrieved from Virginia Tech Spotlight.

Product being developed by Virginia Tech University

Website: <http://www.vt.edu/spotlight/innovation/2015-08-31-beacon/safetyvests.html>

General description from the National Work Zone Safety Clearinghouse:

“Virginia Tech researchers created ‘InZoneAlert’ vest which combines radio sensors that construction workers can wear on or inside vests with connected vehicle technology that allows cars to ‘talk’ to one another, roadside infrastructure, and personal electronics such as mobile phones. The concept is, if a collision is about to occur between a vehicle and a worker, the vest can warn the worker in a matter of seconds, thus saving a life. Likewise, the motorist will receive a dashboard notification. The instantaneous alert is possible by short-range communication.” The Virginia Tech Transportation Institute will test the vest in real-world demonstrations that involve highway-speed traffic (National Work Zone Safety Information Clearinghouse, 2016). **Publisher:** Original webpage title Researchers' Prototype Vest Offers a Warning System for Roadside Construction Workers, Rescue Personnel (Virginia Technological University, 2015).



Figure 7: Picture of vest equipped with intrusion alarm (Virginia Tech University, 2015)

Wireless Warning Shield

This hardware was described by Ken Kochevar (Kochevar, 2014). When no current information could be found, an email dialogue with Ken indicated that it was most likely the device never was brought to production or is no longer available.

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