Is the law keeping pace with technology?

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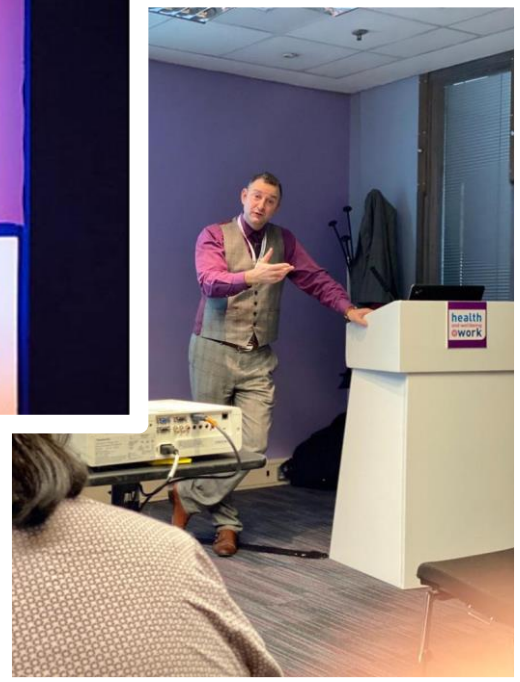
Overview of talk

- How do regulations/associated guidance apply to use of robots and autonomous systems in construction?
- Are there significant gaps?
- If so, how could they be filled?

About the Speaker



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Architecture Today

Duty of Care

Coronavirus may give architects new responsibilities under CDM regulations, say Hawkins Brown's Nigel Ostime and risk consultant Nick Bell

Nigel Ostime

Nick Bell

CONSTRUCTION

Using BIM to support healthy an safe construction

The UK Government describes Building Information Modelling (or BIM) as a tool for supporting the collaborative design, construction and maintenance of buildings other assets[1]. This article by Dr Nick Bell and Mike Ford, briefly explains what BIM is sets out how and why it can improve health and safety in construction.

There are essentially two elements that go into BIM: A 3-Dimensional model made up of numerous different components and data attached to those components. Examples of these are shown below:

CONSTRUCTION

BIM: Designing for safe and smart maintenance

The construction industry is getting to grips with Building Information Modelling (BIM). Here, Nick Bell and Mike Ford use a case study to offer ideas about how and why BIM is being used to support smart and safe maintenance.

During the construction of a large atrium, as shown below, a large mobile elevated work platform (MEWP) was used to install lights and sensors. The arrow shows the position of a light which would, at some point, need to be maintained.

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RIBA JOB BOOK

RIBA Plan of Work

10. EDITION

Setting the scene

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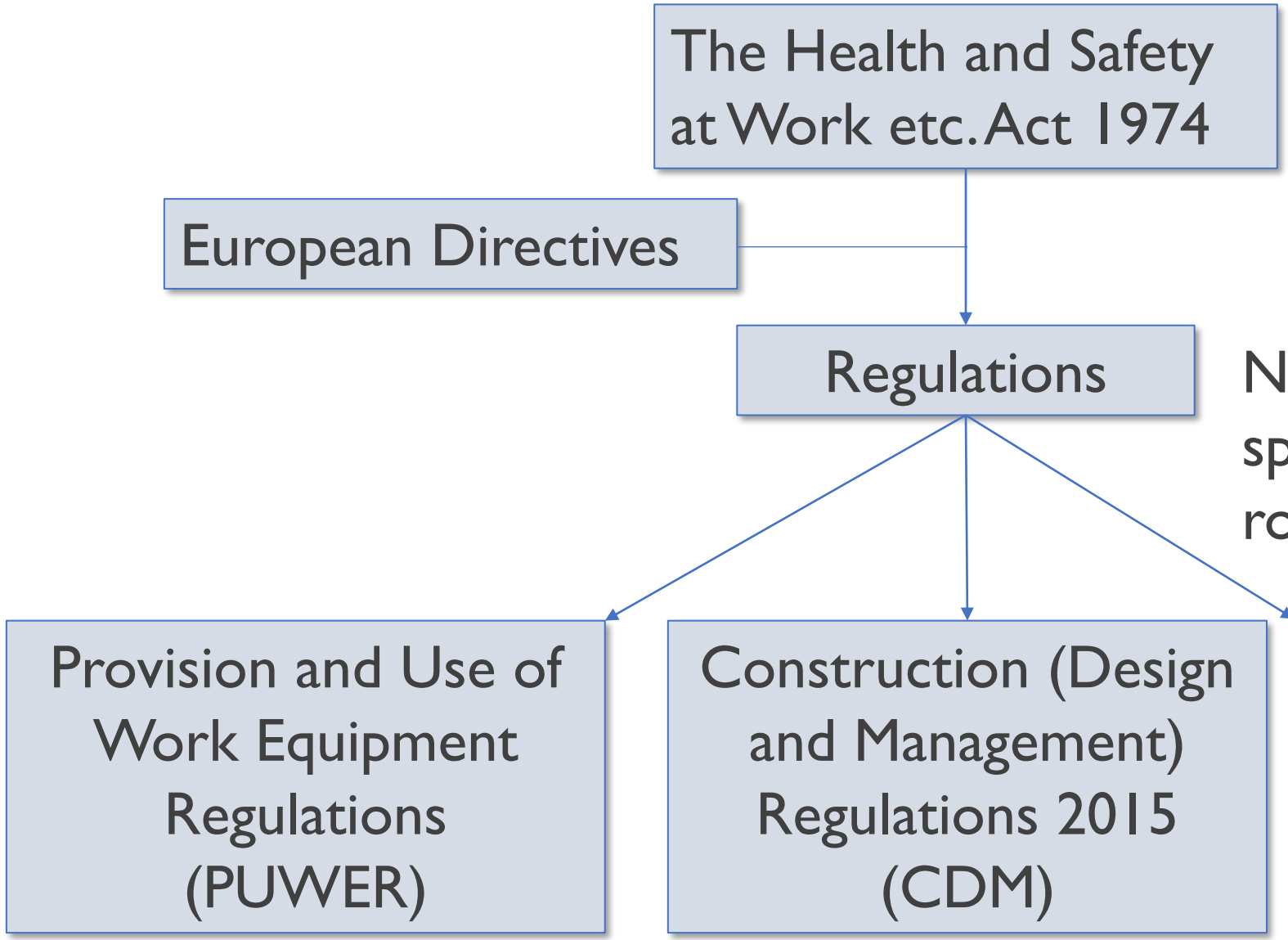
Overview of UK Health & Safety Law



Note: No Regulations specifically dedicated to robots/autonomous systems

UK Parliament

Parliamentary Bills

Retained EU Law (Revocation and Reform) Bill

Bill started in the House of Commons

- [x] 1st reading
- [x] 2nd reading
- [ ] Committee stage
- [ ] Report stage
- [ ] 3rd reading

Bill in the House of Lords

- [ ] 1st reading
- [ ] 2nd reading
- [ ] Committee stage
- [ ] Report stage
- [ ] 3rd reading

Final stages

- [ ] Consideration of amendments
- [ ] Royal Assent

THE SUNDAY TIMES

RED BOX | DEBORAH MEADEN

Wasteful EU law bill will hurt businesses at the worst possible time

FINANCIAL TIMES

UK's dramatic revoking of EU employment law will collide with reality

Courts will be pushed into political judgments on rights while employers and workers are left dealing with uncertainty

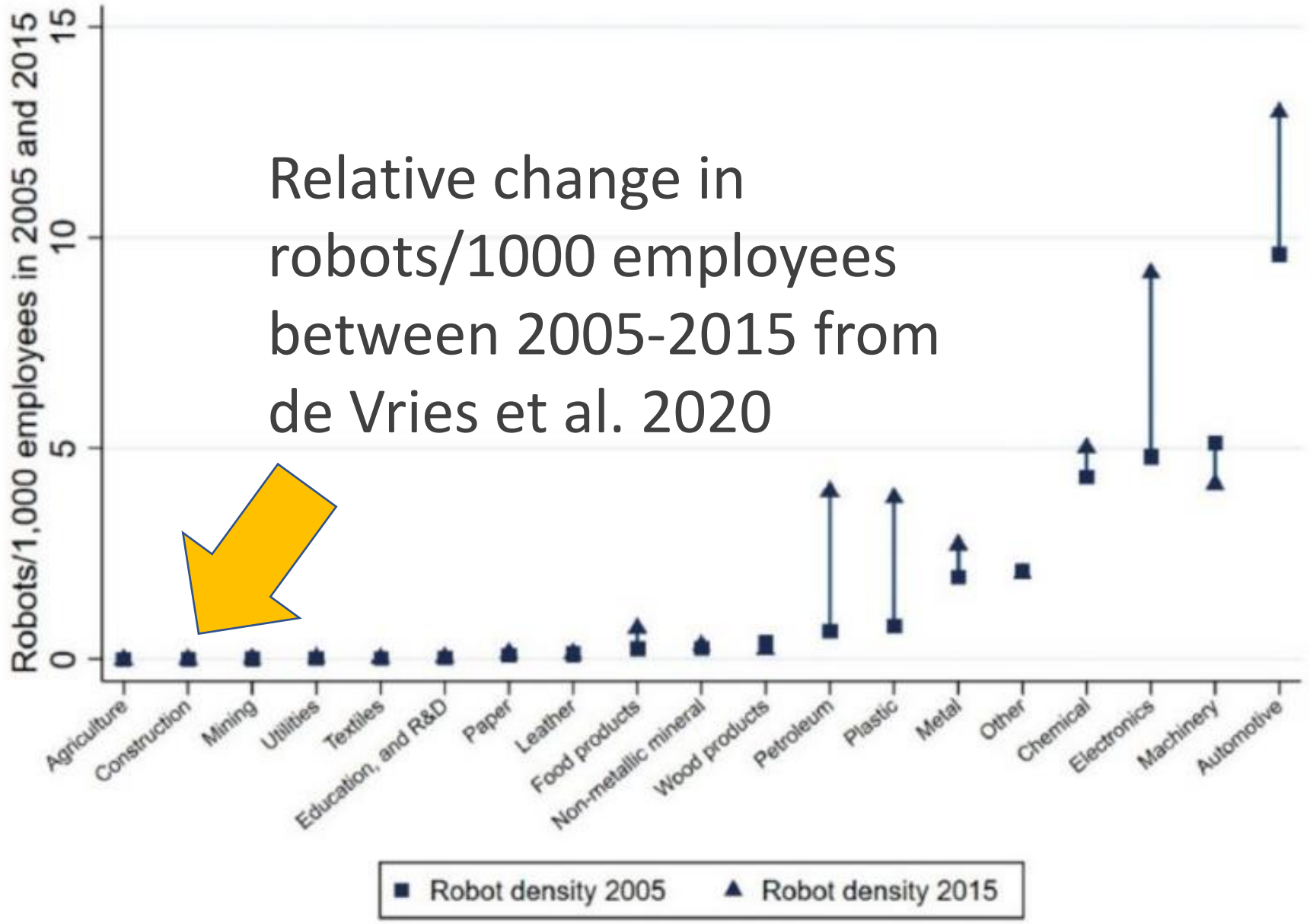
theguardian

Rees-Mogg's plans to axe all EU laws will cripple Whitehall, says leading Brexiter

UNISON

Workers' protections at risk as EU Law bill moves through Parliament

Figure 4: Relative change of robotic density in the given sectors over a 10-year period (extracted from de Vries et al., 2020)



Relative change in robots/1000 employees between 2005-2015 from de Vries et al. 2020

Implications for the Regulators

1) Limited data on risks/best practice for the Regulator to draw on

2) More immediate and prevalent risks to focus their limited resources on e.g. Health Risks

PROTECTING PEOPLE
AND PLACES

HSE

HSE Business Plan 2022/23

Our deliverables in the year will be:

Deliverable	*When*
Establish ill-health activity baseline and develop evaluation strategy	**Q4**
Deliver a programme of interventions focused on ill health in sectors where evidence demonstrates significant incidence of work-related ill health	**Ongoing**

Construction health campaigns	2000	40-55	Enforcement

% of visits which will lead to enforcement action

Deliver the BSR Programme to quality, time and cost to ensure all key functions are ready for deployment	**Q4**
Procure commercial partners to support the design and build of the required operating services for BSR	**Q4**

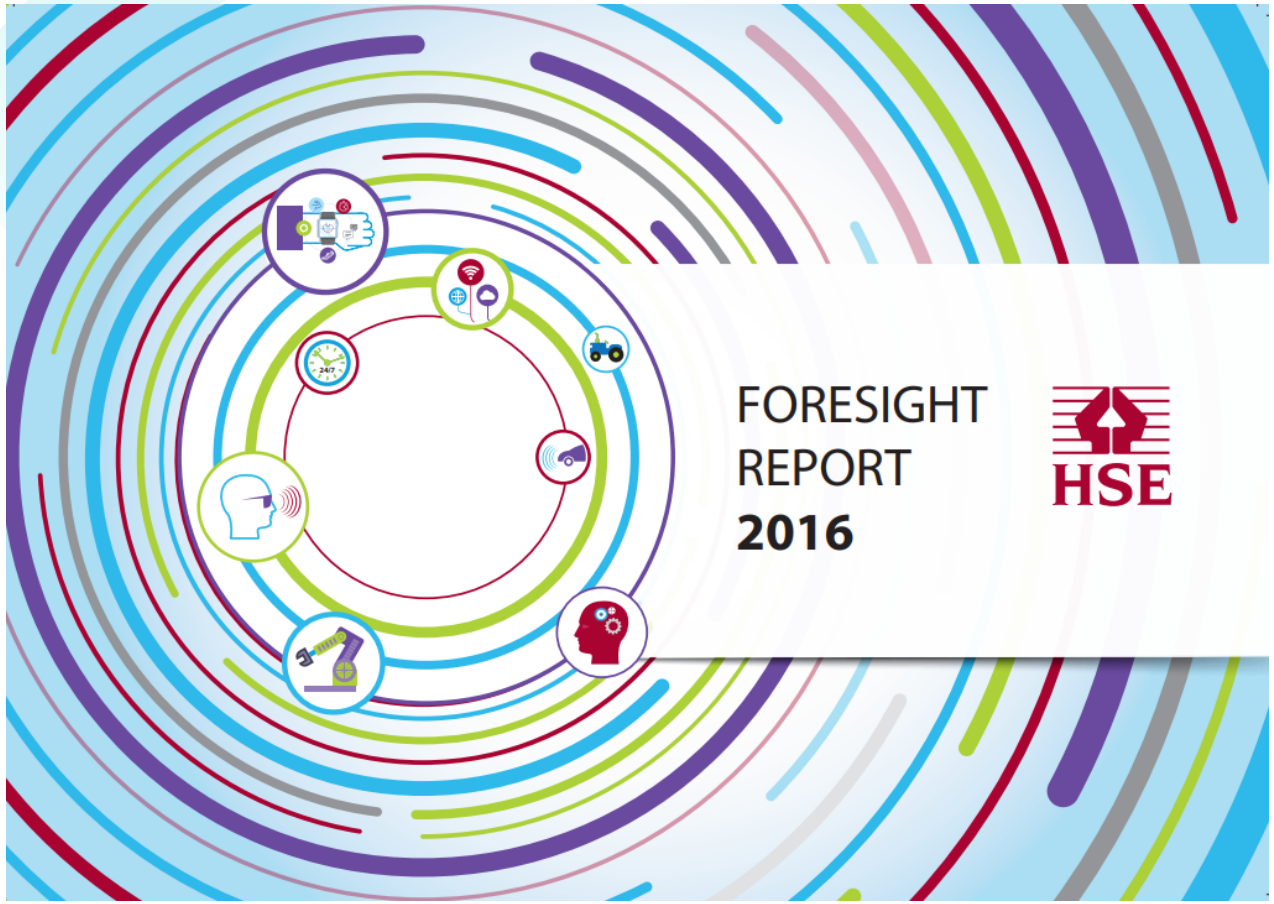
Foresight Centre

How we work

Foresight Reports

- The human impact of the changing nature of work (March 2020) (PDF)
- The future world of work and workplace health (March 2019) (PDF)
- Energy (March 2018) (PDF)
- Digital revolution and the changing nature of work (March 2017) (PDF)

H&S benefits of autonomous vehicles



- AV could take over "highly repetitive tasks and those that expose workers to noise, inhaled air pollutants, diesel engine exhaust emissions (DEEE), carcinogens, vibration and risk of MSDs." *i.e. help protect worker's health*
- "AV such as bulldozers and excavators could make construction faster, cheaper and safer" *i.e. commercial benefits*

March 2020

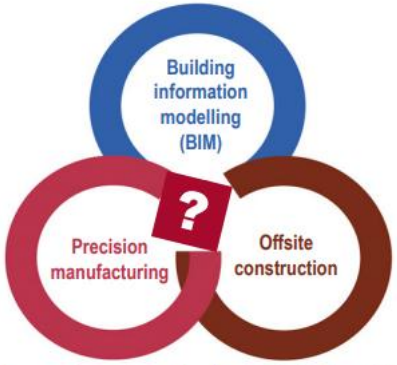
FORESIGHT REPORT

The human impact of the changing nature of work

HSE

Construction

Charlie is one of a growing number of younger people applying his technology skills in a sector that has undergone radical change. Modern methods of construction, using new materials, digital working and precision manufacturing techniques, have facilitated a transition to off-site manufacturing and different ways of managing construction sites, to build quicker and cheaper, whilst maintaining build quality.



In four to ten years time: There has been an increase in the use of technology-based tools and equipment, such as: remotely operated drones and autonomous vehicles, robotics and 3-D printing, which are linked to and help to inform building information modelling systems (BIM) via 5G networks. These systems can identify and manage health and safety risks on-site and ensure that planning and design are realised through the build.

Virtual reality (VR) allows construction teams to view each aspect of the construction process in sequence on the ground, before they happen.

VR is also applied to site induction for new workers. The use of augmented reality and wearable devices enables information to be conveyed to workers on-site, alerting them to risks and to provide monitoring of their exposure.

Combining this with biometric identity, time and attendance solutions, capturing data at site entry/exit, helps contractors to record, manage and report on individuals working on their sites and to inform health tracking through digital health passports.

In response to pressures for the industry to help address climate change, greener, more eco-friendly construction is promoted with re-use and recycling of materials and use of carbon-neutral materials becoming increasingly important.

Changed ways of working may lead to the need for bulk storage of raw materials on-site. Depending on the nature of these materials, this may have the potential to give rise to catastrophic major incidents with off-site consequences.

The average age profile of the sector continues to rise despite efforts to render the industry more attractive to both younger workers and women. Two factors that have driven the uptake of technology are loss in the availability of migrant workers and shortage of key skills.

There has been a shift in the risk profile of the sector, with fewer accidents on site but more occurring within the supply chain. Technological change has removed some of the physical construction risks, but on site, a greater proportion of falls are being reported (in part, due to the increased prevalence of older workers) and there are concerns about the poor risk perception of less experienced workers.

Charlie primarily uses BIM to generate and manage digital representations of new buildings, has played computer games since childhood, and is proficient in using the game controls that now operate many construction tools.

However, Charlie lacks the design experience of older workers, and this may have a negative impact on decision-making which is based on the digital solutions Charlie develops and delivers.

The lack of sufficiently skilled people to use the new technological tools and equipment means that Charlie is under constant pressure to deliver outputs. He may feel unable to cope with the demands of the job resulting in incidences of work-related stress. However, industry initiatives around this area, starting right from the apprenticeship level, have helped to build a responsive and supportive culture.

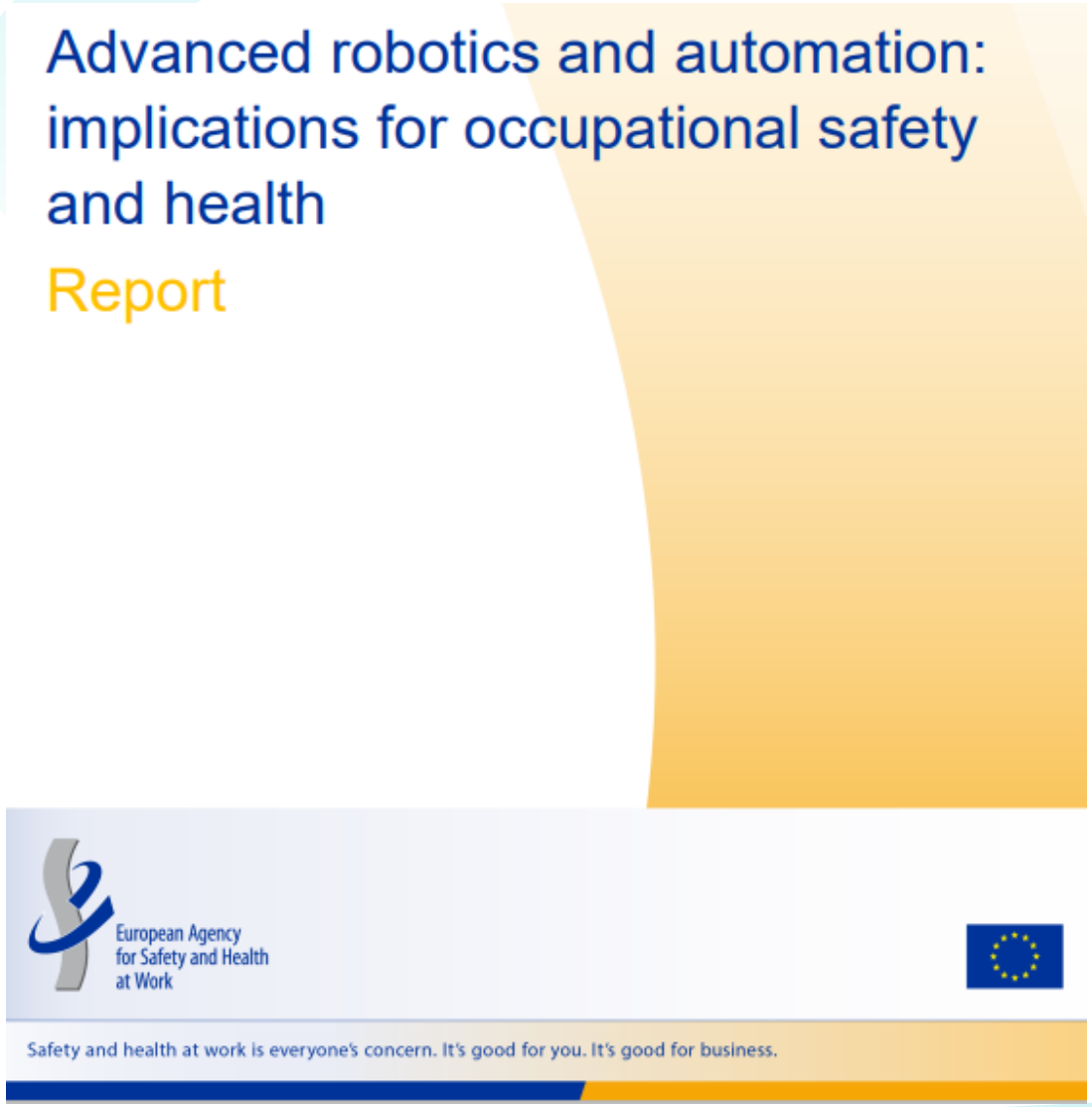
Conversation Starters...

- ✓ What If there are growing numbers of younger vulnerable workers who lack experience of their work environment and tasks?
- ✓ What if technology increases job demands and workplace cultures are not adapted to support the increased demands on workers?

2020 Predictions: In 4-10 years time

- Increase in the use of technology-based tools and equipment e.g.
  - remotely operated drones
  - autonomous vehicles
  - Robotics
  - 3-D printing
- Help identify and manage health and safety risks on-site and ensure that planning and design are realised through the build.

European Agency for Safety and Health at Work: 16/06/22



- Benefits/examples in construction:
  - Moving heavy loads (e.g. automated cranes, robotic arm and gripper)
  - Repetitive movements (e.g. bricklaying)
  - Concrete pumps with specialist sensors
  - Reduce human exposure to hazardous environments
  - Greater accuracy/better quality?
  - Less wastage/reworking?
  - 'Round the clock working?

‘Management Regs’

- i.e. new technologies can help mitigate risks but could introduce new risks
- Risk Assessment
- Apply the ‘principles of prevention’ (e.g. physically segregating a hazard is better than putting up a warning sign)
- Other specific laws and associated guidance can help us to determine what the risks and controls should be

Specific Regulations: PUWER and CDM

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PUWER 1998

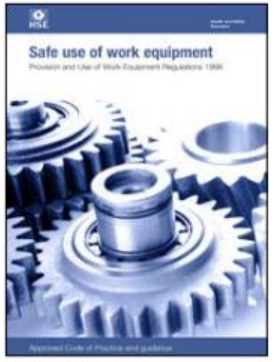
HSE

Health and Safety Executive

Safe use of work equipment

Provision and Use of Work Equipment Regulations 1998

Approved Code of Practice and guidance



L22 (Fourth edition)
Published 2014

This Approved Code of Practice and guidance is aimed at employers, dutyholders and anyone who has responsibility for the safe use of work equipment, such as managers and supervisors. It sets out what is needed to comply with the Provision and Use of Work Equipment Regulations 1998.The Regulations, commonly known as PUWER, place duties on people and companies who own, operate or have control over work equipment. PUWER also places responsibilities on businesses and organisations whose employees use work equipment, whether owned by them or not.

Changes since the last edition:

- The guidance material has been revised and updated, and there are small changes to some ACOP paragraphs to clarify and update information.
- Time-limited information has been removed or updated, and more use has been made of lists.
- This edition updates references to legislation and links to further guidance.

- ACOP last updated 2014
- Just one passing reference to ‘robot’
- No reference to autonomous systems

No mention of robots etc. in EU Directives

DIRECTIVE 2009/104/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 16 September 2009

concerning the minimum safety and health requirements for the use of work equipment by workers at work (second individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

DIRECTIVE 2006/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 17 May 2006

on machinery, and amending Directive 95/16/EC (recast)

The basic principles of PUWER

- Must ensure work equipment is suitably
  - Designed/selected
  - Installed
  - Maintained
  - Inspected
- Appropriate training and supervision is given
- Etc.

- i.e. regulations are broad enough to address robots/autonomous systems

- But so broad that employers may need more specific guidance

What specific risks are regulators worried about?

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HSE Research Report of 2012

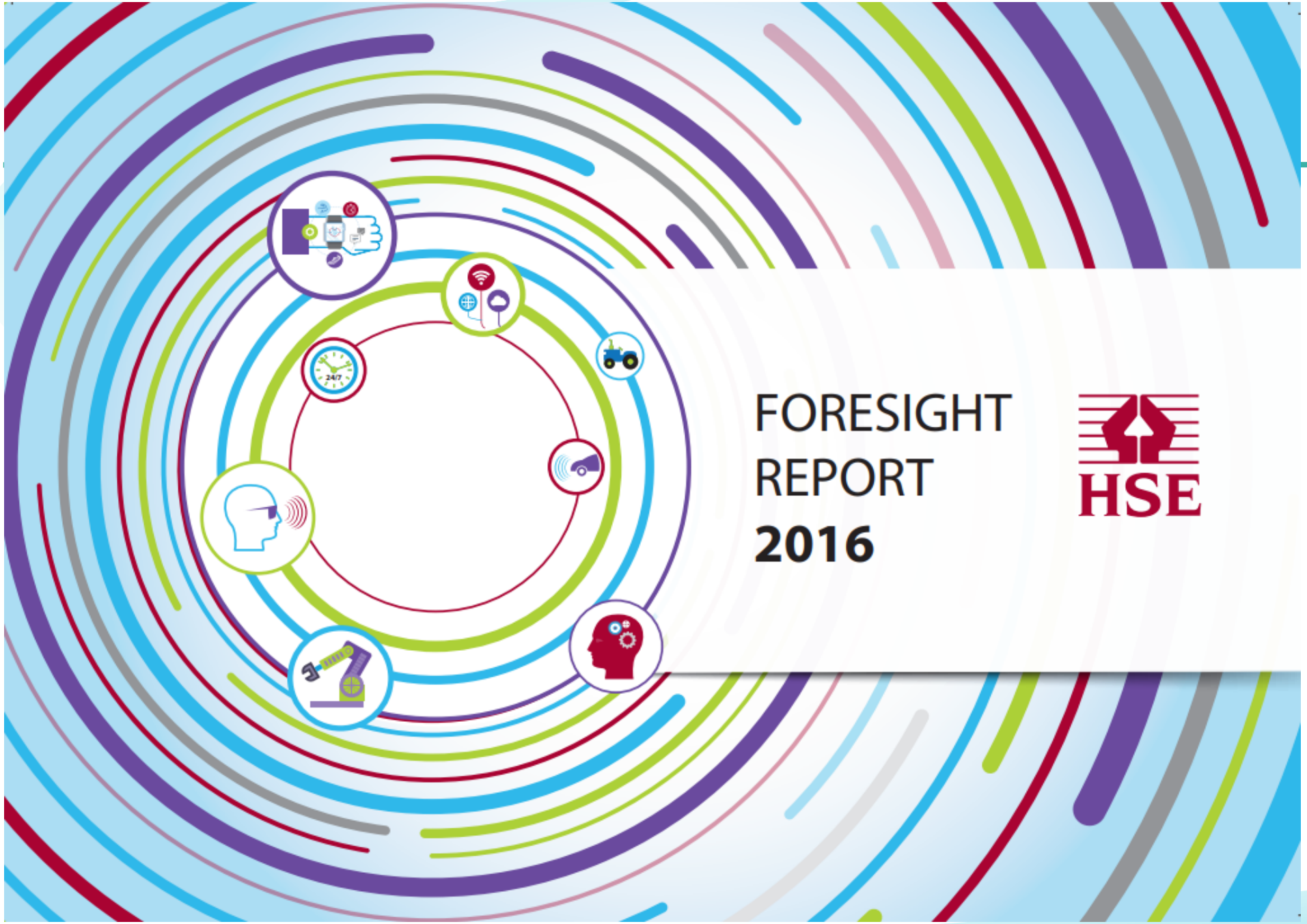
Collision and injury criteria when working with collaborative robots

Prepared by the **Health and Safety Laboratory** for the Health and Safety Executive 2012

This report was a review/ commentary on ISO/TS 15066

i.e. HSE recognised the emergence of 'cobots' a decade ago

Main risk being addressed is collision/impact

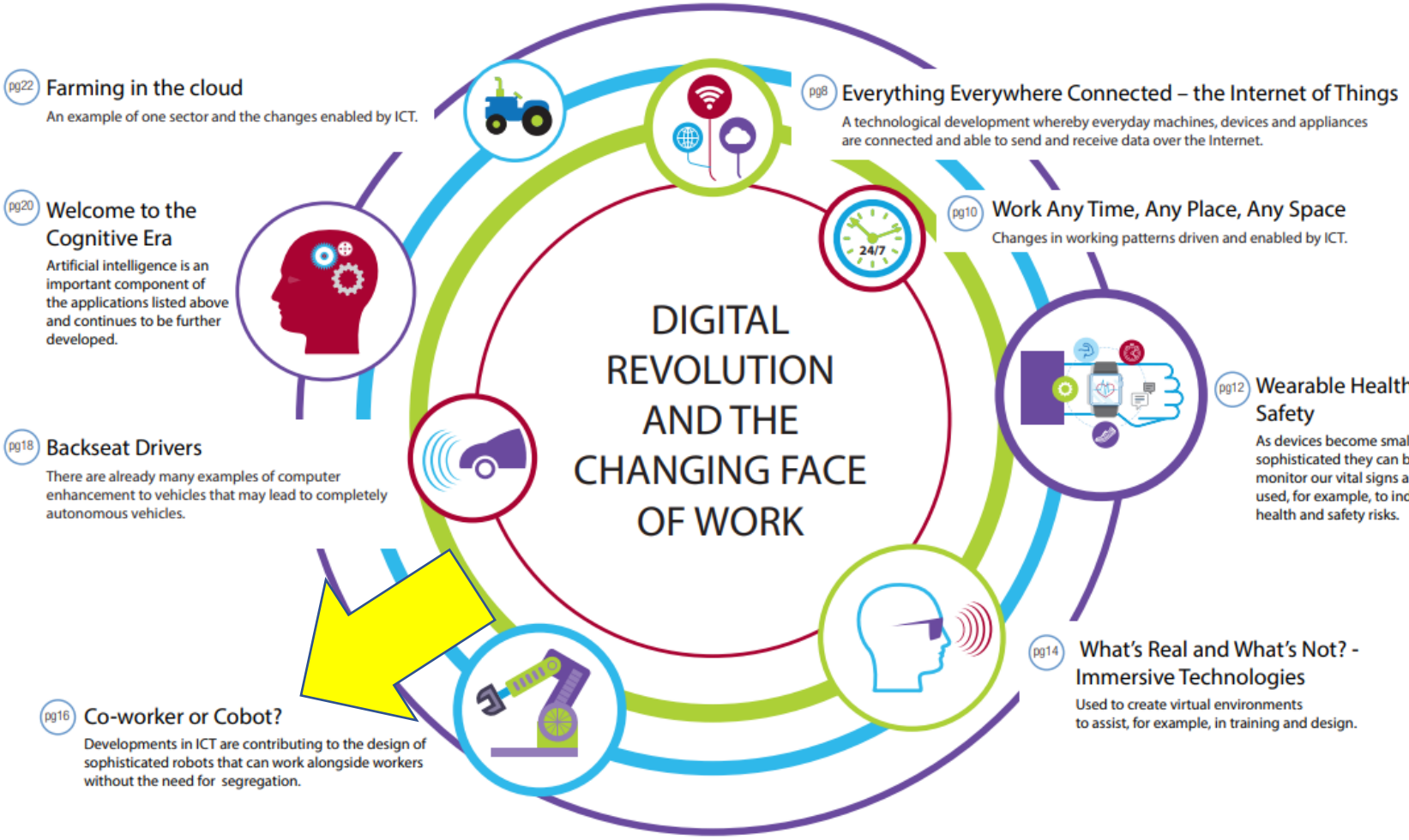


FORESIGHT REPORT 2016

HSE

‘Digital Revolution’

CONTENTS



2016: Focus is on the idea of workers and robots sharing same space

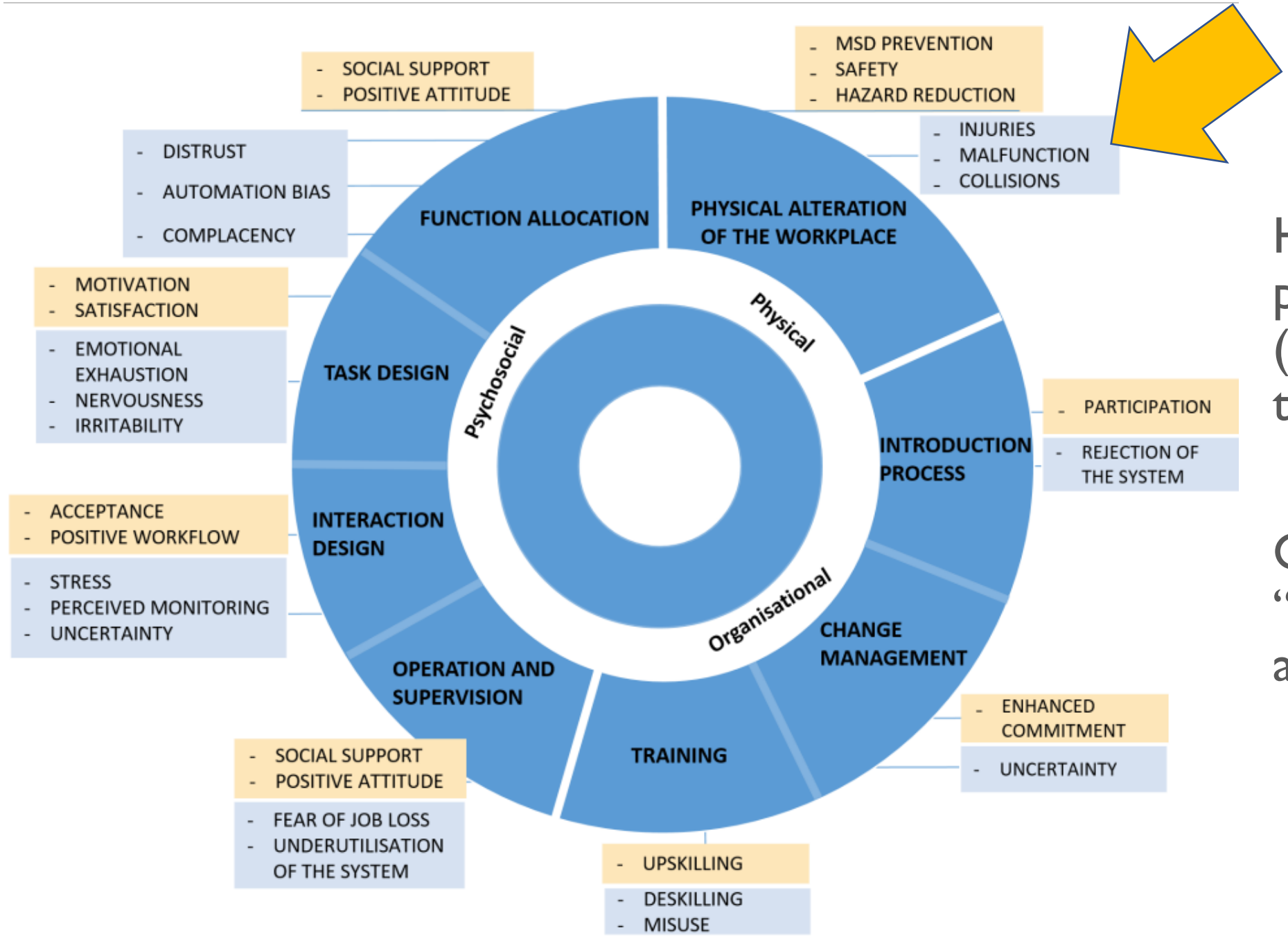
“Design of sophisticated robots that can work alongside workers without the need for segregation”

March 2020

FORESIGHT REPORT

The human impact of the changing nature of work

HSE

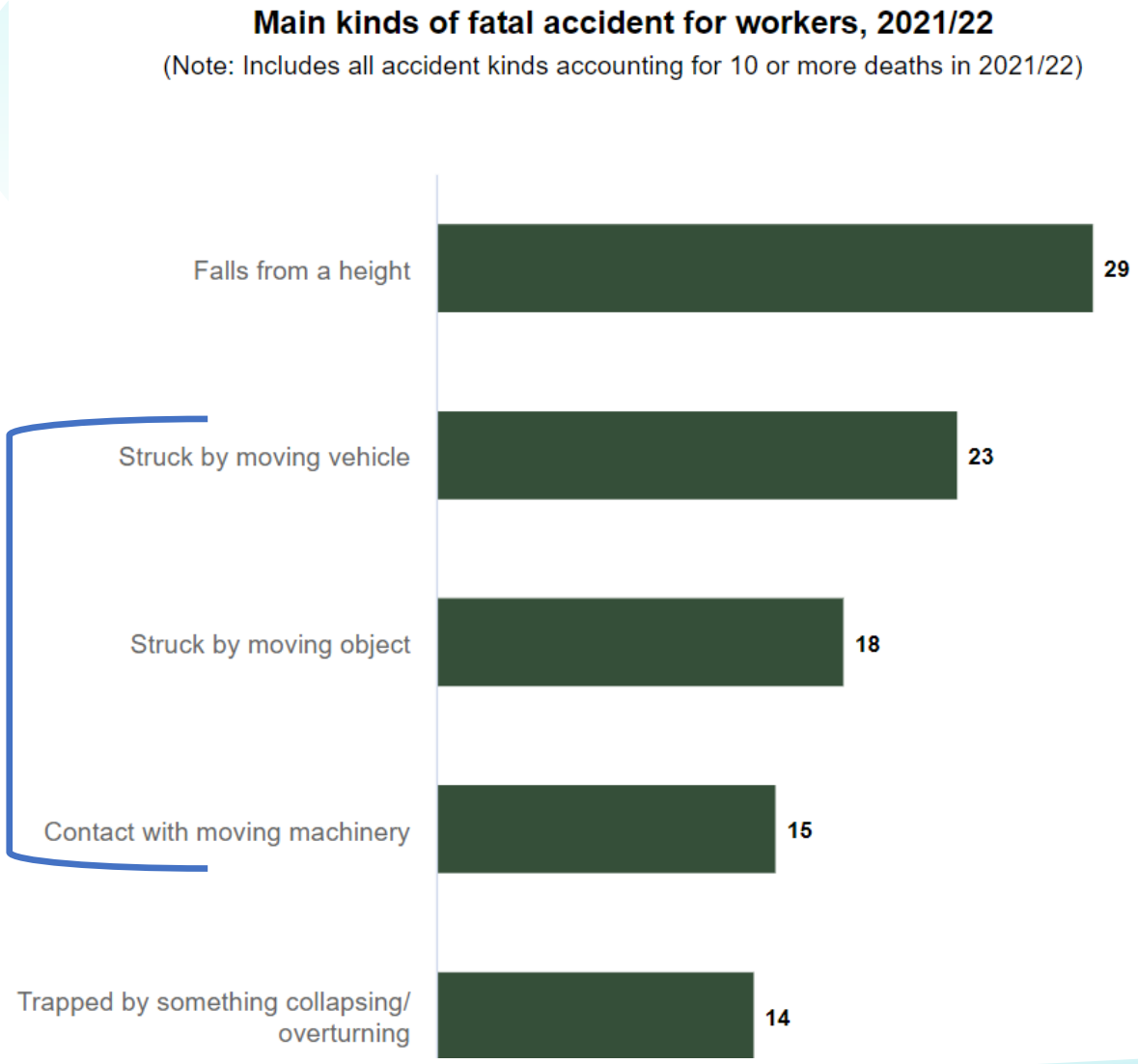


HSE mindmap of pros (pink) and cons (blue) of these new technologies.

Cons include "Injuries, Malfunction and ***Collisions***"

Segregation prevents contact with a hazard that would otherwise cause harm

123 fatal injuries to workers in the UK 2021-2022



- The focus on collision/impact injuries may be obvious…
- 56 fatalities caused by being struck by a moving vehicle, object or machinery
- Psychological bias?
- The research serves as an important aide memoire for risk assessors

Principles of ISO/TS 15066: 2016

- Guidelines for designing and implementing a workspace to control risk when humans and robots interact in the same space
- In the event of accidental contact, no pain or injury occurs
- "Combat risk at source" – making something intrinsically safer is better than segregation

Summary of PUWER

- Broad enough to cover robots/autonomous systems
- Lack of specific guidance
- An apparent over-emphasis on risk of collision

Construction (Design & Management) Regulations 2015

HSE

Health and Safety Executive

Managing health and safety in construction

Construction (Design and Management) Regulations 2015

Guidance on Regulations

L153
Published 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) came into force on 6 April 2015, replacing CDM 2007. This publication provides guidance on the legal requirements for CDM 2015 and is available to help anyone with duties under the Regulations. It describes:

- the law that applies to the whole construction process on all construction projects, from concept to completion; and
- what each dutyholder must or should do to comply with the law to ensure projects are carried out in a way that secures health and safety.

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Part 4

- Traffic Routes
- Vehicles

Note: No specific references to robots/autonomous systems

Definitions – could cover mobile robots etc.

- "vehicle" includes any mobile work equipment
- "work equipment" means any machinery, appliance, apparatus, tool or installation for use at work (whether exclusively or not)
- Traffic routes must be organised to allow safe movement of vehicles and pedestrians.
- Starting point: Segregation of access routes.
- Vehicles:
  - Must be driven/operated in a safe manner
  - Unintended movements must be prevented or controlled
  - Suitable warnings from the driver/operator

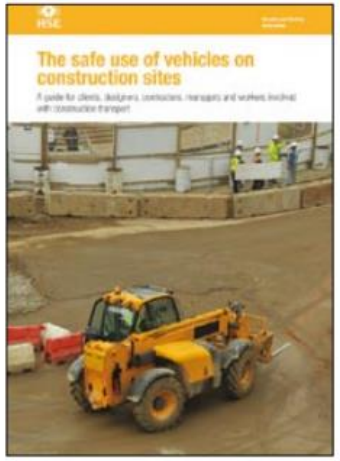
HSG 144, 2009

HSE

Health and Safety Executive

The safe use of vehicles on construction sites

A guide for clients, designers, contractors, managers and workers involved with construction transport



This is a free-to-download, web-friendly version of HSG144 (Second edition, published 2009). This version has been adapted for online use from HSE's current printed version.

You can buy the book at www.hsebooks.co.uk and most good bookshops.

ISBN: 978 0 7176 6291 3
Price £9.95

Every year in the construction industry, people are killed or injured as a result of being struck by moving plant. Accidents occur throughout the construction process, from groundworks to finishing works. Managers, workers, site visitors and the public can all be at risk if construction vehicle activities are not properly managed and controlled.

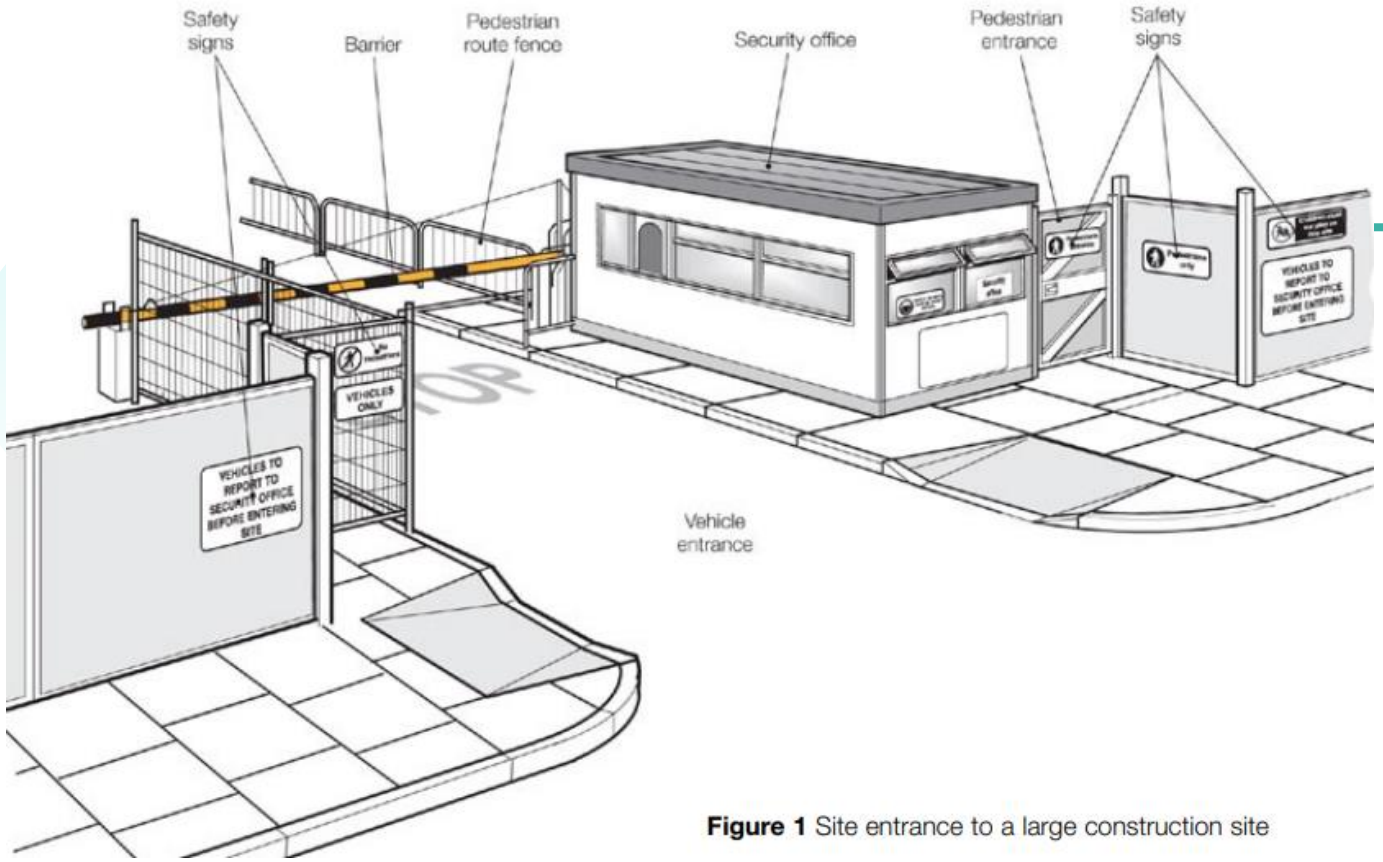


Figure 1 Site entrance to a large construction site

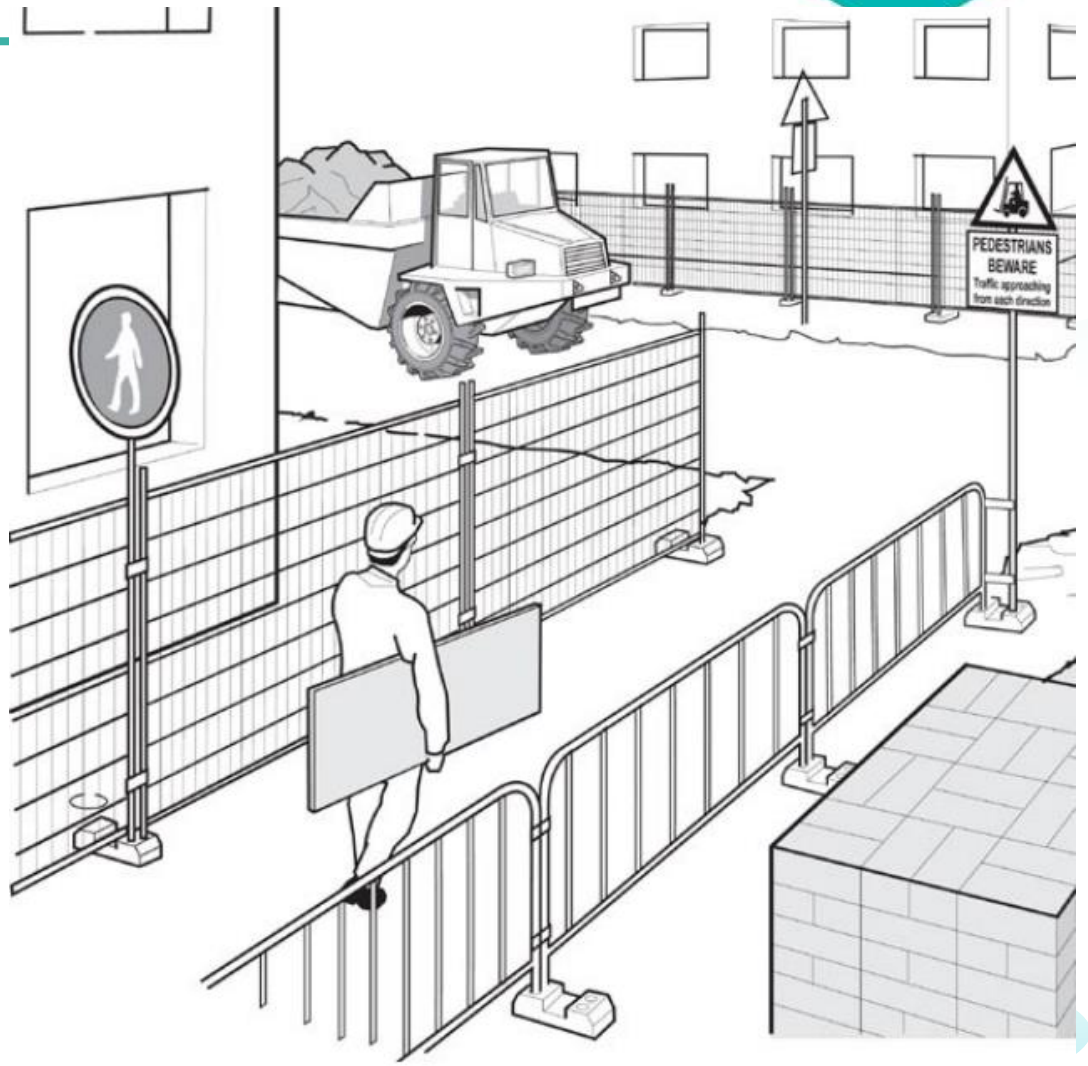


Figure 2 Pedestrian walkway crossing a vehicle route

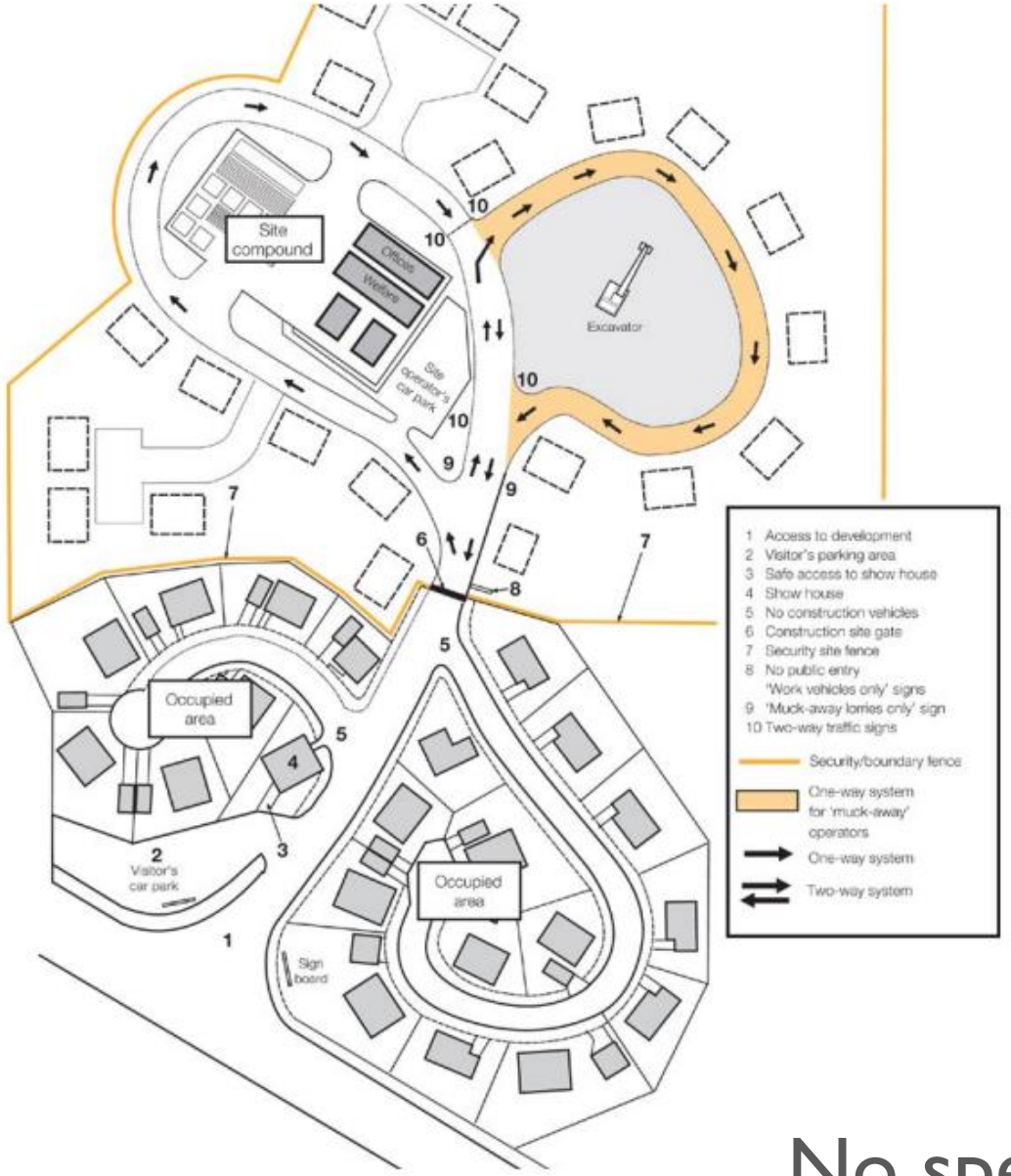


Figure 5 Example of traffic routes on a housing development site (road markings omitted for clarity)

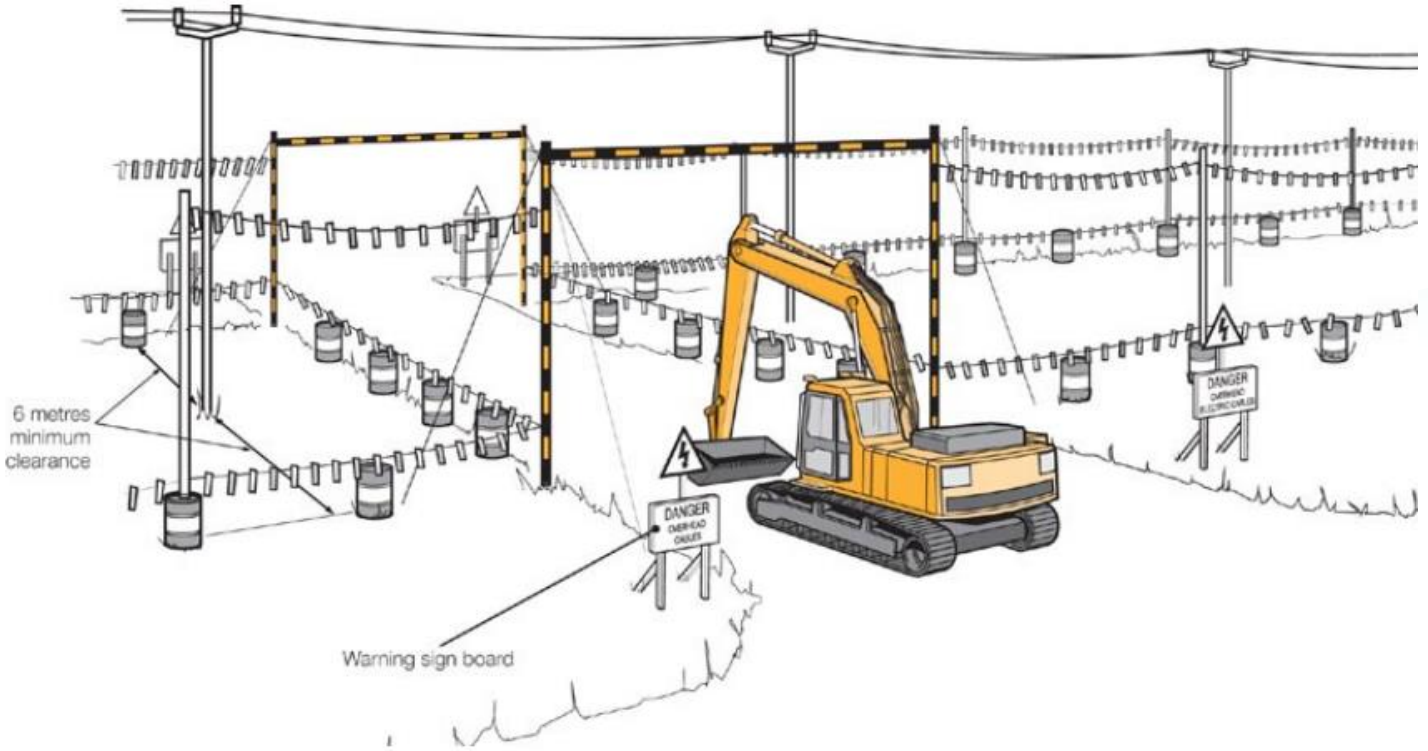


Figure 3 Overhead cable protection on a vehicle traffic route

No specific reference to robots etc.

Designing/planning for use of robots

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Duty of care of designers

- Must identify and seek to eliminate/control risks to people throughout building lifecycle including people carrying out construction work

RIBA Plan of Work 2020

The RIBA Plan of Work organises the process of briefing, designing, delivering, maintaining, operating and using a building into eight stages. It is a framework for all disciplines on construction projects and should be used solely as guidance for the preparation of detailed professional services and building contracts.

Stage Boundaries:

Stages 0-4 will generally be undertaken one after the other.

Stages 4 and 5 will overlap in the **Project Programme** for most projects.

Stage 5 commences when the contractor takes possession of the site and finishes at **Practical Completion**.

Stage 6 starts with the handover of the building to the client immediately after **Practical Completion** and finishes at the end of the **Defects Liability Period**.

Stage 7 starts concurrently with Stage 6 and lasts for the life of the building.

Planning Note:

Planning Applications are generally submitted at the end of Stage 3 and should only be submitted earlier when the threshold of information required has been met. If a **Planning Application** is made during Stage 3, a mid-stage gateway should be determined and it should be clear to the project team which tasks and deliverables will be required. See *Overview* guidance.

Procurement:

The RIBA Plan of Work is procurement neutral – See *Overview* guidance for a detailed description of how each stage might be adjusted to accommodate the requirements of the **Procurement Strategy**.

ER Employer's Requirements

CP Contractor's Proposals

	0 Strategic Definition	1 Preparation and Briefing	2 Concept Design	3 Spatial Coordination	4 Technical Design	5 Manufacturing and Construction	6 Handover	7 Use
	← Projects span from Stage 1 to Stage 6; the outcome of Stage 0 may be the decision to initiate a project and Stage 7 covers the ongoing use of the building. →							
Stage Outcome at the end of the stage	The best means of achieving the **Client Requirements** confirmed If the outcome determines that a building is the best means of achieving the **Client Requirements**, the client proceeds to Stage 1	**Project Brief** approved by the client and confirmed that it can be accommodated on the site	**Architectural Concept** approved by the client and aligned to the **Project Brief** The brief remains "live" during Stage 2 and is derogated in response to the **Architectural Concept**	Architectural and engineering information **Spatially Coordinated**	All design information required to manufacture and construct the project completed Stage 4 will overlap with Stage 5 on most projects	Manufacturing, construction and **Commissioning** completed There is no design work in Stage 5 other than responding to **Site Queries**	Building handed over, **Aftercare** initiated and **Building Contract** concluded	Building used, operated and maintained efficiently Stage 7 starts concurrently with Stage 6 and lasts for the life of the building
Core Tasks during the stage **Project Strategies** might include: – **Conservation** (if applicable) – **Cost** – **Fire Safety** – **Health and Safety** – **Inclusive Design** – **Planning** – **Plan for Use** – **Procurement** – **Sustainability** See *RIBA Plan of Work 2020 Overview* for detailed guidance on **Project Strategies**	Prepare **Client Requirements** Develop **Business Case** for feasible options including review of **Project Risks** and **Project Budget** Ratify option that best delivers **Client Requirements** Review **Feedback** from previous projects Undertake **Site Appraisals** No design team required for Stages 0 and 1. Client advisers may be appointed to the client team to provide strategic advice and design thinking before Stage 2 commences.	Prepare **Project Brief** including **Project Outcomes** and **Sustainability Outcomes**, **Quality Aspirations** and **Spatial Requirements** Undertake **Feasibility Studies** Agree **Project Budget** Source **Site Information** including **Site Surveys** Prepare **Project Programme** Prepare **Project Execution Plan**	Prepare **Architectural Concept** incorporating **Strategic Engineering** requirements and aligned to **Cost Plan**, **Project Strategies** and **Outline Specification** Agree **Project Brief Derogations** Undertake **Design Reviews** with client and **Project Stakeholders** Prepare stage **Design Programme**	Undertake **Design Studies**, **Engineering Analysis** and **Cost Exercises** to test **Architectural Concept** resulting in **Spatially Coordinated** design aligned to updated **Cost Plan**, **Project Strategies** and **Outline Specification** Initiate **Change Control Procedures** Prepare stage **Design Programme**	Develop architectural and engineering technical design Prepare and coordinate design team **Building Systems** information Prepare and integrate specialist subcontractor **Building Systems** information Prepare stage **Design Programme** Specialist subcontractor designs are prepared and reviewed during Stage 4	Finalise **Site Logistics** Manufacture **Building Systems** and construct building Monitor progress against **Construction Programme** Inspect **Construction Quality** Resolve **Site Queries** as required Undertake **Commissioning** of building Prepare **Building Manual** Building handover tasks bridge Stages 5 and 6 as set out in the **Plan for Use Strategy**	Hand over building in line with **Plan for Use Strategy** Undertake review of **Project Performance** Undertake seasonal **Commissioning** Rectify defects Complete initial **Aftercare** tasks including light touch **Post Occupancy Evaluation**	Implement **Facilities Management** and **Asset Management** Undertake **Post Occupancy Evaluation** of building performance in use Verify **Project Outcomes** including **Sustainability Outcomes** Adaptation of a building (at the end of its useful life) triggers a new Stage 0
Core Statutory Processes during the stage: Planning Building Regulations Health and Safety (CDM)	Strategic appraisal of **Planning** considerations	Source pre-application **Planning Advice** Initiate collation of health and safety **Pre-construction Information**	Obtain pre-application **Planning Advice** Agree route to **Building Regulations** compliance Option: submit outline **Planning Application**	Review design against **Building Regulations** Prepare and submit **Planning Application** See ***Planning Note*** for guidance on submitting a **Planning Application** earlier than at end of Stage 3	Submit **Building Regulations Application** Discharge pre-commencement **Planning Conditions** Prepare **Construction Phase Plan** Submit form F10 to HSE if applicable	Carry out **Construction Phase Plan** Comply with **Planning Conditions** related to construction	Comply with **Planning Conditions** as required	Comply with **Planning Conditions** as required
Procurement Route Traditional Design & Build 1 Stage Design & Build 2 Stage Management Contract Construction Management Contractor-led	Appoint client team	Appoint design team	ER Appoint contractor ER	Pre-contract services agreement Preferred bidder	Tender / Appoint contractor ER / CP / Appoint contractor CP / Appoint contractor CP / Appoint contractor			Appoint **Facilities Management** and **Asset Management** teams, and strategic advisers as needed
Information Exchanges at the end of the stage	**Client Requirements** **Business Case**	**Project Brief** **Feasibility Studies** **Site Information** **Project Budget** **Project Programme** **Procurement Strategy** **Responsibility Matrix** **Information Requirements**	**Project Brief Derogations** Signed off **Stage Report** **Project Strategies** **Outline Specification** **Cost Plan**	Signed off **Stage Report** **Project Strategies** Updated **Outline Specification** Updated **Cost Plan** **Planning Application**	**Manufacturing Information** **Construction Information** **Final Specifications** Residual **Project Strategies** **Building Regulations Application**	**Building Manual** including **Health and Safety File** and **Fire Safety Information** **Practical Completion** certificate including **Defects List** **Asset Information** If **Verified Construction Information** is required, verification tasks must be defined	**Feedback** on **Project Performance** **Final Certificate** **Feedback** from light touch **Post Occupancy Evaluation**	**Feedback** from **Post Occupancy Evaluation** Updated **Building Manual** including **Health and Safety File** and **Fire Safety Information** as necessary

RIBA Architecture.com

Core RIBA Plan of Work terms are defined in the *RIBA Plan of Work 2020 Overview* glossary and set in **Bold Type**.

Further guidance and detailed stage descriptions are included in the *RIBA Plan of Work 2020 Overview*

RIBA Plan of Work 2020 Overview

RIBA Plan of Work www.ribaplanofwork.com

RIBA Architecture.com

2 Concept Design

3 Spatial Coordination

n from Stage 1 to Stage 6; the outcome of Stage 0 may be th

Architectural Concept approved by the client and aligned to the **Project Brief**

The brief remains "live" during Stage 2 and is derogated in response to the **Architectural Concept**

Architectural and engineering information **Spatially Coordinated**

Prepare **Architectural Concept** incorporating **Strategic Engineering** requirements and aligned to **Cost Plan**, **Project Strategies** and **Outline Specification**

Agree **Project Brief Derogations**

Undertake **Design Reviews** with client and **Project Stakeholders**

Prepare stage **Design Programme**

Undertake **Design Studies**, **Engineering Analysis** and **Cost Exercises** to test **Architectural Concept** resulting in **Spatially Coordinated** design aligned to updated **Cost Plan**, **Project Strategies** and **Outline Specification**

Initiate **Change Control Procedures**

Prepare stage **Design Programme**

Health and Safety Strategy

The Health and Safety Strategy needs to be considered early on in the project because it is key to securing the safe construction, occupation, maintenance and future re-use or demolition of the project. The client's role is fundamental to this, to establish and maintain a health and safety-conscious approach to delivery of the project from the outset. The Health and Safety Strategy should set clear health and safety objectives.

i.e. designers are obliged to consider the health and safety implications of their designs and this includes considering their 'buildability'

Practical guidance to help designers fulfil their duties including identifying and managing risks

Industry guidance for

Designers

Note: No specific references to designing for use of robots/ autonomous systems

HSE

Questions for designers

1. Is the project likely to use robots, autonomous systems etc.? (Will the client accept the potential uncertainties & costs vs commercial and H&S benefits?)

2. If so, which technologies might be used?

3. How would designs need to change to facilitate use of those technologies?

Designing for use of robots etc.

- How would the team get this equipment into/onto our site/building or temporary works (such as scaffolding)?
  - E.g. ramps or cranes
  - What are the implications for temporary works design? (e.g. width or loading bearing capacity of scaffolds, suitable locations for crane)
- Will site constraints permit use of this equipment?
- Will specifications need to change (e.g. limiting weight or size of components to enable robots to lift them)
- Where could expensive equipment be securely stored/maintained on site?
- Will phasing or sequencing need to change?

My take home message

- The use of robots and autonomous systems cannot be an afterthought…
- It needs to be a fundamental consideration in project plans/designs from the start of a project

Adopting good practices from other industries

- E.g. Failure Modes and Effects Analysis (FMEA)
- Used in manufacturing

Function	Potential failure mode	Potential effect	Potential cause of failure	Current process controls

Summary

- Regulations are suitably broad to encompass robots, autonomous vehicles etc.
- Risk assessments are critical for examining what could go wrong and decide what controls are needed. We could borrow good practice from other industry sectors (e.g. FMEA)
- The research paper can serve as an aide memoire for risk assessors.
- The decision to use new technologies must start with clients & designers.