Creating the first Industrial Safetytech Regulatory Sandbox for the UK Construction sector

Regulators' Pioneer Fund Round 3 project

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Report number: SDD/OTH/2023/01

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Date of Issue:	3 October 2023
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Project number:	PE20703

Acknowledgments

The project team would like to thank the HSE and Industry mentors for their support and contribution to this project, without which the Sandbox would not have been possible.

Thanks go to Alexandra Neal, Chis Lucas, Chis Steel, Darren Nash, Gavin Bull, Gordon Crick, Jean-Philippe Gorce, Nicholas Hall and Sam Bradbrook from HSE.

And to Laurence Webb, Jeremiah To, Andrew Rippington, Rohail Latiff, George Mosey, James Hickman, Keith Prince, Mike Phillips, Craig Streak, Jake Harrison, Rob Cairns, Mark Saunders, Vaibhav Tyagi, Simon Langley, Arjun Thirunavukarasu, Richard Roft and Adam McMahon, who acted as industry mentors.

The project team would like to acknowledge the Department for Science, Innovation and Technology's Regulators' Pioneer Fund for supporting and funding this project and for more generally encouraging the exploration of innovative approaches to regulation in the UK.

Key Messages

The Industrial Safetytech Regulatory Sandbox, funded by the Regulators' Pioneer Fund[1], provided a successful framework for HSE to explore the potential for new technology to help improve health and safety performance and compliance.

HSE worked with the Safetytech Accelerator (STA) as a delivery partner and several companies from the UK construction sector to identify a set of health and safety challenge areas to be explored in the Sandbox.

Six tech companies, from an initial field of over 200, were chosen via the Sandbox selection criteria to participate in investigative studies exploring these challenges. These were:

Eave - Using intelligent hearing protection to explore how continuous monitoring of noise on worksites changes the game for countering Noise Induced Hearing Loss.

Flyd - Exploring how the adoption of AI technologies across the construction industry can drive dynamic risk assessment and improved safety outcomes.

HAL Robotics - Using modular software and adaptive programming to explore how increasingly flexible and collaborative robots should be regulated.

Machine Eye - Identifying and countering the key blockers to the uptake of computer vision within the construction sector.

PLINX - Using wireless sensors to create zonal working standards to establish a stronger connection between the design and construction phases of projects and empower data-driven decision-making.

Oculo - Using digital twins to build risk identification into the design and construction of projects.

The Sandbox investigative studies explored the opportunities for improving health and safety, and the specific barriers to adoption associated with each technology application. An additional set of 19 cross-cutting barriers were also identified and grouped into the themes of technical, financial or cultural issues.

Feedback from the Sandbox participants was sought, and it was noted that the Sandbox had accelerated the ability of four of the tech companies to work in a new sector, allowed one tech company to identify and implement new features for their product, and fostered an open and constructive environment for working with the regulator across all the industry and tech companies involved.

A set of 10 recommendations are suggested for government, industry and the tech sector to improve technology adoption in the construction sector.

[1] The Regulators' Pioneer Fund is delivered by the Department for Science, Innovation and Technology. The RPF is a grant-based fund to enable UK regulators and local authorities to help create a UK regulatory environment that encourages business innovation and growth. The current £12m round is being delivered by DSIT.

Executive Summary

HSE was awarded funding from the third round of the Regulators' Pioneer Fund (RPF), run at that time[2] by the Better Regulation Executive (BRE), to create the first Industrial Safetytech Regulatory Sandbox (ISRS) for the UK construction sector. The RPF is a grant-based fund to enable UK regulators and local authorities to help create a UK regulatory environment that encourages business innovation and growth. The current £12m round is being delivered by DSIT.

The aim of the ISRS project was to explore the opportunities for improvements in health and safety performance and compliance using Industrial Safetytech (IS), and to understand the barriers to adoption of these new technologies by industry. The project aimed to use a Sandbox approach to develop recommendations for the health and safety system, government, and industry to help accelerate improvements in the workplace through the use of technology.

The ISRS project set about establishing a Sandbox environment to enable HSE, as the regulator, and key construction sector stakeholders to come together and work collaboratively with technology companies. The goal was to explore the potential of new technologies to address a set of defined health and safety risks in a structured way. The Sandbox was not about suspending established regulations or trialling new ones, nor was it about technology field trials. This Sandbox was run as a desk-based set of investigative studies to collaboratively explore the defined challenges, including the practicalities of overcoming barriers to adoption of IS in specific contexts across the construction sector.

The project was led by HSE and delivered with the Safetytech Accelerator (STA). It combined HSE's regulatory expertise and construction industry networks with STA's expertise and contacts across the global safetytech sector to deliver the project. Six investigative studies were identified and run through the Sandbox process; each was led by a tech company supported by mentors from HSE and industry.

A framework was established to identify appropriate health and safety challenges for the Sandbox; this involved canvasing HSE and construction industry views and then applying a set of prioritisation criteria to ensure we had areas that were regulatory priorities for HSE, of interest to industry and where there was a viable technology application.

Over 200 tech companies were initially identified through the open call published by STA. STA then applied a set of selection criteria, reducing this to a short list of 20 organisations covering a wide range of industrial safetytech, including Robotics, Drones, Computer Vision and Wearables amongst others. From this shortlist, 12 organisations were invited to pitch their proposals on how their technology could address one of the priority health and safety challenges.

Six tech companies were invited to join the Sandbox and work on investigative studies to address these challenges. The six companies and the technology solutions they provide

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[2] The Regulators' Pioneer Fund is now delivered by the Department for Science, Innovation and Technology (DSIT)

are shown below, along with a summary of their investigative study and headline recommendations.

Company	Technology	Investigative study focus	Summary of Recommendations
EAVE	**Smart ear protection** which continuously collects data on environmental noise and the wearer's exposure to noise linked to their movements around workplaces; the technology also incorporates an online platform for viewing the data and gathering insights.	How can technology help earlier identification of Noise Induced Hearing Loss (NIHL) and contribute to its prevention. Is it reasonably practicable to implement as a control measure in place of traditional hearing protection? And how should guidance on what is "reasonably practicable" be updated to account for technological advancements in hearing protection.	**HSE** should consider integrating data from smart hearing protection platforms into their guidelines for noise exposure. Also explore whether smart hearing protection data could be used to replace traditional methods of noise exposure assessment. **Industry** should address NIHL underreporting, including how insights from smart hearing protection data can inform the development and implementation of more effective and targeted noise control measures.
FYLD	**Analytical digital platform** that automatically transforms video and audio footage into real-time workflow and risk assessments.	Exploration of barriers to adoption of point of works dynamic risk assessment technologies using AI to support health and safety management by contractors working on UK construction projects.	**HSE** should convene an industry and tech sector focus group to continue exploring the utilisation of technology, through use cases to demonstrate how compliance can be achieved and to close the gap on regulator and industry understanding. **Industry** should work with FYLD to co-develop an AI Digital Training Programme and seek to share content at scale, to break down the barriers to the use of AI in industry.
Hal Robotics	**Extensible and modular software** which facilitates inter-device communication, adaptive programming of robot tasks, and motion planning for one or	Exploration of opportunities for use of reprogrammable robotic automation technology to support works on construction projects. Exploration of barriers to adoption linked to how use of such software is	**HSE** should explore options for simplified access to information to guide the certification of a robotic cell. **Industry and the tech sector** should explore building a tool to simplify access to the regulatory information required for certification when

Company	Technology	Investigative study focus	Summary of Recommendations
	many robots working together.	regulated and certified for use in UK construction.	designing and building robotics systems.
Machine Eye	**Computer vision** system that uses AI techniques to identify humans in real-time and understand their likely interaction with vehicles, heavy plant or machinery, enhancing safety at people-plant interfaces.	Exploration of barriers to adoption of computer vision technology to support safe operation of heavy vehicles, plant and machinery on UK construction sites.	**Government** should provide financial incentives to promote and accelerate AI adoption in the construction sector, particularly on Government infrastructure projects. **HSE** should support SME tech companies through Sandboxes and Knowledge Exchange opportunities and be more proactive and timelier in issuing clarification with respect to new technologies. **Industry** should explore collaborative approaches to highlight best practice and work collectively through innovation zones and Sandboxes.
Oculo	**Digital Twin** development using SLAM (Simultaneous Localisation and Mapping) and photogrammetry to document a worksite and create a 3D model that can facilitate collaboration.	Opportunities for use of SLAM technology to support compliance with CDM regulations over the lifecycle of construction projects, incl. in design and construction phases, and once asset is operational	Project currently ongoing.
PLINX	**Wireless sensors** designed to make construction sites safer by restricting access to areas of hazardous activity based on role and purpose.	Exploration of the use of wireless sensor technology to support active monitoring of zonal working procedures on construction projects, with the potential to create a technology-supported cross-industry zonal working standard for use by the UK construction industry.	**HSE** should work with industry to develop industry-wide standards for zonal working. **Industry and the tech sector** should develop a digital tool to simplify and standardise the zonal working process.

The six tech companies invited to join the Sandbox

Feedback was sought from all the participants involved with the project and will be used to improve any further Sandbox initiatives undertaken. In summary the Sandbox was seen as a success by all involved and helped:

- accelerate the development of new business areas, for example for EAVE, FYLD, Machine Eye and PLINX
- facilitate an open exploration of solutions between Industry and tech companies without the pressure to sell or build business cases for investment
- encourage a new way to work with the regulator to explore options, barriers and opportunities collaboratively

Contents

1 Background to work

HSE was awarded funding from the third round of the Regulators' Pioneer Fund (RPF), run at that time[3] by the Better Regulation Executive (BRE), to create the first Industrial Safetytech Regulatory Sandbox (ISRS) for the UK construction sector. The RPF is a grant-based fund to enable UK regulators and local authorities to help create a UK regulatory environment that encourages business innovation and growth. The current £12m round is being delivered by DSIT.

This project aimed to create a unique environment to explore the opportunities for industrial safetytech to improve health and safety performance and compliance in construction, and to understand the barriers to adoption in that sector. It ran from January to August 2023 and was led by HSE in partnership with the Safetytech Accelerator (STA). This report describes the process of designing the Sandbox, the roles played by the regulator, the construction industry and the SME tech community, and presents the findings and recommendations from the Sandbox.

1.1 The scale of the health and safety challenge

Health and safety performance across Great Britain (GB) has seen significant improvements over the last thirty years. However, recent HSE statistics show that over a million workers are still injured or made ill through their work each year. These cases of injury and ill-health pose a significant burden on individuals and their families, employers, government and wider society. Due to the diverse range of health and safety risks faced by its workers, the GB construction sector is particularly impacted. These risks include those linked to working at height, manual handling, working in the vicinity of moving vehicles, work with heavy plant and machinery, and activities exposing workers to hazards such as noise, vibration and dust. Monetary costs incurred by GB society linked to construction work-related injury and ill-health are estimated to be of the order of £700 million annually.

1.2 Wider context on innovation and regulation in the UK

The UK government's UK Innovation Strategy, Industrial Strategy and National AI Strategy collectively set out the UK's vision to:

- make the UK a global hub for innovation by 2035 (referenced in the UK Innovation Strategy)
- put the UK at the forefront of the industries of the future, ensuring that it takes advantage of major global changes, improving people's lives and the country's productivity (referenced in the Industrial Strategy),
- support the transition to an AI-enabled economy, capturing the benefits of innovation in the UK and ensuring all sectors and regions benefit from AI (referenced in the National AI Strategy)

In addition, in an independent report published by the Department for Business, Energy and Industrial Strategy in June 2022, recommendations were made by the Regulatory Horizons Council regarding how best to enable industrial innovation through regulation. Central to all the recommendations was government, regulators, industry and innovators

[3] The Department for Science, Innovation and Technology now deliver the Regulator's Pioneer Fund.

working more collegiately to create an environment that fosters industrial innovation. Specifically, recommendation 9 of the report advocated that:

> "regulators and policymakers should make more use of regulation that is explicitly adaptive, i.e. designed to change over time and avoid rigidity. This includes more use of experimental approaches such as Sandboxes and scaleboxes, and also includes greater sharing of information to build best practice in the use of such tools."

and recommendation 12 that:

> "regulators should share their experiences of collaboration and co-creation, with a view to developing their tool kit, so these techniques can be more used both domestically and internationally. The Government (Better Regulation Executive / Brexit Opportunities Unit) should design a regulatory pathway that takes into account not just what but also how that regulatory intervention has been developed. This includes considering the extent to which regulation has been developed in collaboration, and the way that collaboration has been done (specifically how inclusive it has been beyond incumbents)."

The HSE strategy Protecting People and Places, 2022-2032, also recognises in its vision and strategic objectives that the world of work is changing, and there is a need to keep pace with change and recognise the importance of enabling industry to innovate.

1.3 Industry 4.0 and the use of Industrial Safetytech

The way technologies are used to support operations in industrial workplaces has been subject to major change throughout history, and this change continues at pace today. The last technology revolution was characterised by the widespread emergence of computer-controlled systems and automation within workplaces. The current revolution, often termed the fourth industrial revolution, introduces the concept of cyber-physical systems; essentially, networked integrations of complex physical plant and machinery, sensors and computer software, often communicating and sharing information wirelessly via the internet. Technologies of the fourth industrial revolution are transforming how workers, equipment and processes operate collectively in industrial workplaces. They are enabling a range of industrial processes to be digitalised, joined up and then their delivery to be significantly augmented and, in some cases, completely automated. Common application areas in the workplace include supply chain management, process optimisation, production efficiency maximisation, quality assurance, logistics, plant maintenance and workplace security.

The rise of technologies of the fourth industrial revolution in workplaces is also having major effects on workplace health and safety, and the consensus is that this is only likely to gather pace. ***Industrial Safetytech*** (IS) is the collective term for innovative technologies, products and services linked to the fourth industrial revolution when used to support health and safety risk management and regulation within workplace settings. These include technologies such as wireless sensor networks, wearable devices, digital twins, exoskeletons, autonomous systems, drones, augmented and virtual reality, artificial intelligence, computer vision and advanced data analytics. The market for IS is forecast to expand rapidly, led by start-ups and innovators applying technologies in a diverse range of work scenarios to address key industrial health and safety challenges. A recent report on the emergence of the IS market, published by Lloyd's Register Foundation in 2020, estimated that the combined global market potential could be as much as $863 billion by 2023.

1.4 Industrial Safetytech adoption in the Construction Sector

Industrial Safetytech (IS) offers the potential to improve health and safety performance across the construction sector on multiple fronts. For example, it offers opportunities for clients, designers and contractors working on projects to improve health and safety outcomes through better contracting and procurement on projects, and through better design, planning, management, monitoring and co-ordination of works. Use of IS also offers opportunities to improve how health and safety risks are dealt with, including prioritising the elimination and reduction of risks over control measures through use of administrative processes and personal protective equipment. A good example is the use of technology to automate construction work tasks, totally removing humans from those tasks and, therefore, the risks to them. Used in a regulatory context, IS also affords opportunities to enhance how construction health and safety is regulated. Examples include making the regulatory process less burdensome for both HSE and businesses, and making the detection of regulatory non-compliance and demonstration of ongoing compliance easier. However, realising the full potential that adoption of IS offers requires that the practical barriers to industry adoption are addressed. Such barriers include:

- **Legal Barriers** - how the development and usage of different tech fits into current legal frameworks
- **Financial Barriers** - costs of piloting and formal deployment, ability to build business cases and demonstrate return on investment
- **Technology Barriers** - a lack of awareness of different solutions and their application. Low readiness for implementation of such solutions in the health and safety domain. The practicalities of embedding technology in day-to-day industrial/health and safety operations and the challenges of implementing the necessary digital transformation. The digitising of regulation, compliance, enforcement and assurance and the development of machine-readable regulations, standards, good practice and day-to-day operations.
- **Governance Barriers** - data governance, data handling, legacy IT systems. GDPR, privacy and security considerations. Public/workforce perceptions associated with different technologies including ethical considerations, e.g. linked to privacy, rights and equality particularly with respect to use of AI, wearable and tracking technologies.

1.5 The health and safety regulatory regime in Great Britain

1.5.1 ALARP (As Low As Reasonably Practicable) principle

The health and safety regulatory regime in Great Britain is goal-based in nature, in contrast to the health and safety regimes operated in other countries which are often much more prescriptive. The system in GB is founded on the principle of allowing duty holders flexibility as to how best they mitigate health and safety risks to meet their statutory responsibilities. HSE supports duty holders in their legal duties through the provision of industry guidance, informed in part by learning accrued from investigations carried out following serious health and safety incidents. It monitors whether industry is meeting its statutory responsibilities by undertaking a programme of targeted workplace inspections. When serious material breaches in health and safety legislation are observed in workplaces, then commensurate prosecution action is taken.

The goal-based system of health and safety regulation in GB requires HSE to clearly define the credible bounds of acceptable health and safety performance for a given area of industrial operations. From a legal standpoint, this is recognised to be where residual health and safety risks, following steps taken by an employer to mitigate them, are judged to be at a level that is “reasonably practicable”. In practice, judging whether a risk is “as low as reasonably practicable” (or ALARP) often requires one or a combination of:

- referral to existing industry standards,
- benchmarking against recognised industry best practice, or
- a direct comparison of risk versus sacrifice by way of a formal cost-benefit analysis.

Two well-recognised merits of the health and safety regulatory system in GB are: 1) that it is responsive to changes in recognised good practice, and 2) it encourages innovation in the approach to managing health and safety risk. However, it does pose its own set of challenges, particularly where the introduction of new technologies has the potential to also introduce new risks into workplaces or provide new opportunities to manage risks in a better way. In these two situations, a key challenge facing both the regulator and regulated is deciding whether any health and safety risks from the use of a new technology are as low as reasonably practicable. This is because, unlike for established technologies, industry standards often do not exist, best practices are often not yet defined and the implications of processes going wrong are often not fully characterised.

1.5.2 Construction (Design and Management) Regulations

The Construction (Design and Management) Regulations 2015 (CDM) are a fundamental set of regulations for the construction industry in GB. For clients, principal designers and principal contractors working on construction projects, the regulations require projects to be designed, planned, managed, monitored and co-ordinated so that foreseeable risks to health and safety are eliminated wherever possible. Where this is not possible, steps must be taken to reduce or control them. The regulations apply to all phases of a project, including preconstruction phases, once works have started, and once the assets being built are commissioned or decommissioned.

Fundamental to the CDM regulations is that health and safety risks are managed by applying what are known as *general principles of prevention*. These set out the principles that dutyholders should use in their approach to identifying the measures they should take to control risks to health and safety linked to works on a particular project. Central to the general principles of prevention is the avoidance of risks where possible, evaluation of those risks that cannot be avoided, and implementation of proportionate measures that control them at source. CDM 2015 requires designers, principal designers, principal contractors and contractors to take them into account in carrying out their duties.

The general principles of prevention are to:

- avoid risks;
- evaluate the risks which cannot be avoided;
- combat risks at source;
- adapt the work to the individual, especially regarding the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view to alleviating monotonous work;
- work at a predetermined rate to reduce effects on health;
- adapt to technical progress;
- replace the dangerous by the non-dangerous or the less dangerous;
- develop a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment;
- give collective protective measures priority over individual protective measures;
- give appropriate instructions to employees.

The general principles of prevention are often represented figuratively as a hierarchy of risk controls, see Figure 1. As you move up the hierarchy, the effectiveness of a given risk control strategy increases. Figure 1 also attempts to locate different categories of digital technology on the hierarchy of controls, based on the way a technology aims to mitigate a risk, e.g. eliminate or reduce risk is at the highest level, isolating workers from risk through an engineering control is mid-way on the hierarchy, and information about risks, so that steps can be taken by individual workers to protect themselves, sits at the bottom of the hierarchy.

Technology examples

Eliminate risk through design, planning using BIM, digital twins

Substitute humans with tech e.g. drones, robots, cobots

Wireless sensor networks, IIoT

Enhanced training and instruction using VR/AR, Enahnced KM using Regtech, Robotic process automation, Common data environments

Wearables, computer vision

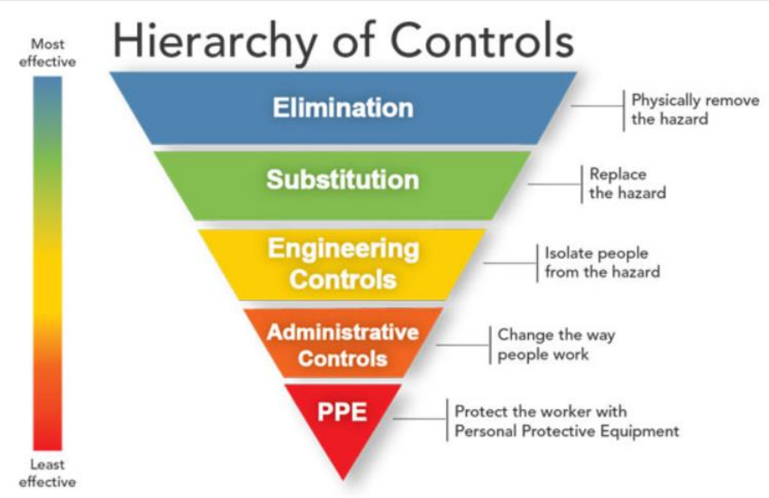


Figure 1 – The hierarchy of control of health and safety risks.

1.6 Discovering Safety programme

The HSE Science and Research Centre has been delivering the Discovering Safety programme for several years. Discovering Safety is funded by a grant from Lloyd's Register Foundation and aims to deliver step change improvements in health and safety performance globally through the use of data and new analytical techniques. Discovering Safety is currently focused on the construction industry and is supporting this sector to exploit datasets and emerging digital technologies more effectively, enabling better-informed health and safety decision-making.

At the centre of Discovering Safety are a range of construction industry-endorsed use case projects, which have been developed with active and engaged industry stakeholders to address specific current challenges. Discovering Safety also has an innovation strand which connects with small tech companies creating innovative approaches that can be tested for application to health and safety. The RPF ISRS project has been able to leverage these diverse networks from across the GB construction and SME tech sectors to benefit delivery and impact for businesses.

Discovering Safety has previously developed a strategic relationship with the SafetyTech Accelerator to help explore and deliver innovation projects. The SafetyTech Accelerator is a not-for-profit organisation established by Lloyd's Register and the Lloyd's Register Foundation. It is the first fully dedicated technology accelerator focused on safety and risk in industrial sectors and has a mission to make the world safer and more sustainable through wider adoption of industrial safetytech. SafetyTech Accelerator focuses its R&D efforts around eight core technologies: Analytics, AI, Computer Vision, AR/VR, Sensors, Wearables, Drones and Robotics. It operates globally, supported by extensive technical and commercial networks and, since its inception in 2018, has engaged over 600 early-stage technology businesses and launched more than 20 cutting edge innovation pilots, including three delivered as part of Discovering Safety.

2 Overview of the ISRS project

2.1 Project aims

The aim of the Industrial Safetytech Regulatory Sandbox (ISRS) project was to explore the opportunities for improvements in health and safety performance and compliance using Industrial Safetytech (IS), and to understand the barriers to adoption of new technologies by industry. The project aimed to take the Sandbox approach to developing recommendations for the health and safety system, government and industry to help accelerate improvement in the workplace.

The Industrial Safetytech Regulatory Sandbox set about establishing an environment whereby the regulator and key construction sector stakeholders could come together and work collaboratively with technology companies, exploring the potential of new technologies to address a set of defined health and safety risks in a structured way. The Sandbox was not about suspending established regulations or trialling new ones, nor was it about technology field trials. This Sandbox was run as a desk-based set of investigative studies to collaboratively explore the defined challenges, including the practicalities of overcoming barriers to adoption of IS in specific contexts across the GB construction sector.

The project was led by HSE and delivered with the Safetytech Accelerator (STA). It utilised HSE's expertise in the health and safety regulatory domain and its construction industry networks alongside STA's expertise and contacts across the global safetytech sector to deliver the project. Six investigative studies were identified and run through the Sandbox process; each was led by a tech company supported by mentors from HSE and industry.

2.2 Project approach

The project team from HSE and STA worked with construction industry stakeholders and the tech community to consider how adoption of IS across the GB construction industry in specific contexts might be accelerated. The project was split into the following tasks:

Defining the challenge areas

- Initial scoping and definition of health and safety regulatory challenge areas by HSE
- Mobilisation of construction industry partners and wider interested groups to directly participate in a Sandbox
- Viability checking and further development of challenge areas with industry partners
- Drafting of challenge statements for consideration by the tech community

Designing the Sandbox

- Review of other Sandbox initiatives and identification of best practice and lessons learnt.
- Identification of different broad technology solutions options
- Sourcing of long list of technology solutions providers
- Shortlisting of tech providers to participate in a Sandbox
- Setting up of Sandbox environments, including the design of Sandbox investigative studies

Running the Sandbox

- Running the Sandbox investigative studies including engagement, mentoring, and reviewing progress

- Capturing lessons learned for each discrete project run through a Sandbox
- Synthesis of lessons learned across Sandbox studies

Recommendations and Dissemination

- Wider industry consultation, canvassing of wider industry opinion on Sandbox project findings, wider mobilisation of interest in the Sandbox initiative
- Reporting of findings, opportunities and recommendations
- Planning and delivery of the final dissemination event

Further detail on these tasks is provided in the following sections of this report.

3 Sandbox challenges

3.1 Identifying the health and safety priorities

Initially, HSE specialists were consulted to identify their priority risks for inclusion in the Sandbox. These included representatives from HSE's Construction Division Inspectorate team and Technology and Innovation Unit, HSE Science Division's Futures team and technical specialists, plus HSE's Policy Division. A series of facilitated group workshops and one-to-one discussions were held to gain opinions from the subject matter experts on the priority risk areas for the Sandbox.

Following the HSE consultation exercise, targeted industry engagement and consultation was then undertaken separately. A total of 26 tier 1 contractors, clients, industry associations, trade bodies, research networks and communities of practice were approached. The industry stakeholders included contacts of HSE's Construction and Science Divisions, including several current contributors to Discovering Safety. The industry consultation also took the form of one-to-one discussions, to enable industry contributors to talk openly and honestly about key challenges, plus facilitated group workshops. The 26 organisations that took part are listed in Annex A.

A good level of similarity was found between the risk identified through each consultation, which provided reassurance that the areas identified would be the most appropriate from a priority and an engagement point of view. In addition, a selection of HSE regulatory data was also analysed to identify the most prevalent accident and incident types occurring over the last seven years. This information was also used as part of the prioritisation process and agreed with the priorities emerging from the consultation exercise, giving further reassurance that the correct risk areas were going into the Sandbox. Analysis of the HSE data is shown in detail in Annex B.

HSE and industry contributors to the consultation exercise were also invited to act as mentors to the tech companies for the Sandbox Investigative Studies .

3.2 Framework for prioritising challenge topics

The intelligence gathered from the consultation work with HSE and industry, along with analysis of HSE regulatory intelligence, enabled a list of priority risk topics, opportunities and challenges to be developed. This prioritised list was shared with the team from Safetytech Accelerator who used it to start the process of longlisting the technology companies.

To facilitate the identification of the final challenge topic areas for the six Sandbox investigative studies, a prioritisation framework was developed built around the key considerations for delivering a successful, impactful study. These were:

1. Size of health and safety benefits potentially realisable linked to the challenge area in the event of it being tackled effectively through use of a technology
2. Practical challenge of undertaking a successful investigative study as part of the Sandbox
3. Health and safety rationale for intervention linked to the challenge area
4. HSE interest in tackling challenge area
5. Industry interest in tackling the challenge

Details on each priority area are described in Table 1 below:

A framework for prioritising challenge areas
Size of health and safety benefits potentially realisable? • Addressing a challenge area where the burden of injury, ill-health or other adverse consequence linked to challenge area is high, size of benefit potentially realisable by better managing risk linked to challenge area is high
Practical challenge of undertaking a successful investigative study as part of the Sandbox? • Known to be a host of technology solutions out there to address challenge area, on verge of breaking onto market, at a suitably high TRL • Practicalities of running a successful study around challenge area, given funding/time available to study, given ability to source required subject matter expertise within HSE/from industry
H&S rationale for intervention linked to challenge area? • Addressing a challenge area higher up hierarchy of risk controls, i.e. eliminating or reducing risk, better than informing workforce about risk, and controlling via engineering controls, PPE • Addressing a challenge area earlier in the lifecycle of construction project, i.e. preconstruction (in design, planning), better than during construction, better than once asset is operational/commissioned
HSE interest in tackling challenge area? • Challenge area linked to a risk topic of strategic priority for HSE • Challenge area linked to a risk topic where associated levels of regulatory non-compliance are high • Challenge area linked to a complex regulatory landscape (health and safety, and wider), in terms of range of regulations in scope, ISO standards, industry guidance, therefore ripe for dealing with through Sandbox • Challenge area not politically sensitive for HSE currently
Industry interest in tackling challenge area? • Challenge area linked to a risk topic of high priority to industry • Challenge area linked to an area of health and safety management improvement of particular interest to industry, e.g.: ○ better risk assessment of works ○ safer works (linked to human performance, competence) ○ safer works (linked to operation of plant, machinery, equipment, tools) ○ better supervision of works ○ better engineering controls linked to works ○ better monitoring and assurance of risk controls linked to works (active/reactive monitoring, active/passive monitoring) ○ better HS arrangements in event of a loss of control

Table 1 – Prioritisation framework.

3.2.1 Challenge topics identified by HSE

The consultation exercises identified a set of risks which were then initially prioritised by the HSE and STA team using the above prioritisation framework, the results from the HSE consultation are shown in Table 2.

	Priority after application of framework	Key reasoning for prioritisation	Potential categories of technology solution able to tackle challenge area
		Safety	
Work with heavy plant and machinery risk of struck by, contact with	Y	Big risk challenge for sector (risk of fatal/major injury)	IIoT, computer vision, drones
Temporary works risk of structural collapses	Y	Big risk challenge for sector (risk of fatal/major injury)	IIoT, computer vision, drones
Working at height risk of fall from height	Y	Big risk challenge for sector (risk of fatal/major injury) Big compliance challenge for sector	IIoT, computer vision, drones
Building fire (post Grenfell)	N	Regulatory sensitivity, remit of BSR	
Ground excavation works risk of underground service strikes	N	Regulatory sensitivity, remit of NUAR initiative	
		Health	
Asbestos Asbestos related diseases	Y	Big risk challenge for sector (potential fatal health consequence)	Exposure & personal monitoring tech, wearables
Silica dust Occupational respiratory diseases	Y	High strategic priority for HSE	Exposure & personal monitoring tech, wearables
Noise, Vibration Noise induced hearing loss, Hand arm vibration syndrome	Y	Big risk challenge for sector (chronic health consequence)	Exposure & personal monitoring tech, wearables
Stress, fatigue	Y	High strategic priority for HSE	Exposure & personal monitoring tech, wearables
Manual and material handling	Y	High strategic priority for HSE	Wearables, exoskeletons

Musculoskeletal injuries			

Table 2 – Priority risks from HSE consultation exercise.

3.2.2 Challenge topics identified by Industry

The results of the industry consultation are shown in Table 3. This identified challenge areas linked to effectiveness of specific health and safety management arrangements routinely employed on projects, which can be mapped onto the HSE risks in Table 2.

Challenge areas linked to specific health and safety management arrangements	Priority after application of framework	Key reasoning for prioritisation	Potential categories of technology solution able to tackle challenge area
Exclusion of workers from hazardous areas on site, site traffic management, implementation of zonal working procedures	Y	Significant industry interest in area, reduce risk through better risk control	Drones, computer vision, IIoT
Compliant behaviours in frontline workforce, management and supervision of frontline workforce	Y	Industry interest in area, reduce risk through better discipline	Behaviour monitoring, IIoB
Dynamic risk assessment process, generation of risk assessment method statements	Y	Industry interest in area, reduce risk through better administration	Regtech
Design for health and safety, digital rehearsal of works	Y	Significant industry interest in area, potential to eliminate risk through design	BIM, visualisation
Management of change on projects	N		Challenge more for Enterprise Project Management solutions rather than small tech?
Safety linked to use of connected and automated plant	Y	Significant industry interest in area, potential to eliminate risk through removal of human from loop	Automation, robotics, cobots
Offsite manufacturing, modular construction	N		Challenge more for innovations in manufacturing rather than small tech?
Project data analytics	Y	Industry interest in area, reduce risk through better administration	Advanced analytics, predictive analytics, machine learning

Challenge areas linked to specific health and safety management arrangements	Priority after application of framework	Key reasoning for prioritisation	Potential categories of technology solution able to tackle challenge area
Site inspection, active monitoring	Y	Industry interest in area, reduce risk through better administration, potential to remove human from loop	Drones, computer vision, IIoT

Table 3 - Industry challenges linked to specific health and safety management arrangements.

3.3 Identification of technology solutions and providers

With a series of challenge areas identified from the HSE and industry prioritisation work, STA were able to start the process of identifying technology companies with potential solutions in scope. An open process was followed to ensure that any organisation could have responded and/or the tech companies participating had the knowledge or assets that meant they are suited to the challenges selected. The steps of the process were as follows:

- Identification of technology and challenge brief
- Identification of solution providers to form the longlist
- Longlist narrowed against criteria
- Shortlist take part in a pitching event
- Select final companies for the Sandbox

A range of marketing and communication activities were initiated by STA to encourage technology companies to get involved. This included creating a dedicated website to allow companies to express an interest in participating in the Sandbox and to provide high level details of their technology solutions and the specific health and safety use cases they were designed to tackle. STA also conducted targeted outreach activity across the UK tech community. From this activity an initial longlist of over 200 companies potentially in scope was compiled by STA.

3.3.1 Shortlisting of the tech companies

Considering the timeframe of the project, it was decided that six investigative studies would be a reasonable number to include in the Sandbox. It was agreed that this would provide wide coverage of risks and technology applications but be achievable.

The initial step was for STA to reduce the longlist of over 200 companies down to 20. The criteria for achieving this involved a tech company having:

- technology potentially able to help HSE innovate in how it regulates the construction sector
- technology potentially able to help duty holders to innovate in meeting regulatory responsibilities, prevent accidents, better manage risks
- technology needing regulatory input to take it to market, release investment funds etc.
- technology needing the regulator to consider the implications of its routine use in construction health and safety contexts

Additional criteria included:

- whether or not the technology directly targeted a risk or challenge area of interest to the project
- the technology of interest was a stand-alone product
- the company was UK-based or had a UK office
- the technology was ‘product ready’ with an established market, not in the R&D stage
- the tech company had a reference customer
- the tech company had an interest in participating in an industrial safety tech and regulatory initiative such as this
- the tech company was regarded by STA as possessing the organisational capacity (generally, sufficient staff) to deliver a successful investigative study in the time available

Each of the 20 tech companies on the shortlist were mapped to one or more of the challenge areas previously identified by HSE and industry stakeholders, as shown in Table 4 below.

HSE - Safety	**Tech companies identified**
Work with heavy plant and machinery, risk of struck by, contact with	**9 companies**
Temporary works, risk of structural collapses	9 companies
Working at height, risk of fall from height	
HSE - Health	**Tech companies identified**
Asbestos, asbestos related diseases	1 company
Silica dust, Occupational respiratory diseases	
Noise, vibration, noise induced hearing loss, hand arm vibration syndrome	2 companies
Stress, fatigue	1 company
Manual and material handling – musculoskeletal injuries	
Industry - Challenges linked to health and safety management	**Tech companies identified**
Exclusion of workers from hazardous areas on site, site traffic management, implementation of zonal working procedures	9 companies
Compliant behaviours in frontline workforce, management and supervision of frontline workforce	2 companies
Dynamic risk assessment process, generation of risk assessment method statements	3 companies
Design for health and safety, digital rehearsal of works	2 companies
Safety linked to use of connected and automated plant	2 companies
Project data analytics	2 companies
Site inspection, active monitoring	8 companies

Table 4 – Mapping of the 20 technology companies to challenges areas.

The HSE and STA teams then worked together to reduce the 20 tech companies down to a list of 12 to invite to the pitching session. To achieve this, the project team went back to HSE colleagues to gather opinions on specific technology solutions and also to confirm the availability of an HSE subject matter expert to act as a mentor in the next stages of the work. Both the prioritisation framework described in Section 0 and the criteria used by STA to shortlist tech companies described above were used to generate the shortlist of 12 companies.

These 12 companies were then invited to formally pitch their solutions to the project team at an event held in March 2023. The process to get to the final six companies is summarised in Figure 2 and further details are provided of each stage in Annex C.

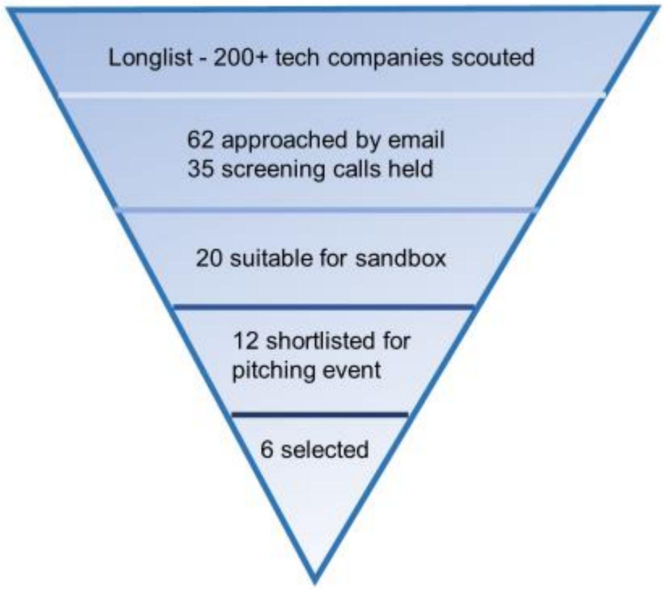


Figure 2 – Schematic to illustrate the shortlisting of tech companies for the Sandbox.

3.3.2 The Pitching event

The 12 shortlisted tech companies were invited to a pitching event hosted online on 28 March 2023. They were asked to evidence how their technology solutions could be used to help the UK construction sector in tackling one or more of the challenge areas and were invited to suggest a set of research questions, linked to these, that they would be interested in addressing through the Sandbox.

The audience for the pitching event was the project team along with HSE and industry subject matter experts. The attendees scored each tech company pitch using a standard score card. After the pitch event, information from all scorers was compiled and the final shortlist of six companies agreed. The evaluation criteria used for the pitching event are shown in Figure 3.

The final six were notified of their selection and a collaboration agreement was signed between them and STA. The six companies joined the Sandbox from April to work on their investigative studies.

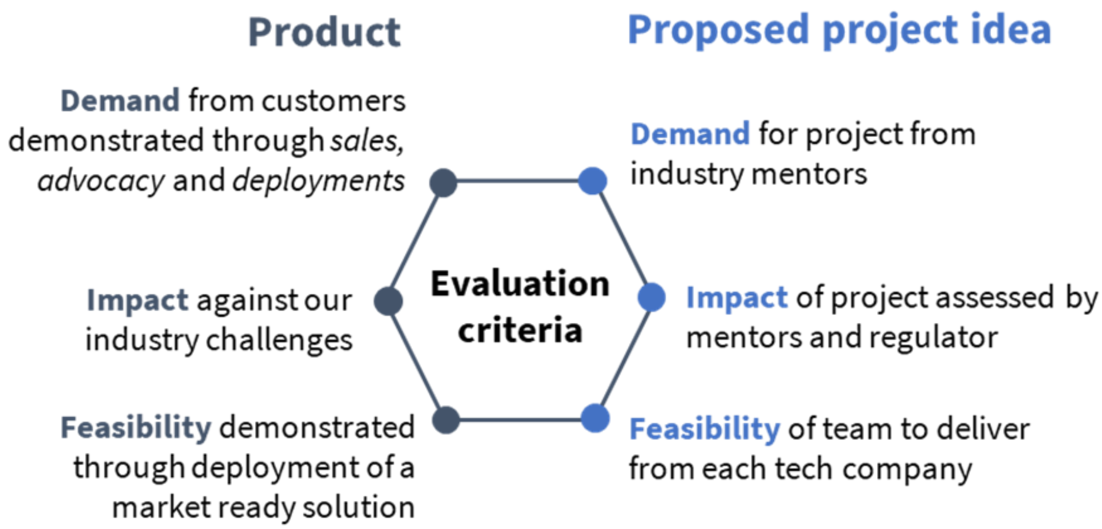


Figure 3 – Evaluation criteria for pitching event.

The six companies selected from the pitching event are shown mapped against the challenges in Table 5 below.

Challenge	Key reasoning for prioritisation	Technology solution	Technology companies selected
Work with heavy plant and machinery, risk of struck by, contact with	Big risk challenge for sector (risk of fatal/major injury)	IIoT, computer vision, drones	PLINX , Machine Eye
Noise, vibration, noise induced hearing loss, hand arm vibration syndrome	Big risk challenge for sector (chronic health consequence)	Exposure & personal monitoring tech, wearables	Eave
Exclusion of workers from hazardous areas on site, site traffic management, implementation of zonal working procedures	Significant industry interest in area, reduce risk through better risk control	Drones, computer vision, IIoT	PLINX , Machine Eye,
Dynamic risk assessment process, generation of risk assessment method statements Project data analytic	Industry interest in area, reduce risk through better administration	Regtech Advanced analytics, predictive analytics, machine learning	Fyld
Design for health and safety, digital rehearsal of works	Significant industry interest in area, potential to eliminate risk through design	BIM, visualisation	Oculo

Challenge	Key reasoning for prioritisation	Technology solution	Technology companies selected
Safety linked to use of connected and automated plant	Significant industry interest in area, potential to eliminate risk through removal of human from loop	Automation, robotics, cobots	HAL Robotics

Table 5 - Industry challenges linked to specific health and safety management arrangements.

An overview of each of the companies' technology and their suggested research questions pitched at the March event are shown in Table 6 below, further details are given in Annex D.

PLINX
Overview of technology
PLINX is a safety system using wireless sensor technology designed to make construction sites safer; the system protects construction workers by restricting access based on role and purpose to areas of hazardous activity.
Focus of investigative study
• Exploring opportunities for use of wireless sensor technology to support active monitoring of zonal working procedures on construction projects • Potential to create a technology-supported cross-industry zonal working standard for use by the UK construction industry

Machine Eye
Overview of technology
Machine Eye employs deep learning AI techniques to identify humans in real-time and understand their likely interaction with vehicles, heavy plant or machinery, to assist, inform and support decision-making linked to how works can be carried out safely at people-plant interfaces.
Focus of investigative study
• Exploration of barriers to adoption of computer vision technology to support safe operation of heavy vehicles, plant and machinery on UK construction sites

EAVE
Overview of technology
The EAVE system comprises smart ear defenders which continuously collect data on environmental noise and the wearer's exposure to noise linked to their movements around workplaces; the technology also incorporates an online platform for viewing the data and gathering insights; the system helps prevent excessive levels of noise exposure by identifying those workers at higher risk and capturing intelligence about how their exposures can be prevented at source, or reduced through changes to working practices.
Focus of investigative study

• How can EAVE technology help earlier identification of problem cases of Noise Induced Hearing Loss (NIHL)? • How can smart hearing protection technology contribute to the prevention of NIHL, and is it reasonably practicable to implement it as a control measure in place of traditional hearing protection? • How should guidance on what is "reasonably practicable" be updated to account for technological advancements in hearing protection, and what are the implications for businesses and regulatory bodies?

FYLD
Overview of technology
FYLD is a digital platform that automatically transforms video and audio footage captured by a frontline worker about to start a work task, into a real-time workflow and risk assessment; through the use of innovations in data science, analytics and AI the platform transforms health and safety procedures that were previously heavily paper-based and bureaucratic into an exercise where the focus is on instilling safe working practices in workers about to start a work task.
Focus of investigative study
• Exploration of barriers to adoption of point of works dynamic risk assessment technologies using AI to support health and safety management by contractors working on UK construction projects

Hal Robotics
Overview of technology
HAL Robotics is an extensible and modular software which facilitates inter-device communication, adaptive programming of robot tasks, and motion planning for one or many robots working together.
Focus of investigative study
• Exploration of opportunities for use of reprogrammable robotic automation technology to support works on construction projects • Exploration of barriers to adoption linked to how use of such software is regulated and certified for use in UK construction • Are current regulations a barrier to use of the technology by the UK construction industry?

Oculo
Overview of technology
Oculo apply elements of SLAM (Simultaneous Localisation and Mapping) and photogrammetry to create an automated process that documents a worksite and creates a 3D model that can facilitate collaboration.
Focus of investigative study
• Opportunities for use of Simultaneous Localisation and Mapping (SLAM) technology to support compliance with CDM regulations over the lifecycle of construction projects, incl. in design, construction and once asset is operational

• Design – Analyse how 3D visual risk registers can enable designers to capture and annotate potential hazards in a more comprehensive, intuitive manner, examine how visual risk registers can facilitate smoother project handover • Construction – Use of 3D visual risk registers in the construction phase, how registers can be updated to reflect changing site conditions, potential to enhance H&S inductions for new teams, help streamline work sequences • Operational – Use of 3D visual risk registers in the operations phase for maintenance work planning, examine use for safe works planning, reducing need for preparatory site visits • Surveying – Use of 3D visual risk registers in surveying work, how preparatory work can be streamlined through remote environmental H&S assessments using visual captures, potential for more detailed, visual reports of H&S issues to enable safer and more efficient future work, e.g. in asbestos surveys

Table 6 – The six companies selected from the pitching event.

4 Designing the Sandbox

4.1 Learning from other Regulatory Sandbox initiatives

As part of the Sandbox design process STA undertook a review of other UK Sandbox initiatives, with a view to learning lessons on best practice. The full review is published in Annex D. Highlights include:

- A regulatory Sandbox is typically a controlled environment in which innovative businesses can test their products, services, or business models in a limited, supervised way without being subject to full regulatory compliance. However, in scenarios where it is not possible to relax regulation in a live environment, regulatory Sandboxes offer the opportunity for regulators and industry to collaborate and explore the interaction between technology and regulation, with the aim of fostering greater productivity on both sides through better guidance, more efficient regulatory compliance and closer integration of relevant regulation into product roadmaps.
- Regulatory Sandboxes are becoming popular because they allow start-ups and innovators to test new products and services in a safe and controlled environment, reducing the regulatory burden and costs associated with compliance. This can accelerate innovation and bring new products and services to market faster, benefiting consumers and the economy.
- Regulatory Sandboxes also allow regulators to gain insights into emerging technologies and business models, enabling them to adapt regulations and policies to keep pace with innovation.
- The first 'Sandbox-like' initiative was created in 2012, although the term "regulatory Sandbox" was not coined until 2015. Since then, there have been six regulatory Sandboxes either mobilised or planned in the UK, not including HSE's own programme; see Table 7 below.
- STA analysed existing Regulatory Sandboxes from key regulators to gain lessons that could be applied when designing the Industrial Safetytech Regulatory Sandbox. The Sandboxes reviewed involved the following regulators: Financial Conduct Authority (FCA), Office of Gas and Electricity Markets (Ofgem), Information Commissioner's Office (ICO), Care Quality Commission (CQC), Civil Aviation Authority (CAA), Office for Nuclear Regulation (ONR).

Authority	**Date started**	**Rounds run**	**Average participants per round**
Financial Conduct Authority (FCA)	2016	8	12
The Office of Gas and Electricity Markets (Ofgem)	2017	2	5
Information Commissioners Office (ICO)	2019	2 (including 1 beta)	10
Care Quality Commission (CQC)	2019	3	
Civil Aviation Authority (CAA)	2021	2	6
Office for Nuclear Regulation	Received funding in late 2022	-	-

Table 7 - Summary of regulatory Sandboxes in the UK

Key considerations were identified around the development of challenges, participant sourcing, and value proposition and design.

Challenge and cohort development

There's a difference in approach between the regulators in terms of the level of structure implemented in the challenges. The FCA has been successful in holding a relatively open-ended approach, partly because there has been a critical mass of Fintech start-ups who are keen to test their solutions against regulatory compliance elements. Others, such as the ICO, concluded that they needed to drive greater strategy and clarity at the front end of the Sandbox to produce a portfolio of projects that better represented their aims. The CAA started out by stipulating clearly what they wanted from the market and produced a cohort that tackled those specific aims.

Sourcing and qualification

Qualifying applicants is a crucial step for a Sandbox – the key here is for regulators to focus on the requirement for and potential exploitation of the Sandbox in the qualification phase, as much as evaluating the solution itself.

Value proposition and design

The value proposition and make-up of the Sandbox is key to being able to attract quality organisations and ideas into the Sandbox. Ensuring that one structures both the support and the marketing material around the wants and needs of tech companies (e.g. market acceleration) is critical; many won't have initially considered the regulatory issues relating to their product or the value of engaging with the regulator.

Input to the ISRS

The following key points were incorporated into the design of the ISRS:

- HSE should allow the market to drive the direction of the Sandbox to a degree, but in most cases an understanding of the priority areas for research prior to release of challenges will enable the regulator to scope the direction of the Sandbox, be it around certain regulatory challenges or technologies.
- Putting in an 'expression of interest' stage either formally or informally, by conducting initial engagements with prospective companies to better understand their needs and ambitions within the Sandbox.
- Ensure the needs and wants of the tech companies and industry are included in the value proposition for the Sandbox.

4.2 Sandbox Design

The Sandbox was designed as a series of stage and gate activities to ensure progress could be closely tracked and monitored. The development and sign off of the statement of work (SoW) from each tech company was Gateway 1, with Gateway 2 being the delivery of the investigative study report. A summary of the Sandbox design in show in Figure 4 and the timeline is shown in Table 8.

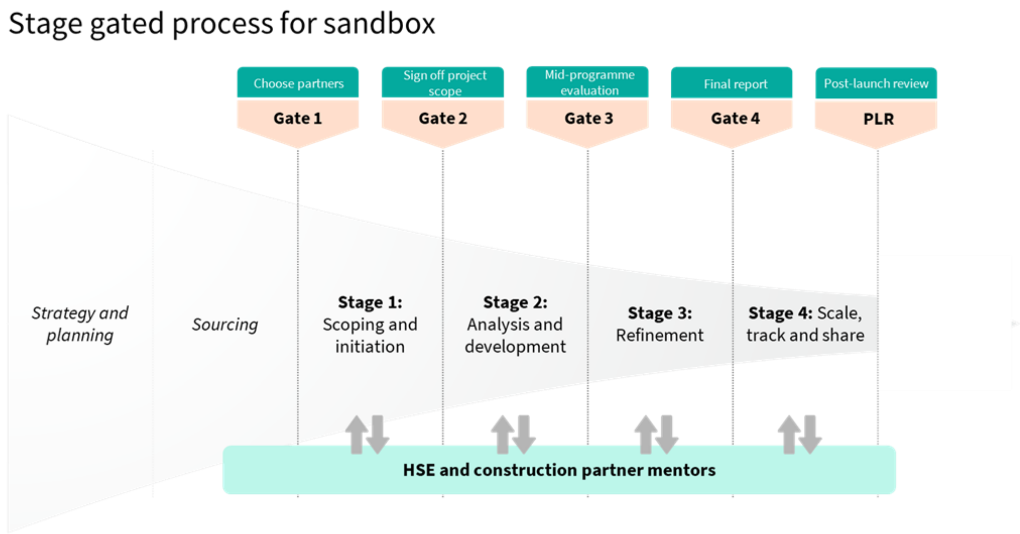


Figure 4 - Stage and gate process for the Sandbox

Key dates in the Sandbox process are included in the table below, these started after the signing of the collaboration agreement.

Key Date	Activity
April 3rd 2023	Mentor briefing meeting and confirmation of mentees
April 3rd W/C 3rd April	Kick-off meeting with all tech companies 1-2-1 meeting with tech companies and notification of mentors Develop plan of activities and SoW for each pilot using common approaches
April 17th	Statement of work and activity plan submitted
April 27th	**GATEWAY1:** HSE/STA internal review, sign off Statement of Work (SoW) and 1st payment made
27th April – 30th July	HSE and STA run Sandbox activities are per design and SoW Weekly check-ins to assess and document progress Monthly DSIT reports.
May 31st	Tech company interim presentation Presenting progression and providing feedback
June 1st	Industry midpoint feedback session
June 30th	Submission of final reports

Key Date	Activity
July 1st	Final presentation of process, results and insights to HSE/Industry mentor
W/C July 10th	1-2-1 feedback sessions with Industry mentors
W/C 10th July	**GATEWAY 2:** HSE/STA internal review, sign off and final payment made
W/C 17th July	1-2-1 Feedback with tech companies

Table 8 - Summary of the key dates in the Sandbox process.

Throughout the process, STA had bi-weekly meetings with the tech companies and kept a monitoring document with updates, issues and lessons learnt. These were then added to the monthly report to the RPF and DSIT.

4.2.1 Mentor matching to tech companies

Assigning appropriate mentors to each tech company was a key step in the Sandbox process; to ensure this was successful, the project team took a 1-2-1 approach to onboarding the mentors and explaining the process. They were then invited to join the pitching session and provide feedback to help select the final six. STA asked the mentors to complete a survey indicating which company or companies they felt they could contribute to, and which they felt were of most interest to their organisation. STA used these responses to ensure a good spread across the tech companies.

STA categorised the different mentors as:

- Industry ‘core’ mentors: The mentors who have agreed to have regular meetings with the tech companies.
- Industry ‘optional’ mentors: mentors who have expressed interest in those tech companies but will only engage if their diaries allow.
- HSE SME: HSE persons who have the technical insight into the different regulations.
- HSE project support: HSE colleague who can advocate and support the project

	FYLD	HAL Robotics	Eave	Oculo	PLINX	Machine Eye
HSE project support	HSE project support	HSE project support	HSE project support	HSE project support	HSE project support	HSE project support
HSE SME	HSE SME	HSE SME	HSE SME	HSE SME	HSE SME	HSE SME
Core 1	Costain	Balfour Beatty	Amey	Balfour Beatty	BAM	Skanska
Core 2	Laing O'Rouke	BAM	Laing O'Rouke	Arup	Heathrow	Colas
Core 3	HS2	Heathrow	Skanska	Costain	Laing O'Rouke	HS2
Optional	Colas	Costain	Colas	Colas	HS2	
Optional	Skanska	Laing O'Rouke	HS2	HS2		
Optional		HS2				

Table 9 – Matching of mentors to each tech company.

4.3 Sandbox Investigative Studies

The investigative studies were split into three sections. Section 1 involved describing the problem and the research questions being addressed and agreeing the Statement of Work. Section 2 included the running of the Sandbox, weekly progress meetings with the STA team and the mentor discussions. Section 3 involved synthesising the learnings and presenting the results. The templates that were used to gather information for each section are shown in Figure 5 below.

Industrial Safetytech Regulatory Sandbox Research Report   Company name

Name of research	Research name 1	Lead individual(s) from company	
Technology area		Industry mentor(s)	
Lead company		HSE mentor (s)	

Section 1 - Test

Guidance notes

- This section constitutes your 'plan', which will be submitted for review at Gate 2 of the Sandbox, however, this section ALSO constitutes the first section of your final report, which will comprise all three sections together in a single document.
- We are looking for quality over quantity here, and are only expecting 2-3 pages max for this section.

The problem we are addressing is...

Problem definition

- *Outline the reason why your research is important, this could be a lack of knowledge, a risk, a barrier that exists, or an unfulfilled opportunity. There should be some background and context to introduce the issue, but the problem statement itself should clear and precise.*

We believe that...

Research question

- *A good research question explains what you are hoping to find out.*
- *It should be focused on a specific problem or issue.*
- *The research question can either be explorative – with no clear hypothesis, in this case the objective might be to gain knowledge and understanding with a given area, OR confirmatory – with a clear hypothesis and set of assumptions that must be tested in the project.*

Industrial Safetytech Regulatory Sandbox Research Report   Company name

- *A research question CAN have multiple parts that are inter-related, or a company may simply be addressing multiple issues, therefore multiple research questions should be expressed*

To verify this we will...

Method, approach and resources

- *Outline your approach to tackling the problem.*
- *Detail the key activities you will be completing in order to execute the research.*
- *Give the reasoning for why you've chosen this approach and activities.*

And measure...

Data sources and acquisition strategy

- *Identify the data sources you will be using the tackle the problem, this could be interviews with people or analysis of datasets etc.*
- *Outline how you will go about collecting this data and why it's important to the project.*
- *Outline any processing techniques you might use*

We know we will have been successful if...

Success criteria

- *Good success criteria are closely linked to the problem statement and research question*
- *They should detail standards around "what you're trying to find out", and "whether your approach was successful" or not.*
- *If the research question is centred around knowledge generation and understanding, the success factors should detail what knowledge, for who*
- *If the research question is confirmatory, then the success factors should detail whether the hypothesis was assessed effectively – did you reach a conclusion?*

Industrial Safetytech Regulatory Sandbox Research Report   Company name

Section 2 – The Sandbox

Guidance notes

- *This section constitutes the middle section of the final report and summarise 'what you did in the sandbox'.*
- *It should comprise a concise overview of the activities undertaken, processes followed and an 'in flight' view on what's working and what's not.*
- *This section will be submitted towards the end of the Sandbox; however, we suggest logging findings as you go.*
- *We are looking for quality over quantity here and are only expecting 2-3 pages max for this section.*
- *Language should be concise and scientific in nature – the document should be easily interpreted by a layman not familiar with the project.*

To execute our plan, we are doing...

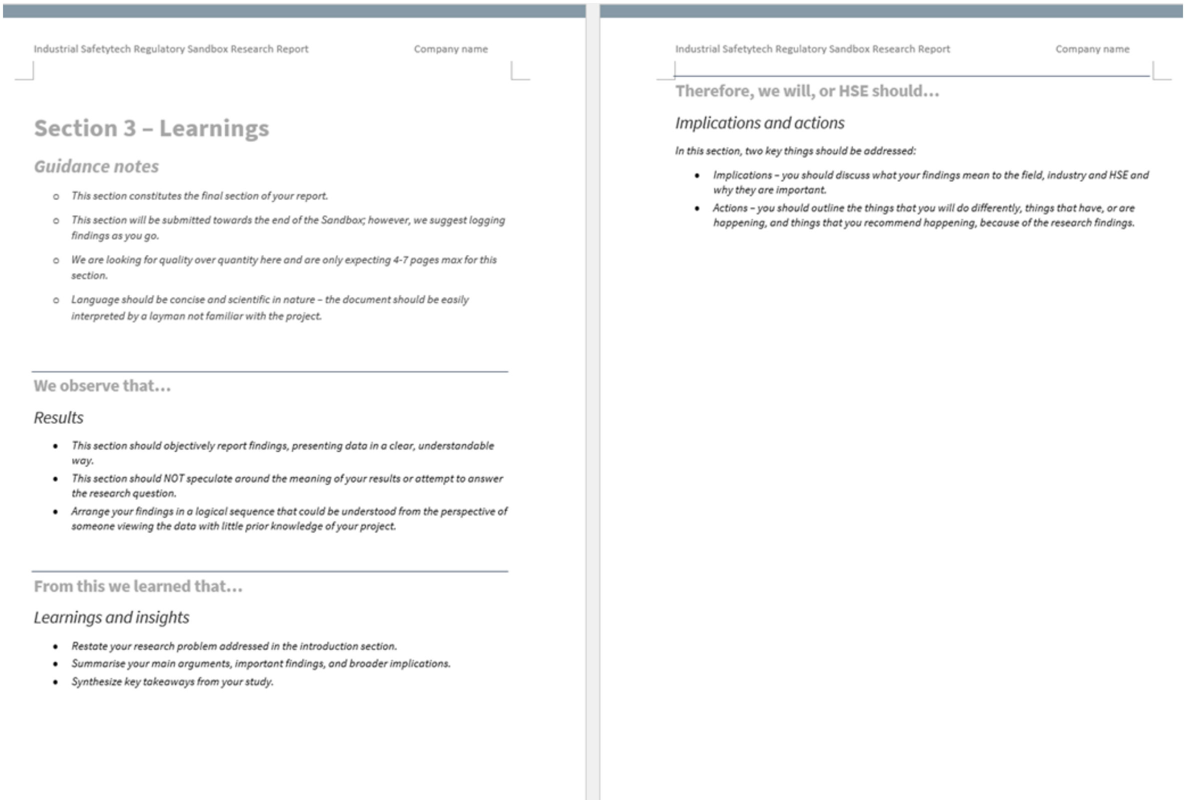
Activities and actions

- *This section should summarise what you did, who you spoke to and how you conducted your sandbox, it should work as a natural follow on from Section 1*
- *Log basic activities, engagements, and actions as you go.*

We are finding that...

Lessons from being in the sandbox.

- *What's working and what isn't in terms of being in the sandbox?*



Industrial Safetytech Regulatory Sandbox Research Report — Company name

Section 3 – Learnings

Guidance notes

- *This section constitutes the final section of your report.*
- *This section will be submitted towards the end of the Sandbox; however, we suggest logging findings as you go.*
- *We are looking for quality over quantity here and are only expecting 4-7 pages max for this section.*
- *Language should be concise and scientific in nature – the document should be easily interpreted by a layman not familiar with the project.*

We observe that…

Results

- *This section should objectively report findings, presenting data in a clear, understandable way.*
- *This section should NOT speculate around the meaning of your results or attempt to answer the research question.*
- *Arrange your findings in a logical sequence that could be understood from the perspective of someone viewing the data with little prior knowledge of your project.*

From this we learned that…

Learnings and insights

- *Restate your research problem addressed in the introduction section.*
- *Summarise your main arguments, important findings, and broader implications.*
- *Synthesize key takeaways from your study.*

Industrial Safetytech Regulatory Sandbox Research Report — Company name

Therefore, we will, or HSE should…

Implications and actions

In this section, two key things should be addressed:

- *Implications – you should discuss what your findings mean to the field, industry and HSE and why they are important.*
- *Actions – you should outline the things that you will do differently, things that have, or are happening, and things that you recommend happening, because of the research findings.*

Figure 5 – Reporting template used as part of the Sandbox process.

As part of Section 1**,** the technology companies were required to submit their Statement of Work, including the research questions that their investigative studies would focus on. These are shown in Table 10 below.

Solution provider	Research Question(s)
PLINX	**Using zonal working standards to establish a stronger connection between the design and construction phases of projects and empower data-driven decision-making.** PLINX 's proposed research aimed to understand whether the statements below are correct: • We believe that adopting cross-industry zonal standards will create a safer working environment by improving on-site situational awareness. • We believe that adopting cross-industry standards will lower barriers for contractors to adopt safety-enhancing zoning technologies. • We believe that digital systems, enabled by cross-industry standards, can aid proactive management of risk. To verify their hypotheses, they focused on primary research, working within the Safetytech Regulatory Sandbox and leveraging the expertise of the HSE specialists and mentors. They held 1:1 meetings and conducted surveys amongst contractors and their workforces with the overall objective of testing their technology on a live construction site.
Eave	**How continuous monitoring of noise on site changes the game for countering Noise Induced Hearing Loss**

<table>
<tr><th>Solution provider</th><th>Research Question(s)</th></tr>
<tr><td></td><td>Eave’s project aimed to address the following research questions to gain a comprehensive understanding of noise-induced hearing loss (NIHL) in the context of workplace safety and explore the potential benefits of incorporating new technology into the regulatory framework:
• To what extent is NIHL underreported and underrepresented in the UK, and what are the potential contributing factors to this underreporting? This explorative question seeks to determine the scope and magnitude of the NIHL issue in the UK and identify possible reasons for its underrepresentation in existing data and regulations.
• What are the costs and benefits of including NIHL in RIDDOR, and how would this change impact businesses, individuals and the healthcare system? This confirmatory question examines the hypothesis that incorporating NIHL in RIDDOR will result in a net benefit, through the lens of economic, social and healthcare perspectives.
• How can smart hearing protection technology contribute to the prevention of NIHL, and is it reasonably practicable to implement it as a control measure in place of traditional hearing protection? This explorative question investigates the potential effectiveness of smart hearing protection as a solution to NIHL and assesses its feasibility as a control measure in different workplace settings.
• How should the guidance on Reasonable Practicability (RP) be updated to account for technological advancements in hearing protection, and what are the implications for businesses and regulatory bodies? This confirmatory question tests the assumption that updating RP guidance will lead to improved outcomes in preventing NIHL and explores the potential impact of such changes on various stakeholders.</td></tr>
<tr><td>HAL Robotics</td><td>How should increasingly flexible and collaborative robots be regulated?
HAL Robotics believed that current regulations impede small-batch manufacturing where the jobs of robots change frequently and inhibit the uptake of automation through ambiguous or contradictory regulations for static, autonomous equipment and mobile machinery. Their project intended to break this question down into the following:
• Are current regulations a barrier to the uptake or innovation of robots in industry?
• How can software which automatically reprograms robots be regulated or certified?
• How can sensor-driven equipment, whose job is by definition variable based on sensor data, be regulated?
• If a robot job is no longer a static entity which can be validated once and for all, what is the entity which needs to be regulated or certified? And how do we classify the aspects of this entity which can be changed before it is considered a new entity?</td></tr>
<tr><td>Machine Eye</td><td>Identifying and countering the key blockers to the uptake of computer vision within construction</td></tr>
</table>

Solution provider	Research Question(s)
	Machine Eye believed that creating a 'best practice' document that outlines how to implement AI computer vision systems in health and safety operations involving humans and heavy vehicles would be useful for industry and HSE. They aimed for their report to be aligned with current compliance and certification requirements in similar industries, helping to stimulate and guide this industry, leading ultimately to growth.
FYLD	**How can we drive the adoption of Artificial Intelligence technologies across the construction industry to deliver improved safety outcomes?** FYLD's investigative study was broken down into three key research questions: • What are the barriers to widespread adoption within the construction industry of proven health and safety AI products? • How do we better enable industry to adopt proven AI technologies to drive a step change in injury frequency rates through removing any barriers that exist? • How does FYLD's predictive analytics and predictive safety technology relate to the construction industry through the lens of the UK safety regulator and industry-leading construction companies?

Oculo	**Using digital twins to build risk identification into the design and construction of projects.** Oculo investigated the potential of 3D virtual representation of a building (in the form of a virtual walkthrough like Google Streetview) to enable better H&S planning and risk communication through visualizing and contextualizing the site conditions and hazards. They sought to identify ways to make H&S teams more efficient and effective, ultimately contributing to a safer working environment with fewer accidents and injuries. Their hypothesis was that utilizing such technology throughout the building lifecycle (from design to construction and operations) can improve the H&S of teams involved in each phase: *Design phase:* Analyse how 3D visual risk registers, particularly for retrofit projects, can enable designers to capture and annotate potential hazards in a more comprehensive and visually intuitive manner. Examine how these risk registers can facilitate smoother handovers to principal contractors, in accordance with CDM 2015 requirements. *Construction phase:* Explore the role of visual risk registers in the construction phase, focusing on how principal and specialist contractors can update the register to reflect changing site conditions. Investigate the potential for virtual risk registers to enhance H&S inductions for new teams and streamline work sequences in collaboration with BIM models to minimize accidents in work hotspots. *Operations phase:* Assess the use of visual archives during the operations phase for maintenance work planning. Examine how these archives can ensure safe planning and reduce the need for extensive preparatory site visits. *Surveying work:* Investigate the impact of 360° image-based risk registers on surveying work, considering how preparatory work can be streamlined through remote environmental H&S assessments using visual captures. Also evaluate the potential for more detailed visual reports of H&S issues to enable safer and more efficient future work, such as asbestos surveys.

Table 10 - Research questions and Statement of Work for each Sandbox investigative study.

4.4 Marketing and communications

Throughout the Sandbox, Discovering Safety and STA ran a comms campaign to promote different developments of the project.

Open call: Engaging the market to seek expressions of interest from tech companies to join the Sandbox.

The Open Call was launched on 1st February 2023, inviting technology companies to register their interest. It closed on 1st March. The call was hosted on STA's website and promoted through an extensive campaign:

- 12 articles identified in earned media outlets highlighting campaign content
- Campaign coverage read by estimated 23.2k people through tech, business and trade media
- Campaign video watched 2.2k times
- Social posts achieved 5.3k impressions
- 374 people visited campaign landing page
- 19 applications to Sandbox programme
- Five organisations, at least, promoting campaign content to their communities

Safetytech Accelerator PR Coverage : February 2023

Media	Date	Headline	Audience	Views	Domain Authority	Backlink	Contact
Business Mondays	1-Feb-23	UK Technology Companies Invited To Join The World's First Regulatory Sandbox For Industrial Safetytech	11,924	1,752	28	NO	James Taylor
Professional Engineering (Institution of Mechanical Engineers)	1-Feb-23	Taskforce searches for AI, drone and wearable tech to make construction safer	96,510	902	67	YES	-
Startups Magazine	1-Feb-23	UK tech companies invited to join sandbox for industrial safetytech	32,253	4,551	41	YES	Paige West
World Construction Today	1-Feb-23	Taskforce searches for AI, drone and wearable tech to make construction safer	7,482	2,182	28		-
Build in Digital	2-Feb-23	Government calls on companies to provide 'life-saving' construction tech	1,998	670	22	NO	Sion Geschwindt
SafetyTech News	7-Feb-23	STOP THE PRESS! | World's First Regulatory Sandbox for SafetyTech	2,042	204	-	NO	Cameron Stevens
Access Point	17-Feb-23	UK technology companies invited to join the world's first regulatory sandbox for industrial safetytech	619	361	22	YES	-
Computer Weekly	22-Feb-23	UK HSE to launch regulatory sandbox for industrial safety tech	1,091,207	1,949	86	NO	Sebastian Klovig Skelton
Business Mondays	23-Feb-23	Investment In Uk Industrial Safetytech Startups Tops £150m Since The End Of 2020	11,924	1,752	28	NO	James Taylor
IndustryWatch24	23-Feb-23	UK HSE To Introduce Regulatory Sandbox For Industrial Safety Technology	100	10	10	NO	Sandy B
Startups Magazine	23-Feb-23	Investment in UK industrial safetytech startups tops £150m	32,253	4,551	41	YES	Sheryl Miles
Tech Informed	27-Feb-23	UK tech firms invited to join regulatory sandbox for industrial safetytech	13,839	4,399	28	NO	Emily Curryer
BIMplus	28-Feb-23	HSE accelerator targets safety technology innovators	22,857	1,835	46	YES	Denise Chevin

Figure 6 – List of STA publicity and press activity to promote the Sandbox

External press coverage:

- Jan – March:
    - 20 pieces
    - 47.29K impressions
- April – July:
    - 4 pieces
    - 13.4k impressions

Blogs and Articles include:

- **Website**: Industrial Safetytech Regulatory Sandbox - Safetytech Accelerator
- **Press release:** Three major industrial companies join safetytech regulatory Sandbox - Safetytech Accelerator
- Shaping the world's first Industrial Safetytech Regulatory Sandbox - Safetytech Accelerator
- **Reports**:
    - Understanding the UK Industrial Safetytech Landscape - Safetytech Accelerator
    - Key Takeaways from Our Industrial Safetytech Panel - Safetytech Accelerator

5 Sandbox Outputs

5.1 Results from each Sandbox Investigative Study

Each investigative study was asked to produce a report. These have been reviewed and put into a standard format as shown in the sections below. It is intended that these will be reviewed and then published separately to promote and disseminate the work.

5.1.1 EAVE

How continuous monitoring of noise on site changes the game for countering Noise Induced Hearing Loss (NIHL)

About EAVE

The EAVE system consists of smart ear defenders, which continuously collect data on environmental noise and the wearer's exposure to noise, beacons which work with the ear defenders to map worksite noise, and an online platform for viewing the data and gathering insights; the system is used to protect over-exposed workers, adjust working methods, and remove noise hazards at source.

Objective(s)

The project set out three core questions to be answered within the Sandbox:

1. *What are the potential contributing factors to the underreporting of NIHL?*
2. *How can smart hearing protection technology contribute to the prevention of NIHL, and is it reasonably practicable to implement it as a control measure in place of traditional hearing protection?*
3. *How should the guidance on Reasonable Practicability (RP) be updated to account for technological advancements in hearing protection, and what are the implications for businesses and regulatory bodies?*

Method

1. Literature review and data analysis:
2. Technological assessment and feasibility study:
3. Stakeholder engagement and consultation

Results

The extent of overexposure

It was observed that HS2 subcontractors used the Eave solution and digital platform to gain insight into external and internal noise exposure, to understand the extent of the hazard, the actual protection achieved and to explore how the technology could inform redesign of hazard, or workforce at source.

The initiative reached across a selection of the HS2 early works contract scopes of work, including demolition, ground works, temporary works and utilities contract companies.

The **table** below shows extremely high levels of dangerous noise exposure across the contractor group, measured using the smart hearing protection devices. Over exposure results from a lack of adequate hearing protection combined with both a noise level and length of period that exceeds healthy levels

Identifying reasons for underreporting

	Days	Smart Ear Defenders Used	Recorded Overexposures	Recorded Unprotected Events	Recorded Time in >85dB (hrs)	Recorded Hearing Protection wear rate
Contractor B	996	84	92	26536	2194.34	53.5
Contractor C	794	142	20	13541	751.86	59.7
Contractor D	637	100	16	13075	701.99	40.5
Contractor E	457	34	7	6235	284.72	59.5
Contractor F	277	61	8	3318	207.44	50.6

1. **Lack of awareness**: When workers and employers do not understand the risks and symptoms of NIHL, they cannot accurately identify the condition or prioritize prevention measures. This lack of awareness can lead to an underestimation of the impact of noise exposure.
2. **Delayed onset:** NIHL typically develops gradually over time, making it hard for workers to establish a clear connection between their hearing loss and their exposure to noise at work. Because there are no immediate symptoms, individuals may not consider workplace noise as the source of their hearing loss.
3. **Stigma and fear of job loss:** The fear of stigma associated with hearing loss and potential job loss can deter individuals from reporting NIHL. Many workers hide their symptoms or fail to seek help due to concerns over job security and fear of being perceived as weak or less capable.
4. **Inadequate noise exposure assessments:** If the methods used to assess noise exposure in the workplace are inaccurate or incomplete, it can lead to underestimating the risk of NIHL. Inaccurate assessments mean that dangerous levels of noise can go undetected, and workers exposed to these noise levels might not realize they're at risk.
5. **Insufficient enforcement and compliance:** When there is inadequate enforcement of regulations, workers are more likely to be exposed to harmful noise levels. In turn, this increases the likelihood of underreporting of NIHL as workers may not realise the extent of their risk.
6. **Challenges in establishing causality**: Identifying the exact cause of NIHL can be complex due to various potential confounding factors such as

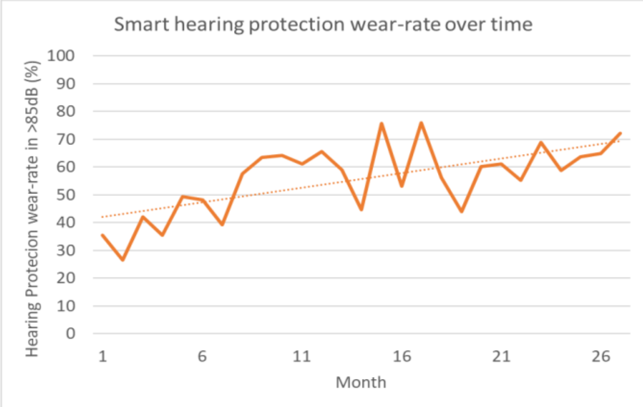
genetics, medications, and other sources of noise exposure. This difficulty can discourage workers from reporting their hearing loss as they may not attribute it directly to their workplace noise exposure.

7. **Misdiagnosis or lack of diagnosis:** NIHL symptoms can be similar to other forms of hearing loss. Without proper diagnosis, workers suffering from NIHL may believe they have a different type of hearing loss that is not work-related, leading to underreporting.
8. **Absence of immediate effects:** The gradual nature of NIHL often results in a lack of immediate symptoms. This delayed reaction can make it harder for individuals to link their hearing loss to their workplace noise exposure, leading to underreporting.
9. **Lack of accessible reporting channels:** If the process for reporting NIHL is complicated or not clearly communicated, workers may feel discouraged or confused about reporting their symptoms, resulting in underreporting.
10. **Limited healthcare access:** In regions where healthcare services are less accessible, routine health check-ups and hearing tests that could detect NIHL are less likely to occur. This can lead to many cases of NIHL going undiagnosed and unreported.
11. **Age-related misconceptions:** Some individuals might attribute their hearing loss to age rather than their exposure to noise. This misconception can result in many cases of NIHL being misattributed and underreported.
12. **Compensation systems:** Navigating workers' compensation systems can be daunting and confusing. If workers find it difficult to claim compensation for NIHL, they may choose not to report their symptoms.
13. **Failure to recognise early symptoms:** Early signs of NIHL such as tinnitus or temporary threshold shift can be easily overlooked. Workers might dismiss these symptoms as minor or temporary, not recognizing them as signs of ongoing noise damage, leading to underreporting.

The impact of continuous monitoring of noise on site

1. **Wear rates of PPE increase significantly over time**

The direct feedback of noise exposure causes an increase in positive behaviours by operatives during operation.



2. **New sources of noise were discovered during the trial**

Noise hazard incidents were identified from the noise mapping functionality that had been overlooked on the initial Risk Assessment and Method Statement (RAMS). These areas included jet wash, hot works burner and basement working which generated unplanned noise hazard. The below image shows newly identified areas of exposure (red).

3. **Contractors began to remove noise identified at source**

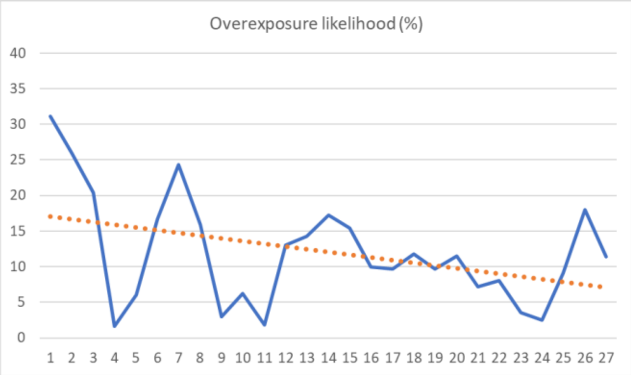
For one HS2 subcontractor it was observed that there was a total of 694 days of usage and over 7000 hours of

data. From the 694 days, there were 148 overexposures. The key insight here was that on 21% of days, operatives were overexposing themselves to noise which led to 148 incidents of overexposures.

The raised awareness from the data and insights, lead to the RAMS being reviewed, and attention placed to relocate the workers and reduced from high to low hazard risk.

4. **This led to a halving in the overall level of exposure for workers**

Due to the measures outlined above, the extent of exposure was halved in the trial group.



Key learnings and insights

1. **Over exposure to noise is rampant within construction and is completely at odds with the official figures for reported RIDDORS**

These findings have profound implications for the industry, as they underscore the necessity of addressing the myriad factors leading to underreporting of NIHL. Raising awareness about NIHL, improving noise exposure assessments, addressing stigma and fears, and simplifying the reporting process are vital steps to rectify underreporting.

2. **Continuous monitoring of noise at a granular level on construction sites enables contractors to understand where and how to fix over exposure**

The results revealed that smart hearing protection not only helped reduce the risk of NIHL but also enabled duty holders to focus efforts on reducing noise at the source.

The Eave platform that was deployed for smart hearing protection offers continuous monitoring and more comprehensive assessments of noise exposure levels.

Recommendations, actions and impact

For the HSE

- **Noise exposure assessments and investigations – reasonable practicability**

The findings indicate that smart hearing protection data could be used to replace traditional methods of noise exposure assessment, such as the HSE Noise Exposure Ready-Reckoner. The study suggests that HSE consider the integration of data from smart hearing protection platforms into their guidelines for noise exposure.

Data from smart hearing protection offers a more comprehensive approach to assessing noise exposure levels in the workplace. By continuously monitoring noise exposure both inside and outside of the hearing protection devices, the Eave platform provides continuous data on workers' noise exposure levels. This information can be used to inform appropriate noise control measures and ensure compliance.

For Industry

- **Driving industry adoption**

The findings have profound implications for the industry, as they underscore the necessity of addressing the myriad factors leading to underreporting of NIHL. Raising awareness about NIHL, improving noise exposure assessments, addressing stigma and fears, and simplifying the reporting process are vital steps to rectify underreporting. These actions should be accompanied by efforts to enhance compliance with noise exposure regulations and improve access to healthcare services.

It has been demonstrated that the use of smart hearing protection can help reduce the risk of NIHL. Thus, the insights from smart hearing protection data should also inform the development and implementation of more effective and targeted noise control measures.

5.1.2 FYLD

How can we drive the adoption of Artificial Intelligence technologies across the construction industry to drive improved safety outcomes?

About FYLD

FYLD is an award-winning digital platform that automatically transforms video and audio footage into real-time workflows, visual risk assessments and analytics dashboards; by harnessing the power of machine learning, it eliminates paperwork, saves time and creates safer sites.

Objective(s)

'How can we drive the adoption of Artificial Intelligence technologies across the construction industry to drive improved safety outcomes?'

This was broken down into three research areas:

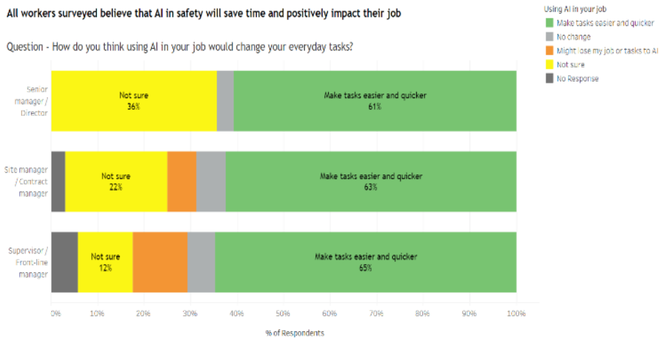
1. What are the barriers to widespread adoption within the construction industry of proven health and safety AI products?
2. How do tech companies better enable industry to adopt proven AI technologies to drive a step change in injury frequency rates through removing any barriers that exist?
3. How does FYLD's predictive analytics and predictive safety technology relate to the construction industry through the lens of the UK safety regulator and industry leading construction companies?

Method

- Industry and regulator surveys across 12 construction organisations and the HSE
- 15 Industry interviews with operatives and senior leaders
- Seven interviews with subject matter experts from the HSE
- Focus groups and workshops across industry partners and the regulator
- Two live Proof of Concept trials with industry partners

Results

Overall, 48% of survey respondents had seen AI utilised in safety processes, with over 60% stating that they felt positively about it and believed it would make tasks quicker and easier.



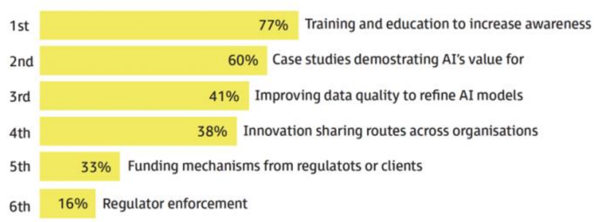
Key barriers to adoption of AI were also identified and grouped into three areas: Financial, Regulatory and Technology.

Key barriers

1. Financial barriers

100% of industry participants regarding perceived cost implications linked to AI adoption in the construction industry. This perception acts as a barrier to driving adoption, especially among key decision makers in organisations.

Which methods do you think would be most effective in removing barriers to the adoption of AI within your industry?



Ranking exercise results from the industy survey.

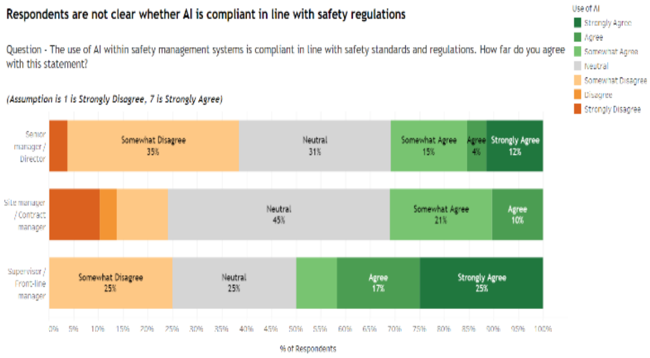
The assumption was that AI technologies would either be expensive to procure or implement in comparison to Software as a Service (SaaS) products that are already widely used, or that they were unclear of the costing or cost model of proven AI products.

Both industry and regulator surveys identified the demonstration of ROI case studies as a key means of eliminating barriers to adoption. 59% of respondents from industry stated that ROI case studies are key to showing the technology can pay for itself multiple times over, where profit margins on construction projects are modest. At Senior Manager / Director level where technology decisions are made, this proportion was even higher at 61% of respondents believing ROI case studies will be most effective in helping drive adoption of safety technologies.

2. Regulatory Barriers

There is a general concern from industry over how regulation impacts the use of AI platforms within safety processes. However, there is also a general concern on over-reliance on predictions, and how AI predictions used in a decision making is seen from the angle of the regulator.

69% of senior managers surveyed felt either neutrally or negatively when asked whether the use of AI within safety management systems is compliant in line with current regulation, including the Management of Health and Safety at Work Act (1999) alongside Approved Codes of Practice for high-risk activities. The more senior the respondent, the higher proportion of negative responses, indicating senior managers and leaders were more concerned.



3. Technology Barriers

A clear message received during industry interviews was that there is resistance to change stemming from traditional mindsets and a reluctance to embrace new technologies.

Many professionals in the industry may be hesitant to adopt AI solutions due to a lack of familiarity and comfort with these innovative tools, and widespread concern regarding technical capabilities of front-line workers.

FYLD used the sandbox to collaborate with Colas' construction and asset management fieldworkers and operatives. They worked directly with them to conduct training and demonstrate how to use FYLD AI technology and explained how the AI analysis works for them within their workflow. Following training, the workers were asked how the training programme changed their perception and understanding of AI. 100% of respondents answered positively and 71% said their perception had significantly improved.

Key learnings and insights

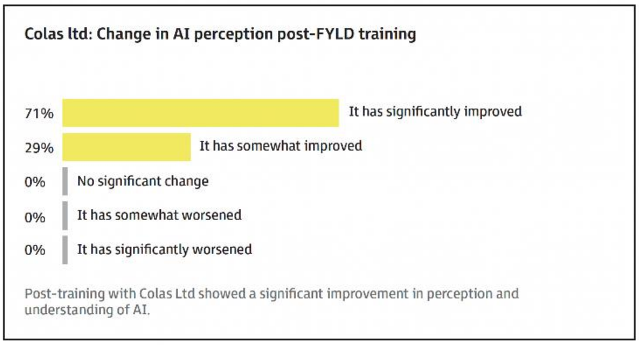
1. **Verified models of ROI are crucial to driving investment, and these must factor in wider benefits than just safety**

Platforms that can improve safety need to demonstrate how they can improve other areas of the operations not just safety.

Feedback from the industry leads showed that these RoI cases need to be relevant to their sector. Therefore, a FYLD developed the key strategy to rapidly produce an ROI case study with outcomes in the construction industry.

2. **There is a gap between the position of the regulator and the understanding from industry leaders who are making decisions regarding technology.**

The industry is generally wary and unsure of whether adopting AI in a safety management system is compliant in line with the Management of Health and Safety at Work Regulations 1999 (MHSW). Less than a third of senior leaders in construction felt confident that it is compliant.



3. **Direct engagement can have a big impact on perceptions**

The survey responses from industry were clear that developing an understanding of AI and how it can be utilised in construction projects by non-technical workers is critical to enable adoption. 79% of respondents stated that this was critical to support widespread adoption, whilst the regulator focus group also acknowledged this as a key method to eliminate barriers to adoption.

4. **The HSE focus group felt predictive safety would be beneficial for the industry through delivering safety improvements**

100% of respondents from the HSE felt either neutral or positively that Predictive Safety will be beneficial for the construction sector. A similar positive response was seen from industry, with 74% of respondents answering positively that FYLDs predictive safety would benefit the industry.

Recommendations, actions and impact

For FYLD

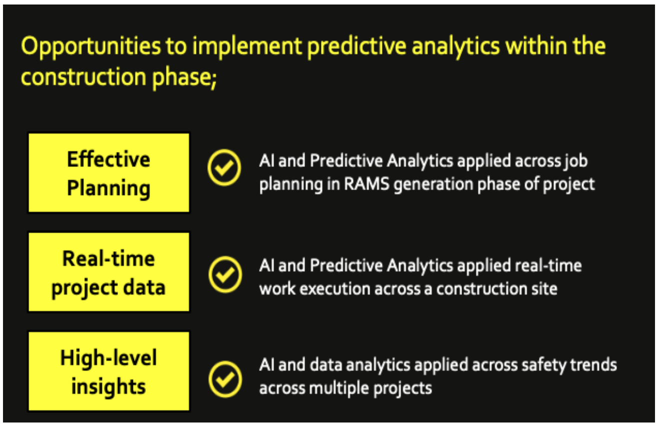
- **Product development -** FYLD has identified a product development area which is being developed as a direct result of this research project, and from feedback from our PoC with Colas. A digital signing solution is being built and deployed into the FYLD product, to fit the nature of the construction industry with a large proportion of supply chain partners working on separate safety systems.
- **ROI model development** - FYLD will continue the on-site work with Colas to demonstrate further proof points for ROI outside of just safety improvements for a public case study that applies to construction projects.

For HSE / Safety Tech Accelerator;

- **Digital education campaign -** FYLD recommends continuing work via a focus group led by the HSE, to improve communication and clarify how technology can be utilised in a compliant way through publication of case studies or suitable material. This would be best achieved through an HSE led digital education campaign. The key outcome here should be to close the gap between industry understanding and the regulatory position.
- **Bringing stakeholders together –** FYLD's recommendation would be to run further focus groups between technology companies, industry and the regulator, to share outcomes on a wider scale and directly with industry.
- **Case studies -** Case studies from the regulator showing where Safety Tech is improving and compliant with Safety Management Systems could further develop confidence in industry that AI adoption can lead to best practices. This is without the need for the understandably complex nature of updating regulation with current market conditions and the rapidly growing AI presence in the market.

For Industry

- **Training in AI** - FYLD will co-develop an AI Digital Training Programme with industry leaders and seek to share content at scale, to break down the barriers in industry through demystifying AI use in safety.



5.1.3 HAL Robotics

How should increasingly flexible and collaborative robots be regulated?

About HAL Robotics

HAL Robotics is an extensible and modular software which facilitates inter-device communication, adaptive programming of robot tasks, and motion planning for one or many robots working together.

Objective(s)

"How should increasingly flexible and collaborative robots be regulated?"

HAL Robotics intend to break this question down into the following:

a. Are current regulations a barrier to the uptake or innovation of robots in industry?

b. How can software which automatically reprograms robots be regulated or certified?

c. How can sensor-driven equipment, whose job is, by definition, variable based on sensor data, be regulated?

d. If a robot's job is no longer a static entity which can be validated once and for all, what is the entity which needs to be regulated or certified? And how do we classify the aspects of this entity which can be changed before it is considered a new entity?

Method

The research questions were approached in two parallel tracks. The first investigated sub-question a, whilst the second will tackle b, c and d.

1. For the first track, HAL Robotics leveraged their industry contacts to establish what the perceived barriers to adoption are through conversational interviews. Additionally, interviews were conducted with manufacturers of goods, construction companies, equipment manufacturers (industrial robots, on-site robots, mobile robots and manually operated machinery), system integrators and robotic software companies.

2. The second track relied on building upon existing use cases of flexible robotic solutions in dynamic and collaborative environments. Through developing a series of case studies which exemplify different levels of adaptability required by autonomous equipment. These theoretical case studies then had the necessary documentation drawn up to certify them with a view to identifying exactly where the regulations are missing or lack clarity.

Key learnings and insights

1. **The current standards are fit for purpose but the processes, information and guidance to develop those certification documents could be greatly improved.**

This was affirmed by the development of HAL's own case study of an autonomous mobile manipulator robot for inspection tasks and the requirements to certify it. It would need to comply with (at least):

- Machinery Directive 2006/42/EC
- ISO 10218-1: Robots and robotic device: Safety requirements for industrial robots — Part 1: Robots
- ISO 10218-2 Robots and robotic device: Safety requirements for industrial robots — Part 2: Robot systems and integration
- ISO/TS 15066 Safety of Collaborative Robots
- ISO 13849 -1 Safety of machinery: Safety-related parts of control systems - Part 1: General principles for design
- IEC 60204-1 Safety of machinery: Electrical equipment of machines - Part 1: General requirements

All of which need to be covered by ISO 12100 risk assessments for the machinery and its context of use as well as other technical documentation including drawings, specifications, calculation notes, test results, declarations of conformity for included machinery and more, to ensure compliance with the standards. So, whilst the standards and regulations aren't directly impeding the deployment of robots the level of expertise required to safely deploy a robotic system along with the costs associated to certify it are slowing the uptake of robotics in manufacturing, construction and likely other industries.

2. **There is a resistance to introducing any new risk into a process regardless of how much risk a change removes.**

One example would be introducing a robot to drill holes in soffits on construction sites which would remove working at height with a drill in hand and cementitious dust falling on the labourer. It is difficult to tell whether the resistance to this is comparisons aren't being made with the status quo or whether there is a culture of liability avoidance meaning that nobody will put their name on a change. This is analogous to the discussions around the introduction of autonomous/driverless cars which have a lower accident rate than human drivers but are a novelty and therefore liability and accountability are unprecedented.

3. **People new to robotics have unachievably high expectations for the technology to revolutionise their industry from day one**

They expect proof that quality is considerably better than what humans are currently delivering which creates technical barriers with considerable financial knock-on effects. Whilst it is not unreasonable for quality to improve with automation, unless an entire process and all input components are robotically produced the tolerances will always build upon the least precise component.

4. **In parallel to the above, the marketing of robotic systems (but not exclusive to robotics) often exaggerates the capabilities of the equipment or disregards environmental constraints.**

This is often seen with collaborative robots which are sold with the promise of cageless operation near human workers but can only perform limited functions at limited speeds in this context. This, along with the previous point, create a disillusionment with robotics which make users who have been disappointed once less likely to adopt robots in the future.

5. **The initial cost and Return on Investment (RoI) of a robotic solution are of key importance.**

The initial capital expenditure is the first hurdle for most companies. It is likely that a robot will reduce costs in the long term, but it shifts costs from operational to capital expenditure which is perceived as a high-risk decision. The other important issue around RoI was the different calculations performed in the UK vs the EU and USA. In the UK an expected payback period is 18-24 months for a robotic setup whilst in the EU and USA it is more acceptable to work with payback over 36-48 months. No obvious reason for this was discovered during the interviews. As discussed above, a Robots as a Service business model could return costs to Opex for common processes.

6. **Certain manufacturing processes are more inhibited by overly prescriptive testing methods in the regulations to demonstrate the quality of their output than the process itself.**

For example, anecdotally, there are no standards for hollow concrete columns which means that 3d printed concrete columns have to be back filled to tick the certification box when their structural integrity could be proved another way.

7. **Micro-factories or near site factories were proposed as a means of keeping work in a local area and helping with the social value proposition of automation, mitigating some fear of job losses through centralisation.**

These micro-factories could be installed semi-temporarily and therefore would be disproportionately affected by long integration and certification times.

Recommendations, actions and impact

Building a tool to access regulatory information when designing and building robotics systems

HAL Robotics' findings provide a unique insight into the different attitudes across the industry and highlight the knowledge gaps between different stakeholders. As such, the key action would be to provide simplified access to information and a tool to guide the certification of a robotic cell. Even if that only covered relatively simple installations it would allow many new companies to use automation.

Such a tool could take inspiration from the NBS Chorus system for the creation of building specifications and the eco-system approaches a number of robot manufacturers are taking which ensure that all documentation is provided with a piece of equipment as well as certificates of incorporation. It should draw information from a library of existing equipment and processes complete with templates and documentation but remain fully editable (like NBS Chorus) so that no processes or equipment are excluded.

A provisional outline for the tool and its workflow could be:

1. **Define the Cell** – the user selects the equipment they have in their robotic cell. This would include equipment like the robot which would use the library to pull all the documentation proving its compliance to relevant standards, as well as define key data like its payload, reach etc. which will impact the way it performs a process. This would be followed by the end effector (tool attached to the robot) which would define its mass, compliance with standards, the process it performs and other key metadata. The same would be true for the jigs & fixturing, controllers & PLCs, sensors, guarding

etc. which would cover the physical setup of the cell.

2. **Define the Process** – the user would setup phases of the process e.g. loading, unloading of parts, quality control, replacing consumables, robot processing the parts etc. Each of these phases would then define which of the Cell components are in use and what their state is i.e. the drill is on, what change of state is created by the phase i.e. what is where before and after the phase, etc. Phases could be sequenced to understand the full process and understand material flow. Templates for phases would also be provided e.g. spraying process would ask for the material being sprayed, its toxicity, ask questions about ventilation or extraction etc.

3. **Define the Interactions** – the user would specify how each piece of equipment; operator and the environment are expected to interact during each Process phase and how the risks associated with those interactions are mitigated. Some of these could be pre-generated for the user by the tool based on the Process and equipment chosen previously e.g. if a collaborative gripper, which can sense the forces it’s applying and detect trapping a finger, is used then an operator loading a part into the machine is less of a risk than a non-collaborative gripper being used.

4. **Generate Report** – the user will then be able to collate all of the documentation for a certain certification process by drawing together their answers in the previous sections and the library. This would also flag any missing documents so that the user is fully guided through certifying their robotic system.

A tool like this would require the input of a number of disparate stakeholders but would not be an insurmountable technical challenge in which HAL Robotics would be keen to participate. There are a number of specifications for communication which purport to define processes and equipment in standard formats but research into those protocols has shown that these would not be appropriate for this purpose and don’t actually seem to be as standardised as they allege. Work being done to create the Open Regulation Platform funded by Department for Business and Trade (DBT) through the Better Regulation Executive (BRE) would act as a critical data source for a tool like this.

5.1.4 MACHINE EYE

Identifying and countering the key blockers to the uptake of computer vision within construction

About Machine Eye

Machine Eye employs the latest deep learning AI techniques to identify humans in real-time and understand their likely interaction with a machine to assist, inform and support decision making, leading to safer workplaces

Objective

To uncover the key blockers to and recommend key drivers for the adoption of computer vision within construction and civils.

Method

1. Identifying construction industry requirements
2. Conducting interviews with industry and regulatory stakeholders
3. Developing a list of recommendations for implementing AI Machine vision systems in the construction industry

Results

Funding Risk

Costs of Solutions

Organisations engaged in large, long-term projects often lack the budgetary flexibility to adopt new technologies, once a project has commenced. Large construction projects are often fixed-price, with little ability to adopt innovation mid-project.

Innovation funding for Safety

The main support to startup businesses is Risk Capital, or Equity Funding. The funding organisations are usually sectoral specific, or technology agnostic, and driven by commercial returns. This means they will focus their investment on businesses in areas of high growth, significant return, or emerging technology.

Building Effective Partnerships

AI machine vision will evolve with increasing access to sites and data. Therefore, end users will not have a perfect system until AI machine vision ecosystems evolve to the right level which will take time.

Technical Risk

By addressing the technical risk developers can confidently invest time and money into their product development.

Technical Standards

An initial design for technical standards without appropriate testing and trials will often miss key technical functional and performance requirements.

Safety Standards

By working closely with regulators, standards can be introduced at an early stage ensuring there are no surprises for system developers.

The revision of standards can often happen at a different pace to the development of technology. This constant pull against one and other can have detrimental results.

Changing requirements from end users and OEMS

Without a close relationship between suppliers, end users and OEMs there is a risk of a disconnect where end users may develop requirements that do not align with the developer's product development plan or the OEMs requirement.

Designs moving forward without comprehensive and successful testing or trials

Planned trials that prove the technology will allow for a staged introduction with minimal risk and therefore de-risk it only happen with a good working relationship with operators, leasing companies and OEMs.

The use of smaller companies in the product development partnership

Smaller companies can be a perceived risk to deliver costly long-term projects. However, regardless of the size undertaking initial testing or trials any company will have to follow a similar development path to build their internal engineering and product capabilities.

Often larger companies have a fixed development processes that must be adhered as per company policy. If they struggle to be agile in new product development, then the results are often predictable and on-time but take significantly longer.

Working with a smaller more agile company is likely to lead to significantly faster development times and lead to business opportunity in acquiring technology that was specifically developed to meet the needs of larger companies.

Mitigating Financial Risk

Development of AI machine vision technology can be very costly. Because AI technology and capabilities are growing so rapidly, exceptional efforts must be made by the UK government just to keep pace with current growth in this industry.

Managing Supply Chain Risk

There is currently large demand for various edge AI and other automotive compute platforms. When looking at some suppliers of edge AI products, there are already significant lead-times for many of these specialist components (often 6 months or more).

Some larger suppliers will not work with smaller companies in relation to supplying critical AI. This makes it more difficult for smaller companies to get involved without the support of larger partners.

Developing the skills to support future technologies

A barrier to growth is the physical infrastructure (installers, servicing etc) required to retrofit systems into a large number of vehicles.

Key barriers include:

- Lack of qualified people to retrofit AI machine vision systems.
- The number of people along with the time required to retrofit each machine limits the number of installations per year.
- Knowledge loss due to siloed organisation specific team members skills.
- Lack of viable AI machine vision capabilities within OEMs.

Data driven decision making

Calculating operational costs because of workplace injury and the typed of incidents will often reveal that human-machine incidents account for a large percentage of cost, creating the basis for a data driven business case. Sources of data are available include the 'Construction Division RIDDOR - Risk Profiles' created by the HSE[4]. Newer data could be used to help build a business case for the use of AI machine vision in specific businesses in the construction sector.

Managing data under General Data Protection Regulation (GDPR)

Under the GDPR, organisations can be fined up to €20 million or up to 4% of the annual worldwide turnover. The GDPR provides principles that guide the fair usage of data. These principles are stated in Article 5 of the regulation and apply to all personal data.

- Lawfulness, fairness, and transparency
- Purpose limitation
- Data minimization
- Accuracy
- Storage limitation
- Integrity and confidentiality
- Accountability

Sharing data with the appropriate persons should be considered first due to the following:

- The AIMVS in equipment captures human/machine interactions along with PPE monitoring and other telematic information relating to machine performance and operations.
- This machine is leased to a contractor.
- This contractor is subcontracted by a large building contractor to work on a specific project.

Real-world access requirements include the following:

- The original leasing company does not need access to health and safety information but may want access to vehicle telemetry allowing usage to be measured.
- The subcontractor may want data relating to performance of their machine operator but should not have access to data relating to the site (for example monitoring of PPE wearing).
- The large building contractor may want all data and have legitimate reasons to have access to all data.

Insurance

AI machine vision solutions become the norm in the construction sectors, the risk of injury (and therefore cost) will reduce. This is likely to influence the risk profile of companies that use AI machine vision to enhance site safety.

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[4] https://www.hse.gov.uk/construction-dashboard/

Recommendations, actions, and impact

For Government

1) To secure the supply chain which is a clear enabling factor for the rapid growth of AI machine vision systems, the UK government needs to do more to address the accessibility of these components. Encouraging the growth of native AI hardware companies within the UK may help significantly in this effort.
2) Dedicated innovation funding for safety must be provided, to give businesses support to grow and develop. Space must be provided for them to develop alongside industry (such as the Sandbox).
3) Government procured projects (such as national infrastructure) should be mandated to allocate specific funding to adoption of new technologies for safety and a percentage of this should be reserved to enable the participation of smaller sector specific AI companies.
4) Government funding for industry to de-risk new safety technologies for businesses and provide them with an effective incentive to move to higher, technically enhanced safety standards.

For the HSE

5) Support smaller, agile companies to work with larger incumbents through establishment of Innovation Projects, Sandboxes, Knowledge Exchanges etc.
6) Having a resource made available to companies integrating this technology that could advise on all elements relating to the compliance landscape.
7) Product developers should work with independent bodies to define what technical standards need to be. Independent bodies should have a level of support from the HSE to ensure that safety standards align with technical standards.
8) Regulators must be prepared to review standards, issue clarifications, and progress in response to new technology, at an innovative pace.

For Industry

9) A centralised approach to innovation, such that best practice is highlighted and captured, to avoid the risk associated with innovation development, or duplication of efforts.
10) Collaborative approaches to adoption should be explored by industry, such as sandboxes and innovation zones within projects, where technology can be developed and evolved.
11) AI machine vision partnerships can mitigate against financial risk is for large end users of the technology (OEMs) to make special arrangements to accelerate integration of this technology into their vehicles. There should be a focus on the creation of partnerships between organisations at all levels of the industrial safety value chain.
12) Large purchasers of this product should be prepared to work with UK based innovation businesses and OEMs to develop this technology and the respective UK technology ecosystem enabling long-term profitability and growth opportunities in this sector.
13) End customers of this technology should take more risks and make more allowances when working with early-stage suppliers.

For Tech companies

14) Working with insurance companies at an early stage is recommended to ensure that the change in risk profile is fully understood by insurance companies and therefore the potential for cost savings.
15) Product developers should work with independent bodies to define what these technical standards need to be.
16) It may be more prudent to change these processes to suit an often-dynamic development process.
17) For manufacturers of AI machine vision systems, developing hardware agnostic solutions is one way that they can mitigate against a poor supply chain.
18) Companies currently developing AI machine vision systems need to develop mutually beneficial partnerships with large end users of this technology, lessors and OEMs to evolve the technology into a fully integrated package that can meet the long-term needs of the industry.

Developing the skills to support future technologies

19) Those with responsibly for training need to be supported in bringing forward appropriate digital skills upskilling/ training for the workforce.
20) Guidance should be provided to appropriately classify the different levels of users in a construction organisation, and their responsibilities under GDPR.
21) Working with universities and other education institutes to develop skills in the UK workforce to support these technologies.

GDPR

22) As a first step, ensuring that data gathered by the AI machine vision system is shared with the appropriate persons should be the priority.
23) Data gathered should be categorised into a number of different use case scenarios. The use cases should be assigned specific user types. Users can then be given access to only the data they have a valid use for.
24) Data can then also be managed for fair usage which may be affected by the specific user type.

Impact for Machine Eye

The project has helped Machine Eye:

- develop greater penetration into the tier 1 construction market and build relationships with key persons in the construction industry who have a greater understanding and awareness of their technology.
- gain a greater understanding of the challenges they face in implementing AI machine vision systems
- build partnerships to accelerate implementation of ever better safety systems.

From this, they are now working with partners from the project to identify and delivery pilots on site.

“The project has significantly increased the profile of both ours, and similar technologies. We are already seeing good engagement from operators in the sector who want to begin a journey of improving standards through the addition of technology, whereby the presence of this project has encouraged them that they are making a worthwhile investment “

5.1.5 Oculo

Using digital twins to build risk identification into the design and construction of projects

About Oculo

Oculo apply elements of SLAM (Simultaneous Localisation and Mapping) and photogrammetry to create an automated process that documents a worksite and creates a 3D model that can facilitate collaboration.

Objective(s)

Oculo will investigate the potential of 3D virtual representation of a building (in a form of virtual walkthrough similar to Google Streetview) to enable better H&S planning and risk communication, through visualizing and contextualizing the site conditions and hazards. We will also seek to identify ways to make H&S teams more efficient and effective, ultimately contributing to a safer working environment with fewer accidents and injuries.

We propose a hypothesis that utilizing it throughout the building life-cycle lifecycle (from design to construction and operations) can improve the H&S of teams involved in each phase:

1. **Design phase:** Analyse how 3D visual risk registers, particularly for retrofit projects, can enable designers to capture and annotate potential hazards in a more comprehensive and visually intuitive manner. Examine how these risk registers can facilitate smoother handovers to principal contractors, in accordance with CDM 2015 requirements.
2. **Construction phase:** Explore the role of visual risk registers in the construction phase, focusing on how principal and specialist contractors can update the register to reflect changing site conditions. Investigate the potential for virtual risk registers to enhance H&S inductions for new teams and streamline work sequences in collaboration with BIM models to minimize accidents in work hotspots.
3. **Operations phase:** Assess the use of visual archives during the operations phase for maintenance work planning. Examine how these archives can ensure safe planning and reduce the need for extensive preparatory site visits.
4. **Surveying work:** Investigate the impact of 360-degree image-based risk registers on surveying work, considering how preparatory work can be streamlined through remote environmental H&S assessments using visual captures. Also evaluate the potential for more detailed, visual reports of H&S issues to enable safer and more efficient future work, such as asbestos surveys.

Method

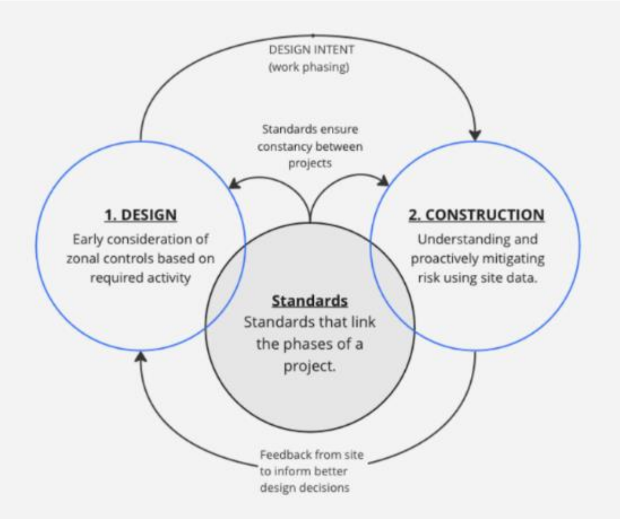
- Analyse current best practices with regard to H&S planning
- Review the data and documentation on the causes of H&S accidents
- Identify those that could be prevented or minimized using a visual risk register and immersive safety induction.
- Collaborate with industry mentors to conduct two sample 360-degree scans using Oculo technology and developing a 3D risk register highlighting key hazards.

Results

This project is currently ongoing and results will be published in the future.

5.1.6 PLINX

Using zonal working standards to establish a stronger connection between the design and construction phases of projects and empower data-driven decision-making



About PLINX

PLINX is a safety system using wireless sensor technology designed to make construction sites safer; the system protects construction workers and employers by restricting access based on role and purpose to areas of hazardous activity.

Objective(s)

To identify best practice within zonal working on construction sites and to establish a standardised way of working to be used across the industry

Method

- Industry stakeholder interviews and workshops
- Regulator interviews
- Analysis of industry best practice guidance and standards
- Analysis of cross cutting regulation in zonal working

The diagram to the right provides a visual representation of each key element that was in focus during the project. By facilitating the seamless flow of information between the design and construction phases it was anticipated that were to be substantial improvements in connectivity and, consequently, enhanced safety throughout the industry.

Results

Design – 'designing in' safety

In an ideal scenario, designers would create a digital and interactive plan for construction projects, allowing for modifications and ensuring safety measures are incorporated. During the design phase, hazards can be considered, and changes can be made to protect the construction team. The optimised digital plan, including pre-planned safety measures, should be shared with the construction teams to enhance communication, progress tracking, and safety awareness. Integrating safety measures early in the design process enables the development of a catalogue of assets and construction tasks, reducing administrative burdens for future projects.

The adoption of 4D technology offers improved project planning, communication, clash detection, cost estimation, resource management, and risk mitigation. While full adoption is limited by cost and skill shortages, digital zoning technologies can enhance safety by alerting workers and visualizing compliance. Advances in technology aim to automate safe design through machine learning, though full autonomy is still distant.

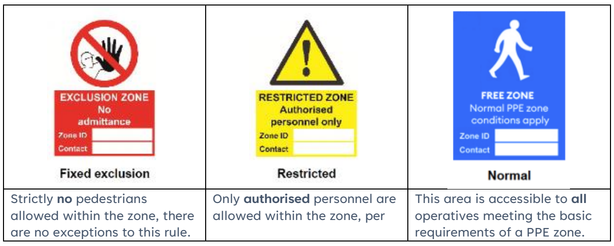
Cross-industry zonal working standard

Zonal working is an effective approach that establishes clear boundaries and delineates where different tasks take place on a construction site. It ensures efficient coordination and promotes safety by preventing unauthorized access to hazardous areas. Implementing zonal working helps enhance organisation, mitigate risks, and optimize the overall workflow.

Currently, zones are created reactively by managers when they identify a hazard linked to an activity during risk assessment. The manual implementation of static zonal controls lacks integration with project outputs, and compliance can only be monitored through visual observations, missing valuable opportunities for lessons learned.

Standardising zonal controls allows for digital compliance monitoring, but it requires upfront information and a clear set of binary rules (the standards) to be established. Ideally, designers should implement zones early, following a mutually agreed standard, as construction teams generally have limited digital skills compared to designers and lack the flexibility to modify the design.

What drives the standard?



To ensure enforceability, it is important for the standard to align with existing regulations. Although the Construction (Design and Management) Regulations 2015 (CDM) does not explicitly mandate the implementation of restriction or exclusion zones, certain provisions within the CDM regulation imply the use of zones to separate individuals in time and space.

The development of these standards would further support the ongoing evolution of regulations. The standard would:

- Assist contractors in demonstrating compliance with specific aspects of the regulation.
- Streamline compliance efforts and enhance safety measures.
- Maintain consistency in responsibilities among all project stakeholders.
- Facilitate the sharing of lessons learned to inform future phases and projects.

Construction – The feedback loop

Improving safety in projects poses challenges when relying solely on human observations. Commercially available technology like PLINX offers a solution by digitally capturing movements on-site and monitoring compliance against hazards. Real-time risk information enables proactive adjustments to prevent incidents, while captured data can inform future projects. Implementing risk management systems, such as sensor or camera-based technologies, requires careful consideration by a working group. Active systems provide real-time alerts but may cause annoyance, while passive systems allow management to understand breaches without disrupting workflow. It is crucial to foster continuous improvement in safety and efficiency through learning from past projects and exploring the potential of Machine Learning in safety decision-making.

Key learnings and insights

It is likely that the greatest value will be in the ability for digital systems to deliver 'live' risk information derived from millions of data points, enabling management to take immediate action to mitigate the risk.

- The concept of 'designing in' safety is crucial for ensuring the successful and safe delivery of construction projects.
- Adopting an 'Early Contractor Involvement' (ECI) model is preferable, allowing the selected contractor to contribute to the design, providing insights into safety, efficiency, and sustainability risks.
- Despite the advantages of 3D and 4D design technology in infrastructure projects, full adoption is limited by high setup costs and a shortage of skilled modellers in the industry.
- However, by planning projects within a 4D environment, benefits such as improved project planning, enhanced communication, clash detection, accurate cost estimation, efficient resource management, and effective risk management can be realised.
- Digital zoning technologies, like PLINX , can complement physical controls and enhance safety by alerting workers and visualizing compliance.
- By implementing zonal controls early in the design phase, the project's ramp-up time is reduced, as phasing, logistics, and safety considerations have already been taken into account and defined.
- Zonal working, which establishes clear boundaries and permissions on construction sites, brings several advantages when standardized. It ensures consistency, efficiency, safety, interoperability, and opportunities for continuous improvement across different projects.
- Standardization allows for digital compliance monitoring, but it requires upfront information and a clear set of binary rules.

Recommendations, actions and impact

Developing a digital tool

It is recommended to develop an 'easy to use' digital tool that represents the standards set in this Sandbox project. Such a tool would simplify the process for designers and construction teams, facilitating the identification and mitigation of risks associated with zonal working.

The tool should dynamically assess risks based on information provided by the designer and construction teams. It would help identify risks directly associated with the task at hand as well as the compounding effects of adjacent works. Integration with a 4D model and leveraging machine learning capabilities could optimize site design and enhance site safety. The tool's output could be a digital representation of the zone or a document outlining the zone requirements and any pre-work conditions.

Standardisation

The HSE should work with industry to develop industry-wide standardisation for zonal working, providing consistent guidelines and enhancing collaboration, communication, and safety. They should also support the creation of an intuitive digital tool to facilitate risk identification and mitigation, dynamically assess risks, and optimize site design using machine learning. Encouraging the adoption of dynamic solutions like PLINX Hazardsense, which integrates physical segregation with digital models, would improve coordination, safety, and efficiency. These recommendations aim to enhance safety, efficiency, and collaboration in zonal working, addressing challenges related to standardization, digitalization, and implementation.

Next steps

In order to drive further progress, we recommend that PLINX and HSE collaborate in identifying additional stakeholders who can contribute to the ongoing development of the ProAct concept. This group should include representatives from HSE (science and inspector divisions), clients, designers, and contractors.

By conducting comprehensive value analysis and providing evidential support, the eventual goal is to influence regulatory changes.

The group will conduct the following activities:

1. Deconstruct existing legislation to enable its digital application, aligning with the ProAct initiative's objectives.
2. Collaboratively develop and establish rules that form the basis of the zonal working standard.
3. Further enhance and thoroughly document the standardised approach for zonal working.
4. Create a dynamic risk assessment tool derived from the established standard.
5. Analyse and address the legal implications for clients, designers, and contractors involved in zonal working.
6. Develop a comprehensive assessment of the 'value add' return on investment (ROI) in terms of time and safety benefits.
7. Identify suitable projects to serve as test cases for the zonal standard and evaluate technologies that enhance zonal control.
8. Produce compelling case studies that showcase the value and effectiveness of the standardised approach and complementary technologies.
9. Investigate and document the impact of emerging technologies on zonal control, ensuring the ProAct initiative remains up-to-date and adaptive.
10. Foster connections with academia and other industry-led groups such as Human Form Recognition, facilitating knowledge exchange and collaboration.

5.2 Synthesis of lessons learned across Sandbox Investigative Studies

The investigative studies conducted through the Sandbox provided examples of specific applications and a detailed consideration of barriers within those specific areas. By looking across all the studies, several common themes started to appear; the consensus view from the studies being that the main current barriers to technology adoption in the construction sector are less regulatory focused and more associated with technical, financial or cultural issues. These are discussed below.

5.2.1 Cultural

- The complex nature of construction projects increases the challenge for tech providers to access the sector. This complexity arises out of the multi-layered delivery landscape with multiple stakeholders including clients, designers, contractors, sub-contractors and the wider supply chain such as manufacturers and leasers of machinery.
- Tech companies need access to the right mix of people within organisations to explore adoption opportunities, i.e. combination of people with responsibilities in digital, innovation and business improvement as well as health and safety. Establishing different organisational structures or creating roles more aligned to fostering innovation and technology adoption could help alleviate this.
- Current uncertainties regarding liability in the event of the malfunction of a tech solution or tool, particularly with respect to the use of AI applications, is a big barrier. The current culture of liability avoidance means that anything which introduces a new risk into a process and requires a new risk owner is unlikely to be adopted. There are various ways that this could be addressed, for example through the development of an assurance framework, contractually or by using the general principles of negligence and duty of care. In the case of autonomous vehicles, insurance is used under the Automated and Electric Vehicles Act 2018, Legal Liability Options for Artificial Intelligence. A clear UK regulatory framework to address liability is required to change the current culture.
- Understanding how to remain compliant with GDPR and ensuring worker rights to privacy are protected when using many digital technologies, for example computer vision technologies and wearable devices, represents a challenge. This could be addressed by working with the ICO and by establishing case studies and sharing of best practice.
- There is resistance in the health and safety community to implementing major changes in how duties linked to health and safety compliance are met. This is especially the case with respect to the replacement of traditional management approaches by technology-led ones, including the extent to which frontline workforces have the technical capability to make greater use of technology. This could be addressed by placing a stronger emphasis on digital technologies and innovation in formal health and safety qualifications such as the NEBOSH diploma or certificates, the NCRQ level 6 diploma and degree/ postgraduate qualifications.

5.2.2 Financial

- Tech companies need confidence there is likely to be a return on their investment in research and development of specific solutions. Industry also needs confidence of a likely return on investment if they look to adopt specific solutions, including confidence that there are no regulatory barriers. HSE have a role to play in further understanding what new technologies are being developed and trialled in different sectors. This may justify the formal establishment of a health and safety Sandbox for new and emerging tech, specifically including industrial safetytech.
- Financial support for tech companies to field trial their solutions would encourage innovation. A potential solution could be the formal establishment of a government financial support scheme that could be used to support pilot work, as in other countries such as New Zealand.
- Clients overseeing major projects need to be incentivised to routinely include trialling of new technologies into the projects being commissioned. For example, government-procured projects, such as national infrastructure, could be mandated to allocate specific funding to adoption of new technologies for safety as a percentage of the overall innovation spend. This would act to influence industry and, potentially, facilitate a shift in culture.
- The cost of introducing new technology, for example robotics, is such that it typically needs to be productive for almost 100% of the time to achieve a return on investment. This often means using the technology for a number of different activities, which in turn makes certification a challenge. With robotic technology, for example, current industrial certification focuses on the process it is being used for; any significant change in use requires re-certification, which is a significant expense. It also requires a knowledge of the many relevant standards for certification, which for robotic controlled industrial processes include the Machinery Directive 2006/42/EC, ISO 10218, ISO/TS 15066, ISO 13849, IEC 60204 and ISO 12100.
- In the UK construction sector, users typically expect payback on technology such as robots over 1-2 year periods, whereas it is twice that in other countries such as the US. Understanding how the payback periods currently used could be expanded would make adoption more viable. Providing technology as a service may have potential as a way of tackling prohibitive initial costs.

5.2.3 Technical

- Clarity on the health and safety challenges industry are facing is required for tech companies to better address them. Tech companies need to be able to access health and safety data and expertise. It may be appropriate to consider establishing a more formal mechanism to understand such challenges and address data access.
- Industrial safetytech solutions can be quite niche, and industry appears to value solutions able to deliver benefits across multiple areas of business. Not only addressing health and safety, for example, but also productivity, sustainability, quality and information management. The identification of synergies across disciplines could provide focus for future research and development to accelerate adoption.
- Barriers to adoption were observed to be lower for tech used to perform non-contact activity, such as inspections or administrative tasks. In these cases, technology can be treated like more traditional plant, machinery or equipment which is well catered for by existing standards and regulations. It may be that there should be a focus on these use cases, as an easier way to demonstrate application and credibly, then use these to establish requirements for more complex areas.
- Barriers to adoption were seen to be greater for technology used by the frontline workforce, such as robots working in the vicinity of human workers. In these situations, where there is the potential to introduce new risks to a worksite, the sign-off requirements in terms of new risk assessments, method statements, briefings, training and instruction can be significant. Often, a lack of understanding of the use of the technology and the associated new risks plus the

competency to implement suitable risk assessments can add significant financial cost to piloting phases.

- To accelerate the adoption of robotic technology, there is a requirement to develop a framework to guide the certification of a robotic cell. The NBS Chorus system, used to create building specifications, could be used as an example. This system draws information from a library of existing equipment and processes and provides templates and documentation, but remains fully editable so that no processes or equipment are excluded. This may be an appropriate model to apply in this case.
- Construction projects are transient by nature, which can make it difficult to transfer lessons learned from one project to another, particularly with respect to the trialling of new tech. Developing a mechanism for capturing lessons learned and making it available to future projects would be very beneficial.
- The dynamic nature of construction projects and sites means that repeat piloting is likely to be needed. Common risks are likely to be better understood and can be covered by suitable plant, machinery or equipment certification, risk assessment and a standard job method statement. However, site-specific risks, such as the risk of vehicle collisions, contact with overhead powerlines, underground service strikes or contact with people in the immediate vicinity of works, will vary from site to site and, potentially, from one day to another on a single site. Acceleration of the transition to modular construction and off-site manufacturing is a potential way of tackling this.
- There is a need to adapt existing sites and procedures to new ways of working with technologies to accelerate their implementation. For example, there may be overly prescriptive testing methods to demonstrate the quality of output, regardless of how safe a process is. There is also an absence of suitable operator certifications able to demonstrate user competencies for new technologies. The establishment of the required tests and certifications would remove this barrier.
- The expectations of technologies new to an industry to revolutionise them for the better are often unachievably high, meaning that progressive improvements in performance can be hard to demonstrate. The setting of more realistic, achievable expectations is recommended.

5.3 Feedback on Sandbox process

During the Sandbox process the project team keep a log of lessons learnt over the course of the project. An interim group session was also held with the mentors to gather their feedback along with a 1-2-1 meeting at the end of the Sandbox. The team also held 1-2-1 meetings with the tech companies to gather their feedback at the end of the Sandbox. Table 11 below summaries these lessons and provides useful recommendations on how to build from these for future Sandbox-type work.

Feedback/Lesson learnt	Description	Source	Recommendations
The Sandbox running time was short	Time was too short to develop new relationships to reach piloting stage during the Sandbox. It was those with previous relationships that reached this stage.	Tech company 1-2-1 feedback sessions	Additional preparation with the mentors before the kick off to facilitate engagement with the right people would have been beneficial
The project required more time than first anticipated	This Sandbox process required a lot of time and resources	Tech company 1-2-1 feedback sessions	Be upfront with the expectations and times that will be needed. Make the benefits clear.
Companies at different stages of commercial development would have different abilities to participate	Different stage companies will benefit in different ways: 1) Early stage would struggle with this approach 2) Later stage but new to the market will gain new insights 3) Later stage and progressing will allow for quick pilots	Tech company 1-2-1 feedback sessions	Ensure the selection process considers the input, type of support and outcome we are looking for
A lot was gained when tech companies met at London Tech week event	More in-person networking opportunities and events would have been beneficial	Tech company 1-2-1 feedback sessions	Build in in-person kick off and networking events to the process and budget
More lead up time required to mobilise	Generally, well run. Ideally, more lead up time to understand the ask and enable engagement with the 'right' people.	Industry partner 1-2-1 feedback sessions	Be upfront with the expectations and times that will be needed. Make the benefits clearer.
Industry needs to be involved in the selection of the challenges and companies	Mentors want to be more involved in selection of the challenges and the tech companies	Industry partner 1-2-1 feedback sessions	Consultations with the mentors to make sure they are aligned with the challenges

Feedback/Lesson learnt	Description	Source	Recommendations
Some mentors didn't feel they had a lot to offer the tech company	Mentor match-making was okay, but could be more refined to ensure they are benefiting from one another	Industry partner 1-2-1 feedback sessions	Give the mentors as much info on the tech companies as possible before selection, including the type of support they are looking for
Value was in having open conversations	A strong benefit was access to innovators who were not selling. Therefore, open conversations around limitations could be had.	Industry partner 1-2-1 feedback sessions	Emphasise the expectations and benefits of an open conversation
Certain personalities did not work well together and can create a barrier to collaboration	Personalities should not be underestimated in terms of who will work well with whom and which tech companies will put in the effort	Industry partner 1-2-1 feedback sessions	In the selection process, understand who will be participating and check that they are engaged and can provide the right level of decisions and input

Stage of project	Lesson learnt	Source	Recommendation
Challenge/ Sandbox design	Important to engage smaller organisations for input into brief, not just the larger players. This could take the form of trade bodies and/or representatives.	Internal team lessons learnt	Engage earlier for the challenge workshop and consider that they may be be able to offer different levels of support
Challenge/ Sandbox design	Learning gained from reviewing other Sandboxes showed this was unique as we are providing funding and we have a more focused brief, using an accelerator to ensure we have the right companies in the Sandbox.	Internal team lessons learnt	Continue to review other Sandboxes and collaborate with other regulators around this model
Mentoring	Asking industry partners during the selection process to submit their preference to mentor ensured they were engaged from the start and lead to a smooth and quick assignment of mentors.	Internal team lessons learnt	Even though we did this, mentor feedback suggested they wanted more engagement.
Contracting	Ensuring the tech companies had reviewed a template of the collaboration agreement before the pitching session meant the selected ones were able to sign these quickly before the start of the project.	Internal team lessons learnt	Worked well and allowed us to start on time.
Selection	Different companies require different levels of support to form their ideas into actionable projects - we need to be prepared to support with forming projects when necessary, at the beginning	Internal team lessons learnt	Make sure there is an understanding of the type of support when they are selected.

Monitoring	Keeping the bi-weekly catch-ups casual ensured the tech companies had a 'safe space' to share any issues.	Internal team lessons learnt	Allowed early detection of issues
Monitoring	Putting in a more formal interim presentation and ensure they have a mid-point deadline to work to and for us to provide feedback.	Internal team lessons learnt	Keep the momentum up; provide good feedback and directions
Selection	Due to enthusiasm of the participants, many projects are ambitious with larger scope than anticipated. This needs monitoring to ensure they are realistic.	Internal team lessons learnt	Good to encourage, but make sure participants are aware of the limitations and approach with realism
Engagement / Collaboration	We set up a LinkedIn group for the participants as a joint space to discuss the project (this was preferred instead of Slack etc). This needed a lot of interaction from the STA team but has yet to yield any conversation.	Internal team lessons learnt	Look to use Slack instead
Engagement / Collaboration	At the beginning of the Sandbox, we need to make sure there is a more in-depth and structured kick off meeting between the mentors and the tech companies to ensure the mentors know what the timeline and project plan is.	Internal team lessons learnt	Run a kick off session with mentors, and not just rely on tech companies to run through their plan and timeline.
Engagement / Collaboration	Allow space for further collaboration after the project. Set up a structure that will allow for the tech companies to collaborate and share learnings further.	Internal team lessons learnt	This could be done through Slack or in-person meetings. It is also being covered to some extent by the dissemination event
Time frame	Time frame between selection and 1st deliverable was potentially too short and included Easter break	Internal team lessons learnt	Need to consider the time of year and allow longer for tech companies to plan.
Engagement / Collaboration	Worked well to have face-to-face meetings for large deliverables of the project.	Internal team lessons learnt	Request to have more face-to-face meetings with the internal team.

Selection	Worked well to test the value proposition with tech companies and refine it to ensure we are reaching the right type of company	Internal team lessons learnt	Keep doing this
Selection	Worked well to use a variety of sourcing channels to ensure we got a spread of the tech in the UK market	Internal team lessons learnt	Keep doing this. Identify the right publications to market the project.
Market knowledge	Worked well to use the scouting as an opportunity to gain new insights into the UK construction market. For instance, we learned that there are no UK companies producing exoskeletons.	Internal team lessons learnt	Keep doing this
Selection	Worked well to group tech companies around their technology type; ensures that the final six will make up the preferred portfolio.	Internal team lessons learnt	Keep doing this
Selection	Worked well to engage industry partners early on and ensure their input into selecting the six finalists	Internal team lessons learnt	Keep doing this; look to do this through a survey or a meeting
Engagement / Collaboration	Worked well to run an open and honest session with the mentors to hear their feedback halfway through and to ensure they are engaged for the final report.	Internal team lessons learnt	Keep doing this
Engagement / Collaboration	Having live sessions to facilitate knowledge exchange at the end of the project between tech companies and industry worked well. Potentially needed 5 minutes longer for the tech companies' presentations.	Internal team lessons learnt	Keep doing this
Monitoring	Having 1-2-1s for feedback works well	Internal team lessons learnt	Keep doing this
Report/Outcome	It was necessary to have a 1 pager for each that will allow for clear public-facing overview.	Internal team lessons learnt	Need to add in a specific section in the report template for tech companies to spell out the success and impact of their project

Table 11 - Research questions and Statement of Work for each Sandbox investigative study.

Overall, the Sandbox was seen as a success by all involved and facilitated:

- acceleration of the development of new business areas, for example for FYLD, EAVE, Machine Eye and PLINX
- open exploration of solutions between Industry and tech companies without the pressure to sell or build businesses for investment
- exploration of a new way of working with the regulator to understand options, barriers and opportunities to work collaboratively

6 Recommendations and next steps

6.1 Insights, Recommendations and Next Steps from each Investigative Study

A summary of the key learnings, recommendations and next steps coming from each of the investigative studies is shown below.

EAVE

- **Key learnings** – Over-exposure to noise is widespread in the construction sector and is not reflected in the official reported figures (RIDDOR), highlighting the need to address under-reporting. Continuous monitoring of noise at a granular level on construction sites enables contractors to understand where and how to fix over-exposure.
- **Recommendations**

  1) HSE should consider the integration of data from smart hearing protection platforms into their guidelines for noise exposure. Explore whether smart hearing protection data could be used to replace traditional methods of noise exposure assessment.

  2) Industry should address the underreporting of NIHL, including how insights from smart hearing protection data can inform the development and implementation of more effective and targeted noise control measures.

- **Next Steps** – EAVE has received an Innovate UK grant for the development of an Occupational Health and Safety platform that utilises a novel approach to risk assessment and control. An Industry Steering Group has been established and HSE has been asked to present a regulatory perspective.

FLYD

- **Key learnings** – Verified models of ROI are crucial to driving investment, and these must factor in wider benefits than just safety. There is a gap between the position of the regulator and the understanding from industry leaders who are making decisions regarding technology.
- **Recommendations**

  1) HSE should convene an industry and tech sector focus group to continue exploring the utilisation of technology through use cases demonstrating how compliance can be achieved and to close the gap on the regulator and industry positions.

  2) Industry should work with FYLD to co-develop an AI Digital Training Programme and seek to share content at scale, to break down the barriers in industry by demystifying the use of AI in safety.

- **Next Steps** - FYLD are continuing the on-site work with Colas to demonstrate further proof points for ROI beyond safety improvements which can be published as a case study for construction projects. FYLD have also identified a product improvement as a direct result of the work with Colas. A digital signing solution is being built and deployed into the current product, to fit the nature of the construction industry.

HAL Robotics

- **Key learnings** – The current standards are fit for purpose but the processes, information and guidance to develop the certification documents could be greatly improved.
- **Recommendations**

  1) HSE should explore options to provide simplified access to information to guide the certification of a robotic cell. If this initially covered relatively simple installations, it would allow many new companies to use automation.

  2) industry should explore building a tool to simplify access to the regulatory information required for certification when designing and building robotics systems.
- **Next Steps** - HSE is working with STA and the Better Regulation Executive to explore funding opportunities to facilitate the development of tools to improve compliance in the area of flexible robots.

Machine Eye

- **Key learnings** – A set of 15 key blockers to the adoption of computer vision within the construction and civil engineering space were identified and grouped into financial and technical risks. Mitigation to these blockers were identified.
- **Recommendations**

  1) Government should provide financial incentives to promote and accelerate the adoption of AI in the construction sector, particularly on Government infrastructure projects.

  2) HSE should support SME tech companies through Sandboxes and Knowledge Exchange opportunities, and be more proactive and timelier in issuing clarification with respect to new technologies

  3) Industry should explore a collaborative approach to highlight best practice and work collectively through innovation zones and Sandboxes
- **Next Steps** - Machine Eye have built new relationships with the construction sector and are now working with partners from the project to identify and deliver pilots on-site.

Oculo

- **Key learnings** – This project is still ongoing.

PLINX

- **Key learnings** - The greatest value of this type of technology applied to zonal working is likely to be the ability to deliver 'live' risk information to enable immediate mitigation actions to be taken.
- **Recommendations**

  1) HSE should work with Industry to develop industry-wide standards for zonal working, providing consistent guidelines to enhance safety.

  2) Industry and the tech sector should develop a digital tool to simplify and standardise the zonal working process, and facilitate the identification and mitigation of risks associated with zonal working.

- **Next Steps** - HSE and PLINX are coordinating an industry working group to continue to progress the standards and tool development work, known as the ProACT initiative.

6.2 Wider recommendations

There are also a number of wider recommendations arising from this work:

- Sandboxes are an effective way to undertake investigative work exploring complex or novel topics in a collaborative way and at pace. It is recommended that this approach is considered for use by other safety regulators as well as HSE for topics such as reducing work-related ill health.
- Cross-regulatory issues were noted during the Sandbox, for example GDPR compliance, or access to regulatory expertise, data or information to improve compliance across regulatory areas in a particular sector. It is recommended that a review of the potential funding opportunities for a cross-regulator Sandbox to explore these issues is undertaken.
- There is a role for Government to play in helping to support, encourage and incentivise innovation adoption. This could be through financial initiatives, mandating the inclusion of innovative technologies on government projects, helping improve confidence in ROI through supporting field trials, and helping to foster a robust supply chain. It is recommended that a detailed examination of options is undertaken.

Annex A Organisations that contributed to the prioritisation exercise

Company	Sector
Costain	Contractor
BAM Nuttall	Contractor
Laing O'Rourke	Contractor
HS2	Construction client
Heathrow Airport	Construction client
Manchester Airport Group	Construction client
Birmingham Airport	Construction client
Multiplex	Contractor
Morgan Sindall	Contractor
Ferrovial	Contractor
Amey	Contractor
Colas	Contractor
Skanska	Contractor
FM Conway	Contractor
Kier	Contractor
John Sisk	Contractor
Sir Robert McAlpine	Contractor
Balfour Beatty	Contractor
I3P	Industry community of practice
Forum of Private Businesses	Industry professional association/advisory body
Federation of Master Builders	Industry professional association/advisory body
Construction Industry Advisory Committee	Industry professional association/advisory body
Construction Leadership Council	Industry professional association/advisory body
Atkins	Design/consultancy
Arup	Design/consultancy
Jacobs	Design/consultancy

Table 12 – companies contributing to the prioritisation exercise

Annex B HSE Data review

The plots below illustrate the sample of RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013) reports, NOCs (Notices of Contravention), notices and prosecution reports that were manually reviewed. The cases are categorised by risk topic and the plots illustrate % of records reviewed falling into different risk categories

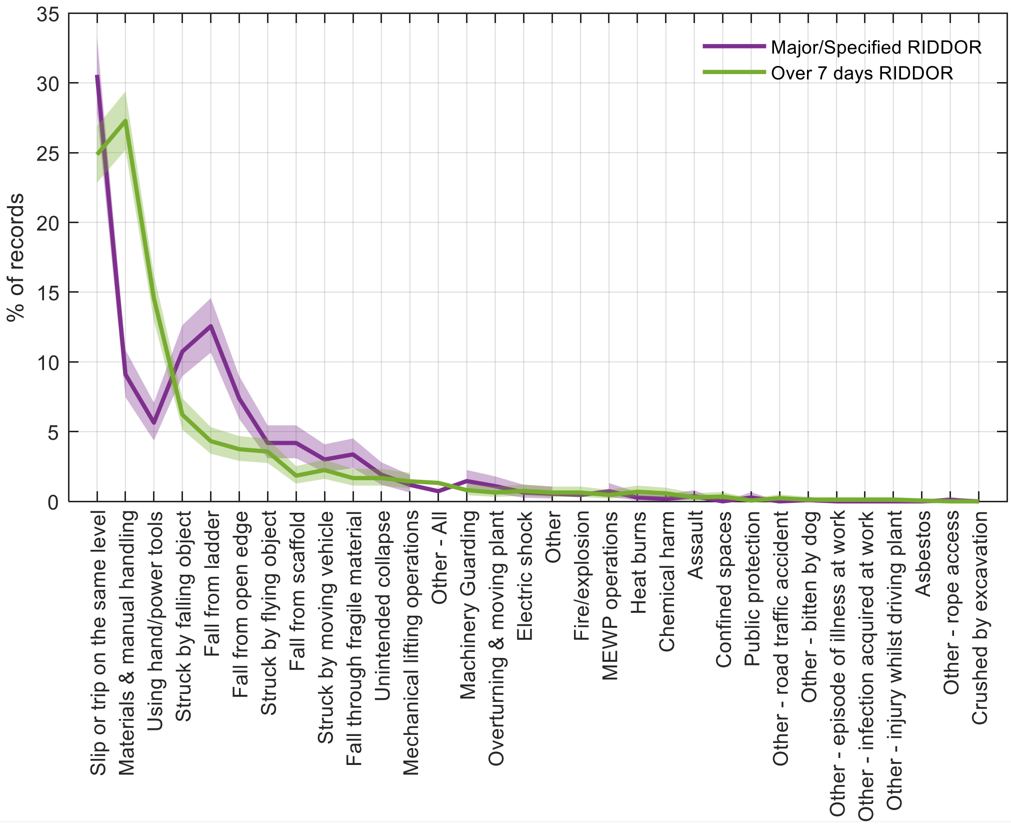


Figure 7 – % of RIDDOR records reviewed falling into different risk categories

Top six risks based on reporting under RIDDOR:

- Slip or trip on same level
- Materials and manual handling
- Using hand/power tools
- Struck by, falling/flying object, vehicle
- Fall from height
- Mechanical lifting operations

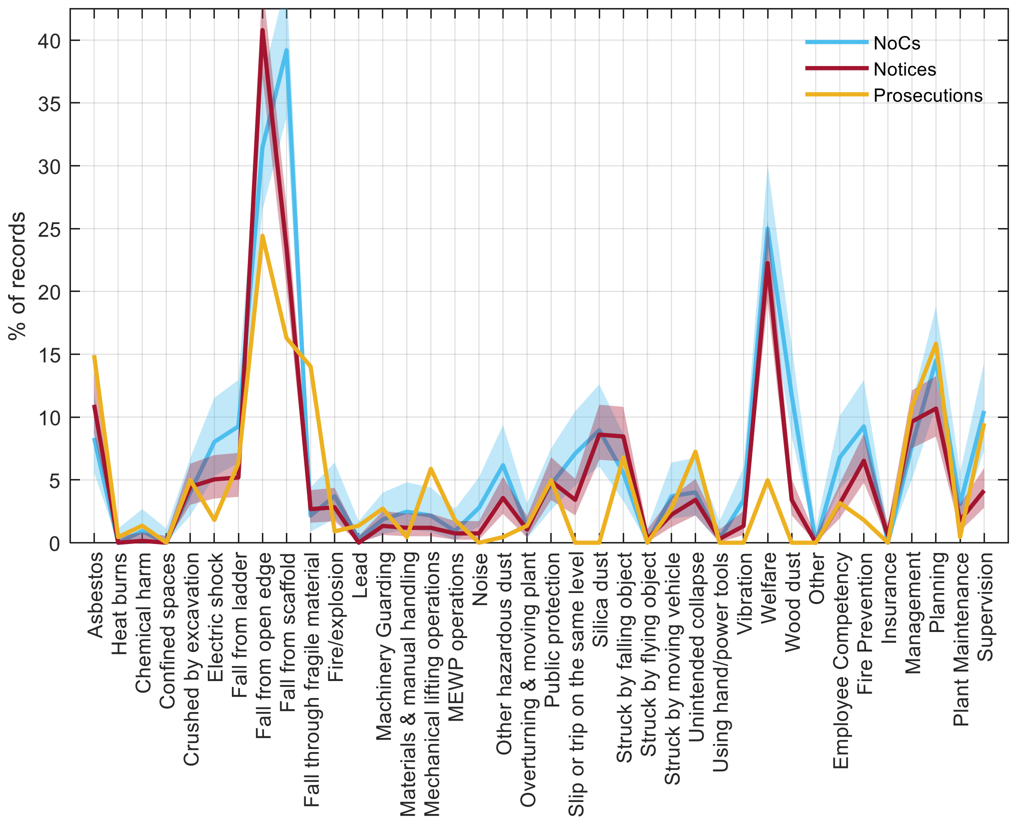


Figure 8 – Top risks based on material breach detection and issue of notices

Top six risks based on issues of notices of non-compliance:

- Fall from open edge (approx. 40% of notices, 25% of prosecutions)
- Fall from Scaffold (approx. 40% of breaches, 15% of prosecutions)
- Welfare (approx. 25% of notices and breaches, 5% of prosecutions)
- Inadequate design, planning and management (approx. 10% of notices and breaches, 15% of prosecutions)

And the associated key regulatory compliance challenges are:

- Working at height
- Construction design and management

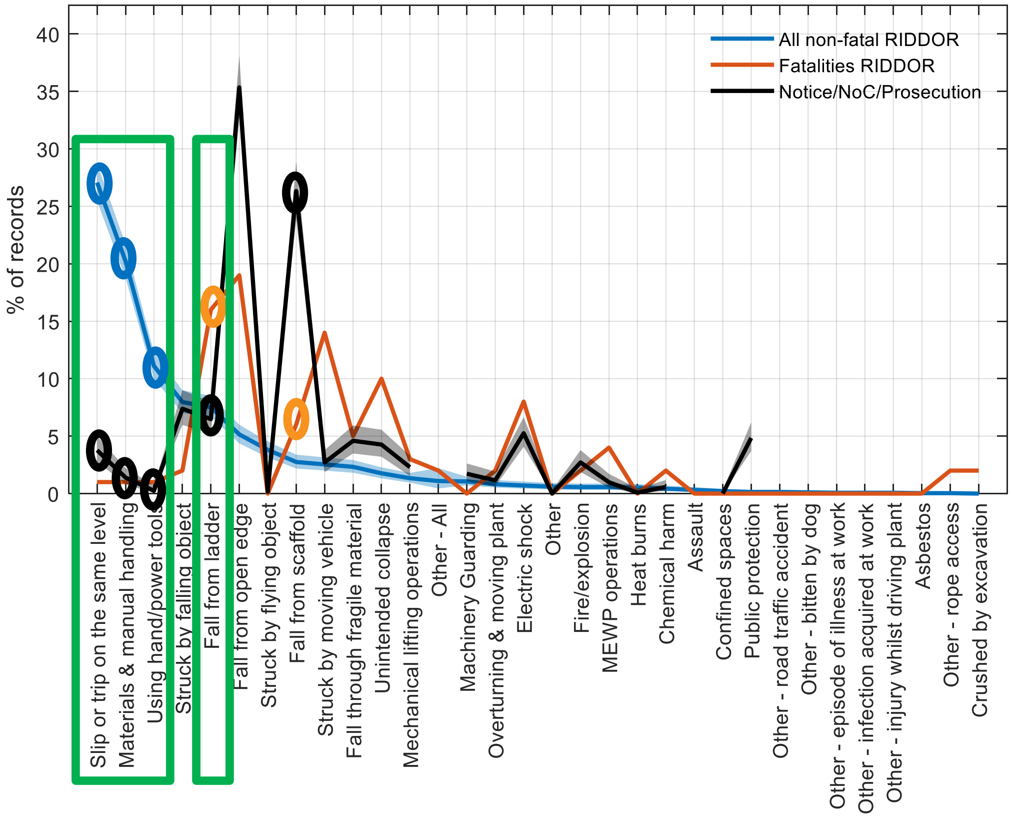


Figure 9 – Top risk by number of records from different notifications

Figure 9 potentially illustrates where there might be a challenge in regulating or enforcing. With the following areas potentially showing evidence of under-enforcement based on a comparison with risk prevalence from RIDDOR:

- Slip or trip on same level
- Materials and manual handling
- Using hand/power tools
- Fall from ladder

Annex C Mapping of Tech Companies

Available on request.

Annex D Tech Companies chosen for the Sandbox

Available on request.

Annex E STA Review of other Sandboxes

Available from STA.

Annex F HSE Review of Technologies

Available on request.

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