

# **Safety controls for the use of mobile plant, vehicles, and machinery**

A review of emerging technologies

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# Acknowledgement of Country

SafeWork NSW acknowledges the Traditional Custodians of the lands where we work and live. We celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the lands and waters of NSW.

We pay our respects to Elders past and present and acknowledge the Aboriginal and Torres Strait Islander people that contributed to the development of this report.

We advise this resource may contain images, or names of deceased persons in photographs or historical content.

## Safety controls for the use of mobile plant, vehicles, and machinery

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Information contained in this publication is based on knowledge and understanding at the time of writing, November 2025, and is subject to change.

This report summarises, for general information purposes only, the findings of research to identify and describe new and emerging technologies that may be used for the aim of minimising injury from mobile plant, vehicles and fixed machinery. It does not represent a comprehensive statement of all technologies that may be available to address that aim.

SafeWork NSW does not represent that any of the technologies discussed in this report have been tested for use and/or are recommended or endorsed by SafeWork NSW.

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# 1

## Executive summary

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## 1.1 Introduction

SafeWork NSW aims to reduce injury from mobile plant, vehicles and fixed machinery as part of its 2025-26 Annual Regulatory Priorities.

As the work health and safety regulator in NSW, SafeWork NSW has functions that include providing information to persons conducting a business or undertaking (PCBUs) and other duty holders under the *Work Health and Safety Act 2011* (WHS Act), as well as the community, about work health and safety issues.

Keeping people and plant separate, preventing access to moving parts of machinery, and encouraging safe worker behaviour are areas of interest to SafeWork NSW.

This report aims to provide a summary for general information purposes of a review of existing literature on:

- The use of emerging safety technologies, such as artificial intelligence (AI), sensors, and computer vision, which may improve work health and safety (WHS) via isolation and engineering controls within sectors such as construction, manufacturing and warehousing, and agriculture.
- Barriers and facilitators to technology adoption, which may also help inform effective practices for the implementation of safety technologies.

**A literature review of academic and other sources was conducted by SafeWork NSW to address the following aims:**




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<b>1 To synthesise evidence on new and emerging safety technologies that can be applied with the purpose of:</b>	<ol style="list-style-type: none"><li>a. Keeping people and plant separate</li><li>b. Preventing access to moving parts of machinery</li><li>c. Promoting safe worker behaviours (e.g., seatbelt or helmet sensors)</li></ol>
<b>2 To identify barriers and facilitators to the adoption of new safety technologies by PCBUs and workers</b>	

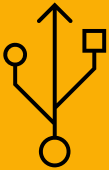
## 1.2 Key findings

Vision-based technology, location-based technology, and sensors were commonly identified as emerging technologies for application across the three topic areas.

The reviewed literature indicated:

	<p><b>Vision-based technologies</b> include the use of AI cameras and object detection to identify WHS hazards and detect when workers enter a dangerous area or are near a dangerous part of machinery. Object detection technology can also determine whether workers are wearing appropriate personal protective equipment (PPE), such as safety helmets, safety vests, or seatbelts.</p>
	<p><b>Location-based technologies</b> include the use of radio frequency identification devices (RFID), ultra-wide band (UWB), Bluetooth low energy (BLE) and other similar devices to locate when a worker is in proximity to dangerous areas or moving parts. Location-based technologies can also be attached to mobile plant or other machinery to help prevent collisions with pedestrians.</p>
	<p><b>Sensors</b> can be attached to wearable devices, such as wristbands, or attached to mobile plant to detect proximity of individuals to moving parts of machinery. Effective uses include an output mechanism that trigger an automatic stop, or other safety control, when sensors detect dangerous activity.</p>

### Technology adoption is influenced by many factors, including:

	<ul style="list-style-type: none"><li>• <b>the characteristics of the technology itself,</b></li><li>• <b>cost, data and privacy concerns,</b></li><li>• <b>organisational and user readiness, and</b></li><li>• <b>external influences.</b></li></ul>
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Technology adoption could be focused on the **areas of highest risk**, include **consultation** and involvement of workers, and ensure **adequate worker training**. The adoption of new safety technologies may also introduce new safety hazards or lead to overreliance on technology.

## 1.3 Glossary

Table 1. Glossary of terms

Term	Definition
Artificial intelligence	The ability of computers or other machines to perform activities that require human intelligence, such as learning, reasoning, and self-correction (ScienceDirect, 2025).
Barriers and facilitators	Barriers are factors that hinder or limit PCBUs or individuals from implementing a certain behaviour or intervention. Facilitators are factors that enable or support certain behaviours or interventions.
Computer vision	A field of artificial intelligence that enables machines to interpret, analyse, and pull meaningful data from images and videos (Microsoft Azure, 2025).
HSR	Health and safety representative.
Internet of things (IoT)	The collective network of connected devices and the technology that facilitates communication between devices and the cloud, as well as between the devices themselves (Amazon Web Services, 2025). This includes sensors, smart devices and other equipment that give PCBUs real-time data related to their worksite.
Machine learning	An aspect of artificial intelligence that competently performs automation in the process of building analytical models that allow machines to adapt independently to new scenarios, enabling software to successfully predict and react to the deployment of scenarios based on past results (França et al., 2021).
Mobile plant	Plant that is provided with some form of self-propulsion that is ordinarily under the direct control of an operator (Office of the Federal Safety Commissioner, 2024).
PCBU	Person conducting a business or undertaking.
Plant	Plant includes machinery, equipment, appliance, container, implement and tool components or anything fitted or connected to those things. Plant includes items as diverse as lifts, cranes, computers, machinery, conveyors, forklifts, vehicles, power tools, quad bikes, mobile plant and amusement devices (Safe Work Australia, 2024).
Plug and play	The ability of a computer or device to automatically recognise and configure compatible hardware components without requiring manual intervention or additional software installation (Lenovo US, 2025).
Radio frequency identification device (RFID)	Broad term encompassing any technology that utilises radio waves to identify, monitor, and thereby manage various objects (Chacón et al., 2025).
Technology adoption	Acceptance, integration, and embracement of new technology (Granić, 2023).

# 2

## Introduction

## 2.1 Background

Interaction with mobile plant, vehicles, and fixed machinery is an ongoing cause of workplace injury and fatality in New South Wales (NSW), Australia, and internationally. From 2003 to 2023, 571 worker fatalities in NSW involved a vehicle incident and 61 fatalities were the result of being trapped by moving machinery or equipment (Safe Work Australia, 2025b)<sup>1</sup>.

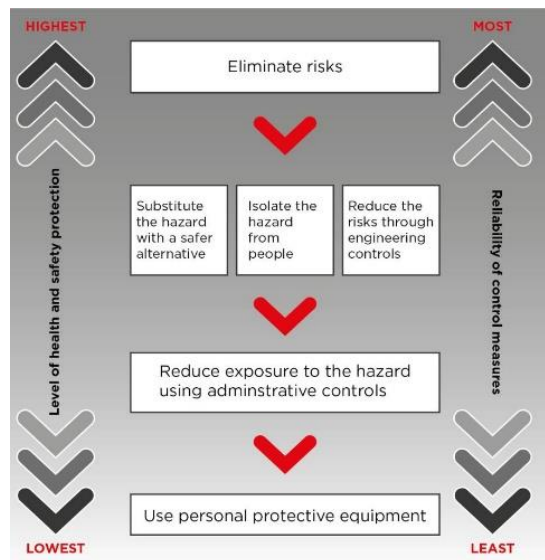
As part of its 2025-26 Annual Regulatory Priorities, SafeWork NSW aims to minimise injury from mobile plant, vehicles and fixed machinery (SafeWork NSW, 2025a). In 2022-23, there were 2012 workers' compensation claims related to injury from self-propelled plant, semi-portable plant, and other mobile plant (Safe Work Australia, n.d.)<sup>2</sup>. In the same time period, 4122 claims related to machinery and fixed plant were lodged, particularly relating to injury from conveyors and lifting plant, and cutting, slicing, and sawing machinery (Safe Work Australia, n.d.). To address this regulatory priority, SafeWork NSW is interested in researching controls for keeping people and plant separate, for preventing access to moving parts of machinery and for improving safe worker behaviour.

The separation of people and plant refers to controlling risks to prevent collision or other dangerous interactions between mobile plant, vehicles, or fixed machinery, and individuals. This includes the use of physical barriers around dangerous areas or maintaining appropriate distance between people and plant (Safe Work Australia, 2024).

Preventing access to moving parts of machinery is generally achieved through the use of physical barriers, such as machine guards (Safe Work Australia, 2024). Where physical barriers are not reasonably practicable, presence-sensing systems such as photoelectric light beams, laser scanners, and foot pressure mats may be used (Safe Work Australia, 2024).

Despite available control measures, workers continue to engage in risky behaviour, such as bypassing machine guards (Haghighi, 2020) or entering dangerous areas. To address this persistent issue, SafeWork NSW aims to examine literature that focuses on higher-order controls, as per the hierarchy of controls (Figure 1; Safe Work Australia, 2025a). The implementation of isolation or engineering controls may reduce reliance on human behaviour and supervision to minimise risk.

Figure 1. Hierarchy of controls (Safe Work Australia, 2025a)



<sup>1</sup> The use of the alphabetical character in this citation, i.e., 2025b, indicates that there were multiple sources used from Safe Work Australia in 2025. The use of the alphabetical character after the year provides a unique indicator for each citation where this occurs, which can be matched in the reference list.

<sup>2</sup> "n.d." indicates the citation had no date.

The focus of this literature review on emerging technologies aligns with the concept of ‘Safety 4.0’, which refers to the incorporation of advanced digital technologies, automation, and machine learning into existing safety controls (Haleem et al., 2025). The integration of advanced technologies into safety systems can lead to improved compliance with work health and safety (WHS) regulations, better-informed decision making through the use of predictive algorithms (EU-OSHA, 2025), and reduced harm.

Available literature may also address the factors influencing the adoption of safety technologies by PCBUs. Identifying these factors through literature can provide information related to effective practices for the implementation of technologies. This may be particularly important for sectors that may have limited willingness or resources to upgrade machinery, such as agriculture.

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## 2.2 Objectives

The aim of this literature review is to identify new and emerging safety technologies relevant to improving WHS around mobile plant, vehicles, and fixed machinery.

This includes the following aims:

1. To synthesise evidence on new and emerging safety technologies that can be applied with the purpose of:
  - d. Keeping people and plant separate
  - e. Preventing access to moving parts of machinery
  - f. Promoting safe worker behaviours (e.g., seatbelt or helmet sensors)
2. To identify barriers and facilitators to the adoption of new safety technologies by PCBUs and workers

The objective of this report is to provide PCBUs and the community with general information based on the findings of this literature review.

# 3

## Method

### 3.1 Scope

This review identified and synthesised evidence related to new and emerging safety technologies that keep people and plant separated, prevent access to moving parts of machinery and promote safe worker behaviours. A rapid scoping review approach was utilised for this review, given that it is appropriate for mapping evidence on a topic, identifying main concepts, and identifying or addressing knowledge gaps (Tricco et al., 2016).

An existing review identified 30 technology categories relevant to encouraging Safety 4.0 (Haleem et al., 2025). Based on relevance to the topic areas of this review, the following technology categories were a focus: sensors, augmented reality and virtual reality, internet of things, real-time location systems, artificial intelligence, drones, machine vision, and smart personal protective equipment (PPE). These technologies were chosen based on their potential for application in existing infrastructure and on a smaller scale. However, the large-scale design of smart factories and use of advanced computer architecture may also be relevant as new factories, warehouses, and other industrial and agricultural sites are developed.

Literature relevant to technology adoption, such as barriers and facilitators to adoption, were also included. Technology adoption refers to the acceptance, integration, and embracement of new technology (Granić, 2023). Technology adoption models focus on various factors that can influence acceptance of technology, including attitudes, social norms, behavioural intentions, previous experience, perceived ease of use, and perceived usefulness (Taherdoost, 2018). The Participants, Concept, Context (PCC) framework below details the scope of the review (Table 2). The use of the PCC framework was informed by JBI methodology guidance for scoping reviews (Peters et al., 2020).

Table 2. PCC framework

Element	Description
<b>Participants</b>	Workers PCBUs
<b>Concept</b>	<p>Digital technologies used for safety purposes, that can be applied for the purpose of:</p> <ul style="list-style-type: none"> <li>• Keeping people and plant separate               <ul style="list-style-type: none"> <li>— Forklifts used as the key example of mobile plant</li> </ul> </li> <li>• Preventing access to moving parts of machinery</li> <li>• Promoting safe worker behaviour</li> </ul> <p>Barriers and facilitators to adopting new safety technology, including aspects such as:</p> <ul style="list-style-type: none"> <li>• Knowledge</li> <li>• Trust</li> <li>• Resource constraints</li> <li>• Privacy concerns</li> </ul>
<b>Context</b>	<p>All industries where mobile plant, vehicles, or fixed machinery may be used.</p> <p>Specific focus on case studies from the following industries:</p> <ul style="list-style-type: none"> <li>• Manufacturing and Warehousing</li> <li>• Construction</li> </ul>

Element	Description
	<ul style="list-style-type: none"> <li>• Agriculture</li> </ul> <p>Evidence reported or published within the last 5 years (i.e., from 1 Jan 2020) was included.</p>

Technologies related to rollover of mobile plant, quad bikes, or other vehicles were out of scope for this review. Additionally, technologies that detected environmental exposures (e.g., exposure to particulate matter), wearable technologies that tracked the health status of workers (e.g., heart rate monitoring, fatigue monitoring), and technologies related to the maintenance of machinery (e.g., lockout/tagout procedures, detection of faulty parts) were excluded.

## 3.2 Literature review

Google Scholar was searched using keywords such as “technology”, “safety”, “sensor”, “artificial intelligence”, “machine”, and “vehicle”. This search was supplemented with searches in other academic and grey literature databases, including the websites of Australian and international WHS regulators, such as the European Agency for Health and Safety at Work (EU-OSHA).

Information including title, authors, year of publication, and key findings, was extracted from each identified source. Information relevant to the following areas was also extracted: preventing access to a dangerous area, preventing collisions, preventing access to moving parts of machinery, safe worker behaviour, technology adoption. Sources were indicated as relevant to three sectors of interest: manufacturing and warehousing, construction, and agriculture.

Identified literature was summarised based on the use of common technologies, and common applications within workplaces.

## 3.3 Identified sources of evidence

Sixty-six sources were included as part of this review; sources could cover multiple topic areas. Sources were sorted based on topic:

- preventing access to an area (n=15)
- preventing collisions between forklifts and pedestrians (n=11)
- preventing access to moving parts of machinery (n=14), and
- promoting correct use of PPE (n=13).

Twenty-eight sources focused on technology adoption.

Of the summarised sources, around half (n=29; 44%) were peer-reviewed journal articles. The remaining sources included websites (n=11), conference papers (n=10) and policy briefs (n=5). Case studies for each area were typically identified through academic literature.

# 4

## Technologies for keeping people and plant separate

People and plant separation refers to the use of safety controls to minimise interaction between plant and workers. This can include preventing or minimising access to hazardous areas (n=15 sources), or improving detection and alert systems related to interaction between forklifts (or other mobile plant) and pedestrians (n=11). This section provides an overview of technologies that were presented in literature as relevant to separate people and plant. Examples of how these technologies can be applied are presented at the end of the section.

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## 4.1 Minimising access to dangerous areas

### 4.1.1 Vision-based technology

Over half (n=8) of the sources that described technologies that could minimise access to dangerous areas used computer vision or object detection technologies. These vision-based technologies typically defined dangerous areas and identified the entry of workers or other personnel into the defined area (ADLINK Technology Inc, 2022; Feng et al., 2020; FleetSafe Pty Ltd, 2024; Nie et al., 2023; Regazzoni & Spryridopoulos, 2024; Wang et al., 2023; Yang et al., 2023; N. Zhang et al., 2024).

These vision-based systems generally used camera systems installed across a worksite, which were connected to a central computer. The central computer processes the images received to form a display of the overall worksite. From these images, a 'virtual fence' can be determined using image processing and geometric modelling. Image processing can be based on traditional feature extraction algorithms (e.g., detection based on object edges, shapes, textures) or deep neural network algorithms, which incorporate feature extraction into a more sophisticated object detection process (Yang et al., 2023). Deep neural network algorithms may perform better in settings where lighting, object angles, and occlusion may occur (Yang et al., 2023).

This 'virtual fence' is used to delineate safe areas and dangerous areas of the worksite. Multiple areas can also be defined, such as a safety area, a warning area, and a hazardous area (Nie et al., 2023). The image processing system is then trained to detect personnel crossing or nearing the 'virtual fence' that demarcates a dangerous area, which can also be supplemented by algorithms that predict the movement of the individual (see Box 1 for example) (Nie et al., 2023; N. Zhang et al., 2024).

Once the processing software detects that an individual has entered the dangerous area, various outputs can be activated. Examples include the use of sirens, alarms, or automated messages to alert individuals to leave the area (ADLINK Technology Inc, 2022; Nie et al., 2023; N. Zhang et al., 2024). Emergency stops where the individual enters the space of hazardous machinery have also been implemented (Nie et al., 2023).

### 4.1.2 Location-based technology

The creation of a 'virtual fence' (geofencing) using predominantly vision-based systems are often highly accurate but can be computationally intensive (Ifuku et al., 2025; Liukkonen, 2025). Location-based technologies, such as the use of global positioning systems (GPS), Bluetooth low energy (BLE), ultra-wide band (UWB), and radio frequency identification devices (RFID) provide resource-light alternatives for this geofencing approach (Liukkonen, 2025). However, these alternatives also have limitations. Notably, GPS does not perform reliably in indoor environments (Liukkonen, 2025), so may not be suitable for sectors such as manufacturing and warehousing.

Smart gates, such as those with RFID technology embedded, can be used to delineate areas of a worksite and track mobile plant, which can help reduce collisions (Motroni et al., 2021). RFID systems consist of an RFID reader and RFID tags; when a tag receives a signal, it sends a radio wave back to the reader, allowing stationary and moving objects to be detected (Liukkonen, 2025). In a smart gate system implemented in a warehouse in Italy, RFID tags were embedded within gates and on forklifts, so that once a forklift passes through a gate, the initial position and direction of the forklift could be tracked (Motroni et al., 2021). The forklifts were also installed with a collision detection system, which combined with the information about the forklifts' position via the RFID data, can be used by

workers and other individuals to identify areas with the highest risk of collisions. This information can then be used in conjunction with other safety controls to improve people and plant separation (Motroni et al., 2021).

BLE, UWB, RFID and other wireless location technologies can also be embedded into wearable devices. For example, BLE technology within a smart armband can detect the proximity between one worker and another wearing an armband (Skoczylas, 2024), or the proximity between the worker and another BLE signal. Location-based technologies can also be adopted in combination with vision-based technologies, such as the use of BLE to define a dangerous area and computer vision to identify object intrusion (see Box 2 for an example) (Ifuku et al., 2025). These technologies can also be configured to provide alerts when individuals enter a dangerous area, such as through sending warnings to wireless bone conduction earphones worn by workers (Ifuku et al., 2025).

### 4.1.3 Other technology

Based on the literature search, geofencing appears the most common emerging technology used to restrict access to an area. However, other technologies have been implemented. One example is a work ticket system, which only allows authorised personnel into an area based on facial recognition algorithms (Feng et al., 2020; Wang et al., 2023). Another example is electronic lock and key systems which have been implemented as part of a systems approach to site safety (Chan et al., 2024).

Augmented or virtual reality may also be used as an alternative to physical safety signage that alert individuals to dangerous areas (M. Zhang et al., 2025). When using these technologies, when an individual enters a pre-defined dangerous area, they can receive a visual warning in their direct field of vision, alerting them to the safety risk (see Box 3).

Box 1. Case study: using vision-based technology for minimising access to a dangerous area

This study implemented a vision-based safety system in a worksite in China to detect when workers entered a dangerous zone. This safety system also included detection of workers' use of PPE, using object detection technology.

For the creation of a virtual danger zone, cameras were used to capture locations on a worksite. Geometric modelling technology was used to create a virtual danger zone using these images, whereby the boundaries of that zone were superimposed onto a real-time monitoring screen. The boundaries of the dangerous area were determined in this case study by the distribution of high-voltage equipment and required standards for minimum safe distances around such equipment.

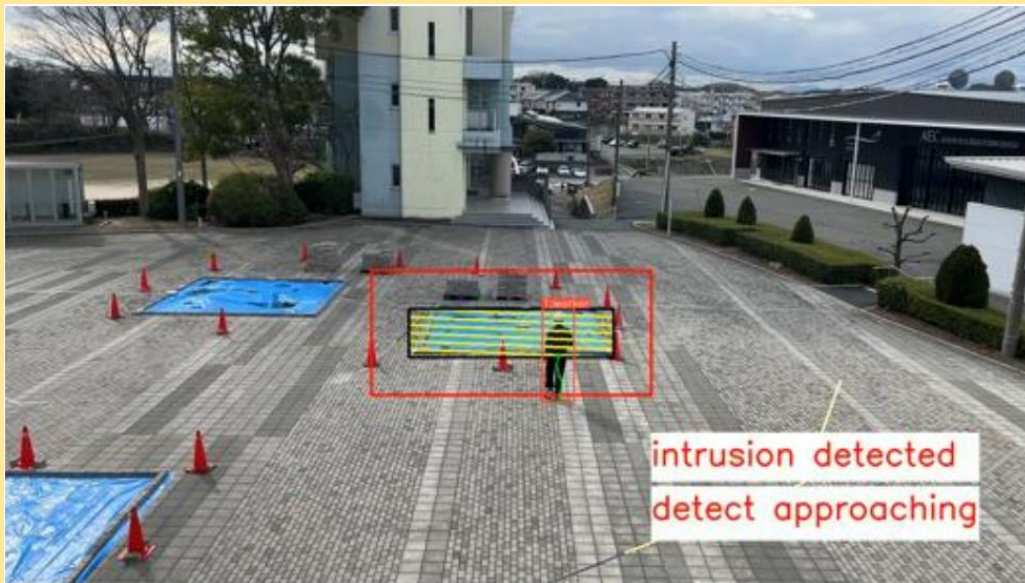
Detection of workers entering the dangerous area used the You Only Look Once (YOLO) v5 target detection algorithm and movement trajectory algorithms. The system used object detection and geometric calculations to determine whether the worker has entered the boundary of the danger zone. Algorithms were also used to determine 'short-term non-threatening' behaviours, such as a worker staying near the boundary but not fully entering the danger zone.

The system was designed so that an alarm is issued when a worker is detected to completely enter the virtual danger zone. The alarm information included the number of people who have crossed the boundary, the time of crossing the boundary, and the specific location.

Experimental results showed higher false alarms at night-time or rainy scenarios, where visual detection may be complex. In daytime simple scenarios, the accuracy of detecting workers entering a danger zone was 95%, with an average response time of 150ms.

Zhang et al., 2024. *Automatic identification and early warning technology of non-stop operation behaviour risks in distribution network based on machine vision*. 2024 IEEE 7<sup>th</sup> International Conference on Automation, Electronics and Electrical Engineering.  
<https://doi.org/10.1109/AUTEEE62881.2024.10869730>

This study utilised a combination of image recognition and BLE technology to track the trajectory of construction workers, detect when workers entered a dangerous area, and to warn them of nearby hazards. YOLOv8 software was used for image recognition, bytetrack was used to track detected objects (i.e., the workers), and location estimation was performed using BLE technology. The combination of vision-based and location-based technology ensured high reliability of the system, such as in the case that there are blind spots or signal interference for vision-based technology. The figure below shows what the safety system would output onto a central computer.



*Situation when entering a dangerous area.*

*Figure copied without changes from source article (reference below), under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).*

In this technological system, workers wore bone conduction wireless earphones, allowing them to hear warnings when entering dangerous areas. Bone conduction earphones were used as they do not block ears, therefore allowing workers to continue hearing surrounding sounds in the worksite. The communication distance between the transmitting devices and the earphones was up to 100 metres.

The safety system was demonstrated to be effective in experimental studies, however, requires several improvements to ensure accurate object detection and to allow for the identification of individuals who enter dangerous areas.

*Ifuku et al., 2025. Approach detection and warning using BLE and image recognition at construction sites. International Journal of Advanced Computer Science and Applications, 16(4).*

[https://thesai.org/Downloads/Volume16No4/Paper\\_9-Approach\\_Detection\\_and\\_Warning\\_Using\\_BLE\\_and\\_Image.pdf](https://thesai.org/Downloads/Volume16No4/Paper_9-Approach_Detection_and_Warning_Using_BLE_and_Image.pdf)

This article develops a virtual proactive warning system for use in the construction sector, which aims to caution workers about potential hazards as they approach dangerous areas. The dangerous area is defined using the input of 3D coordinates into an online software (Unity). Within Unity, the edges of the danger zones are defined. Feedback systems are also developed in Unity; there are two feedback modes depending on the position.

While wearing a virtual reality headset, if the worker approaches the edge of the risk area, the system shows a red wall to warn the worker they are near the dangerous area. If the worker enters the dangerous area, the red walls are also displayed, and the worker experiences a visual and audio warning message: "Entering the dangerous area".

In experimental scenarios, participants who used the virtual proactive warning system were exposed to the dangerous area for a shorter duration compared to participants who saw traditional fixed safety signs. The response time in relation to warnings was also faster for participants using the virtual proactive warning system. There was also evidence that the system did not overly consume the attention of participants.

*Zhang et al., 2025. Evaluating the impact of proactive warning systems on worker safety performance: An immersive virtual reality study. Safety Science, 186, 106774.*  
<https://doi.org/10.1016/j.ssci.2024.106774>

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## 4.2 Detection systems related to mobile plant and pedestrians

Eleven sources focused on collision avoidance systems related to forklifts and pedestrians in the worksite.

### 4.2.1 Sensors

Location-based technologies, such as the use of RFID, BLE, and ultrasonic sensors, can be used to prevent collisions between mobile plant and pedestrians (Bodyguard Safety Solutions, 2025; Garcia-Carrillo et al., 2024; Motroni et al., 2021; Shete et al., 2021). These technologies generally have two components: a sensing unit attached to the forklift, and a sensor on the pedestrian worker. When the sensors detect the two components within a pre-defined distance, alerts (e.g., sound, light, vibrations) are activated to warn of the potential collision (see Box 4 for example). These technologies build on existing radio sensing devices, which may only activate under certain scenarios (e.g., the forklift reversing) (SafeWork NSW, 2022).

Forklifts have also been developed that have built-in automation, such as features that slow or stop forklifts based on a pre-determined location (Crown Forklifts AU, 2025). These technologies may also help prevent collisions, for instance, if a forklift is programmed to slow down in areas of high traffic or danger.

#### 4.2.1.1 Limitations of collision avoidance systems

Each type of sensor or location-based technology has strengths and limitations (Liukkonen, 2025), which may impact usefulness for safety applications. For example, in a study that implemented ultrasonic sensors for forklift blind spot monitoring, the range of the sensing system was only up to one metre from the forklift (Shete et al., 2021), which may not be sufficient to prevent collision considering stopping distance and forklift speed.

Implementation of sensor-based detection systems also relies on correct calibration and installation of equipment. For example, the sensor system in Box 4 was tested on an excavator, which would require different calibration to forklifts based on velocity and other plant characteristics (Garcia-Carrillo et al., 2024). Accuracy may also depend on the sensors used; one study improved the accuracy of a Bluetooth and Received Signal Strength-based Positioning (RSSI) system by using the Kalman filter (Garcia-Carrillo et al., 2024). Another study also found the accuracy of a detection system for approximating forklift location was reliant on forklifts operating at a speed between 0.5m/s and 1.5m/s; speeds outside this range decreased the accuracy of the system (Motroni et al., 2021). Similarly, the angle and height of fixed sensors (e.g., in RFID antennas) can contribute to the accuracy of the system (Motroni et al., 2021), thus requiring careful installation.

Collision avoidance systems may also have limitations related to the number of hazards it can detect in a certain time period. In the case study described in Box 4, accounting for detection, prediction of collision, and activation of operator feedback, alerts could only be generated 6 times per second (Garcia-Carrillo et al., 2024). The appropriateness of this detection frequency would depend on the specific mobile plant (e.g., excavator vs forklift) and the need of the PCBU. Higher speeds of mobile plant can also decrease detection accuracy (Motroni et al., 2021).

Most identified collision avoidance systems still rely on operator action once alerted to a potential collision. For example, in the example in Box 4, the lights and vibrations are designed to alert the forklift operator to hazards (Garcia-Carrillo et al., 2024), however, human factors such as attention and reaction time would influence the effectiveness of this system for preventing incidents. Workers and other individuals may also become insensitive to alerts, especially if they are frequently activated (SafeWork NSW, 2022).

## 4.2.2 Other technology

Computer vision systems can also be used to monitor forklift movements and provide alerts when there is a risk of collision (Kang et al., 2024; Regazzoni & Spryridopoulos, 2024), such as when a person is detected in the forklift's blind spot (Foster, 2025). One study has also utilised YOLO deep learning technology to detect objects in a forklift's path (X. Liu et al., 2024).

Existing forklifts often have embedded cameras and a video feed so that operators can see beyond their direct line of sight. However, this requires an operator to turn their attention to the video, which may increase the risk of collisions or other hazards. As a solution, a real-time augmented reality system has been developed to superimpose concealed information into a display located in the operator's line of sight, see Box 5 (Overmeyer et al., 2023).

"Plug and play" solutions have also been developed to improve safety around mobile plant. An example is the Safety Halo, which can be easily attached to a forklift and projects a single-coloured line as a perimeter around the forklift (Incident Zero, 2025). Therefore, this technology defines a visible exclusion zone that moves with the forklift, which may be adhered to by pedestrian workers and others in the vicinity.

Box 4. Case study: use of collision avoidance sensors for keeping pedestrians safe around forklifts

Bluetooth technologies have been used in collision avoidance systems for forklifts, or other mobile plant, in a warehouse. This safety system required a Bluetooth system in each forklift, and a Bluetooth device located on each worker; this Bluetooth device could be placed on existing PPE, such as safety helmets. In this system, when a forklift or pedestrian was at risk of collision, based on a pre-programmed distance, the forklift operator would be notified via coloured lights and vibrations in their seatbelt. A traffic light system was used, with orange and red lights indicating the severity of potential collision.



*Warning in the left zone of the mobile plant.*

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*Garcia-Carrillo et al., 2024. Ad-hoc collision avoidance system for industrial IoT. Journal of Industrial Information Integration, 38, 100575. <https://doi.org/10.1016/j.jii.2024.100575>*

This case study presents a real-time augmented reality system for forklifts, whereby vehicle components in the operator's view are superimposed with visual information of the concealed areas. This is achieved using a multi-camera system, which records the forklift's surroundings in real time, and feeds back to a visual output located in operator's field of view. Sensor technologies are also used to track the forklift, the lift mast, and the head of the operator, to ensure that the visual output reflects the position and orientation of the forklift and operator.

Experimental results show basic suitability for the technological system. However, spatial and temporal errors are present, which may reduce the use of the system, even if it adheres to relevant safety requirements.

*Overmeyer et al., 2023. A real-time augmented reality system to see through forklift components. CIRP Annals, 72(1), 409-412. <https://doi.org/10.1016/j.cirp.2023.03.010>*

# 5

Technologies for  
preventing access to  
moving parts of machinery

The use of guards is recommended in Codes of Practice related to preventing access to moving parts of machinery (Safe Work Australia, 2024). This includes the use of fixed physical guards, or interlocking physical guards where reasonably practicable. Interlocking guards are systems that require a guard to be closed before the machinery can be operated, thereby providing an engineering control to prevent workers accessing moving parts (Safe Work Australia, 2024).

In the absence of physical guards around moving parts of machinery, presence-sensing systems should be used (Safe Work Australia, 2024; SafeWork NSW, 2022). These presence-sensing systems include the use of photoelectric light beams (light curtains), laser scanners, and foot pressure mats, which use trip mechanisms to detect when an individual enters a defined area or part of a danger zone (SafeWork NSW, 2025b). These detection mechanisms can then be configured to trigger an automatic stop or machine slowing.

Beyond these established guarding systems, ten sources in this review focused specifically on new or emerging technology that could be used for preventing access to moving parts of machinery. These technologies also generally used sensors and other detection techniques to identify when an individual enters a defined area of machinery. An example for how these technologies can be applied is presented at the end of the section. There was generally limited evidence for new technologies in this topic area, which may reflect the established use of presence-sensing guarding systems in plant (Safe Work Australia, 2024).

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## 5.1 Sensors for detecting proximity to a moving part

Six sources described the use of sensors for detecting proximity of an individual to moving parts of machinery (Ağseren & Şimşek, 2024; Asha et al., 2023; Chacón et al., 2025; Jacksha & Raj, 2021; Naaman Shibi, 2023; SICK Pty Ltd, 2024). The types of sensors used include touch sensors (Ağseren & Şimşek, 2024), passive infrared sensors (Asha et al., 2023), and laser triangulation sensors (SICK Pty Ltd, 2024). As noted in Section 4.2.1.1, the use of sensors as WHS controls rely on correct calibration and need to account for aspects such as machine stopping time and speed at which a worker crosses the sensor path (Safe Work Australia, 2024).

Two sources reported the use of wearable sensors, whereby a transmitter would be located with the workers, and a receiver would be in the danger zone of the machinery (Chacón et al., 2025; Naaman Shibi, 2023). The transmitter could be attached to PPE, a wristband, or another tag worn by the worker (Chacón et al., 2025; Naaman Shibi, 2023); Box 6 provides details of the implementation of such sensor system within the agricultural sector.

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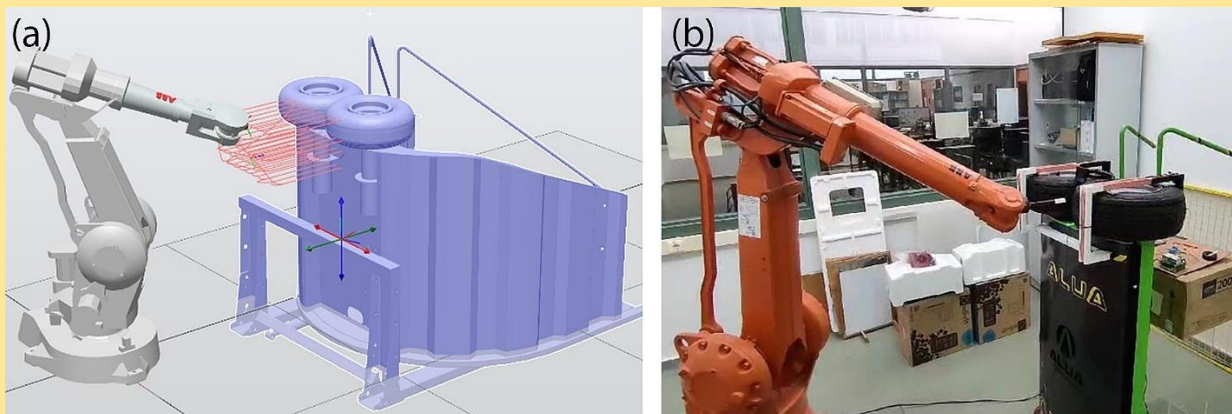
## 5.2 Vision-based technology

Four sources described the use of vision-based technology to detect hazards related to minimising access to moving parts of machinery (Foster, 2025; Perleybrook, 2025; Regazzoni & Spryridopoulos, 2024; WorkVis.io, 2023). Two sources reported the use of cameras to set up a virtual fence around the machine (Perleybrook, 2025; Regazzoni & Spryridopoulos, 2024), for general hazard recognition (Regazzoni & Spryridopoulos, 2024), or in line with a specific presence-sensing system (Perleybrook, 2025). The integration of computer vision into machine guarding includes using cameras to set up a virtual perimeter around machines, which then signal audio alerts when individuals walk into the dangerous area and can also interface electronically with the machine's braking system to facilitate emergency stops (Perleybrook, 2025).

Two sources reported the use of intelligent video monitoring systems that could be specifically programmed to detect hazards related to machine guarding (Foster, 2025; WorkVis.io, 2023). For example, a camera equipped with AI could be used to verify that physical machine guards are in place and notify operators and managers if a guard is removed or bypassed (Foster, 2025). A similar system also generates insights and reports related to safety violations and hazardous situations to strengthen training and process changes (WorkVis.io, 2023).

This safety system was designed to prevent injury related to a moving part of an olive net collector, used in agriculture. The system utilised RFID technology, including an RFID transmitter embedded into a wristband for the operator to wear and an antenna positioned on the dangerous part of the machinery. The system also included LoRa wireless technology, which is built for low energy, long distance communication (Core Electronics, 2025). In practice, the operator wears the wristband containing an RFID tag. If the tag in the wristband is detected by the antenna, an automatic stop is triggered in the machine.

In all prototype experiments, the automatic stop in the olive net collector machine was triggered before the operator body part reached the dangerous area (see figure below for depiction using a robotic arm; red zone indicates danger). It was highlighted that the wristband had no usability issues if it was the appropriate size, and that the system is more reliable as a safety control than existing functions.



Simulation (A) and experimental test (B) with antenna prototype and olive net collector. Red zone indicates danger.

Figure copied without changes from source article (reference below), under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

Chacón et al., 2025. Accident prevention in agricultural machinery using radiofrequency technology: A prototype application to olive net collectors, *Safety Science*, 188, 106875. <https://doi.org/10.1016/j.ssci.2025.106875>

# 6

## Technologies for detecting use of PPE

The correct use of PPE and other safety equipment is an important factor for maintaining safety in industrial contexts. While lower on the hierarchy of controls (as an administrative control), the use of PPE is essential. Thirteen sources that described technologies for detecting use of PPE and other safety equipment were summarised. An example for how these technologies can be applied is presented at the end of the section.

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## 6.1 Computer vision technologies

Most sources detecting correct use of PPE (n=11) utilised aspects of computer vision and object detection (ADLINK Technology Inc, 2022; Feng et al., 2020; Godoy et al., 2024; Hayat & Morgado-Dias, 2022; Li et al., 2020; Y. Liu et al., 2024; Muanme et al., 2023; Regazzoni & Spryridopoulos, 2024; Shao et al., 2024; Wang et al., 2023; Yang et al., 2023). In these systems, cameras are set up across the worksite to collect images. A central computer is connected to the camera systems. The central computer contains object detection software, such as the YOLO algorithm. These algorithms are neural or AI networks that are trained with images to identify the relevant objects. For example, for the detection of safety helmets, the algorithm would be trained to detect helmets in various angles and use cases. The algorithm can, therefore, detect the correct use of PPE when an image is transmitted from the camera system to the central computer.

The identified literature shows reasonably accurate detection of PPE objects such as safety helmets (Godoy et al., 2024; Hayat & Morgado-Dias, 2022; Li et al., 2020; Shao et al., 2024; Yang et al., 2023) and other objects such as safety vests, gloves, and glasses (ADLINK Technology Inc, 2022; Godoy et al., 2024; Muanme et al., 2023; Regazzoni & Spryridopoulos, 2024; Yang et al., 2023), and seatbelts or safety tethers (Y. Liu et al., 2024; Wang et al., 2023). These computer vision systems are typically adopted in fixed camera networks; there is evidence that these systems can be integrated with existing CCTV networks, reducing the implementation burden for the PCBU (Regazzoni & Spryridopoulos, 2024). Computer vision technology can also be connected to unmanned aerial vehicles (drones), which capture the PPE at various heights and from multiple angles (Y. Liu et al., 2024).

Inputs and decisions made via the computer vision system can be connected to other output technologies, such as triggering alarms for incorrect use (Shao et al., 2024) or opening doors to dangerous areas for correct use (see Box 7) (Muanme et al., 2023). These technologies can also be combined with face recognition technology, which may be particularly useful for worksites where personnel authorisation is required for entry (Feng et al., 2020; Wang et al., 2023).

### 6.1.1 Limitations of vision-based technologies

Vision-based technologies, such as computer vision-based object detection, can be prone to error based on illumination and occlusions on the worksite (Bangaru et al., 2021), or the rotation angle of objects (Li et al., 2020). They also require robust AI models to allow for the software to be trained to detect appropriate images accurately (Shao et al., 2024). AI solutions usually require clear, standardised data, such as simple images of PPE to be trained on, which may require additional work before the AI solution can be implemented (SafetyIQ, 2024). Moreover, AI systems may make decisions within a 'black box' (Jenuwa et al., 2025), limiting the ability of PCBUs to understand how decisions are made. As such, it is recommended in the literature that AI and machine learning algorithms should be built with processes for transparency and rigor, to ensure clarity in how data is collected and interpreted within a digital safety system (Spryridopoulos & Broughton, 2024).

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## 6.2 Other detection technologies

Wearable sensor technologies have also been developed to determine the correct use of PPE (Abbasianjahromi, 2022; Kim et al., 2021). These technologies typically embed a sensor into the PPE and are programmed to provide information to a control centre to notify whether a worker is wearing the PPE. For example, Kim et al. (2021) describes a photoplethysmogram (PPG) sensor and

accelerometer being successfully embedded into the chin strap of a safety helmet to detect appropriate use of the safety helmet and to send the location of the user and other information to a monitoring webpage.

Box 7. Case study: use of computer vision for detecting PPE equipment

An AI camera system was set up in a factory in Thailand to detect the use of safety vest, gloves, and glasses on workers before they entered a hazardous area. The camera utilised object detection technology (YOLOv3) and was trained to recognise each PPE item; a central computer was needed to process the images and execute commands.

The camera was positioned to identify workers as they approached an automatic door that provided access to the plant floor. The door was configured to open only once the camera system and central computer had successfully identified all three PPE items.

The system had a high level of accuracy, however, successful object detection relied on the workers standing an appropriate distance from the camera in a fixed pose. The system was tested with 78 employees, and use of PPE improved following the implementation of the system.

*Muanme et al., 2023. An artificial intelligence camera system to check worker personal protective equipment before entering risk areas. In: Hung, J.C., Chang, J.W., Pei, Y. (eds) Innovative Computing Vol 2 – Emerging Topics in Future Internet. IC 2023. Lecture Notes in Electrical Engineering, vol 1045. [https://doi.org/10.1007/978-981-99-2287-1\\_102](https://doi.org/10.1007/978-981-99-2287-1_102)*

# 7

## Technology adoption

Twenty-eight sources were summarised that related to the adoption and acceptance of safety technologies for use around mobile plant, vehicles and fixed machinery.

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## 7.1 Barriers and facilitators to adoption of technology

### 7.1.1 Characteristics of technology

The adoption of technology is influenced by the characteristics and usability of the considered technology system, such as technical reliability and ease of integration into existing systems.

In a study of construction professionals, technical issues were identified as the most influential barrier to the adoption of sensing technologies (Arabshahi et al., 2022). This included technical issues such as range issues, power supply, data processing, maintenance calibration, and IT infrastructure (Arabshahi et al., 2022; Ibrahim et al., 2025). Sensor durability has also been considered an important factor (Howard et al., 2022).

Ease of integration with existing systems was another commonly reported aspect to consider when adopting new safety technology (Foster, 2025; Ibrahim et al., 2025; Perera et al., 2025; Regazzoni & Spyridopoulos, 2024). This includes the ability to exchange data between existing technologies (Perera et al., 2025), and being compatible and integrated with existing WHS processes and operations (Ibrahim et al., 2025; Perera et al., 2025). For example, in the adoption of a proactive safety event recognition system utilising computer vision, the ability for the system to integrate with existing CCTV infrastructure was a key consideration for many PCBUs (Regazzoni & Spyridopoulos, 2024).

Safety technologies may also be adopted more if they are user-friendly, of low complexity, and reliable (Olausson & Broughton, 2023; Perera et al., 2025; Spyridopoulos & Broughton, 2024). Using existing and easily understood alerts, such as sound, vibration, or lights, are common ways to notify about potential hazards (Spyridopoulos & Broughton, 2024). The need for extensive technical training may be a barrier to the adoption of technology (Tabatabaee et al., 2022) while technologies with observable results, such as dashboards, may be preferred (Perera et al., 2025).

### 7.1.2 Cost

The cost of new safety technologies is a common factor influencing implementation (Arabshahi et al., 2022; Hess, Spyridopoulos, et al., 2024; Howard et al., 2022; Ibrahim et al., 2025; Jacksha & Raj, 2021; Jenuwa et al., 2025). Safety monitoring systems can be beneficial for reducing worker turnover, reducing incidents, decreasing worker compensation costs, and improving compliance (Hess, Spyridopoulos, et al., 2024; Jenuwa et al., 2025). However, these benefits are only visible in the long-term, which may deter PCBUs from adopting new technologies, especially if they are budget-constrained (Jenuwa et al., 2025).

Although some sensing and AI technologies may be “plug and play” (e.g., Incident Zero, 2025), more integrated systems, such as those including complex data-processing, may require significant time and costs related to their installation, maintenance, and operation (Ibrahim et al., 2025; Jacksha & Raj, 2021; Jenuwa et al., 2025). These ongoing costs may be a substantial barrier to adoption, particularly for small to medium enterprises (Jung et al., 2021). PCBUs may also be discouraged from adopting new safety technology due to a lack of technological maturity, which raises costs (Hess, Spyridopoulos, et al., 2024; Ibrahim et al., 2025), or uncertainty regarding technology obsolescence (Jenuwa et al., 2025).

### 7.1.3 Data and privacy

The adoption of any new safety technology requires careful consideration of the risks associated with cybersecurity, data privacy, and data sharing. The EU-OSHA (2024) advocates for two approaches to data privacy: privacy by design, which integrates anonymisation of collected data, data minimisation, compliance with regulations, and secure storage into the design of the

technology; and privacy by choice, which restricts data access to certain roles (e.g., data only accessed by health and safety representatives (HSRs)). The application of each approach may depend on the safety technology and PCBU requirements.

In a survey of construction trade union workers in Finland, individuals were most concerned that their data could end up in the 'wrong hands', such as individuals outside their organisation (Häikiö et al., 2020). This element of cybersecurity is an important concern (Bragatto & Ansaldi, 2022; Howard et al., 2022), as data being hacked or manipulated by external sources may lessen the reliability of the safety technology and potentially lead to increased harm (Jenuwa et al., 2025). However, given the societal move towards automated and intelligent technologies, the concept of data sharing and data privacy within organisations may be of lesser concern for workers (Strawderman et al., 2025) and less of a hindrance than previously expected (Bragatto & Ansaldi, 2022).

#### 7.1.4 Organisational readiness and culture

The organisational characteristics, culture, and readiness of a PCBU are important factors related to the adoption of new and emerging safety technologies (Hess, Spryridopoulos, et al., 2024; Ibrahim et al., 2025; Jacksha & Raj, 2021; Jenuwa et al., 2025; Olausson & Broughton, 2023; Perera et al., 2025; Strawderman et al., 2025; Yap et al., 2023). PCBUs with management that prioritise research, innovation and continuous improvement may be more likely to adopt new technologies (Jenuwa et al., 2025; Olausson & Broughton, 2023); these PCBUs tend to be larger in size (Olausson & Broughton, 2023). Moreover, PCBUs that have compliance-based or rigid approaches to safety may encounter resistance or difficulty when adopting innovative safety technology (Jenuwa et al., 2025), especially if regulatory codes or guidelines are not updated to include new technologies. The geographical spread, age, structure, and ownership structure of PCBUs (Perera et al., 2025) can also be influencing factors relevant to the adoption of technology. In general, a facilitator for the adoption of new technology is the managerial perception that the technology will have tangible benefits for work performance or safety (Perera et al., 2025).

A key component of organisational readiness is the existing technical and IT capability within the PCBU. One source reported that an excessive amount of time was spent troubleshooting the technical aspects of an implemented safety system (Jacksha & Raj, 2021), highlighting the importance of technical knowledge either internally to the PCBU, or through partnership with vendors. A lack of digital skills and IT infrastructure may be a significant barrier for small to medium PCBUs (Hess, Spryridopoulos, et al., 2024) who may require substantial training to successfully adopt new technologies (Yap et al., 2023). Workforce shortages of engineers and IT specialists (Jenuwa et al., 2025) may also negatively impact the ability of PCBUs to adopt innovative safety technologies.

#### 7.1.5 Technology users

The acceptance and correct usage of new safety technologies can also be influenced by user-related factors, such as the person's age, gender, experience and attitudes toward technology, perceived self-efficacy, and IT competency (Perera et al., 2025). Experienced users of technology have been found to be more interested in adopting new safety technologies (Häikiö et al., 2020), while former unsuccessful experiences with innovative technologies can lead to resistance of acceptance (Arabshahi et al., 2022; Ibrahim et al., 2025). This links to knowledge as a facilitator: workers and other users who are well-trained and understand data and its application may be more likely to accept the use of technology (Arabshahi et al., 2022; Ibrahim et al., 2025).

Experience can also influence workers' willingness to embrace new safety technologies. When surveyed about their interest in using wearable devices, workers with less work experience were more interested (Häikiö et al., 2020), signalling a potential openness to change and innovation compared to workers with more work experience.

In the context of adopting augmented reality, workers may perceive a loss of competence related to being guided through previously autonomous tasks (Schein & Rauschnabel, 2023). Similarly, the application of augmented reality that presents simple and common-sense information was

perceived to increase workers' fear of paternalism, that is, being limited or overruled by technology (Schein & Rauschnabel, 2023). These negative perceptions may contribute to resistance to new safety technology.

For technologies that involve a wearable component, the voluntariness of use was perceived as an important factor for adoption (Strawderman et al., 2025). For instance, if workers perceive that they are being forced to use the technology, and if there are perceptions that the technology will be used for purposes other than safety, acceptance of technology may be negatively impacted.

### 7.1.6 External influences

External influences for the adoption of innovative safety technologies include the influence of industry clients, government agencies and regulators, and trade unions. The promotion of new technologies at external events such as trade shows can facilitate PCBUs to identify technological solutions for safety issues (Arabshahi et al., 2022). Support from external parties such as clients, the government, developers and suppliers, and ministerial authorities could also facilitate widespread adoption of these innovative technologies (Arabshahi et al., 2022). For example, as a main client for construction projects, government agencies could encourage the adoption of technology on their worksites, enabling a top-down approach to adoption across the construction sector (Yap et al., 2023). Client demand to use new safety technologies, and the adoption of technologies by industry competitors may also motivate PCBUs to adopt safety technologies (Arabshahi et al., 2022; Perera et al., 2025). However, for the construction sector, the temporary nature of projects may be a barrier to adoption of technology (Ibrahim et al., 2025), whereby the perceived cost and time loss for a short-term project could overrule safety benefits.

Government policies, regulations, and industry standards may also be relevant factors to encourage the adoption of new safety technologies (Jenuwa et al., 2025; Perera et al., 2025; Tabatabaee et al., 2022). The absence or inadequacy of government policies and incentives for adoption of emerging safety technologies may be a barrier to adoption by PCBUs (Tabatabaee et al., 2022). Conversely, pressure from government mandates and regulations may facilitate the adoption of safety technology through requirements for compliance (Perera et al., 2025). However, in a study that ranked the strategies that influenced the adoption of safety technologies in construction, regulatory frameworks and standards were rated as less important compared to strategies like training and education, and communication and collaboration (Jenuwa et al., 2025). Trade unions may also oppose the introduction of mandates for sensing technology, given that it involves data collection from individuals, which might impose on worker rights (Arabshahi et al., 2022).

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## 7.2 Technology introducing new safety hazards

The adoption of new safety technologies has many benefits and may minimise the risk of injury from moving parts, mobile plant, and other machinery. However, the adoption of new technologies may also introduce new hazards, which based on the literature, is relevant for consideration when implementing safety management systems. For example, the use of head-mounted augmented reality designed to improve hazard detection, may actually impair hazard identification in complex and intense situations (J. Liu et al., 2024). Wearable sensors, such as RFID tags embedded into a wristband (Chacón et al., 2025), may cause skin irritation, or chemical or thermal burns based on the use of a battery (Howard et al., 2022). System malfunction may also create physical safety risks such as electrical hazards (EU-OSHA, 2025).

Workers may also experience frustration related to equipment malfunctions, and the continuous monitoring and alert systems in place, representing psychosocial risks that could increase stress or other mental health issues (EU-OSHA, 2025). The constant monitoring of data via a central computer may cause increased screentime and cognitive workload for operators and WHS professionals, which could contribute to information overload and fatigue (Regazzoni & Spryridopoulos, 2024). Additionally, if the purpose of the safety technology is not communicated and integrated effectively, workers may perceive that they are being monitored for performance evaluation (Regazzoni & Spryridopoulos, 2024; Spryridopoulos & Broughton, 2024), which could cause

psychosocial harm (Regazzoni & Spryridopoulos, 2024). Previous research conducted by SafeWork NSW included the design of an AI WHS Scorecard, which provides a framework for PCBUs to explore the WHS risks associated with implementing an AI-based solution, and could assist PCBUs and workers in minimising related hazards and harms of new safety technologies (Cebulla et al., 2021).

### 7.2.1 Overreliance on technology

The use of digital technologies as engineering or isolation controls can also cause PCBUs and workers to become over-reliant on technologies as safety measures. This can be problematic, especially considering technologies can be prone to information mistakes (Schein & Rauschnabel, 2023), and malfunction. For instance, an AI system could incorrectly identify a worker engaging in an 'unsafe' behaviour. If this data is relied upon without seeking direct feedback from the worker or other operational infrastructure (e.g., standard CCTV), it could lead to unfair disciplinary action or sub-optimal decision-making (Hess, Skoczylas, et al., 2024; Jenuwa et al., 2025). The training of AI models can also be influenced by social and cognitive biases, which may lead to unfair targeting of certain worker groups (Jenuwa et al., 2025). Moreover, if workers and other individuals have limited training or technical skills related to safety technology, there is a risk of misinterpreting system data (Regazzoni & Spryridopoulos, 2024), or for the implementation of technology to create extra work (Foster, 2025). In line with these concerns, an EU-OSHA implementation guide notes that these safety technology systems "can augment but not replace existing occupational safety and health procedures" (Nicosia et al., 2025, p. 7).

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## 7.3 Encouraging adoption of new safety technology

Several sources outlined aspects of practice that they identified as effective for encouraging adoption of new safety technology. The suggested aspects in the literature generally use a participatory approach between PCBUs, workers, and technology suppliers, and acknowledge the training requirements and limitations of implementing safety technologies.

### 7.3.1 Prioritising adoption based on highest risk areas

When scoping potential safety technologies to adopt, PCBUs could assess the general climate for technology adoption within their organisation (Schein & Rauschnabel, 2023) and prioritise applications based on the existing work systems with the highest safety risk (Foster, 2025). Within this scoping process, it is suggested by the literature that there should be ongoing collaboration between PCBUs, workers, and product developers to ensure that implemented safety systems address the specific risks present in each workplace (Hess, Spryridopoulos, et al., 2024). Solutions may be evaluated based on their integration with existing safety systems, ease of use, and previous evidence of effectiveness (Foster, 2025; Hess, Spryridopoulos, et al., 2024; Howard et al., 2022) before complete adoption into a workplace. It is also important for PCBUs and workers to manage expectations related to the effectiveness of the system, such as recognising that there are limitations to every implemented safety system (Nicosia et al., 2025). Conducting WHS risk assessments via a framework such as the AI WHS scorecard (Cebulla et al., 2021), can also ensure that the limitations and impacts of a new safety technology are carefully considered during the adoption process.

### 7.3.2 Involving workers in adoption

The literature suggests that workers and their representatives should be involved in the process of technology adoption, especially if the technology has a component that will be attached to the worker, such as wearable sensors (EU-OSHA, 2025; Howard et al., 2022). This participatory approach could involve consultation sessions, trial periods of the technology, regular and improved communication and collaboration between individuals in the workplace, and general transparency during the adoption process (Hess, Spryridopoulos, et al., 2024; Howard et al., 2022; Jenuwa et al., 2025; Schein & Rauschnabel, 2023). An example of a trial period includes the placing of safety

technologies in common areas (e.g., staff rooms) so that workers can test them and provide feedback (Nicosia et al., 2025). The socio-cultural context of the workers and/or the organisation could also be considered when adopting new technologies, such as considering worker age or experience with technology (Nicosia et al., 2025).

For wearable technologies, PCBUs could consider voluntary participation at an initial stage of adoption, to help demonstrate 'quick wins' and encourage more widespread adoption of safety technologies (Howard et al., 2022). However, when considering voluntary or gradual adoption, it was identified in literature that PCBUs should ensure that the responsibility for worker safety does not shift from the collective to the individual (Hess, Skoczylas, et al., 2024).

### 7.3.3 Providing comprehensive training and resources

The adoption of new safety systems requires PCBUs to ensure proper training, coaching, feedback, and informational resources are provided to workers and other users (EU-OSHA, 2025). Training and education may be most effective when it is ongoing, such as through refresher courses and training updates when technology may be updated (Jenuwa et al., 2025). Resources for workers could be kept short and simple, relevant to the main job processes, and should clearly explain the purpose, use, and limitations of the adopted safety system (Nicosia et al., 2025). More complex documentation regarding the intricacies of the safety technology could be developed for individuals such as WHS professionals (e.g., HSRs) or technical staff (Nicosia et al., 2025). Training could include multimedia strategies, on-the-job training, or 'walk and talk' strategies where workers can be shown the safety technology applied in real-time (Nicosia et al., 2025).

### 7.3.4 Ensuring data security and privacy

Identified sources highlight that data outputs and storage should conform to the latest data governance and cybersecurity requirements (Howard et al., 2022). Australian legislation and standards related to data governance and cyber security are emerging (e.g., Cyber Security Act 2024), and several principles have been outlined by Stepanovic et al. (2023) and other sources relevant to the application of smart technologies in a WHS context. These principles outline that any data collected should be lawful, fair and transparent, workers should be informed and consent to data collection, and data should only be collected and stored as adequate and necessary for a specified purpose. Several sources highlight that PCBUs should communicate all aspects of data collection and storage to workers, including how their data will be used and who owns the data (Hess, Spryridopoulos, et al., 2024; Howard et al., 2022; Skoczylas, 2024; Stepanovic et al., 2023). Data analysis and visualisation could also facilitate ongoing data-driven decision-making (Jenuwa et al., 2025); the use of data for these purposes should also be communicated to workers and other individuals in the workplace. Based on the principles proposed in literature, the data collected should also only be stored for as long as necessary and be protected from unauthorised or unlawful processing, accidental loss, destruction, or damage (Stepanovic et al., 2023).

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## 7.4 Considerations for WHS regulators

In the context of the adoption of new safety technology, several sources highlighted specific considerations for WHS regulators and inspectors (Bragatto & Ansaldi, 2022; Hess, Skoczylas, et al., 2024; Jenuwa et al., 2025). Safety technologies should be integrated by PCBUs in the context of the hierarchy of controls and regulators could be mindful to ensure that the responsibility for a safe working environment remains primarily on the PCBU (Hess, Skoczylas, et al., 2024).

There is a need for technical regulations and standards to be updated at the pace of the evolution of technology (Bragatto & Ansaldi, 2022), particularly in relation to cybersecurity requirements (Jenuwa et al., 2025). Regulators could ensure compliance with updated technological standards through regular inspections and certifications (Jenuwa et al., 2025). Inspectors could also consider potential overreliance on safety technologies and consider emerging technologies as a support to existing safety controls rather than as a replacement (Hess, Skoczylas, et al., 2024).



# Conclusion

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## 8.1 Key findings

The literature review suggests that people and plant separation is typically controlled through safety technologies that minimise access to dangerous areas and through detection systems embedded within mobile plant. Minimising access to dangerous areas often utilises vision-based or location-based technology (or a combination of both) to define dangerous areas and detect when individuals are within the area. Detection systems use a variety of sensor-based technologies; augmented reality may also be an emerging technology for enhancing the visual field of operators within a worksite.

Identified technologies for preventing access to moving parts of machinery rely primarily on sensor-based technology. This builds upon existing guidance, whereby presence-sensing systems detect when an individual enters a defined area of a dangerous zone. There is some evidence that vision-based technology can be used to prevent access to moving parts of machinery and limited evidence for technologies to identify personnel who engage in risky behaviour, such as removing machine guards. The limited evidence for this topic may reflect the well-established use of presence-sensing devices such as light curtains, laser scanners and foot pressure mats, where physical guards are not reasonably practicable.

Vision-based technologies were an emerging technology for detecting use of PPE, such as safety helmets, safety vests, gloves and glasses, and seatbelts. The detection of correct use of PPE and seatbelts via a vision-based technology system, such as AI cameras, could also be linked to alarms or door systems.

Technology adoption is influenced by many factors, including the characteristics of the technology itself, cost, data and privacy concerns, organisational and user readiness, and the external environment. The adoption of new safety technologies may also create new WHS hazards and contribute to an overreliance on technology in lieu of other safety controls.

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## 8.2 Limitations

This literature review comprised multiple broad areas of WHS and was not focused on a particular sector or industry. While efforts were made to report the breadth of new and emerging safety technologies, it is infeasible to cover every technology available. As such, the report focuses on the most relevant and frequently reported technologies for each focus topic area. Case studies were chosen to demonstrate various applications of technologies in different sectors.

To capture the most recent developments, identified technologies were limited to those published within the last five years. This ensures that the review captured the most recent and emerging technologies. However, it may have missed foundational literature. However, consultation with subject matter experts and project sponsors was used to cross-check the relevance of the technologies identified within this literature search.

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## 8.3 Implications for practice

The literature review and synthesis of the sources discussed in this report suggests that:

- Adoption of safety technology could be considered for the work systems of highest risk, since application in these areas may be most acceptable to workers and other individuals within a workplace.
- Organisational readiness and culture are important factors for adoption. PCBUs who wish to adopt technology could assess existing IT infrastructure and technical capabilities to ensure successful adoption of safety technologies.
- PCBUs could aim to understand potential errors or limitations of the implemented technology and have systems in place to control for errors if they arise.

- PCBUs could be mindful of the creation of new safety risks upon the implementation of safety technologies. Appropriate safety risk assessments should be conducted upon adoption of any new technology.
- Safety technologies should not be implemented as complete replacements for existing safety systems. Instead, as suggested by the literature, safety technologies could be used to augment existing systems, to ensure that PCBUs and workers do not become reliant on technologies.
- Workers should be involved in processes of technology adoption, such as through collaboration and consultation, user testing and trial periods, and overall transparency.

# 9

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