Global Safety Evidence Centre

Foundation

The impact of emerging technology on safety at work

- Safe Work
- Evidence Review
- Briefing

1. The quick read

A review of the evidence on the impact of emerging technologies on safety at work found that:

- **The evidence base is patchy,** with newer technologies lacking in high-quality studies.

- **The evidence comes mainly from high-income countries** and focuses on some workers and occupations which may not be those most affected.

- **Emerging technologies can provide high quality data for evaluations**, but few of them are used to understand worker safety.

- **Research and regulation are not keeping up** with the pace of technological change. Practitioners' experience of testing new technologies is crucial for identifying opportunities and risks.

There is evidence that some technologies are safe and effective, while others may present unintended risks for workers:

- **Smartphone apps** may encourage managers to prioritise safety, promote healthy habits in workers and improve wellbeing, although there is mixed evidence of their effect on performance or sickness rates.

- **Augmented Reality (AR) and Virtual Reality (VR)** may improve workers' engagement in learning and motivation to apply safety knowledge, although there is mixed evidence that they improve safety knowledge on their own.

- **Wearable devices, Algorithmic Management and Emotional Artificial Intelligence (AI)** may have negative impacts on workers' health and on relationships at work, but design improvements and collaborative implementation may reduce these risks.

- **Collaborative robots (cobots)** could have benefits and risks for worker safety, but the evidence base is not developed enough.

Technologies have the potential to make transformational changes to safety at work, but more high-quality evaluations are needed to give employers confidence to implement them.

2. Why this is important

New technologies are revolutionising the world of work and have the potential to transform how we support the safety of workers.

Digital and automated technology can warn workers of nearby hazards, carry out dangerous tasks, and create virtual worlds that prepare workers for real-life emergencies. New technologies can also pose new risks for workers, including to their psychological and emotional health, and create workplace tensions.

Organisations are adopting new technologies for both safety and other purposes, but they often lack knowledge about their impact. To ensure workers benefit from these new technologies, researchers and regulators need to provide evidence of their effectiveness and advice on how to implement them.

Innovations in engineering and workplace culture can and have transformed workplace safety. By learning from the past, we can ensure emerging technology is designed and used in ways that support safe work for everyone in the future.

We wanted to understand what is known about the effect of key technologies on worker safety, and the evidence gaps that still need to be filled.

Emerging technologies that affect worker safety

'Emerging technology' refers to new or rapidly developing tools and processes that are growing in use but still not widespread or fully understood. They may be designed specifically to improve safety, or they may affect safety while having other uses.

Safetytech are technologies designed to improve safety. For example:

- **Smartphone apps** warn of environmental safety conditions or prompt people to adopts healthy habits.
- **Augmented and Virtual Reality** is used to simulate situations and carry out safety training.
- **Wearable devices** can monitor workers' temperature or heart rate or track their location in hazardous environments.
- **Robots, 'cobots' and drones** which undertake dangerous tasks instead of or alongside people.
- **Digital twins** (digital representations of industrial systems) to monitor risks in real-world settings.

Technology designed for other purposes, but which has an impact on worker safety, includes:

- **Algorithmic management** uses software to assign tasks and assess performance of workers.
- **Emotional AI** uses machine learning to monitor workers' emotional state.
- **Internet of Things technology** to enable connected devices to communicate and automate tasks, and to capture real-time safety data.
- **Autonomous vehicles** used in transportation and logistics, which may pose safety risks.

3. The research

Researchers from RAND Europe mapped the evidence on the interaction between emerging technologies and occupational safety and health, reviewed the evidence for key sectors, and brought in expert voices through interviews and a workshop.

3.1 Mapping the evidence base

The primary aim of this review was to scope the extent of existing knowledge and assess the nature and quality of the evidence. Initially over 1.2 million studies published in English between 2021 and 2024 were identified. After being ranked by relevance the 'meta-data' (titles, abstracts and keywords) for 2,000 studies was analysed to provide an overview of the evidence landscape, helping to inform the selection of topics for the evidence review.

Using Artificial Intelligence to review the evidence

The evidence base on his topic is growing rapidly – the initial searches found around 1.2 million results. New tools are used to manage and make sense of this complex and growing field.

The research team used artificial intelligence (AI) tools to:

1. Develop a **clustering map of the evidence** based on the abstracts of 2,000 studies. Summaries of the main themes were generated, providing an overview of the evidence landscape.

2. **Retrieve information** from the study abstracts and thematic clusters based on questions asked by the researchers. This created concise answers with references to the evidence.

The research team used these tools to **refine the search terms** and exclude topics which were not relevant to the research questions. Researchers thoroughly reviewed the included studies identified by these AI tools.

3.2 Focus on specific sectors

The research team drew on 91 relevant academic and grey literature studies about six emerging technologies. They are a mix of 'safetytech' designed to support worker safety and other technologies with safety implications

3.3 Evidence from practice

The research team conducted seven expert interviews and a workshop with practitioners and experts in occupational safety and technology. These conversations brought in further insights, identified gaps and helped validate the findings of the review.

4. The findings

New technologies are used both to improve productivity and to protect worker safety, but while their adoption is growing quickly, the evidence base is not keeping up with the pace of change.

The more established technologies, such as smartphone apps and AR and VR, have some robust research showing positive impacts, but this is not the case for newer tools.

Much of the evidence is focused on concerns about the technology without looking at its effects on safety. This makes it difficult to weigh up the benefits and potential risks, and to implement new processes in a way that works for workers and employers.

Emerging technologies have the potential to generate rich data for evaluations, but they are currently not being used to understand worker safety.

Studies should continue to gather evidence on unintended consequences for different groups of workers as well as the acceptability of new technologies in different settings. The evidence base shows that unintended risks can often be managed with better design and collaborative implementation.

The safety impacts are not the only important part of the evidence base. We also need to know how to implement them and address unintended impact. We can learn from how workplaces have managed the transition to new technologies in the past to ensure implementation works well.

Overview of the evidence base for each technology type

Technology	Volume of evidence	Quality of evidence	Type of evidence
Smartphone applications	Moderate	Moderate to high	RCTs and pilot evaluations, systematic reviews
Augmented and Virtual Reality	Moderate	Moderate	Some RCTs and systematic reviews
Algorithmic Management	Moderate	Low	Primarily qualitative, some reviews, focused on the gig economy
Wearable devices	Low	Low	Some worker surveys, focused on acceptability
Collaborative robots (cobots)	Low	Low	Little empirical research
Emotional AI	Low	Low	Little empirical research

4.1 Smartphone apps

Smartphone apps are used to prevent and manage safety and health risks in the workplace. They include apps used by the general public to support health, as well as specially designed workplace apps. They are often combined with training or other support.

- **Where they are used:** Across a range of occupations and settings including offices and high-risk sectors such as construction, agriculture, transport and policing.

- **How they are used:** To guide or prompt healthy behaviours or warn of workplace risks such as hot conditions. Often used in combination with training or other support.

Effectiveness	Workplace context
May lead managers and supervisors to prioritise worker safety (leading to reduced heat strain, improved healthy habits, lower blood pressure in workers).	The HEAT app warned and advised agriculture supervisors of hot conditions.

Training and an app for supervisors in construction was linked to an increase in support for healthy lifestyles of workers. |
May encourage workers to adopt healthy habits (sleep, diet, alcohol, physical activity).	In one study no change was found to sedentary behaviour while at work, indicating desk-workers' limited agency to increase their activity levels.
May improve workers' mental health and wellbeing (lower stress, reduced burnout, depression).	Apps may work best in combination with classes or other support.
No or mixed evidence of changes to worker performance or reductions in sickness absence.	

4.2 Augmented and Virtual Reality

Augmented reality (AR) and virtual reality (VR) are artificial environments that allow people to interact with simulated or real objects and scenarios.

- **Where they are used:** In a range of occupations including high-risk sectors such as construction, manufacturing and transportation.

- **How they are used:** To deliver training, including in using machinery, spotting hazards and responding to emergencies.

Effectiveness	Workplace context
May support better engagement, learning, and participation in safety training.	A systematic review found improved engagement across thirteen industries.
Mixed evidence that AR/VR improves knowledge acquisition compared to traditional training.	One meta-analysis study found a positive user experience but no effect on knowledge acquisition.
Workers may be more motivated to apply safety knowledge.	An RCT of construction workers showed improved knowledge of workplace hazards.

4.3 Algorithmic Management

Algorithmic Management systems use software to carry out tasks previously done by human supervisors. Their main priority is efficiency and they are generally not focused on workers' safety and health.

- **Where they are used:** Widely used in digital labour sectors (for example rideshare driving and other gig economy jobs) and are also used in customer service, transport, logistics, banking and health care.

- **How they are used:** to assign and organise work, track, monitor and manage workers via dedicated platforms or apps.

Effectiveness	Workplace context
May increase stress and social pressures for workers and lower wellbeing.	Qualitative evidence from rideshare drivers shows they feel pressured to take on high or unpredictable workloads. Lack of transparency in how workers are assessed may lead to increased stress. Findings from a European survey shows a link with lower levels of wellbeing across all sectors.
Mixed evidence on increased autonomy and control.	Some gig economy workers experience lack of job autonomy and control over tasks, while others report higher autonomy in being able to select shifts.
May weaken relationships between workers and managers and lower trust in employers.	An imbalance in power between workers and the management platforms causes many to feel cheated or exploited. Workers trust human managers to make decisions in their and the organisation's interest but are wary of errors in the algorithms. Management platforms act as a social barrier between workers and employers.
Collaborative agreement on how they are used may reduce these risks.	In a case study of a call centre in Germany workers and employers agreed that the technology would only be used at an aggregate and not individual level.
Better design may reduce these risks.	Rideshare drivers identified adaptations that would make the technology more acceptable, including enabling peer-to-peer communication and introducing nudges to promote wellbeing. A study from Japan found algorithms designed in one country may not conform to cultural work practices of another.

4.4 Wearable devices

These are technologies that are worn to track people's physical and mental state. They include smartwatches and smartphones, heart rate monitors with Bluetooth, shoe inserts with sensors, and exoskeletons. They are commonly used by the general public and in health settings, and increasingly in workplaces.

- **Where they are used:** across occupations and sectors, including construction and healthcare.

- **How they are used:** to alert workers to hazards in their environment or when they are wearing the wrong safety equipment. To monitor workers' health or psychological wellbeing, stress or fatigue.

Effectiveness	Workplace context
Very limited evidence means we can't be sure of their effect on worker safety, and there is mixed evidence on their acceptability.	A study from the USA and Finland showed workers are willing to use wearables for OSH purposes, while others showed workers were more reluctant.
May increase work pressures and add to work-related stress.	There are concerns about privacy and excessive surveillance.
May increase complacency about safety risks.	They are perceived to push the burden of OSH management onto workers rather than employers.

There is a risk that too much trust is placed on devices, leading to safety risks that are not captured being neglected. |

4.5 Collaborative robots (cobots)

In contrast to industrial robots, which operate independently and often separately form workers, cobots work alongside humans in shared workspaces and tasks. They rely on sensors to locate and respond to workers around them.

- **Where they are used:** in a range of sectors including manufacturing, food production, packing, pharmacy and healthcare.

- **How they are used:** some examples include preparing and distributing medication and handling clinical samples or assisting workers in high-pressure environments.

Effectiveness	Workplace context
Very limited evidence means their effect on worker safety isn't known.	Studies explore: • Sustainability and productivity impacts. • How to integrate them into existing assembly lines. • How they work together with other technologies such as digital twins (digital representations of industrial systems).

4.6 Emotional Artificial Intelligence (AI)

This refers to the ability of machines to detect and interpret someone's emotional state using sensors and machine learning.

- **Where it is used:** in a range of sectors including desk-based occupations (office and remote workers), customer service and healthcare.

- **How it is used:** some examples include identifying the mood of employees through cameras or audio, monitoring workers' attentiveness, detecting the tone of customer service interactions, and using an AI chatbot to identify patterns associated with workplace harassment.

Effectiveness	Workplace context
May enable employers to identify health and wellbeing issues.	Emotional AI was implemented during Covid-19 to spot signs of ill health in remote workers.
May increase workers' stress and anxiety.	Workers reported having to engage in additional 'emotional labour' to remain positive even when faced with stressful situations or abusive customers.
Workers may adapt their behaviour in response.	Workers reported suppressing their true emotions to preserve their privacy.
May erode trust, weaken relationships at work.	Workers saw Emotional AI as a sign of lack of trust from their employers. A survey found that workers feared it would worsen power imbalances.
Better design may reduce bias.	In theory Emotional AI could remove human biases, but studies reported female workers' concerns that they reinforce existing bias and discrimination.

CASE STUDY: A pilot to explore robotic hull cleaning and inspection technology

This review explored the existing literature surrounding the impact of emerging technology on safe work. Through the exploration of technologies such as cobots, which can be used to replace humans in completing dangerous or tedious tasks, it outlined a range of potential applications for these technologies.

A pilot collaboration between Safetytech Accelerator, Cargill and Alicia Bots as part of the Waypoint: Maritime Risk programme provides more details on how robots can be used to avoid occupational risks, as well as improve shipping efficiency.

The challenge:

Seafaring ships accumulate marine organism growth on their hulls, leading to increased drag and lower speed and efficiency over time.

Hull cleaning is generally carried out by underwater divers when a ship is at port. Manual cleaning creates safety risks for workers and increases the time a ship needs to stay in port. Most European ports prohibit full hull cleaning.

The technology:

This pilot tested the RoverClean robot developed by Alicia Bots on two bulk carriers as they sailed between Singapore, Panama and the US over a period of 5 months. By deploying a robot at sea, workers were protected from the risks of cleaning and time spent at port was reduced.

The device was attached to the hull and used cameras and SONAR to detect damage, identify barnacle growth and use brushes to remove it. The robot was able to inspect 100 metres of hull in 45 minutes and maintain visibility even in dark waters.

The pilot identified areas where the robot design and materials could be improved.

The impact:

- By deploying a robot at sea, workers were protected from the risks of cleaning and time spent at port was reduced.
- The tech company has begun providing cleaning services and training in ports in Asia and the Americas so crews can operate the robots themselves.
- They have also made design improvements to the robot and developed adaptations which may allow them to operate in European ports in the future.

Most ships clean their hulls only after fuel use rises by 7–15%. Having a hull cleaning robot permanently located on a ship could allow for more frequent inspections, cleaning and greater compliance with regulations.

5. Recommendations

Researchers, evidence and practitioners all have a role to play in how we respond to the opportunities and risks presented by emerging technologies:

Filling the evidence gaps

1. Primary studies should focus on how safetytech interventions impact worker safety.

2. Research should explore the impacts of workplace technology on safety and other outcomes and consider how different groups of workers or occupations are affected.

3. Evidence is needed on how adaptations, design improvements and implementation guidance can reduce the risks of harm and make new technology more acceptable.

4. Better understanding is needed on how and why technology affects safety, so theories of change should be developed and tested as part of primary studies and reviews.

Research priorities

This review focused on six key technologies, but evidence is also needed on other **emerging tech interventions**, such as:

- Generative AI and AI productivity tools
- Autonomous vehicles and transport safety
- The Internet of Things
- Smart education
- Digital twins

Additionally, research is needed on how **different occupations and workers** are affected by emerging technologies and how the design of those technologies can distribute safety benefits across all workers.

Collaborating with practitioners, workers and tech innovators

5. As these technologies are being implemented rapidly, practitioners, workers and tech innovators can provide essential early information to inform research and guidance.

6. Practice examples should be analysed for insights into the implementation of safetytech and how to support innovation and scaling.

Collaboration Case Study: 'Smarter Regulation Sandbox'

This review highlighted the potential utility of collaborations between regulators, practitioners and industry to share knowledge, data and best practice on emerging technology and safe work.

One example of how collaborations can improve evidence-informed practice is the 'Smarter Regulation Sandbox (SRS)' approach run by the Safetytech Accelerator.

The programme brings together regulators, tech companies and industry to test how digital technology can make it easier to access health and safety regulation information to improve and speed up compliance, improve efficiency and productivity and reduce burdens on industry.

The Sandbox approach provides a safe space to share knowledge, explore opportunities for improvement and identify barriers.

SRS is part of the Discovering Safety programme run by the UK's Health and Safety Executive (HSE) and funded by Lloyd's Register Foundation.

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The Lloyd's Register Foundation Global Safety Evidence Centre is a hub for anyone who needs to know 'what works' to make people safer. The Centre collates, creates and communicates the best available safety evidence from the Foundation, our partners and other sources on both the nature and scale of global safety challenges, and what works to address them. It works with partners to identify and fill gaps in the evidence, and to use the evidence for action.

To find out more about the Global Safety Evidence Centre, visit *gsec.lrfoundation.org.uk*

About Lloyd's Register Foundation

Lloyd's Register Foundation is an independent global safety charity that supports research, innovation, and education to make the world a safer place. Its mission is to use the best evidence and insight to help the global community focus on tackling the world's most pressing safety and risk challenges.

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