WORKtoZERO
an nsc program

Proximity Sensors: Avoiding Equipment Strikes at the Worksite

National Safety Council

Executive Summary

The danger of moving equipment and vehicles is an ever-present threat among most industries where powered industrial trucks or moving machinery are commonplace. In 2016, 93 struck–by-object fatalities and 72 caught in-between/against fatalities occurred in construction (BLS, 2017). Some industries experience equipment and vehicle strikes at a higher frequency than others. For example, the U.S. manufacturing industry constitutes 8.3% of the workforce, but experiences a higher percentage of workplace injuries (12.6%) and workplace fatalities (7.3%) (BLS, 2016).

In 2020, the Work to Zero initiative released its first white paper detailing the top 18 hazardous workplace situations related to serious injuries and fatalities. Struck-by and caught-between injuries are two of OSHA's "Fatal Four" leading causes of workplace fatalities. The Work to Zero initiative looks towards leveraging technology to eliminate workplace fatalities. This report looks at utilizing proximity sensors to avoid equipment and vehicle strikes at the worksite.

Sensors for proximity monitoring are devices that detect objects nearby, or within a set radius, without physical contact up to a nominal range or sensor vicinity. When an object – either person or equipment – enters into the determined range of the sensor, the associated method of detection will record the activity and send data back to the sensor, warning devices or platforms. Common technologies used for vehicle proximity sensing include infrared, radio frequencies, Bluetooth and specialized lasers.

Proximity sensors for equipment monitoring have seen growing use in machine-heavy industries like manufacturing, mining and logistics. Successful implementation of proximity sensors has been shown to effectively protect vehicles and equipment operators from accidental strikes on stationary equipment and reduce the incidence of vehicle-on-vehicle accidents. While benefits point towards the value of proximity sensors for vehicle and pedestrian monitoring, companies should consider the potential technological barriers each technology presents.

Introduction and Background

Work to Zero

Despite concerted efforts to reduce serious injuries and fatalities (SIF), workplace fatalities have not seen a drastic reduction in the U.S. Between 1992 and 2017, the OSHA (Occupational Safety and Health Administration) recordable injury rate dropped from 8.9 injuries per 100 workers to 2.8 injuries per 100 workers, a 67% decrease (National Safety Council, 2018). In the same time span, the workplace fatality rate (preventable fatalities) only dropped 26%, with 4,414 preventable workplace fatalities in 2017 (Bureau of Labor Statistics, 2018). Additionally, 5,250 total fatal work injuries were recorded in the U.S. in 2018, a 2% increase from the 5,147 in 2017, according to the U.S. Bureau of Labor Statistics. Between 2017 and 2018, the fatal work injury rate remained unchanged at 3.5 per 100,000 full-time equivalent workers. The expansive efforts by companies to reduce workplace injuries do not seem to translate into impactful reductions in workplace fatalities.

Recognizing this trend, the National Safety Council (NSC) kicked off its Work to Zero initiative in 2019 – supported by a grant from the McElhattan Foundation – to focus on combatting the lagging decline in workplace fatalities and serious injury events. The end goal of Work to Zero is to eliminate workplace fatalities through the use of technology. Using decades of insight and data, and leveraging the expertise of NSC members and networks, Work to Zero will identify promising technology innovations geared toward eliminating workplace fatalities within our lifetime.

Digital Technology as an Approach to Reducing Workplace SIF Events

In 2020, the Work to Zero initiative released its first white paper detailing the top 18 hazardous workplace situations (e.g. work at height, machinery operation, confined space entry) and associated situational risks (e.g. falls, struck-by, hazardous gas exposure). The report further identified the systemic contributing factors (e.g lack of training, fatigue, work design) that can exacerbate risk within these hazardous situations. Next, NSC worked with Verdantix researchers to identify over 100 relevant EHS technologies that could help mitigate both situational and systemic risks. These risks were also mapped in ways that surveyed EHS professionals perceived to be most effective.

The initial Work to Zero report identified several key technologies that garnered the most interest and value among the surveyed professionals. In addition, safety leaders within the Campbell Institute at NSC have demonstrated interest in assessing and evaluating certain technologies – such as virtual reality, wearables, sensors and unmanned aerial vehicles (drones). This report is one in a series of reports taking a more focused look at specific hazardous risks and an associated promising technology.

Specifically, this report will look at the use of proximity sensor technology for avoiding equipment strikes at the workplace. It will cover the various use cases associated with proximity sensors for equipment strikes at work. Additionally, it will explore the identified and proposed benefits of this technology, as well as the limitations and risks associated with adoption. Finally, this report will shine some light into the vendor landscape associated with proximity sensors for reducing vehicle and equipment strikes at the worksite. As such, this report will not cover proximity sensors for machine operations, emergency cut-offs or non-vehicle specific use cases.

The Danger of Equipment Strikes at Work

The danger of moving equipment and vehicles is an ever-present threat among most industries where powered industrial trucks or moving machinery are commonplace. Struck-by and caught-between injuries are two of OSHA's "Fatal Four" leading causes of workplace fatalities. In 2016, 93 struck-by-object fatalities and 72 caught in-between/against fatalities occurred in construction (BLS, 2017). According to NIOSH, these can occur for several reasons, including (NIOSH, 2014):

- Operators not being able to see in a blind spot
- Pedestrians not hearing alarms for moving vehicles due to workplace or malfunction
- Spotters not seeing a moving truck or vehicle behind them
- Operators assuming the area is safe and clear

Some industries experience equipment and vehicle strikes at a higher frequency than others. The U.S. manufacturing industry constitutes 8.3% of the workforce, but experiences a higher percentage of workplace injuries (12.6%) and workplace fatalities (7.3%) (BLS, 2016). NIOSH estimates at least 100 manufacturing employees are fatally injured annually in forklift struck-by incidents (NIOSH, 2001). It is also estimated that 35,000 employees are seriously injured each year after being struck by forklifts in manufacturing facilities (Marsh & Fosbroke, 2015).

With vehicle and equipment strikes at the worksite such a prevalent risk in multiple industries, many companies have begun to implement procedures, policies and training to protect workers. Limiting worker movement, physical barriers for impacts, comprehensive training and visual aids serve as interventions towards reducing worker strike incidents. Proximity sensors for equipment strikes at work can act as a tool to enhance any worker protection initiatives.

Research Approach

The methodology of this paper consists of two actions:

1) Identification of case studies, clinical trials and use cases for proximity sensors

2) Development of a market landscape shortlist of relevant vendors associated with this technology

Data for this paper came from literature reviews of several academic and industrial journals related to this technology. Additionally, Verdantix researchers used case studies and interview data from previously published reports and interviews (Verdantix, 2020). The vendor shortlist was compiled through a search of Verdantix market databases and external research. Vendors were selected based on the size and maturity of the firm, relevance to risk areas, demonstrable use cases and applicability to the U.S. market. For the purpose of this paper, we look at proximity sensors specifically for monitoring and protecting workers from equipment and vehicle strikes at the worksite.

Introduction to Sensors for Proximity Monitoring

Sensors for proximity monitoring are devices that detect objects nearby, or within a set radius, without physical contact up to a nominal range or sensor vicinity. When an object – either person or equipment – enters into the determined range of the sensor, the associated method of detection will record the activity and send data back to the sensor, warning devices or platforms. Sensors typically have a high rate of response, allowing for quick corrective actions.

Types of Sensors for Proximity Monitoring

Proximity sensor technology for monitoring vehicle and equipment strikes comes in several different forms and methods of detection. A common technology used for proximity monitoring is using radio frequency fields. With radio frequency (RF) technology, a radio transmitter sends out a signal to a determined distance, which can then alert workers when a receiver encounters this transmission. Commonly, radio-frequency identification (RFID) tags are used for automatic identification and data capture. Vendor SiteZone Safety uses this technology to create an RF field around a piece of equipment, and wearable personal responder tags alert workers when they enter within this field. Once a worker enters the field, lights and alerts can be triggered that fit the environment and information is sent to a telematics platform.

Bluetooth technology, a wireless technology standard applicable to the use of ultra-high frequency radio waves, has gained traction in proximity monitoring over the past decade. There is a focus on developing proximity warning systems using Bluetooth low energy (BLE), which allows for lower energy consumption and packet size, allowing for faster transmission of data. BLE wire connections have become popular in consumer electronics, such as mobile phones, and are gaining training traction in industrial use cases. Bluetooth proximity monitoring solutions typically rely on beacon technology attached to equipment and are worn or carried by workers to act as the receiver of Bluetooth wireless communication. Additionally, certain mobile phones have the potential to be used in some cases as a receiver instead of a separate device.

Similarly, infrared (IR) proximity sensors emit a beam of infrared light to detect distance and position. Infrared proximity sensors consist of an IR LED that emits, and a light detector for detection of reflection. Some benefits of using IR proximity sensors is data security through line of sight communication and consistent detection functionality. One downside of this technology is that IR is affected by environmental conditions and unable to pass through solid objects like doors or walls. Several other technologies are in development or used in niche instances. For example, LiDar, short for Light Detection and Ranging, is a higher-end sensing technology that provides high max detection range with fast update rates, but may be too costly for the average consumer.

Proximity Monitoring Sensors Use Cases

Highly hazardous work environments with low visibility can benefit greatly from adopting and utilizing proximity sensors for monitoring and protecting workers. For example, mining and extraction companies face the constant threat of equipment strikes in low-visibility and confined tunnels. Of 562 severe incidents identified by the U.S. Department of Labor, Mine Safety and Health Administration between 2000–2007, machine-related incidents accounted for 41% of all severe incidents during this period (Ruff, Coleman and Martini, 2011).

Warehousing and logistic companies can benefit greatly from implementing proximity monitoring sensors to prevent powered industrial vehicle strikes in typically high-traffic and cluttered environments. According to BLS, from 2011 to 2017, 614 workers lost their lives in forklift-related incidents and more than 7,000 nonfatal injuries with days away from work occurred every year (BLS, 2017). Proximity warning sensors can protect warehouse workers from vehicle dangers in racking aisles and blind spots.

Similarly, proximity monitoring sensors can support EHS professionals who routinely work with heavy machinery, like in the construction industry. In 2009, the U.S. construction industry experienced 151 fatalities resulting from workers colliding with objects and equipment. These fatalities accounted for approximately 18% of the total construction fatalities and 3% of the total workplace fatalities experienced that year (Marks, E., Teizer, J., 2012).

Proximity sensing technology offers another use case called geofencing. Geofencing involves using Bluetooth or other beacon technology to create a virtual barrier around an identified geographic area. This allows companies to label specific areas of a worksite to alert workers or vehicles entering into the “fenced” area. This barrier can typically be controlled and managed via associated tracking software that provides a detailed view of the company’s worksite. In practice, high-hazard areas, or areas of high traffic, can be labeled and workers or machinery entering the area can receive a message to a personal device alerting them to be extra cautious and aware of their surroundings. Similarly, workers in a designated area can be alerted when a vehicle or piece of equipment enters into their work area to maintain enhanced alertness.

Vendor Landscape

Proximity sensors for equipment and operational use cases have existed for decades. The emergence of proximity sensors specifically focused on vehicle and equipment interactions with pedestrians has happened within the last 10 years. Historically, proximity sensors for vehicle strikes were closely tied with vehicle telematics and the use of RF and infrared laser technology. Recent years have seen the growing availability of Bluetooth-enabled proximity sensors used by both pedestrians and equipment. Overall, this market is relatively new, resulting in very few large-scale technology producers of proximity sensors for vehicle strikes but many smaller scale or niche vendors on the market.

Vendor	Employees
Caterpillar	49,304
ESS Safeforce	188
Strata Worldwide	111
Elokon	66
Guardhat	37
Triax Technologies	37
SIS Safety Systems	26
RealTrac Technology	25
ZoneSafe	23
Hit-Not	13
Logical Safety	7
Corvex Connected Worker	6
Shockwatch	5
Proxitron	3

Benefits for Leveraging Sensors for Proximity Monitoring

Successful implementation of proximity sensors for vehicle strikes can provide a variety of benefits centered around:

- **Protecting pedestrians from vehicle and equipment strikes**
- **Protecting vehicles and equipment operators from accidental strikes on stationary equipment**
- **Reducing the incidence of vehicle-on-vehicle accidents**
- **Limiting worker accessibility for identified high-hazard areas**

Using sensors for proximity monitoring can protect workers and operators from equipment strikes. A paper evaluating the effectiveness of radio frequency remote sensing technology in construction shows it can promote safety by providing real-time alerts for workers-on-foot and equipment operators when potentially hazardous proximity situations exist (Marks, E., Teizer, J., 2012). Additionally, the temporary nature of construction sites typically makes implementing technology that requires stationary or extensive infrastructure nearly impossible. Fortunately, proximity sensing technologies for preventing vehicle strikes are usually deployed onto equipment and vehicles with simple sensing technology hardware and associated tags or devices worn by workers. This ability allows the technology to fit into existing worksite layouts, reducing operational downtime to a minimum. This creates a reliable, robust and easily implemented mobile safety solution.

Proximity sensors benefit companies who operate in low-visibility conditions where the risks of collisions of equipment and vehicles is increased. A study into using Bluetooth beacon-based proximity systems in mining in underground tunnels found that, through 50 experiment repetitions, accuracy for warning zone alerts was 95%, demonstrating a reliable tool for protecting workers. The Bluetooth beacon system was demonstrated to be effective in preventing collisions, inexpensive compared to optional methods and its functionality could be expanded through the use of a smartphone application (Baek, J., Choi, Y., 2018)

Additionally, proximity warning sensors can protect warehouse workers from vehicle dangers in racking aisles and blind spots. Recognizing these potential benefits, six Amazon warehouses in Bavaria, Germany deployed ELOKON's ELOprotect vehicle pedestrian safety system on 50 Crown high-level order pickers. The ELOprotect system uses laser-based technology to project a field in front of and behind a forklift in warehouse racking aisles. If an intrusion is detected, the ELOprotect system can bring the forklift to a standstill and emit a warning alarm. Amazon was able to implement the project within six months and saw marked reductions in worker and vehicle strike incidents.

Risk and Considerations in Using Sensors for Proximity Monitoring

Barriers to Adoption

Many proximity sensing solutions require workers to adorn a wearable receiver for better accuracy and tracking of location and proximity. But wearable technology can face barriers in worker uptake due to privacy concerns on the personal data being collected. In a survey of 102 EHS decision-makers, 65% of respondents said data privacy concerns were a significant barrier to their adoption of industrial wearable technology (Verdantix, 2019). Additionally, workers may push back on having to use another piece of equipment, particularly if it interferes with their job activities. To alleviate worker concerns, many vendors have worked to develop minimally-intrusive wearables that can be integrated easily into workers' existing personal protective equipment. For example, Triax Technologies Spot-r tag is just two ounces and can be easily clipped to a worker's belt.

Proximity sensing technology implementation time can be quick, due to smaller footprints and fewer upfront infrastructure demands. However, the total cost of ownership can be a barrier for adoption for some companies, as some proximity-sensing devices require each user to have individual hardware and associated software.

Limitations of the Technology

Depending on the technology being used for proximity sensing, there can be technological limitations that effect overall functionality. Bluetooth technology and other radio frequency technologies have a specific range of functionality. Depending on the class of the Bluetooth receiver, this range can vary from 30 feet (class 3) to 300 feet (class 1). Another disadvantage of Bluetooth is its slower data transmission rate when compared to other hardware interfacing technologies. To be more specific, Bluetooth 3.0 and Bluetooth 4.0 have a theoretical transmission rate of 24Mbps while Wi-Fi Direct has a transfer speed of up to 250Mbps. Wired hardware interfaces such as USB 3.0 have a transmission speed of up to 5Gbps while Thunderbolt 3 supports a transfer speed of up to 40Gbps.

Similarly, laser-based sensing technology faces technological limitations regarding range and line of sight. Laser sensors work best in short to mid-range applications and thus degrade in reliability as distance increases. Also, laser-based sensors will be impeded by physical barriers, such as walls or other equipment. This means that a laser-based sensor in one area of a worksite would not be able to recognize and alert a worker who may be behind a blind corner or wall. Infrared laser proximity sensors can also face communication degradation due to environmental conditions, so very dusty operations or outdoor operations can suffer reliability issues.

Conclusion and Future Direction

The goal of the Work to Zero initiative at NSC is to eliminate workplace fatalities through the use of technology. Initial research for Work to Zero undertaken by NSC shed light on the situational and systemic risks that play pivotal factors in workplace SIF events. Using expert interviews NSC identified promising technologies to combat these high-risk activities. Of these technologies, proximity sensors for reducing vehicle strikes were of interest among survey respondents and NSC members.

Equipment strikes at work are a major risk across a variety of industries. Struck-by and caught-between injuries are two of OSHA's "Fatal Four" leading causes of workplace fatalities. In 2016, 93 struck-by-object fatalities and 72 caught in-between/against fatalities occurred in construction (BLS, 2017). Low visibility, operator error and lack of training can all play a role as risk factors in equipment and pedestrian strikes.

Proximity sensors can play a pivotal role in reducing workplace incidents involving strikes of vehicles and equipment on worksites. A strong safety program is built around proper training, engineering of worksites and adapting policies to lay a foundation for protecting workers from equipment strikes on site. But new EHS technologies, such as proximity sensors, offer a complementary tool that can enhance any safety initiative.

Interest in proximity sensors for equipment and pedestrian safety has been growing despite facing adoption barriers due to data privacy regulations and technological limitations. In a Verdantix survey of 102 EHS professionals, 48% of respondents said they would like to use wearables for proximity monitoring. While interest continues to grow, the current market for proximity sensors for equipment strikes is still young, with a range of smaller start-ups, or niche vendors, and few large-scale enterprise technology solution providers. As new wireless technology enters the market and component costs are driven down, an increasing supply of proximity sensing solutions will be available to protect workers and operators at the worksite.

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