Site Proximity Warning Systems

Prepared for

Scottish Road Research Board

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Document History

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This document has been issued and amended as follows:

Version	Date	Description	Created By	Verified by	Approved by
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Acronyms and Abbreviations

CCTV	Closed Circuit Television
CDM	Construction Design and Management Regulations
db	Decibel
GPS	Global Positioning system
HSE	Health and Safety Executive
HTMA	Highway Term Maintenance Association
ISO	International Organization for Standardization
LED	Light Emitting Diode
MEWPs	Mobile Elevated Working Platforms
ODU	Operator Display Unit
PAS	Proximity Alert System
PWS	Proximity Warning Systems
RFID	Radio Frequency Identification Detection
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
VCAS	Vehicle Collision Avoidance System
VMS	Variable Message Sign
WDR	Wide Dynamic Range

SECTION 1

Introduction and Terms of Reference

43 workers were fatally injured in the construction sector in 2015 and 11% of the 66,000 self-reported non-fatal workplace injuries reported under RIDDOR regulations comprised of accidents caused by being struck by an object (HSE, 2016). It is a legal requirement to manage and control health and safety issues on construction sites in so far as reasonably practicable according to the CDM regulations (HSE, 2015). This requirement means that everybody involved in a construction project i.e. clients, designers, contractors and site operatives are all responsible for ensuring the health, safety and welfare of all parties involved in the project.

Scottish Road Research Board (SRRB) commissioned an investigation into how safety on road construction projects can be improved using site proximity warning systems (PWS). These systems use innovative technology to create safe working environments by reducing the risk of accidental collisions between plant/ site vehicles and operatives as well as valuable assets.

This research investigated:

- The prevailing PWS on the market place, citing projects on which they have been used and their benefits to workforce safety and project delivery.
- The cost implications of adapting the different PWS presented in this report.
- The effectiveness (practicalities /limitations and impact) of PWS when applied to highway/ road sites based on feedback provided by product developers/ suppliers and contractors who have used PWS on their sites.
- The implications of making PWS a contractual requirement for all Transport Scotland contracts to ensure safety on construction sites.

SECTION 2

Site Proximity Warning Systems

A PWS is an audible, visual and vibration warning system which uses geofencing technology to create a detection zone around stationary/moving plant or a restricted area. Geofencing involves the use of Radio Frequency Identification Detection (RFID) and/ or Global Positioning System (GPS) technology to create a virtual perimeter/ geographic boundary around plant/ vehicles and assets. They act as invisible barriers that set off alerts and warnings when personnel, members of the public or other plant breach the specified restricted area / danger zone.

In most systems in general all site personnel are issued with RFID tags / personal (individually identifiable) transponders which set off an audible, visible alarm and/ or vibration when the detection zone is breached. This alerts both the site operatives/ personnel and plant operators. As a result, all personnel have sufficient time to react to a near-miss or potentially harmful situation by retreating to a safer location (site operatives) or by stopping a plant manoeuvre/ vehicle movement (plant/vehicle operatives).

Site visitors can also be issued with tags so that their likelihood of being struck by plant/ vehicles on a construction site is reduced. However, trespassers/ non-tag wearers cannot be protected from collisions with plant/ vehicles as the PWS would not be able to identify them when they enter a restricted zone. Unless, the PWS being used by the driver/ plant operative has live video feed covering all blind spots around the plant/ vehicle (displayed in the cab from cameras fitted to the plant/ vehicle), the risk of trespassers/ non-tag wearers being struck by plant/ vehicles remains.

PWS systems also help to improve driver behaviour on project sites due to improved situational awareness.

PWS are safety aids like any other Personal Protective Equipment (PPE), therefore should never be solely relied upon for protecting personnel. Their effectiveness/ operational efficiency depends on whether they are used/ applied correctly. The use of these safety warning systems should never replace normal operational and safety precautions i.e. risk assessments, method statements and safe systems of work adapted for any given project.

2.1 Available Site Safety Warning Systems

A desktop study was carried out to determine the PWS currently available on the marketplace, the different sites where they have been used and the additional benefits they've brought to the project in terms of safety improvement and project delivery.

PWS were developed to enhance workplace safety by preventing injury and loss of life due to plant operations on construction sites and other high-risk operations or environments. These safety systems are aimed at reducing the risk of personnel and plant collisions. Some PWS that have been used on UK project sites are discussed in this section.

2.1.1 SiteZone PWS

SiteZone PWS uses RFID to trigger vibration, audio and visual alerts, when a specified detection zone is breached.

Figure 2-1 shows how the different components of the SiteZone PWS are used to improve workforce safety around plant operations. The SiteZone PWS comprises of personal transponders/ tags, an external alarm, a base station and an Operator Display Unit (ODU). The latter three components of the system are each fitted to every individual vehicle/ plant operating on the site.

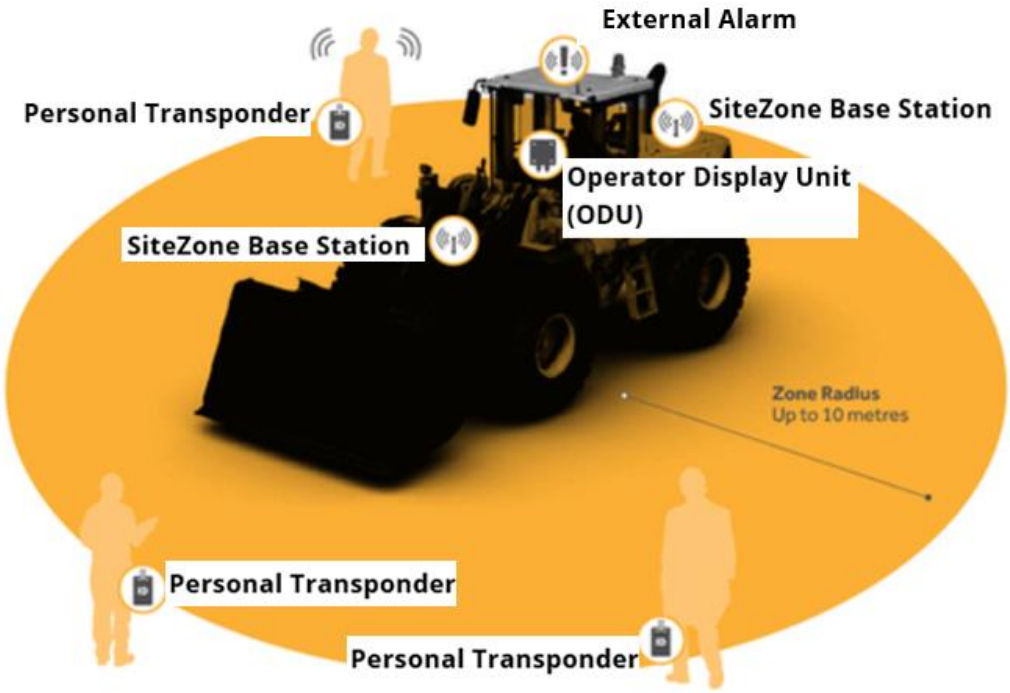

Figure 2-1 Example of how the SiteZone PWS works.

The base station generates a radio frequency field/ bubble/ detection zone around the vehicle. If the bubble is breached by a transponder wearing pedestrian, the SiteZone PWS generates appropriate alarms warning both the vehicle operator and pedestrian. This warning gives time for all parties to take necessary evasive actions. The system recognizes multiple and concurrent breaches and logs all alarm events.

The ODU alerts the machine operator to zone breaches and is used to control authorized approaches into the works area. The external alarm alerts tag wearing personnel that they have breached the safety/ detection zone to allow them to retreat to a safer location.

SiteZone personal tags are designed to be worn as part of PPE; they have their own unique identifiers and therefore, can be traced back to each tag wearer. All tags have a long battery life and are tamperproof, which removes the need for frequent service and repair.

There is no limit to the number of tags that can be applied onsite. SiteZone tags can be adapted to meet different project and site requirements. For example, if there is a requirement for vehicle detection then a tag be fitted to the vehicle(s) to reduce the possibility of vehicle to vehicle collisions i.e. in situations where larger onsite vehicles have limited visibility of smaller onsite vehicles within their proximity.

SiteZone PWS can be customized to meet the requirements of different types of construction and handling plant/ vehicles and operating environments e.g. creation of exclusion zones.

There are a range of additional options, that have been developed by SiteZone, which can be adapted for different projects as summarized in Table 2-1.

Table 2-1 Additional options available from SiteZone PWS.

Option	Benefits	Applicability
SiteZone EasyFit	• Non-invasive installation. • Can be installed in 30-40 minutes.	For mobile / hired plant where quick installations are required.
SiteZone Instant	• Single box proximity warning solution. • Can be instantly fitted thus reducing the downtime. • Create an instant exclusion zone around the blind spots of a vehicle.	Ideal for transient vehicles or those on very short-term hire.
BucketZone	• A separate detection zone is created around the working equipment of the machine.	Useful for excavators and loading shovels.
SiteZone Limiter	• Creates a 'null zone' which hides tag wearers from detection by the SiteZone system.	Has a wide range of applications and uses i.e. sites with space constraints.
Zone Selector	• Two pre-set detection zones can be created on installation via a supervisor switch. • Allows for management of controlled zone selection.	Where different ranges of detection zones are required.

2.1.2 PBE Proximity Alert System (PAS)

This proximity detection and collision avoidance system was developed by PBE Mining Solutions to enhance workplace safety using the latest equipment and technology to implement personnel and vehicle detection.

PBE's Proximity Alert System (PAS) uses geofencing based on a combination of four separate technologies to alert plant operatives/ drivers when they approach predefined physical hazards i.e. dangerous travel ways, dump zones and more.

The four technologies used for asset and personnel detection in this PWS are RFID, GPS, Wi-Fi and near-field electromagnetics. It was developed initially for use in the mining industry where it was recognised that each of the four technologies had limitations in detection in an underground mining environment, but by combining all four a greater level of coverage and detection was available therefore increasing safety for all operatives.

The PAS portfolio consists of 3 products that are used to provide a solution for all types of assets, vehicles and machines. Each of the products uses the same four technologies and provides the same performance parameters and output data. These products were designed to be used on machinery, large and small vehicles such as dumpers, haulers, trucks, cranes, depot machinery, diggers and general works vehicle.

The different versions of PBE's detection and collision avoidance systems are summarized in Table 2-2

Table 2-2 Different versions of the PAS collision avoidance system available

Product	Features	Applicability
PAS-Z	• LED type display. • Simplistic to install & cost effective.	Designed to be used in a cabin environment. For temporary or permanent use.
PAS-ZR	• Ruggedized version of the PAS Z.	For external mounting and protection in harsh environments.
PAS-C	• Offers same technologies and performances as the PAS-Z and PAS-ZR with the additional advantages of: ○ Touch screen radar type display. ○ Optional video cameras.	Various site requirements especially where more extensive local display or video cameras are required.

The main components of the PAS-C system are shown in Figure 2-2. It has four outputs and four inputs allowing optional control and interaction with vehicle and machines. It mainly suits sites where more extensive local display or video cameras are required to enhance work safety by reducing the risk of collisions through improved situational awareness for the driver/ plant operative. With the PAS-C system, the Model PAS -100 Controller screen (Figure 2-2) displays live video feed from the mounted cameras and at the same time also displays other objects detected on the PAS screen. If a person / another vehicle came within the configured 360° zone (geofence) around each vehicle/ plant, the PAS unit will set off an alarm and show the driver the location of the interaction in terms of range and direction of the breach. An external alarm would also be triggered to provide a localized warning to personnel. The tag of the individual/ personnel in breach of the safety zone would alarm with a sounder and vibration.

Figure 2-2 Main components of PBE PAS-C collision avoidance solution.

The three options of PAS are powered via the ignition circuit of the vehicle/ machine or via an auxiliary power source. The system has four user definable ranges (Urgent, Mid, Far and Dropout) and recognizes four user definable groups (personnel, assets, vehicle types, visitors, and obstacles).

Distance to the closest object is displayed and the direction of the object location in relation to the geofence (360º bubble) is displayed on the controller units for the different products (the PAS-ZR is shown in Figure 2-3). All events are logged internally not just events around the vehicle.

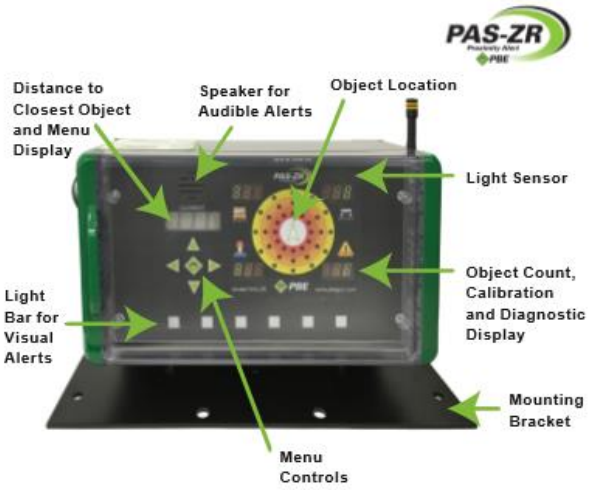

Figure 2-3 PAS-ZR display unit with bi-directional radar used to detect location of objects within the plant/ vehicle's 360º geofence/ bubble.

All PAS products can be installed within 1-2 hours. This includes configuration, commissioning and testing by one technician. Repairs and replacements take less than 5 minutes because the system is Wi-Fi enabled to allow remote monitoring and configuration. This minimizes impact to workforce productivity on site. All the PAS systems have unique characteristics that enhance the plant operator's situational awareness - namely:

- Vehicle to vehicle collision and proximity detection
- Vehicle to personnel collision and proximity detection
- Vehicle to fixed asset/ hazardous area collision and proximity detection
- Personnel detection alert system
- Hazardous area geofencing capability. This can be used to create exclusion zones i.e. areas containing friable asbestos can be defined to prevent personnel from coming into contact with hazardous material
- Audio and visual warnings
- Real-time video surveillance
- Multiple and distinct object recognition
- Combination of multiple technologies for maximum redundancy and safety
- Flexible user interface options
- Detailed customizable reporting capabilities which can be used to manage data. It generates critical reports which can be downloaded via USB port or via Wi-Fi for analysis; daily for review. This is aimed at improving driver behaviour and increase productivity. Safety is improved due to the enabled peer to peer alerting capability
- Start-up system check and built-in system diagnostics to keep the system performing at peak efficiency to ensure each job site is safer and more productive

2.1.3 Safety Shield Systems

Safety Shield systems provide a wide range of technological solutions for object recognition and detection to assist drivers and plant operators in their daily operations. Safety Shields provides various options to suit different project site requirements. Systems from Safety Shield that would suit road/ highway sites were identified as Personnel Safety Shield, Banksman Safety Shield, Traffic Safety Shield and the 360° 3D surround view systems.

The Personnel Safety Shield (Figure 2-4) provides a beacon/ audible warning alarm. The Personnel Safety Shield comprises of antennas, readers, connection box, key switch box & light alarm, flashing beacon, alarm, personnel tag, software and hand-held device for distance adjustments on the reader.

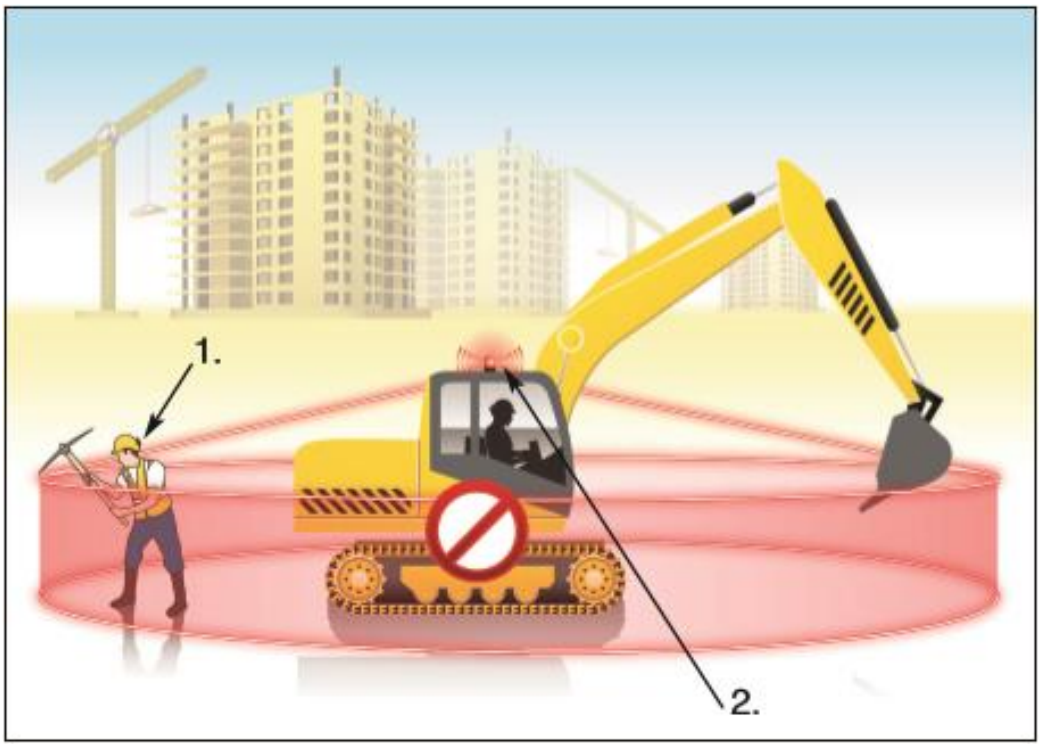

Figure 2-4 Personnel Safety Shield (1. Antenna fitted to the back of the personnel's helmet to pick up signal from the plant's antenna, 2. Antenna fitted to plant to pick up signals from any personnel wearing tag who enters the danger zone).

An additional option, the Banksman Safety Shield, can be used in conjunction with the Personnel Safety Shield system so that a banksman can disable the plant or machinery, turning off its engine, when personnel enter a restricted zone. The banksman can then warn the personnel and the driver of the breach. The benefit of including the banksman option is that a potential dangerous accident in the driver's blind spot can be stopped by the banksman if the zone is breached by a visitor or a member of the public without the Personnel tag. Additionally, if the banksman sees anything problematic like utility systems where the plant machine is working, he can instantly turn off the machine, activate the alarm and warn the driver.

The Traffic Safety Shield system (Figure 2-5) is used to protect personnel working on a highway/ motorway from public traffic using a virtual fence between cones separating the live traffic from the works area. It provides a beacon/ audible warning alarm when vehicles enter the coned area and protects the traffic from the plant slewing in to live carriageways.

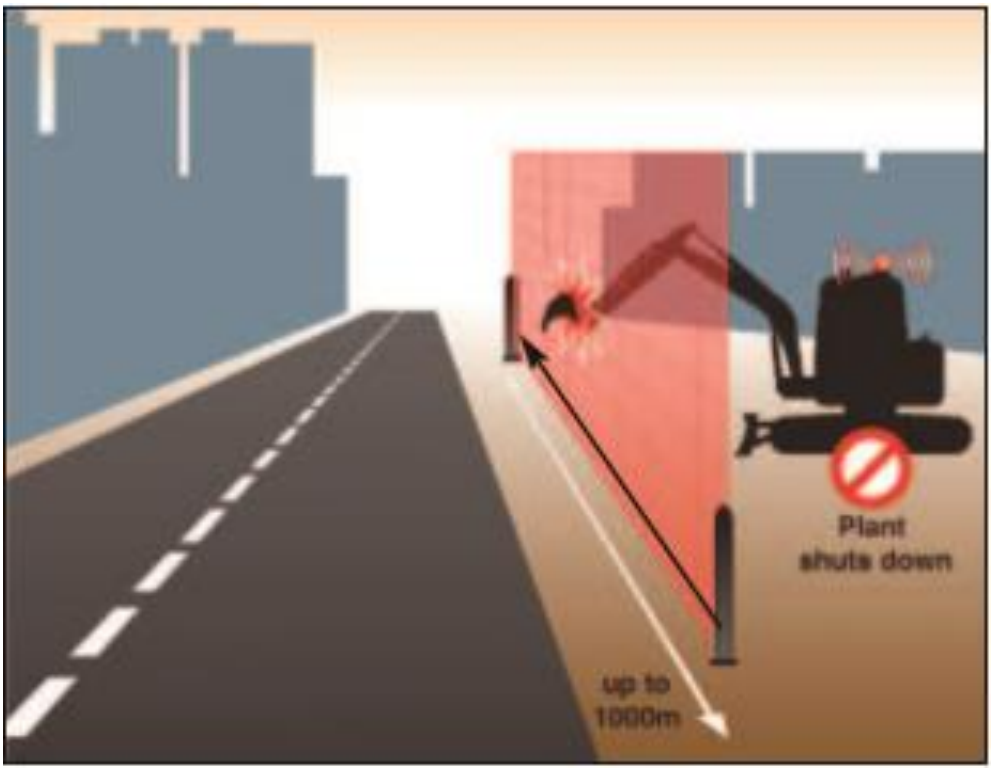

Figure 2-5 Site Safety Shields traffic and plant intrusion detection system (Virtual screen and cone line system).

The traffic safety shield system comprises of a cone line system, a traffic and plant intrusion detection system, an alarm box with on/off switch, a battery, charger, charging plug, beacons and alarm.

Column detection units are placed facing each other at intervals of up to 1000 m forming a virtual screen/ cone line. A plant disable system is installed to each item of plant. When the line between the columns is breached by plant Figure 2-4(Figure 2-5) or a solid object, the alarm box is activated. When the alarm is activated, it disables the plant and sets off an audible and visual alert to warn all personnel present on site. The Traffic Shield system can be used in conjunction with a 360^{o} Camera, Safety Shield Plus Plant and Banksman Safety Shield.

The 360^{o} 3D surround view system can be added to either the Personnel or the Traffic Safety Shield systems. It enables visual monitoring around a vehicle from a dynamically definable perspective or 'free eye point' using ultra 190^{o} fish eye Wide Dynamic Range (WDR) cameras. These cameras display the complete vision of the positioning and moving path of the plant, eliminate blind spots and therefore can be used as a safe driving and operating guide when the view becomes restricted by adjacent vehicles, objects, parking lines etc. Data can be recorded on a USB device or an SD card when the plant ignition is on. It does not record consistently when the ignition is turned off but it recognizes when the plant has been hit, by another machine/ vehicle/ object/ someone trying to break in, through its vibration sensors. Therefore, the system records impact despite the ignition being turned off. All available camera systems can be attached to most plant and all vehicles. No specialist installer is required to set up the system, a manual and in cab display both clearly explain step by step how to calibrate the system.

Installation for Personnel, Banksman and Traffic Safety Shield systems is carried out by trained professionals and can be completed in approximately 10 minutes.

2.1.4 Sylogi Shield

This tag based proximity warning and alert system uses a radio frequency (RFID) proximity detection technology for pedestrian and vehicle detection. It is used to detect people or vehicles in a pre-defined hazard zone, then warns the equipment operator using audible and visual signals in event of a breach of the restricted area. There is an additional option to automatically decrease the speed of plant upon detection of a tag.

The main components of the Sylogi Shield PWS are shown in Figure 2-6. The system comprises of a multiple / rear view closed circuit camera system, an external antenna which picks up signals from individual tags worn by personnel, a sensor which detects the proximity of tags and communicates that to an alarm display which provides visible and audible warning to the plant operator.

A data logger is included within the sensor that digitally records information like hazard detection events, specific equipment, tag identification and date & time of occurrence of tag detection which can be used for analysis later.

The rear-view camera with LED for low light environments enables the operator to view the area around the equipment through an overall viewing angle of 170° through the monitor. The 7" diagonal screen/ monitor enables live feed from up to four colour cameras to be displayed simultaneously.

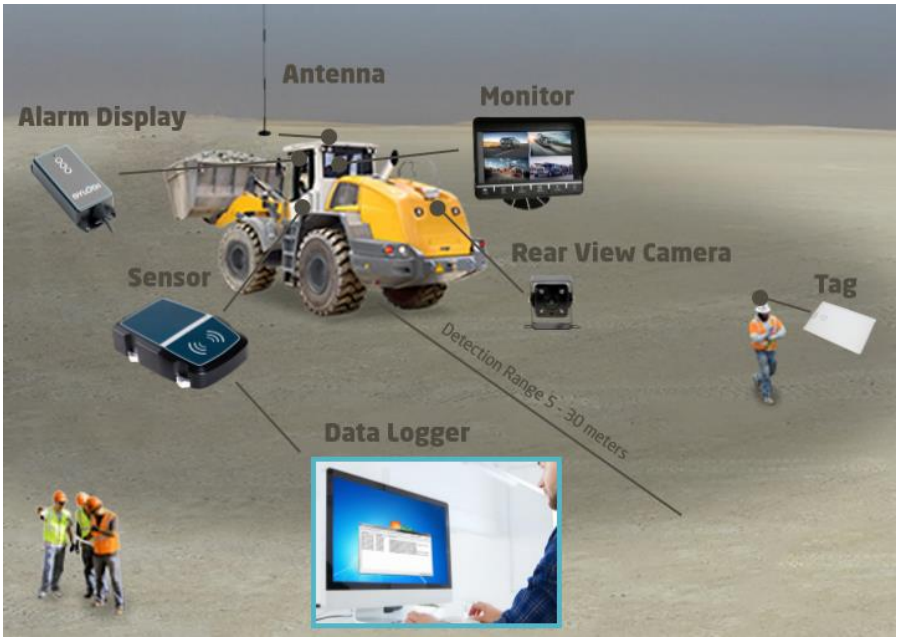

Figure 2-6 Sylogi Shield - Vehicle safety technology main components.

2.1.5 Summary

Table 2-3 summarizes the predominant PWS currently available on the market as described above. These systems use proximity detection technology to enhance the situational awareness for all personnel present on a site and can be used with all types of construction plant, handling vehicles and delivery trucks.

Table 2-3 Summary of Site Proximity Warning Systems reviewed in this research.

System	Features	Benefits	Suppliers	Additional information
SiteZone PWS	RFID technology with detection ranges between 3 to 10 m	Multi-orientation tag detection.	Breezemount ESS safeforce GKD Technik	• Detection zone around vehicle/ plant/ critical asset which is controlled by software can be varied to suit site requirements.
	Personal transponders for individual identification.	Data logging enables use of Individual tags/ transponders to study the behavioural profiles of site workers and can be used in site management.		• Individual tags are tested for integrity prior to daily use.
	Operator Display Unit (ODU) which alerts the operator to zone breaches & used to control authorized approaches.	Access control.		
	External alarm to notify personnel of a safety zone breach.	Proximity warning.		
PBE Proximity Alert System (collision avoidance/ proximity detection system).	Uses four technologies (near field electromagnetics, GPS, Wi-Fi & RFID).	Multiple Detection technologies for redundancy and safety. Wi-Fi enabled to allow remote monitoring & configuration.	PBE Group	• BS EN ISO 9001:2008 Quality Management System. • ANSI/NCSL Z540 -1-1994 Calibration Control system. • Statistical Process Control Program (SPC) • Introductory 24-hr. training program & IPC-A-610 (620) available for commercial contracts.
	Multiple object recognition with real time video surveillance with flexible user interface options, monitoring and reporting systems.	Live video feed from mounted cameras to display objects/ personnel in the plan operator's/ driver's blind spot.		
	Personal detection alert system with audio and visual warnings.	In-built system diagnostics to keep the system performing at peak efficiency to ensure a safer and more productive site.		
	Collision detection for vehicle to vehicle/ personnel/ fixed asset.	Proximity warning and critical asset detection.		
Safety Shield Systems	All systems use RFID technology, transponders and receivers to detect personnel in a pre-set distance of plant and	Different safety shield systems can be used in conjunction to improve overall safety. System sends a text/ voice message to a specified	Safety Shield Systems	• Installation should for the Personnel and Traffic Shield Systems can only be carried out by

System	Features	Benefits	Suppliers	Additional information
	vehicles. Visual and audible warning alarms are triggered when the danger zone is breached to alert work crews.	telephone numbers to notify management, health & safety officers and security when an incident has occurred.		trained professionals. • The unit has a battery life of about 5 days and can be recharged with an adapter (supplied) from a vehicle or 240v socket.
	Personnel Safety Shield Banksman option (if fitted) can enable a banksman to disable plant/ machinery when personnel enter restricted zone.	Transferable (plug and play) system that can be installed and uninstalled within 10 minutes for unsecure sites.		• Tags are designed to become part of PPE and have a battery life of over 1 year and the LED indicator light will flash if the tag needs to be replaced.
	Traffic safety shield system uses motion sensor and alarm units & creates a virtual safety fence (1- 4 m high) around existing traffic management systems.	Can easily integrated into existing traffic management procedures. Protects both road users and the workforce from collision with construction plant working in the coned area.		• Plant is disabled when invisible fence is breached. • Multiple units can be linked together to create the desired distance.
	360^{o} surround view camera eliminates blind spots.	In cab screen display when the plant ignition is on.		• No specialist installation is required, can be attached to any plant using the manual as guidance.
Sylogi Shield	Tag based PWS and alert system with multiple & rear-view closed-circuit camera system for blind spots within the predefined hazard zone. Detection ranges of between 5-30 meters Uses audible & visual signal.	Blind spots within predefined hazard zone captured via cameras & can be viewed on monitor in the cab by the plant operator. Data Loggers used to record hazard detection events for analysis & historical comparison	Groot Jebbink (Netherlands)[a]	• Tags have 2-year life span and are rechargeable. • Saudi Aramco approved
	Optional automatic speed reduction of equipment upon detection of a tag.			
	Optional GPS receiver.			
Table Notes				

System	Features	Benefits	Suppliers	Additional information
Individual tags provided in the different PWS therefore should be worn correctly for effectiveness as is the case for all PPE.				
[a]Developed in Netherlands but available in UK via verified agent.				

2.2 Cost comparison for the available systems

Four companies were contacted to determine the associated costs for hire or purchase of PWS site safety systems. These companies summarized in Table 2-3 have successfully developed and implemented their safety warning systems on various projects in United Kingdom and beyond.

Table 2-4 provides a breakdown of the costs associated with the hire or purchase for the different safety warning systems and their components. The unit costs correspond to price quotations provided in September 2017 and may be subject to change. Equipment unit costs in Table 2-4 exclude Delivery, VAT and installation costs unless otherwise stated. If these systems are required for site operations we recommend that the developers/ suppliers are contacted directly.

Table 2-4 Cost comparison for the available proximity warning systems (Provisional pricing only).

PWS	System components	Unit Costs[b] (Purchase)	Unit Costs[b] (Hire)	Additional costs
SiteZone PWS	Base station, operator display, alarm / beacon combo.	£1350.00	£60 per week for each item	• Installation costs per item £300 to £415 for first machine then £210 to £125 for subsequent machine • Maintenance costs per item for purchases only to be negotiated with the supplier
	Personnel transponders.	£48.00	£1 per week for each transponder	
	Transponder test station).	£595.00	£20 per week for each test station	
	OverSite Telematics.	£475.00	£25 per week for each test station	
PBE Proximity Alert System	Control Unit (PAS-Z).	£2500.00 per item	Depend on the duration of the project and can be negotiated with the supplier (PBE group)	• Not provided, please contact PBE directly.
	Individual tags (PT - tag).	£200.00 per item		
Safety Shield Systems	Personnel safety Shield – 1 sensor unit.	£1220	£14.23 weekly based on minimum rental/ lease term of 2 years	• Please contact the supplier directly to verify additional cost implications associated with each system.
	Personnel Safety Shield – additional sensor / reader unit.	£520		
	Personnel Dumper safety shield – 1 sensor unit.	£1155	£13.48 weekly based on minimum rental term of 2 years	
	Utility Shield - overhead service protection.	£800		
	Banksman Shield.	£500		

PWS	System components	Unit Costs[b] (Purchase)	Unit Costs[b] (Hire)	Additional costs
	360º 3D surround view camera with 1TB hard drive for recording.	£1350	£15.75 weekly based on minimum rental term of 2 years	
	360º 3D surround view camera with 32GB SD card for recording.	£1150	£13.42 weekly based on minimum rental term of 2 years	
	Traffic Safety Shield – workforce alarm unit.	£1375	£16.04 weekly based on minimum rental term of 2 years	
	Traffic Safety Shield – workforce alarm unit.	£2045	£23.86 weekly based on minimum rental term of 2 years	
	Traffic Safety Shield – workforce alarm unit.	£730		
Sylogi Shield[a]	Sensor with data logger.	£1167.89	Depend on the duration of the project and can be negotiated with the developer / supplier (Groot Jebbink).	• Please contact the supplier directly to verify additional cost implications.
	Alarm Display.	£208.95		
	Slave unit (optional).	£351.17		
	Tags (50 pieces).	£33.36		
	7” Quad split screen monitor.	£175.57		
	Colour camera 170º view angle.	£55.31		
	10 m camera cable.	£7.90		
	15 m camera cable.	£10.54		
	20 m camera cable.	£13.17		

Table Notes

All cost estimates for the different PWS were provided by the suppliers/ developer in September 2017 and may be subject to change.

[a]Developed in Netherlands but available in the UK via agent – Price quotation provided by developer in Euros but converted to British pounds based on the exchange rates at the time.

[b] All unit costs provided herein exclude VAT.

2.3 Projects where site PWS have been used

When the product developers and suppliers were approached to provide cost estimates in September 2017, feedback was also requested from each of the PWS suppliers. The aim of this exercise was to establish the benefits and limitations of their systems when used on different projects based on user testimonials. Some of this feedback from projects was used to identify potential mitigation and passed back to the suppliers/ product developers from contractors to ensure continued improvement of the systems used and the overall safety on construction sites.

2.3.1 SiteZone PWS project applications

SiteZone provided feedback on typical sites where their system has been utilised:

- **HE Area depots (Feedback provided by SiteZone)**:

Several regional highways areas in England had concern over the plant personnel interface on their sites. They utilised the SiteZone PWS system to assist safety in these sites.

- **Smart motorway Projects (Feedback provided by SiteZone)**:

SiteZone PWS was used as part of Balfour Beatty's ZoneIn plant training to promote Safe Systems of Work for all personnel (from Balfour Beatty and other principal contractors) working on the strategic roads networks. The system was introduced too late to be incorporated into the site work on the M4-M5 but was featured in the Site Health and Safety training. A video of the training is accessible via: https://www.youtube.com/watch?v=kGoxO7xOOMU

Following the success of the ZoneIn training, the SiteZone PWS was used on several sections of the M3 upgrade project by Balfour Beatty for Highways England (between 2015 and 2017) where hard shoulders were converted into a fourth running lane with a 50-mph speed restriction which created an additional 26.8 miles of new traffic lanes to the M3.

Costain carried out works to upgrade the M1 between junctions 28 to 31 and junctions 32 to 35a by using variable speed limits and converting the hard shoulder into a permanent running lane to relieve congestion on the motorway in January 2017. SiteZone OverSite telematics system, which records live data to cloud storage that is used to analyse causes of collision near misses, was used on different sections of the M1 sites successfully which led to the development of a new variant of the SiteZone PWS aimed at optimizing the performance of forward tipping dumpers.

- **Kennedy St. Student Accommodation - March to May 2016 (Feedback provided by Balfour Beatty).**

Used on a student accommodation construction site, SiteZone PWS was fitted to an 8t excavator and a 6t dumper for a two-week trial. All personnel on site were also issued tags for their helmets. Following on from the trial, the system was fitted onto telehandlers, dumpers, 20t & 30t excavators throughout the duration of the main ground works. The system was only used during the main ground works stage the site logistics and proximity of perimeter fencing, scaffolding etc. would have resulted in too many inaccurate alarms thus reducing the benefit and effectiveness of the system.

The system was overwhelmingly met by approval by site personnel with very few exceptions.

One area of difficulty was found in setting up full boom length exclusion zones for the plant due to the nearness of pedestrian areas to working areas (see Figure 2-7), which resulted in a significant increase in alarms when the plant was operating in areas close to adjacent work zones or designated walkways.

Plant operators were advised not to push the 'authorization' button in situations where alarms had been set off by personnel working in an adjacent fenced off safe zone. Instead operators were requested to make contact with the personnel in the overlap zone then allow the alarm to reset once the overlapped zone was clear. The system would thus still record this as an unauthorized entry.

It became clear that it was important to carefully plan work zones and designated walkways to try and keep them as far apart as possible.

There was an option for no external audible alarm thus utilising the vibration warning only to address nightshift work patterns. The alarm volumes range between 60 -120 db.

The SiteZone system provided an excellent enhancement to people-plant interface management. It was considered an additional tool that can help educate the workforce on exclusion zones as well as giving

plant operatives increased 'visibility' of personnel. The system was used an enhancement to the existing procedures and never considered as a replacement of the site's health and safety requirements.

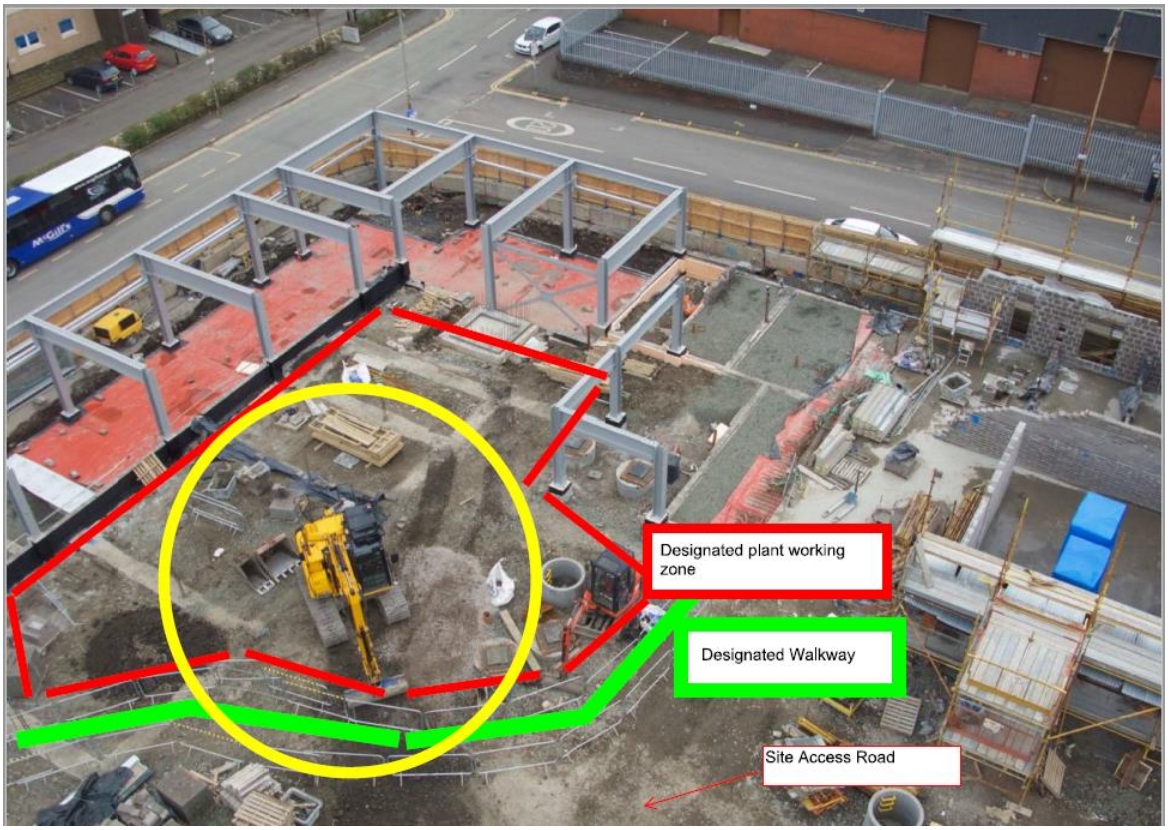

Figure 2-7 Kennedy Street Student Accommodation - SiteZone PWS Trial

Based on the site trial at Kennedy St student accommodation, Balfour Beatty provided feedback on the pros and cons of using SiteZone PWS on a building site as summarized in Table 2-5.

Table 2-5 SiteZone PWS contractor feedback from Balfour Beatty based on site trial for Kennedy St student accommodation.

Pros	Cons
Instant awareness of plant proximity for personnel& visitors fitted with tags helped increased their awareness of proper exclusion zones. This was especially beneficial to personnel working near plant operations e.g. steel fixers during ground beam installation.	Difficult to avoid alarms on restricted sites where exclusion zones are confined by physical restrictions and limited walkway routes are available.
Plant operatives are instantly aware if someone breaches their safe zone.	Tags are required for all present on site including personnel & visitors for the system to work correctly.
In congested areas, alarms notify personnel/ visitors of their proximity to plant e.g. If a designated fenced off footpath is adjacent to a work zone (Figure 2-7) other personnel/ visitors accessing the footpath can set off the alarm to notify the plant operator that people not involved in their operations are nearby.	Mobile plant like dumpers can end up with multiple audible alarm systems (i.e. VCAS badge detection system), which can be confusing to the operator.
If more than tag is within the vicinity of the plant, the system will disable the plant from starting which will make the operator aware that it is not safe to operate.	It takes up to a week to get an ESS Safeforce Engineer to attend site and set up the system. This can be problematic if

	you need to change over plant items at short notice due to breakdowns.
The operator can control the number of personnel working within the vicinity of the machine/plant zone such that any unauthorized persons will trigger the alarm.	Cost benefit analysis should be undertaken for purchase versus hire comparison. The unit costs for hire were £60/ week for each machine and £1/ tag.

The following areas of improvement in implementation were also highlighted by Balfour Beatty:

- The location of designated walkways in relation to work zones needs to be carefully thought through by the site team. This is because mobile plant (i.e. dumpers and telehandlers) are prone to setting off a significant number of alarms when they pass near designated walkways. Balfour Beatty advised that in these situations, the walkway can either be relocated or the danger zone of the plant can be assessed and carefully reduced.
- Some work operations require the number of authorized personnel near the plant to be increased from the maximum of 3 to 6 e.g. during excavations for concreting / deep drainage loads more personnel will be required to work near the plant (i.e. 2 in the trench, 1 banksman, 1 dumper driver, a supervisor and an engineer).

Based on the customer feedback from Balfour Beatty for the site trial at Kennedy St for a student accommodation development, SiteZone improved its system to include:

- Zone Selector – this key operated system allows authorized personnel to change between two pre-set zones. This is particularly useful where restrictions exist between designated safe areas and work zones.
- Hazard Location camera – this additional feature enables the plant operator to view the location of personnel/ visitor in relation to the machine.
- Adjustment of number of authorized personnel permitted to work within the confines of the safe zone, it was set to 3 (as standard) at the time of the trial but can now be adjusted to suit individual site and client requirements.

Balfour Beatty also identified further options (that are available from SiteZone) which would provide improved safety on other sites:

- Crossing Point Alert which warns pedestrians of approaching vehicles.
- SiteZone Remote Display provides wireless display that communicates with the SiteZone instant (battery powered system in single enclosure for instant fit to transient/ hired site vehicles) to warn Mobile elevated working platform (MEWPs) operators in basket.
- Telemetry – all alarm conditions reported to client accessed cloud based server where data can be analysed and reports generated.
- Bucket Zone which allows for independent zone to be set up around an excavator/ loading shovel bucket.
- Banksman alert which has a very high intensity LED display that can be located on any vehicle/ plant to alert the banksman of any zone intrusion. This option is ideal for plant that is banked and where an external alarm is not required.
- Driver ID tag to stop unauthorized use of the PWS – only the driver bearing this tag can use the SiteZone System.

- **A9/ A85 Junction Improvement and Link Road to Bertha Park (Feedback provided by Balfour Beatty)**

SiteZone PWS was used for a trial in February 2017, for Phase 1 of the Perth Transport Futures Project. The system was trialled on 2 excavators and 15 pedestrian operatives; it took about 1 hour to set up on each excavator. Checks were carried out to ensure personnel tags were activated to sound off alarms at maximum reach of bucket. The level of the alarm was set at maximum such that it could be heard by the operator at 12 db but this could be adjusted for each case and location.

Questionnaires were sent out to plant operators, site personnel and other operatives involved who all agreed that it was a good piece of kit which could save lives but its use requires planning as it is not suited to all locations.

The pros and cons of using SiteZone PWS on a highway site based on Balfour Beatty's experience are summarized in Table 2-6.

Table 2-6 SiteZone PWS contractor feedback from Balfour Beatty based on site trial for A9/A85 Junction Improvement and Link Road to Bertha Park.

Pros	Cons
The alarm is very irritating which is encouraging the operatives to stay away from the excavators as much as possible.	The zone of influence has to be adjusted each time the control unit is taken off a piece of plant and fitted onto a different sized plant.
The system is relatively easy to install and can be set up and fully operational within approximately 45 minutes.	The system is not wireless yet although the product representative said this feature is still under development.
Whenever there is someone within the zone of influence, the plant operator is notified as the alarm is set off for every tag wearer. If two tag wearers approach, the machine at the same time, the alarm will sound until both tag wearers leave the zone or the plant operator presses the alarm cancel button twice.	The cost of hiring the PWS could escalate depending on the number of kits and personal tags used over the duration of the contract. For this project, each personnel tag cost £10/ week to hire and the machine units cost £20/ week. There were installation costs of £160.
Once a member of staff is trained up, they can easily fit the system to any item of plant where change overs are required.	There are costs associated with installation & removal of system for every hired plant used.
The audible alarm will alert staff to a tag wearer who has approached a machine/ plant in a restricted area where there is potentially no need for anyone to be i.e. near a loading excavator.	If the plant has no safe access to the roof, an access platform/ fall protection is required to fit the receiver/ beacon / audible alarm.
The tag worn by the operatives are bright orange and if worn on the back of a helmet are highly visible thus if not visible it would be evident that there's a person working around machinery without the appropriate tag on.	During concreting operations, where the operatives are constantly in & out of the zone of influence, it was considered a distraction to plant operatives because they focused more on silencing the alarm rather than focusing on the concreting task.
When used in addition to other PPI systems such as segregation and 2 way radios with vehicle marshals and plant operatives can promote a better safety culture.	There is a risk of complacency whereby the visual and audible alarm system is considered to replace the eyes and ears. The system should not be a replacement for mirrors, cameras and paying attention.
The system can be used on dump trucks too but 2 receiving units are required.	
Tags are sealed and have a long battery life.	
Both the plant operative and the tag wearer are alerted when there is an encroachment into the zone of influence of a machine in operation which gives them sufficient time to react in a safe manner.	

2.3.2 PBE PAS project applications.

2.3.2.1 Thames Tidal Way (Feedback from PBE)

A site trial for the PAS collision avoidance system was conducted over an 8-week period starting 16th September 2017. Fifteen tags were issued to the main personnel and PAS -Z controller units were attached to 5 vehicles/ plant i.e. dumpers, excavators, forklifts etc. Each vehicle had a complete 360° zone configured to 5m. When this zone/ bubble was breached by personnel/ another vehicle, alarms were set off in the vehicle with the PAS controller unit showing the direction of the breach. An external strobe/ siren on the vehicle also alerted personnel. Operatives in breach of the 5 m zone set off alarms with a sounder and vibration from their tags.

All events/ interactions were highlighted on the vantage computer in the control room (in real time), showing the location of the interaction on a map and SMS/ emails notifications were sent off. All tags were monitored once issued to provide a record of onsite personnel. Testing of the tags and PAS-Z units in the vehicles was automatic and provided by installed test stations. Visitors or site workers not related to the plant operations/ activity who were deemed to be at larger risk were trained, informed of the 5 m exclusion zone and issued tags.

The system was able to analyse an incident to the accuracy of within a second, providing the position, range and location of an event. This enabled evaluation over time of whether the individual involved and the driver required further training or local site procedures required amendment. When the vehicle was running, PAS was active and monitoring its usage (reliability and redundancy) in terms of speed, time idle, and time moving.

Additional options that would have provided a complete integrated safety and productivity solution were identified as:

- Integrated tracking using 3G, tags and additional tracking beacons can be operated within tunnel areas and above ground.
- Integrated Entry and Exit system which extends the electronic tag functionality to monitor personnel access to site/ tunnel using biometrics, barrier controls etc. to ensure they are trained and have the necessary licences.
- Geofencing was not used but it comes included in the product but it would have been used to keep vehicles out of danger areas on site.
- Integrated communications/ data infrastructure using vantage software i.e. gas monitoring, emergency evacuation, tunnel telephone, data communication and voice communication including fire brigade channel.

2.3.3 Safety Shield Systems Project Applications

2.3.3.1 A1 Leeming to Barton upgrade (Feedback from Morgan Sindall/ Carillion Joint Venture)

The major upgrade works for this £380 million project on the A1 were carried out between May 2014 and May 2017. The Personnel tag and the traffic (road-column) safety shield systems were used on this project where the original dual carriageway was replaced with a new 3 lane motorway. A new local access road was also provided alongside the new motorway to improve safety for local traffic from surrounding communities. Throughout the duration of the project, no accidents/ incidents were experienced. The contractors found the system quick and easy to install. The detection distances were easily adjustable. All plant operators welcomed and embraced the installation/ use of the system.

The Senior Health and Safety manager from Morgan Sindall who was responsible for plant safety on this project said they would be using Safety Shield systems on future Construction and Highway projects

because they believe that it contributed to the reduction/ elimination of plant personnel interface issues and aided the planning process in identifying high risk areas where people were required to work in close proximity to plant.

2.3.4 Sylogi Shield Project Applications

The following feedback was provided by the product developer (Sylogi Shield) to reflect the typical project applications their PWS has been used on.

2.3.4.1 Waste management sites in Belgium and France

This system is used by waste management companies in Belgium and France for wheel loaders. In Belgium a fatal accident had happened where a pedestrian was knocked down by a wheel loader. After this incident, the wheel loader drivers expressed their concerns about having effective warning systems in place to ensure a safe working environment. With the Sylogi Shield detection system, the wheel loader drivers have additional information about pedestrians in their vicinity, which reassures them. In France, the system has been used on wheel loaders and there hasn't been any accident so far, but they are continuously working very hard to improve the safety in their work environment as PWS is recognised as a means of risk mitigation but doesn't completely remove the risk.

2.3.4.2 Construction of pipelines in Saudi Arabia

Sylogi Shield has been utilised on plant constructing oil pipe lines in Saudi Arabia, with in total more than 600 systems. The projects had hundreds of machines/ equipment and even more pedestrians working together. The companies that executed these projects were obliged by the client to use a detection system on their machines in order to be awarded the contracts.

2.4 Intelligent Safety – Intellicone Systems

Whilst undertaking research of site Proximity Warning Systems another system which aims at making working practices on highways safer came to light. Intellicone is a site safety approach developed for AOne+ with the aim of safeguarding operative safety by alerting them to errant public vehicles from an adjacent live carriageway entering the works area. This system differs from the PWS discussed in this report because it mainly focuses on protecting/warning the workforce from errant public vehicles entering the works area. It does not offer proximity protection/warning around plant within a site.

AOne+ are appointed to operate various managing agent contracts by Highways England (HE) on the English trunk road network. The HE network is a dangerous workplace with errant vehicles/ driver incursions into roadworks are the major cause of workforce injuries (66% of the incidents at AOne+ sites). After an incident on the AOne+ network involving an errant vehicle, the company sought technological solutions to prevent this from occurring in the future. They sought a holistic approach aimed at not only protecting their workforce but also aimed towards constantly striving to improve site safety. Intellicone is now (currently) used on 70% of the HE network and is mandatory in some areas.

Highway Resource Solutions (HRS) have developed the Intellicone system, in conjunction with AOne+, to have the flexibility to operate in differing scenarios. This intelligent safety system generally comprises of static cone lamps (Figure 2-8) which are sat on top of standard road cones and are motion sensitive. A 3-axis gyroscope and accelerometer are used to detect movements of the cone lamp. Upon activation, the cone lamp will automatically transmit a wireless alarm message to a Yellow Portable Site Alarm.

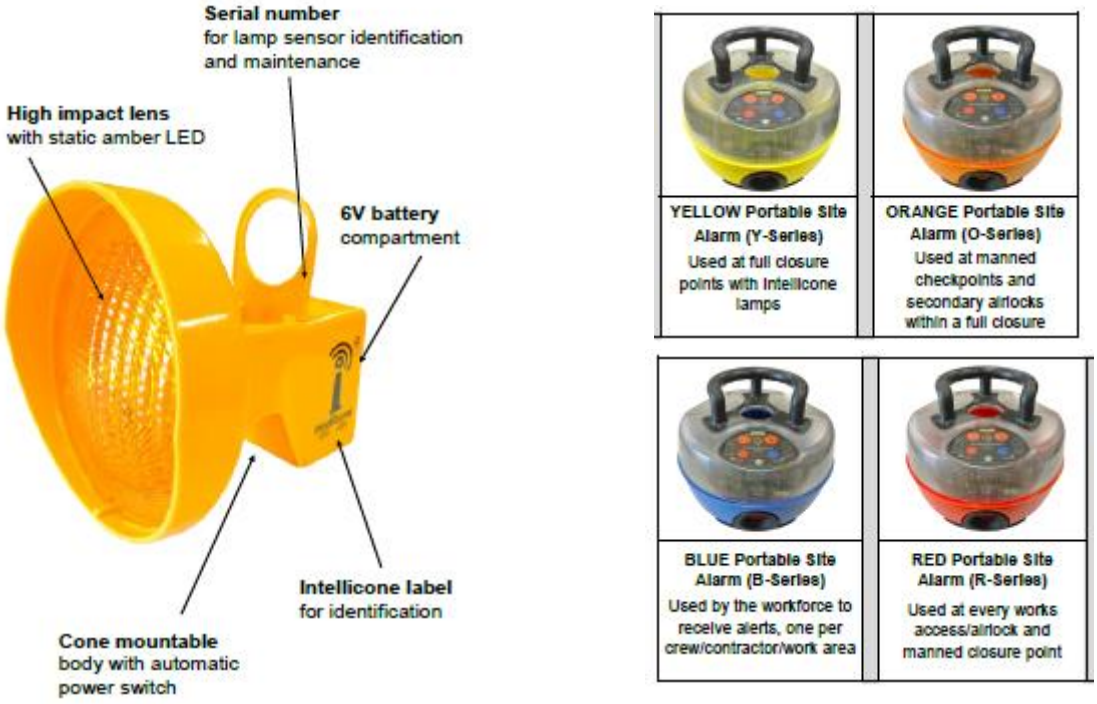

Figure 2-8 Intellicone Static Cone Lamps and various types of portable alarm unit

During development, the Intellicone system was found to be prone to false alarms as if a unit/cone was accidentally knocked over. It automatically triggered an alarm throughout the site which meant operatives had to regularly stop work until the incident was resolved. To counteract this, newer versions of the lamps have been developed with differing sensitivities.

The newer Safelane system can also include a Closed Circuit Television (CCTV) system, individually mounted at strategic locations throughout the site to give a clearer picture when an incident occurs. These can be set to only record when an alarm is triggered and can record number plates including in the hours of darkness. It also provides interconnectivity between individual alarm units to provide an instant alarm to the whole site. Interconnectivity of alarms gives personnel a chance to react before their safety is compromised. The system can be set up to suit individual sites.

Since its development, Intellicone's Safelane technology has been widely used by contractors due to the observable benefits. By combining an intelligent system with physical barriers/cones, additional signage and CCTV, there has been a dramatic fall / decline in the number of errant vehicles that reach a point where the workforce could be put at risk. This system might not be able to stop vehicles from accidently entering the site, but errant vehicles can be contained as quickly as possible to stop incidents from escalating. In 2015, AOne+ recorded zero injuries to operatives due to errant vehicles.

Data gained from the Safelane system when combined with near miss reports from operatives can provide a comprehensive overview of incidents which can be used to identify trends or variations on different sites and geographic areas. This can be key in planning for risk mitigation on future sites in a way that improves the safety of roadworkers and improves efficiency on site. Feedback from site teams stated benefits like enhanced site safety, early warning, communication and confidence when working on road sites at night.

- **A66 Resurfacing using Intellicone Safelane (AOne + Area 14)**

AOne+ Area 14 was contracted to resurface 6 km of the A66 westbound carriageway between Scotch Corner and Hartforth. Site work also included filter drains and junction improvement works started in

July 2015. Intellicone Safelane system was used (in conjunction with Variable Message Signs (VMS) to impose speed limits) to cordon off sections of the works area and to alert staff to any errant public vehicles. The system also enabled businesses accessed through the site to remain open throughout the works whilst safeguarding operative safety. The incursion warning principle that this system is based shown is represented in Figure 2-9.

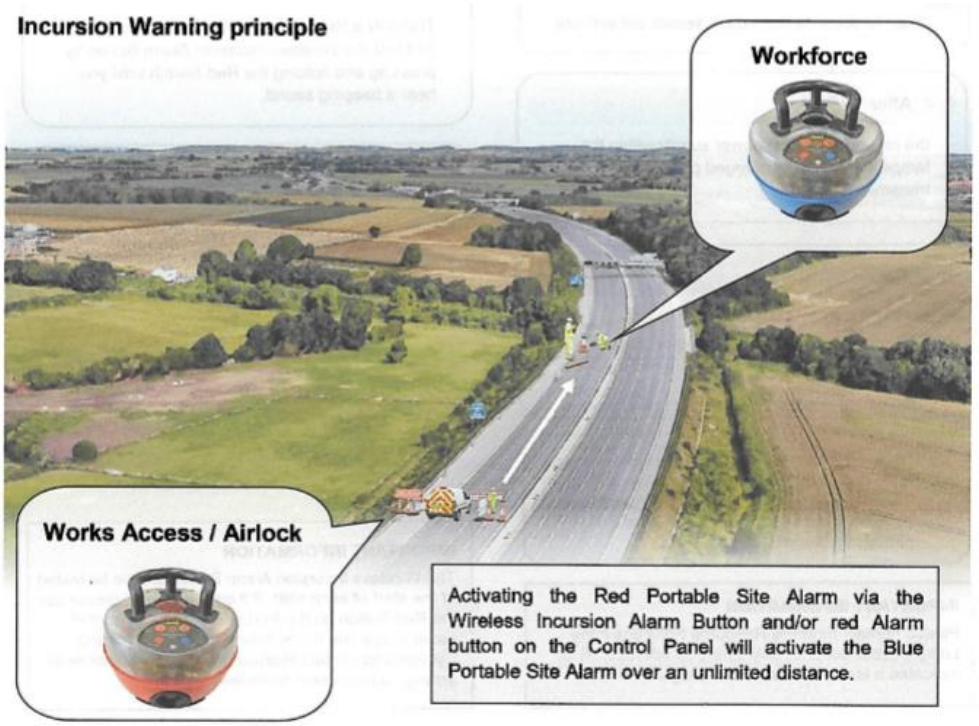

Figure 2-9 Intellicone Safelane incursion warning system.

The Safelane system used different coloured Intellicone base units (green, blue and red – Figure 2-10) to segregate sections of the works area to allow for use of variable speeds whilst providing access gates for workers and businesses affected by the works.

They also have differing colours which illuminate within the unit to highlight differing scenarios. A solid green light is illuminated when all the portable alarm units are linked to the Safelane Incursion Warning System. The blue light warning and single tone sounder indicate a controlled entry i.e. for emergency services, members of the public and other works vehicles. Red flashing lights and a 3-tone siren are activated by the TM crews to warn of a vehicle incursion therefore site operatives are advised to seek a safe place away from the carriageway and await further instructions. Once the errant vehicle is contained, the system is reset by an authorised member of staff i.e. site supervisor/ foreman to display a solid green light. This intelligent system was also reported to improve driver behaviour.

Figure 2-10 Intellicone Safelane alarm units differing illumination and alarms

- **Site trial on M90, A90 and A9 using Intellicone Safelane (BEAR Scotland)**

It should be noted that the site trial carried out on the M90, A90 and A9 for a one month period in 2013 was in the early stages of Intellicone development.

The system provided early warning when public vehicles struck a tape/ entered the traffic management (TM) section in advance of the works. Warning lamps/ proximity sensors were placed strategically from the initial TM cone taper and along the longitudinal length of the TM.

The system was linked to a mobile phone (the duty supervisor's) so dealing with false activations was found to be an onerous task. The lamps were often triggered in error from the buffeting of passing vehicles and were also costly to maintain once they were damaged.

For Type B closures, when the TM was lifted to the side overnight to open the road back up, the signal lamps had to be removed and replaced at the beginning of each shift as they were too costly to leave out as they would be exposed to potential damage or theft. Setting out the TM is also a very manual task, so operatives were concerned about damaging the costly pieces of equipment.

Most of the negative issues like the efficiency of the signal lamps appear to be due to the system being new and in development at the time.

The concept was generally well received but it was considered impractical for use on Scottish trunk roads for standard lane closures and contraflows mainly due to the issues of false alarms being regularly set off, but was found to be more effective for full road closures especially on motorways and high speed dual carriageways, where the system would alert the site team of unauthorised access through the road closure. On unmanned closures, there had been incidents reported on Highway Agency projects where members of the public had deliberately moved cones to access closed roads especially at the top of on-slips. These incidents resulted in close calls. The system also prepared the teams onsite for the possibility of a high-speed vehicle being driven through a closed road.

There was a consensus that in straight forward lane closures, any operatives working within the closure would know straight away if the taper was struck owing to the noise and chaos that would ensue.

When the system was tested against planned activation, where someone had to knock the cones as would be the case in a live event when a vehicle struck the cones, it worked and provided a reasonably good level of audible warning through the motherboard device at the point of work.

At the time of the trial, there weren't as many site closures on the trunk roads in Scotland, most of the work was undertaken under lane closures. This has changed in recent years as road closures are more commonly used but there isn't much data on vehicle incursions.

The HTMA (Highways Term Maintenance Association) Health, Safety and Wellbeing Workgroup have a new sub group being formed, tasked with looking in to vehicle incursions, but hasn't yet developed the data that may be needed to justifiably support a need for this system, other than from a few anecdotal accounts.

SECTION 3

How PWS Should Be Specified in Future Contracts

The overseeing organisation should comply with the prevailing procurement regulations and UK design standards when specifying the use of a PWS in future contracts. Allowances should be made for different types and size of construction site.

Regulation 43 of the Public Contracts (Scotland) Regulations 2015 covers Technical Specifications and it requires that contracting authorities lay down the characteristics required of any works, supply or service. Owing to the size and specialist nature of the market for PWS, the contracting authority should pay special attention to Regulation 43 (11) which states that technical specifications must not, with the effect of favouring or eliminating certain undertakings or certain products, refer to:

- a specific make or source;
- a particular process which characterises the products or services provided by a specific economic operator; or
- trade marks, patents, types, or a specific origin or production

The Regulations further specify that, on an exceptional basis, where it is not possible to comply with the bullet points listed above, the reference must be accompanied by the words “or equivalent”.

The Manual of Contract Documents for Highway Works (Volume 1, Specification for Highway Works - Series 100 – Preliminaries, Clause 124) deals with Health and Safety Restrictions, Precautions and Monitoring. It states that in addition to ‘all other health and safety requirements’ the contractor shall implement the requirements described in contract specific Appendix 1/23. Furthermore, the guidance notes for drafting Appendix 1/23 state that it should be used to describe any specific monitoring requirements that the Overseeing Organisation has.

Therefore, the specification of a PWS should be detailed generally in the main body of the contract requirements, with a cross reference to more specific and detailed requirements contained in Appendix 1/23. When detailing the technical specification for a PWS, the conditions under which the system operates should be specified clearly, unambiguously and nonspecific to a particular type or brand of system.

The specification should be easily understood by the overseeing organisation and potential service providers. Considering the various technical and operational aspects of a PWS, the following text details an approach that might be taken when specifying a PWS in terms of the general and specific requirements.

Warnings Signals

Future contracts should specify a PWS that might include an aural signal and possibly associated vibration that shall persist for as long as the hazard exists and this may be supplemented by suitable lights or ‘blind spot’ cameras. The overseeing organisation may want to specify a recorded human voice giving appropriate advice to operatives. The contract should specify the audio quality (e.g. frequency range) and sound level (e.g. decibel value) of the warnings to ensure rapid perception by operatives. It should also be specified that the aural signals shall not be such as to interrupt vital communication between operatives. It should be specified that the aural warning shall be provided via a loudspeaker on the cabin of moving plant, if appropriate, and, where necessary, through operative’s headwear e.g. hardhat, headphones.

Unwanted and Unnecessary Warnings (abnormal/nuisance warnings)

Future contracts should specify a low probability of a 'abnormal' or 'nuisance' warnings when plant is operating in accordance with permitted limitations and procedures, and the system is operating without failures. There should also be provision for manual controls for deactivating the PWS or modifying its action to prevent an unwanted and unnecessary warning during normal operation. It should be specified that any such warnings should be logged and recorded and raised as a project health and safety risk.

Serviceability

Future contracts should specify a regular testing requirement on the PWS that would enable operatives to determine the reliability of the system before use on site. It should be specified that the results of these tests should be logged and recorded and made available to the contracting authority upon request.

Power supplies

Future contracts should specify that the source(s) of power for the system shall provide the maximum reliability for operation of the system so as not to jeopardise the safety of operatives whom, through regular use, have become reliant to a degree on the PWS.

Environmental conditions

Future contracts should specify that the Equipment comprising the PWS shall be shown to operate satisfactorily in the environmental conditions to which it will be subjected i.e. environmental conditions on a construction site should, at the very least, be written to take account of noise, vibration, cleanliness, heavy moving objects, weather etc. As a result, the contract should specify PWS components with a robust construction and weatherproof capabilities.

Operation Manual/Training

Future contracts should specify that an operations manual is provided that is specific to the operation of the PWS system being used. Operatives should be trained in the operation of the PWS system and a copy of the operation manual should be kept in the cabin of the operating plant where it is safe and practical to do so.

Maintenance Manual

Future contracts should also provide for inclusion of a comprehensive Maintenance Manual for the necessary maintenance of the system.

SECTION 4

Conclusion

Most workforce injuries on highway work sites can be attributed to being struck by site objects/ plant and errant public vehicles. In 2010, a vehicle marshal was tragically killed on a Highways Agency Major Project when he was struck by a reversing dozer.

This research reviewed different types of Proximity Warning Systems (PWS) currently available on the market with the aim of exploring the impact on health, safety and welfare issues on highway work sites when these systems are used in conjunction with other safety measures i.e. risk assessments and method statements.

Suppliers and developers of different site PWS were approached to provide information on the different features of each system, how these various systems work on different sites and the associated costs for hire/ purchase of their products. All PWS systems worked using differing technologies to create geofenced areas which when breached would trigger alarms to alert operatives to potential danger in the zones entered. Differing systems had differing levels of configurability, system features and user information.

Whilst reviewing literature on the different site safety systems that have been used on different project sites to promote workforce safety, another system developed specifically for highways came to light. The Intellicone Safelane system has been commonly used on the HE network, with an earlier development stage version trialled on the M90, A90 and A9 in Scotland. This site safety system was developed for AOne + Integrated Highway Services to protect the workforce from the dangers due to errant public vehicles from adjacent live carriageways entering work sites. Unlike the other PWS discussed in this report, Intellicone does not offer protection at the plant-personnel interface but focuses on improving safety at the personnel-public traffic interface.

Commentary on the benefits and limitations of using the site safety systems reviewed within this report were collated from feedback provided by both the product suppliers/ developers and contractors that have used these different systems on different construction sites i.e. buildings, waste management centres, tunnels and highways. This information was used to gauge the effectiveness of the different PWS used on project sites based mainly on the user/contractor's feedback in relation to the practicalities and lessons learnt when the different systems were applied to different (types of) sites.

4.1 Benefits of using PWS

All PWS reviewed herein include audible alarms which were reported to be very irritating and thus effective in alerting operatives when they stray into plant/ danger zones as they are instantly aware of a zone intrusion. Where these systems have been used on projects, site personnel reported that their awareness of exclusion/ danger zones (i.e. around plant) increased.

The four PWS reviewed are well developed, come with a long battery life, can be installed easily and quickly. For some systems, members of staff can be trained to fit the system to any item of plant when change-overs are required meaning less disruption to site activity/ operations.

Some systems include an option for the triggered alarms to cause plant to shut down, either automatically or, on one system, manually by a banksman. This instantly removes the danger of plant collision allowing the driver and site operatives time to react to an incident especially at noisy sites. This option can potentially prevent fatalities from occurring.

The more advanced PWS options come with data reporting tools which can be used to detail the events of incidents that may have occurred. Different analyses can be carried out (i.e. incidents per shift, danger zone analysis, vehicle monitoring and individual reporting) to identify where training is required.

Some PWS include sensory detectors and 360^0 cameras ensured that blind spots around plant are eliminated, significantly reducing the likelihood of a risk occurring.

4.2 Limitations of PWS

Sites with space limitations may mean many alarms being set off when vehicles/plant are working adjacent to designated walkways or overlapping zones. This can be disruptive to operatives and operations which might lead to decreased efficiency on site as there will be more focus on silencing the alarms rather than getting on with the job at hand. As a minimum, the restricted areas must be physically segregated with barriers to prevent unauthorized persons from accessing the danger zone.

Complacency might arise when workforce become so reliant on the visual and audible alarm systems that they forget to follow conventional safety procedures i.e. eye contact, communication, paying attention and using mirrors.

All visitors to site must be tagged for the systems aimed at people-plant interface management to work effectively.

4.3 Further Considerations

PWS when used correctly can be used to mitigate risks of being struck by plant / traffic at different construction sites. However, the correct system should be selected to suit different project sites.

PWS should not be used as substitute for following safe work practices, thus project specific risk assessments, risk registers and method statements should be developed for each site and strictly adhered to. All operatives should be reminded that they are responsible for their health and safety and that of others present on site as per CDM Regulations 2015.

All site operatives and visitors should be provided the necessary induction and training before they access project sites, unnecessary loitering on the site especially around site operations should be avoided. Extra measures should be taken to keep trespassers/ members of the public out of the works by effectively securing off the works area and providing adequate security measures i.e. CCTV and/ guards.

A cost benefit analysis is required on a project to project basis to determine the most effective PWS solution for each project site. The project complexity and duration would also dictate whether either purchase or hire options would be most cost effective for each site.

SECTION 5

Recommendation

There are a range of PWS on the current market. These products are still evolving as suppliers/ developers continually improve their different systems to suit different environments, site constraints and projects based on user demand and feedback.

PWS are not commonplace on most UK construction sites but, where these systems have been used, they have been reported to improve workforce safety.

Based on user testimonials, PWS have been found effective in reducing incidents due to collisions between plant/ vehicles and operatives on different construction sites. However, it is important to choose the correct system for each site.

Site operatives find them helpful to use. This confidence in PWS has a knock-on effect on the productivity on project sites.

Specification of PWS within Scottish trunk road construction contracts is feasible. In order to include specification of a PWS as contractual obligation, Transport Scotland must comply with the prevailing procurement legislation and design standards.

PWS would help improve workforce safety on construction sites in Scotland and drive improvement in product development of PWS through user feedback.