Safer Workplaces Through Presence Detection

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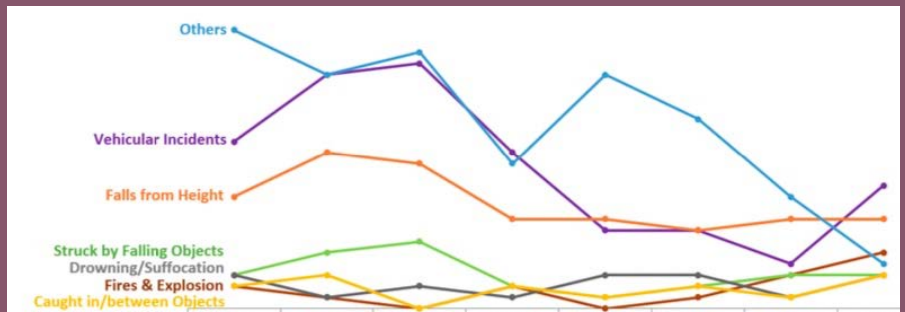


	2014	2015	2016	2017	2018	2019	2020	2021
Vehicular Incidents[12]	15	21	22	14	7	7	4	11
Falls from Height	10	14	13	8	8	7	8	8
Fires and Explosion	2	1	0	2	0	1	3	5
Struck by Falling Objects	3	5	6	2	1	2	3	3
Drowning/Suffocation	3	1	2	1	3	3	1	3
Caught In/between Objects	2	3	0	2	1	2	1	3
Others[13]	25	21	23	13	21	17	10	4

Figure 1: Number of workplace fatal injuries by cause of injury, 2014-2021
Source: WSH National Statistics Report 2021

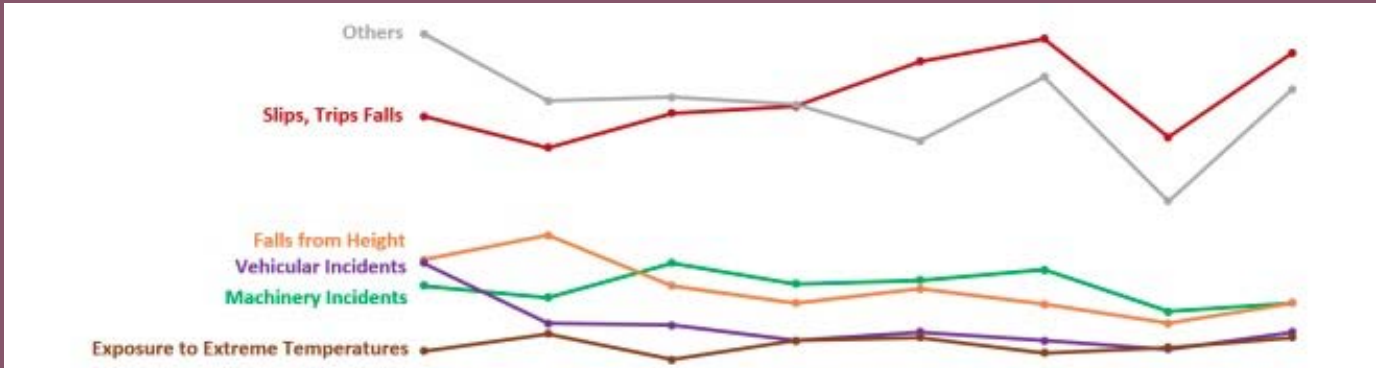
The use of machines (including vehicles) is commonplace in many industry sectors as their use enables companies to become more productive with the ability to do more or better, faster and with reduced manpower.

Increasingly, robots are also being deployed particularly in manufacturing, logistics and construction. Examples include conventional industrial robots, collaborative robots and autonomous mobile robots.

The introduction of machines, robots and/or vehicles, however, undoubtedly present new workplace safety and health (WSH) risks that must be managed in order to prevent accidents.

According to the WSH National Statistics Report 2021, vehicular incidents are a key cause of workplace fatalities from 2014 to 2021. See Figure 1:

Machinery and vehicular incidents also jointly accounted for approximately 20% (on average) of all workplace major injuries from 2014 to 2021. See Figure 2:



	2014	2015	2016	2017	2018	2019	2020	2021
Slips, Trips & Falls	171	153	173	177	203	216	159	208
Machinery Incidents	73	66	86	74	76	82	58	63
Falls from Height	88	102	73	63	71	62	51	63
Vehicular Incidents	86	51	50	41	46	41	36	46
Exposure to Extreme Temperatures	35	45	30	41	43	34	37	43
Others	219	180	182	178	157	194	122	187

Figure 2: Number of workplace major injuries by cause of injury, 2014-2021
Source: WSH National Statistics Report 2021

Machinery Incidents include Struck by Moving Objects, Caught In-Between Objects and Cut/Stabbed by Objects where the agent is an industrial machine, industrial hand tool or other machines and tools. Vehicular Incidents include Struck by Moving Objects and Caught In-Between Objects where the agent is a vehicle.

Above WSH statistics highlight the urgency for more to be done to prevent accidents that are machinery- or vehicular-related.

Possible risk controls typically include safe work procedures, worker training/re-training and closer supervision, but these are administrative controls with limited effectiveness as they are largely behaviour dependent.

A key principle of risk management is to reduce risks at source by designing out the risk through elimination or substitution. Should elimination or substitution not be possible, the implementation of engineering controls comes next in the hierarchy of controls.

Companies are, therefore, urged to put in place engineering controls to protect workers working with machines and vehicles. Engineering controls are more effective as they are designed to protect workers from a dangerous condition, independent of worker behaviour. For machines with exposed parts, the installation of machine guards (which are usually designed not to be easily removed) is an important engineering control-based risk reduction control strategy.

This paper goes beyond machine guards by introducing how non-contact sensor technology can be used as an engineering control measure to prevent machinery- and vehicular-related accidents via real-time detection of human and/or obstacle presence.

Non-contact Presence Detection

The last twenty years has seen significant advancements in sensor technology that make them smaller, easier, less-intrusive and/or more cost-effective to deploy in a variety of workplace situations.

Types of Presence-sensing Devices

The various types of non-contact presence detectors now available include:

Safety Light Curtain

Light curtains (available as a photoelectric transmitter and receiver pair) emit a harmless "curtain" of infrared light beams directly in front of the danger area of a machine (see Figure 3). When any of the light beams are "broken" (e.g. blocked by any part of a person's body), the machine's stopping mechanism will be immediately activated so that it stops before the operator crosses into the danger zone. The advantage of light curtains is that it offers protection at the point of operation (pinch point protection) or around the perimeter (access protection) of a hazardous work area with minimal impact on routine machine operation.

Figure 3: Machine equipped with a safety light (picture courtesy of Omron STI)
Source: WSH Guidelines on Safe Use of Machinery

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Safety Laser Scanner
Laser scanners combine pulsed infrared laser and time-of-flight technology to precisely calculate the location of any detected person or object within a danger area. This location is then compared with the safety and warning zones defined in the device. If the person or object is present inside the warning zone, audiovisual signals can be triggered. If intrusion of the safety zone occurs, the scanner can be programmed to promptly send a stop signal to the machine, robot or vehicle.

The laser scanner can be deployed in stationary (mounted on a fixed object) or in mobile (mounted on a moving object) applications. The advantage of laser scanners is that it can safeguard all points within the perimeter of the danger area. The predefined danger area can be configured to protect areas that are rectangular or circular in shape as well as areas that are irregularly shaped. See Figure 4 for an example of a safety laser scanner.

Figure 4: Example of a safety laser scanner
Source: WSH Guidelines on Safe Use of Machinery

Safety Camera
Safety camera systems are electro-sensitive protective devices based on three-dimensional (3D) image processing technology (see Figure 5). In contrast to simple sensors, a safety camera system can continuously monitor a danger area and record or analyse detailed information concerning the entire area being monitored. The detection zone of a safety camera is typically divided into warning and danger zones. If a person or object enters the warning zone, the system can be programmed to sound the alarm and slow down all movement. Should the person or object approach the danger zone, the system would promptly trigger an emergency stop command to shut down the machine, robot or vehicle.

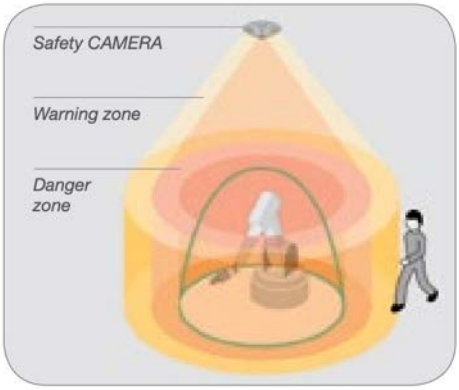

Figure 5: Example of a safety camera system
Source: WSH Guidelines on Safe Use of Machinery

Ultrasonic Detector
Ultrasonic systems depend on the emission of sound waves and time-of-flight technology to determine human presence. A sound pulse (at a frequency higher than humans can hear) is sent out by a transmitter and, as the pulse bounces off objects in its path, it is reflected and captured by a receiver. In an empty room, the reflections will come from the opposite wall and the time taken for the reflection to be received will be proportional to the distance between the transmitter and the wall. When a person enters the work area, the pulses will reflect off the person and the time taken to receive the reflections will be less.

Radar Detector
Radar sensors are based on the active transmission and reception of electromagnetic waves. The radar transmitter emits a signal in the form of radar waves, which move at the speed of light and are not perceivable by humans. When the waves hit a person or object, the signal changes and is reflected back to the receiver. The received signal is then processed to determine human/ obstacle presence and position.

Radar sensors may be used to detect movements as well as stationary objects. Data available include direction of movement, speed, distance, and angular position in relation to the sensor. Key advantages of radar technology is that it is independent from environmental condition, can be deployed outdoors, able to tolerate extreme heat and cold, works in the dark, insensitive to contamination and do not need to be cleaned (i.e. maintenance free).

This means that radar sensors may also be used in harsh working environments including confined spaces.

Other technologies that have been successfully deployed for presence detection include:

- Bluetooth connection for short range detection (typically within a 10-metre range) e.g. for contact tracing applications; and
- Global Positioning System (GPS) tracking for long range detection using satellite technology to determine a person's geolocation.

The sensor technology used for the various types of presence detectors have different strengths and weaknesses. Depending on application, companies will have to evaluate which technology offers the greatest value add to manage the machinery- and/or vehicular-related WSH risk to be addressed.

Use Cases for Presence Detection

As highlighted in the WSH 2028 document published by the Ministry of Manpower and the WSH Council, a key broad strategy to help achieve sustained reduction in workplace injury rates is the adoption of technology-enabled WSH.

The use of presence-sensing devices offers immense potential for WSH practices to be transformed, assisted by technology. The use of presence detectors essentially provides "more eyes on the ground" to effectively detect hazardous situations before accidents occur. Presence detectors therefore present a promising solution to WSH challenges, allowing companies to better manage WSH risks and protect workers from harm, so that the focus can remain on business operations and productivity.

These are example use cases where the deployment of presence-sensing devices may prove useful to prevent machinery- or vehicular-related accidents:

Machine/ Vehicle	Examples	Suggested application
Any machine with exposed moving parts	Power press Bending machine Cutting/shearing machine Sawing machine Conveyor system	Pinch point area monitoring
Robot	Conventional industrial robot (stationary)	360° area monitoring
	Autonomous mobile robot	Forward collision sensor Reverse collision sensor
Transport vehicle	Car Van Bus Truck Lorry	Forward collision sensor Reverse collision sensor Blind spot monitoring
Heavy vehicle	Prime mover Refuse collection truck Dump truck Cement mixer Bulldozer Excavator Wheel loader Road roller	360° area monitoring* Forward collision sensor Reverse collision sensor Blind spot monitoring
Lifting equipment/ vehicle	Lorry loader/crane Mobile crane Crawler crane	360° area monitoring* Forward collision sensor Reverse collision sensor
Manual handling equipment/vehicle	Forklift Reach truck Side loader	360° area monitoring Forward collision sensor Reverse collision sensor
Elevating work platform	Boom lift Scissor lift Order picker	360° area monitoring* Forward collision sensor Reverse collision sensor Overhead collision sensor

* when stationary

As can be seen from the table, presence-sensing devices may be applied to both stationary (e.g. on a fixed machine) or mobile (e.g. on a moving vehicle) work scenarios. The sensor is typically mounted directly on the machine, robot or vehicle, but there are use cases where it may be more practical to mount the sensor directly on the worker (e.g. as a wearable). For example, mounting the sensor on a worker's helmet for overhead collision detection may prove to be a more cost-effective approach versus installation across a fleet of aging boom lifts.

Once human or obstacle presence is detected, the sensor system may be designed to trigger an audio-visual alarm to alert the operator of impending collision. To achieve engineering control, the sensor signals may be interlocked to the machine/vehicle controls to either restrict further movement in the shortest time possible or to carry out an emergency stop in order to avoid the collision.

Above list of machines or vehicles where the use of presence sensors has the potential to make workplaces or work activities safer include construction sites, factories, shipyards, logistics & transport activities including warehouse operations, and facilities maintenance activities.

Concluding Remarks

In line with WSH 2028 and the Vision Zero Movement, companies are encouraged to explore the use of technology to solve WSH challenges.

Regardless of industry sector, the deployment of presence detectors is a good example of how emerging technology solutions can be applied to help prevent machine and vehicular-related accidents. For more real-world use cases on how presence-sensing technology can be applied, one should not just look internally (as in within one's industry sector or subsector), but also externally by looking across sectors and learning from other sectors.

With each passing year, new technology may be able to offer fresh perspectives to how existing WSH concerns can be addressed. Continually finding ways to enhance existing risk controls is a key approach companies can strive for to help ensure accidents remain preventable and that every worker will be able to go home safely at the end of each work day.

Further Information

1. WSH National Statistics Report 2021
2. *"Vehicular accidents top cause of workplace deaths in first half of 2021", The Straits Times (8 Oct 2021)*
3. Vision Zero Movement
4. WSH Guidelines on Safe Use of Machinery
5. IEC 61496 series: Safety of machinery - Electro-sensitive protective equipment
6. IEC 62046: 2018 Safety of machinery - Application of protective equipment to detect the presence of persons
7. IEC/TS 62998-1: 2019 Safety of machinery - Safety-related sensors used for the protection of persons