European Agency for Safety and Health at Work

Foresight on new and emerging occupational safety and health risks associated with digitalisation by 2025

European Risk Observatory

Summary

European Agency for Safety and Health at Work

Safety and health at work is everyone's concern. It's good for you. It's good for business.

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1 Introduction

A connected Digital Single Market (DSM) has been made one of the European Commission's key priorities (EC, 2015). Digitalisation, including ICT-enabled technologies (ICT-ETs) such as robotics and artificial intelligence (AI), are likely to have major impacts on the nature and location of work over the next 10 years. Technologies are diffusing much faster than in the past and many people are talking about a 'Fourth Industrial Revolution'. It is expected to fundamentally change where we work, how we work, who will work and how people will perceive work.

Current European Community strategic documents (EC, 2014; EC, 2017) identify the need for a proactive approach to identifying future risks to workers' safety and health in a continuously changing world of work. The European Agency for Safety and Health at Work (EU-OSHA) looks out for challenges to occupational safety and health (OSH) that are emerging as a result of changes in the workplace in order to better anticipate them and shape heathier and safer workplaces of the future. This report summarises EU-OSHA's project 'Foresight on new and emerging risks associated with information and communication technologies by 2025' (EU-OSHA, 2018).

The basis of foresight is an understanding that the future can evolve in different directions, which can be shaped by the actions of various stakeholders and decisions taken today. Scenario development was, therefore, used as a tool for building visions of possible futures that are relevant to OSH policy.

This project aimed to provide EU decision-makers, Member State governments, trade unions and employers with the information they need on changes in relation to digitalisation and ICT-ETs, their impact on work, and the emerging challenges to OSH that they may bring. It should help them to:

- have a better understanding of longer-term developments that could affect workers and how these may result from current policy decisions;
- consider priorities for OSH research and actions that would prevent the occurrence of the possible new and emerging risks identified or minimise their possible negative impact in the future.

2 Methodology: scenario development

This foresight project was carried out in two distinct work packages, followed by a third work package to disseminate the results. The objective of Work Package One was to identify key trends and contextual drivers of change in relation to ICT-ETs that could contribute to creating new and emerging OSH risks associated with digitalisation (EU-OSHA, 2017a). The objective of Work Package Two was to develop the 2025 scenarios of the world of work and new and emerging OSH risks associated with digitalisation and to test them (EU-OSHA, 2018).

2.1 Identification of trends and drivers of change

- **Horizon scanning**

The first step was horizon scanning to identify a wide range of information relevant to trends and drivers of change in relation to ICT-ETs and the impact on work. This was based on a review of a wide range of publications and research reports, including grey literature. This resulted in 92 trends and drivers classified under five 'STEEP' categories: societal (29 drivers), technological (29), economic (19), environmental (5) and political (10).

- **Consolidation**

Interviews were conducted to consolidate the list of trends and drivers from the horizon scanning and to obtain initial views on which will have the greatest impact on ICT-ETs and work. A purposive sample of 19 experts, including members of EU-OSHA's Prevention and Research Advisory Group, was interviewed individually by telephone. A semi-structured approach was taken to the interviews, based on the 'Seven Questions' technique (Ringland, 2006).

A two-round Delphi-like web-survey was also conducted to open the consultation to a broader audience. In the first round, the respondents (114 from 22 countries) were asked to select up to three trends and drivers (from each STEEP category) that they felt were the most important.

A second round of the survey was conducted in order to share the results with the 30 respondents to the first round who had agreed to be further contacted and to give them a chance to comment on the ranking of the trends and drivers. Only 11 responded to the questions.

For the consolidated list of trends and drivers, see the Work Package One report (EU-OSHA, 2017a).

- **Selection of key trends and drivers of change**

The selection of key trends and drivers was made in a workshop (EU-OSHA, 2017a); they included those with:

1. a high impact and high levels of uncertainty — these are the 'critical uncertainties' that create the key differences between the scenarios;
2. a major impact but more predictable outcomes — it was important that these be taken into account in all the scenarios.

2.2 Scenario-building

- **Development of the base scenarios**

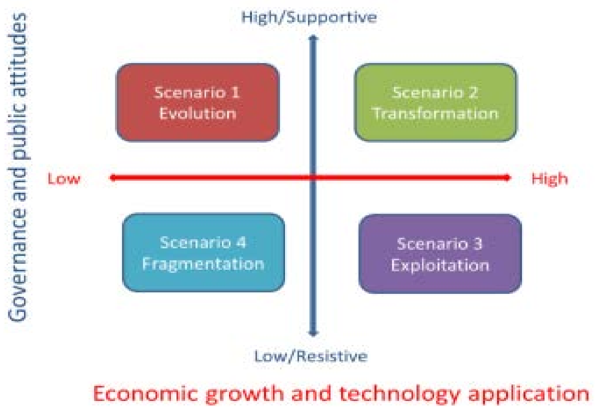
This was done in a second workshop in which the scenario axes (which define the space that contains the potential scenarios) were defined. The axes were formed by the high impact and high uncertainty key trends and drivers (critical uncertainties). As some of the critical uncertainties were related in terms of their impact, they were grouped around two axes:

1. *Governance and public/workers' attitudes*, which covers the environment in which ICT-ETs will be exploited; the acceptance of and demand for developments in ICT-ETs; and the way ICT-ET innovation and implementation are governed. These could be either supportive, with high levels of acceptance, or resistive, with low levels of acceptance.

2. *Economic growth and the application of technology*, which includes the level of economic growth and investments in technology and skills; the level of application of developments in ICT-ETs; and the level of impact on the nature and locations of work, as well as the associated changes to business structures. All these could be high or low.

Combining these two axes gave four base scenarios of what the future could be like in 2025, as illustrated in Figure 1. A cross-scenario impact analysis was carried out to describe the situation with regard to each key trend and driver in each scenario. This defined the key features of the base scenarios.

Figure 1: Scenario quadrants



- **Development of OSH scenarios**

The base scenarios were developed into OSH scenarios in a third workshop of experts and policy-makers by considering how ICT-ETs and the general OSH environment might develop in each base scenario, and what this could mean in terms of new and emerging OSH challenges and opportunities.

The resulting OSH scenarios were peer reviewed by four OSH experts and finally tested in a fourth workshop with policy-makers. The participants reviewed the OSH challenges and opportunities in each scenario and considered potential strategy and policy responses to the new and emerging OSH challenges. These responses were then discussed and reviewed to test their robustness in the other scenarios. This process, often referred to as 'wind-tunnelling', helps to explore ways to optimise future success, identify future risks to meeting objectives, challenge any set 'official views' of the future, and create an environment for an open debate on policy options.

The final scenarios produced are available in the annex.

Further dissemination workshops using the same process also took place between the end of 2017 and 2019 to promote the project findings, including the use of the scenarios as a tool to address future OSH challenges.

3 OSH implications

The trends and drivers indicate that by 2025 ICT-ETs will have changed the equipment, tools and systems that can be used to organise, manage and deliver products and/or services across most occupational sectors. Developments include continuing advances in the automation of work processes that become increasingly complex, interconnected and autonomous in that they self-organise, self-learn and self-maintain. 3D and 4D printing and bio-printing, autonomous vehicles (including drones), robotics (including collaborative robotics), algorithms, Artificial Intelligence (AI), virtual reality (VR) and augmented reality (AR) will increasingly be used for work purposes, and innovation in these technologies will continue. Robots will become uncaged, mobile, dexterous, close to workers, collaborative and increasingly intelligent, bringing automation to previously inaccessible tasks. Even jobs that are not replaced by robots will change considerably, as workers will work with, use and interact with a wide range of digital technologies. There is also a clear trend towards the miniaturisation of ICT-ETs, which are increasingly 'smart' and connected to the internet (referred to as 'the Internet of Things' — IoT). These, along with bionics or exoskeletons, will be worn to enhance or monitor human performance, generating considerable amounts of data. There will be ongoing development in human-machine interfaces that allow humans to interface with machines and one another remotely via ICT-ETs in ways that are much more similar to how humans interact face to face. The trends indicate that by 2025 direct brain-to-machine interfacing may have begun to emerge but will not be particularly widespread.

The extent of innovation in and adoption of the ICT-ETs described above and their impact on OSH will depend on the social, economic, environmental and political trends and drivers that exist between now and 2025. The horizon scanning undertaken during this foresight project, along with the four alternative scenarios of the future that were developed (in annex), enabled a number of OSH challenges and opportunities that could emerge as ICT-ETs change to be identified; these relate to:

- the work equipment, tools and systems used;
- how work is organised and managed;
- employment status, hierarchies and relationships;
- the characteristics of the workforce;
- responsibilities for managing OSH;
- skills, knowledge and information requirements.

3.1 Work equipment, tools and systems

Exposure to hazardous substances: automation, robotics, remote interfaces and VR for training purposes can help to reduce workers' exposure to hazardous substances. Monitoring of workers' exposure to toxic substances could be facilitated by the use of smart sensors incorporated into wearable devices.

Affordable and increasing computer power, along with the availability of large datasets, could also enable DNA profile sequencing to be used to screen out workers who are more susceptible to specific hazardous substances, although this could raise ethical concerns. Conversely, ICT-ETs such as 3D and 4D printing and bio-printing have the potential to increase exposure to a range of new substances the hazards of which are not yet fully understood. Moreover, these technologies are likely to be available to and used by micro-enterprises and (pseudo) self-employed who may not have the adequate resources and skills to handle the associated substances safely.

Exposure to physical hazards: automation, robotics and autonomous vehicles or drones can reduce the need for workers to work in hazardous environments such as confined spaces, to work at height, to be exposed to noise and vibration or to come into contact with moving machinery. They also offer the opportunity to hand off routine or repetitive tasks to machines. However, the same technologies could be a source of harm, through trapping, entanglement, impact, noise and vibration, for example in the case of collaborative robots or bionic exoskeletons. Traditionally, OSH in relation to robotics has been managed through the segregation of workers and robots. With robots working in close proximity to workers, new techniques will include the use of soft, rounded edges and reduced speeds and force, sensors and vision systems. However, if the sensors fail, or suffer from electrical interference or cyber-attack, the safety systems may fail. The equipment that robots may be using (e.g. lasers, welding electrodes, mechanical equipment) could also pose dangers to workers. With closer and more innovative interaction between machines and workers, it could become increasingly important to understand how workers will behave.

Manual handling: mobile autonomous robots or exoskeletons could assist workers with manual handling tasks and strenuous work. Such innovations could allow older workers to continue to do jobs that involve physical effort and create better access to work for disabled people. Not only can collaborative robots take manual handling tasks away from workers, they can also offer a novel way of managing workers’ manual handling risks, as electromyography sensors could be built into the clothing of people working alongside collaborative robots; the sensors would then be monitored by the robots so that they could warn wearers when they were in potentially harmful postures. However, an over-reliance on robots or exoskeletons for manual handling could have implications for workers’ physical fitness, resulting, for example, in loss of muscle/bone density or joint flexibility. Exoskeletons could give workers a sense of invulnerability that could tempt them to take greater risks, owing to the additional strength given to the worker by the exoskeleton.

Sedentary work: ICT-ETs can make work more sedentary. While this has the potential to remove workers from hazardous situations, the fact that work processes can be controlled and also increasingly maintained remotely removes the physical activity associated with attending to them in person. A more sedentary lifestyle can increase the risk of poor postures, cardiovascular disease, obesity, stroke and diabetes, and may also increase anxiety. However, digital technology can also help to reduce sedentary behaviour, for example through the use of wearables to alert users to hazards and influence them to adopt healthy behaviour. New human-machine interfaces such as voice recognition, gesture control or eye tracking could also allow workers to use ICT-ETs while physically active.

Workstation ergonomics: mobile ICT-ETs allow people to work anywhere. Hand-held mobile devices are not ergonomically suitable for use for long durations and can cause injury to the upper limbs, neck and back. Homes, public places or transport may not be ergonomically suitable for work purposes either. It is not possible for employers to control such environments and how people work in them. Interfacing by gesture, voice or eye could improve ergonomics and also make work more accessible to a wider range of people with certain physical impairments or who do not have the skills to use today’s devices. However, more frequent use of gestures, the voice or the eyes for this purpose may result in overloading certain body parts, which could lead to new types of and/or an increase in health disorders such as eye and voice strain. Such interfaces may also involve the use of head- or handsets, potentially leading to musculoskeletal disorders (MSDs).

Risk intensification: automation, while removing workers from situations involving hazardous exposures, could also leave to workers only very repetitive tasks, or the most difficult ones, and reduce the scope for job variety and rotation. For example, what is left could be a limited range of manual handling tasks that require high dexterity, which could lead to an increased risk of repetitive strain injury. There is a trend towards the massive specialisation of tasks, for example in warehousing, transport and distribution functions in the retail sector. Tasks that are more difficult to automate also include fault-finding or unplanned maintenance activities, which tend to be more hazardous than normal operations.

Control commands lost in transmission: human-machine interfaces, such as those based on gesture, voice, eye tracking or brain signals, could be misinterpreted by the work equipment or process under control. This could be caused by low signal strength or electromagnetic or malicious interference with the signal. Misinterpretation could also occur because of the use of dialects or the ambiguity of human language. Incorrect commands could also be sent if someone was stressed or distracted. If work equipment and processes are controlled remotely, there is also the potential for commands to be accidentally sent to the wrong equipment or process. As gesture, voice, eye tracking and brain signal controls are more immediate than hitting 'enter' on a keyboard, it could be important for safety-critical commands to require a means of giving unambiguous confirmation before they are executed. Noise levels in working environments, public places and transport could also increase owing to increasing use of voice-controlled interfaces.

Human-machine interaction: real-time, interactive, direct and immersive human-machine interfaces could make it very difficult for workers to be able to pause or relax. Automation of work processes could also result in some operators' roles becoming supervisory, possibly with them overseeing several work processes in several different locations at the same time, which could increase cognitive demand. Continuous high cognitive demand placed on workers has the potential for negative impacts on OSH, particularly on mental health. OSH risks could also be created by unforeseen interaction between people and robots, autonomous vehicles or drones, if people's expectations of how the technology should behave are incorrect.

Unforeseen situations: when designing robots, even if every effort is made to plan for all possible scenarios, it is impossible to foresee all situations. Ultimately it depends on how the robot is used (possibly incorrectly), unforeseen actions by people, unexpected situations, software interacting with other software in unanticipated ways or a scenario arising that had not been considered. Incidents occur in particular outside of normal operation, such as during installation, testing or maintenance of robots. It is therefore important to consider the entire life cycle of robots.

Lack of transparency of algorithms: a lack of transparency about how AI is analysing data and learning could lead to it behaving in unpredicted and unsafe ways. In the case of deep learning algorithms, it is not possible to identify which factors the program uses to reach its conclusion. If workers do not understand how systems are working they may have difficulties in interacting with them correctly, recognising when they go wrong and knowing how to respond in such cases. Workers could also suffer from stress if they do not know what is happening, what data may be collected about them and for what purposes.

Situational awareness: workers could become dependent on ICT-ETs to inform them about hazards such that they are much less able to spot them on their own should the systems fail. VR devices can cause motion sickness and/or a loss of awareness of the user's actual surroundings during and even for some time after use. AR devices overlay reality with computer-generated information, which could make it less easy to see OSH-critical situational information because of distraction, disorientation or information overload. However, AR could also improve situational awareness by providing supplementary contextual information on hidden hazards, such as the presence of asbestos, electricity cables or gas pipelines. AR can incorporate instructions, which could reduce human error, as workers would not need to refer to separate guidance while their hands were needed for maintenance activity. However, the reliability of AR is dependent on maintaining access to the relevant information sources, the quality of the information and whether or not it is up to date.

Adaptive, socially and emotionally intelligent robotics: some experts believe that the greatest industrial benefits will be achieved if the functional and analytical abilities of robotics and AI complement the skills of the workers who interact with them. Adaptive automation uses software to monitor people working with robots to adapt the speed of the process and to prevent overloading. It allows workers to remain in control of the work process and workload, and also results in greater acceptance of automation in the workplace. Workers should be consulted and involved in strategies for deploying ICT-ETs in the workplace to ensure better OSH as well as to increase acceptance.

Customisation: ICT-ETs often allow users to personalise them. This can make them more user friendly for the person who has customised them, but less so for someone else. If a worker has to use a device customised by another and, for some reason, does not re-customise it, this could lead to stress, ergonomic-related harm or human error. Customisation culture could also lead to work equipment being used for a purpose for which it was not designed. The rapid reconfiguration of work processes in response to demand for and expectation of customisation from consumers may mean that the risk profile of a factory changes frequently. This could make it difficult to standardise procedures, risk assessments and other aspects of the management of OSH.

Pace of technological change: pressure to bring a new design to market quickly could increase the risk of design flaws not being found before work equipment is put into service, so that it could fail in unpredictable and hazardous ways. A high pace of technological change could cause mental health problems or exclusion from good-quality work for those unable to cope with constant change or 'newness' (sometimes referred to as 'technostress'). If workers' skills are unable to keep pace with change, this could have OSH consequences as a result of human error. If the rate of technological change is high, OSH research and regulation may also struggle to keep up.

Mix of old and new: there is the potential for OSH risks during the transition from old to new technology when both are in service. Infrastructure designed for old technology may not be suitable for new technology and could as a result introduce unforeseen OSH risks. If workers need to interact differently with old and new technology, they may make incorrect and unsafe assumptions about how the technology will behave. There is also the potential for confusion and accidental use of the wrong procedures if old and new versions are both current. Clear communication will, therefore, be essential.

Big data for better OSH: more powerful computing enables machine learning and AI to sort and analyse, at high speeds, the large amount of data collected by monitoring of increasingly complex systems. This has the potential to provide better insight into OSH problems, to support better OSH decisions, to predict OSH problems before their occur, and to allow more timely and effective interventions. It can even allow businesses to more easily demonstrate compliance with OSH standards and regulation, and labour inspectorates to more easily investigate breaches.

Smart personal protective equipment (PPE): mobile miniaturised monitoring devices embedded into PPE could allow real-time monitoring of hazardous substances, noise, vibration, temperature, poor postures, activity levels or a range of biological vital signs. New types of data analytics that enable real-time analysis based on big data flows can make autonomous decisions. This could be used to provide early warning of harmful exposures, health problems, fatigue and stress. Real-time tailored advice could then be provided to influence worker behaviour to improve safety and health. Collated information could also be used by organisations to spot where OSH interventions at an organisational level were required. However, effective strategies and systems as well as ethical decisions will be needed to allow the handling of the large quantity of sensitive personal data that could be generated. Malfunction, or incorrect data or advice generated, could cause injury or ill health.

Integration and interconnectivity: could result in undesirable and poorly understood OSH consequences. Cascade failure could occur because of high levels of interconnectedness and inter-reliance of ICT-ETs. All this makes the reliability and safety of AI and machine learning difficult to evaluate. The short-term impact of AI depends on who controls it. In the longer term, the impact depends on the extend to which it can be controlled.

Counterfeit parts: could be more widely available owing to the increasing ease of use and availability of 3D printers. This could cause hazardous malfunction of work equipment after maintenance or repair.

Electromagnetic fields (EMFs): exposure could increase in terms of both duration and intensity if 5G WiFi networks and contactless charging of mobile ICT-ETs become more widespread. Direct brain interfaces could also expose workers to strong EMFs. By 2020, the number of devices connected to the IoT is expected to rise to over 20 billion (Gartner, 2017), and they could be susceptible to electromagnetic interference, inadvertent or malicious.

3.2 Organisation and management of work

Flexibility, availability and blurring of work/private life boundaries: ICT-ETs can allow people to work any time and anywhere. This could lead to a blurring between people's work and private life in terms of both their activities and their safety and health, including a negative impact on mental health and well-being. ICT-ETs' ability to enable working at any time could lead to a real or perceived need to be available all day every day (24/7). For example, people may need to work with colleagues in a different time zone. There are also concerns that people may suffer from addiction to the use of mobile devices and wearables such that the user suffers from severe anxiety if separated from the device or if it stops working — also referred to as digital addiction, separation anxiety, fear-of-missing-out syndrome and nomophobia. This could increase as such devices become more widespread, advanced and necessary for work or life in general. Availability 24/7 could have similar OSH impacts to shift working, such as cancer, particularly when people work nights (IARC, 2007), diabetes and cardiovascular disease (Research EU Results Magazine, 2017). Some workers may consider being seen to be available 24/7 a sign of being successful but nonetheless suffer from ill health, stress and/or burnout as a result.

Digitalised management methods, including algorithmic management: work is becoming increasingly coordinated and overseen by computer algorithms, and in the future management of workers could rely heavily on AI. Digitalised management methods are characterised by, among other things, the use of big data and algorithmic distribution of work; the use of people analytics, such as digitalised profiling, in HR management; tracking wellness and productivity, as well as tone and sentiment analysis; and using the data accumulated to make decisions on, for example, work and workplace distribution, performance appraisals or even hiring and firing. As a result, workers can lose control over work content, pace and scheduling, and the way they do their work (Moore, 2018). This is associated with work-related stress, poor health and well-being, lower productivity and increased sickness absence (HSE, 2017). This could drive unsafe OSH behaviours in workers where OSH and productivity are in opposition. If workers are informed of how their performance compares with that of others — or possibly with that of machines — it could cause performance pressure, anxiety and low self-esteem. However, new types of data analytics/intelligent algorithms combined with access to large datasets could also enable more effective real-time oversight of OSH and a better understanding of OSH risks in general.

Performance pressure: the use of ICT-ETs could cause a mismatch between workers' physical and/or cognitive capabilities and work demands. This could happen when working alongside collaborative robots, AI or automated systems that have been designed to maximise productivity benefits without adequately considering the impact on human workers. When work is overseen by AI, it can contain embedded continuous improvement algorithms that are referred to by some as the 'digital whip'. Workers may be placed under pressure to perform at the speed and with the efficiency of the machine. Performance pressure can also happen when online work platforms reward speed, when there is uncertainty about when the next piece of work will be available or when not accepting work is penalised, so that workers accept new tasks when they are already busy with others.

Constant oversight: mobile, wearable or embedded (in clothes or in the body) digital monitoring devices, used by AI or human managers to constantly monitor workers, can have a negative impact on health and well-being if workers feel that they have to meet challenging performance targets; they have to conform to an expected behaviour that may not come naturally to them; they are unable to interact socially or take breaks when they want to; or their privacy is invaded. This could include monitoring of exact location, what they are doing, vital signs and indicators of mental well-being. Employers may also encourage or require the devices to be worn also during leisure time, to measure sleep patterns and amount of exercise, on the basis of a possible link to productivity and safe OSH behaviours. Direct brain-to-machine interfaces may collect lots of additional information about personal thoughts as well as control signals (Abdlkader et al., 2015). Constant oversight can cause stress and anxiety, particularly if combined with a lack of control (real or perceived) of work pace and schedule or with job insecurity, and, moreover, when there is no information on/understanding of what data are collected, how they are used and for what purpose. There may also be issues related to data protection/privacy; mis-interpretation of data, when data are compared without looking at the context or qualitative data; and the mis-use of data to discriminate against some workers.

Ethics of AI decision-making: the more people work with AI machines able to take more autonomous decisions, the more important the question of ethics will be. Key questions are whether such systems always make better decisions than humans, whether they are able to make ethical decisions — and, if so, who and what should determine what these decisions should be based on — and whether a worker should or actually will accept decisions and instructions from an AI machine even when they disagree. The transparency and ethics of decisions by AI algorithms and machines will have an impact on workers' trust and acceptance of such systems, as well as on their levels of stress and other aspects of their mental health.

Cyber-security: the trend towards work processes and devices being controlled by and communicating with one another via the internet (or GPS technology, wireless networks, etc.) means that there is the potential for hackers to take control of them. Workers using their own ICT devices for work could make cyber-security more difficult because of the range of devices, which may not be secure, connected to work networks. The increasing use of social media for work purposes could also cause a cyber-security risk, as social media is regularly hacked. Quantum computing, which could be widely available by 2025, could in theory break any of today's computer security encryption. This could compromise OSH, as hackers could attack critical infrastructure; take control of devices so that they behave in unexpected, hazardous ways; deny access to essential data; or steal or corrupt personal or OSH-sensitive/critical data.

3.3 Business structures, hierarchies and relationships

Online platforms: online platforms create new business models by matching demand and supply for labour and facilitate labour market access for vulnerable groups. Online platform work comprises a variety of working arrangements — generally 'atypical' in some way — different types of jobs and many forms of non-standard employment, from high-skilled work carried out online to service work carried out in people's homes or other premises and managed via platforms. Consequently, working conditions also vary significantly. All the risks of specific work activities themselves are present in online platform work, but they are likely to be aggravated by the specific features of online platform work/workers: lower average age; lower training levels; working in a variety of private settings; virtualisation of relationships and loss of peer support; loss of the protective effect of a common workplace; work requests issued at short notice with penalties in terms of future work opportunities for not being available; time pressure and rapid pace of work; fragmentation of jobs into tasks with narrowed job content; loss of job control; continuous real-time evaluation and performance rating; increased competition as online the labour market becomes global and accessible to more workers; irregular hours; insecure income; payment by tasks carried out but not for the time spent looking for work, which can extend the working day; blurred boundaries between work and private life; a lack of adequate HR support; unclear employment status; no social entitlements such as sick pay and holiday pay; poor worker representation; and unclear responsibilities for OSH. In some cases, online platform work offers the benefits of desired flexibility in terms of working time and place of work, but in many cases it is associated with forced flexibility. Workers in non-standard, poor-quality forms of work have poorer physical and mental health. The online platform economy creates new challenges for labour protection and OSH management, and there are key questions around responsibility and regulating OSH (EU-OSHA, 2017b). It is a fast-expanding area, and the effects on the labour market and labour protection are disproportionately disruptive.

Autonomous workers: the use of ICT-ETs could enable flatter organisational structures with fewer middle-management posts. This could mean that workers have more autonomy and control over their work (unless middle managers are replaced with algorithms to optimise productivity, resulting in less autonomy and more pressure to perform). However, the loss of supervision by and support from middle managers could also have a negative impact on OSH, as they generally have responsibilities for workloads, schedules, OSH and workers' well-being. Their OSH expertise and tacit knowledge might be lost. Autonomous workers might not have the necessary skills to be able to manage their workloads in a safe and healthy way. Moreover, a loss of peer support and general social interaction at work could have a negative impact on workers' mental health. There are also psychosocial issues associated with the loss of status and financial expectations of those who were, or aspired to be, middle managers.

Lone working: lone working could increase as human peers are replaced by ICT-ETs. Dehumanisation of work and relationships will make jobs less satisfying as the human/social aspects are lost and tasks become less varied. Doctors and nurses will lose contact with patients with the introduction of care robots, diagnostic robots and surgery robots. Even in the service and public sectors, service robots are expected to take over tasks involving contact with customers. As ICT-ETs enable many jobs to be done remotely, people could increasingly work alone without anyone knowing or being able to assist when they have an accident or suffer the sudden onset of a serious health problem. Lone workers in public places and delivery drivers could also be vulnerable to physical violence or verbal abuse from third parties. However, ICT-ETs can be used to reduce risk, for example wearable devices can monitor vital signs and GPS location and be used to communicate with the emergency services if needed.

Loss of social skills and cyber-bullying: increasing dependence on social media and the internet for work purposes could increase the amount of cyber-bulling by competitors, peers, stakeholders or cyber-trolls. Virtual communication does not match the richness of face-to-face communication, and a lack of social contact may lead to less well-developed social skills (e.g. team-working skills and tolerance), leading to an increasingly negative communication tone that may include hostile language, and an increasing sense of depersonalisation that could feel like bullying. Innovative, more immersive, interfaces may counteract this effect at least to some extent.

Collaborative employment refers to freelancers, the self-employed or micro-enterprises working together to overcome limitations of size and professional isolation, for example by jointly employing workers. ICT-ETs can be used to facilitate this. This kind of employment can improve the well-being of individual workers by providing full-time employment where one organisation alone would have been able to offer only part-time or occasional work. It can also allow diversification, improve social interaction and provide support networks.

New collective bargaining models: negotiations on pay and conditions, the organisation of worker representation, and participation in the design of workplaces, activities and equipment have traditionally been done through trade unions. Trade unions have, in general, tended to focus on one or a few closely related sectors and to have representatives based at workplace locations. New business models and structures, enabled by ICT-ETs, mean that workers may work across sectors, work for several employers, not be based at specific locations and/or be (pseudo) self-employed. This could lead to a loss of trade union membership and as a consequence reduced collective bargaining powers with a potentially detrimental impact on OSH. However, ICT-ETs could also facilitate new collective bargaining structures and models that better reflect and work alongside the new business ones.

3.4 Workforce characteristics

Dispersed workforce: ICT-ETs allow an increasing range of work to be done anywhere and any time, so work processes can be decentralised, geographically dispersing the workforce. This can lead to the loss of the office or factory environment on which OSH management, oversight and regulation has traditionally been based. There is also the potential for a dispersed workforce to experience professional and social isolation, as well as being exposed to the risks associated with lone working. Loneliness is associated with a greater risk of cardiovascular disease, depression and anxiety, as well as impairing reasoning and decision-making, which could have implications for OSH (Murthy, 2017).

Diverse workforce: ICT-ETs give access to work irrespective of geographical location, cultural background, physical disability and age group. They can also give organisations easier access to workers from a range of different disciplines. This could lead to a very diverse workforce with a wide range of different OSH needs, social skills, training needs and preferences in terms of their approach to tasks, including what ICT-ETs they use. This could make managing OSH and the transfer of OSH information more difficult. However, ICT-ETs could provide instant translation for voice-activated interfacing with machines or other workers and use AI to incorporate cultural context. This could allow the fundamental principles of OSH practices to be better standardised in multinational organisations, which could have OSH benefits. A multidisciplinary approach including distributive problem solving, which ICT-ETs facilitate, could also be beneficial for solving OSH problems and improving the management of OSH.

Extended working life: ICT-ETs could enable workers to retire at a much older age as the use of autonomous vehicles, bionics and exoskeletons, or on-line platform work enable an ageing population to continue to work. This could mean that they may be exposed to work-related risks for much longer. This could increase the probability of their developing the type of health problems that are caused by cumulative exposure to these types of hazards. In addition, although older workers tend to have fewer accidents, their injuries are often more severe.

New workers: Online platforms can enable workers to frequently change their jobs and the type of jobs they do as such platforms give access to a wide variety of types of work - and may not have mechanisms to check whether workers have the appropriate skills for each job. There could, therefore, at any one time be many more workers who are new to the job and who are statistically more likely to have accidents.

Inequality: ICT-ETs have the potential to drive increased inequalities in the workforce in terms of pay and conditions. Digital entrepreneurs can use ICT-ETs to set up and quickly expand online businesses with low capital outlay. At the same time, ICT-ETs can offer low-skilled workers easier access to work but create competition for work that could, if unregulated, drive down pay. This could also lead to the rise of an online grey economy of unregistered workers who fall outside regulation. All of this could lead to social polarisation.

3.5 Responsibilities for OSH

Online platform economy: on the one hand, online platforms provide a regulatory opportunity to address undeclared work, but, on the other, they also present regulatory challenges as they are a 'moving target' and it is difficult to fit the activities into pre-existing regulatory categories. Specific features of online platforms, such as triangularity of the parties involved, temporariness, informality, autonomy and mobility, make it more difficult to establish an employment relationship. The owners of the platforms tend not to consider themselves employers (and neither do the demand-side users) but to treat workers as self-employed and therefore responsible for their own OSH. However, there is some debate about whether workers dependent on online work platforms are truly self-employed (EU-OSHA, 2017b). As the application of current OSH regulations requires an employment relationship, the question is to what extent does/should employment law, including OSH law, apply to platform work. Labour inspection is also challenged by the blurred role and responsibilities of the employer in relation to the workers, by the lack of clarity on who is responsible for risk management, and by work being done any time and anywhere.

Continuity of OSH surveillance and associated records: ICT-ETs could change the nature of work so that workers frequently change jobs and/or have more than one job. When combined with a lack of clarity about OSH responsibilities, this could cause a loss of continuity of OSH surveillance or records. However, ICT-ETs could also facilitate new ways to organise OSH surveillance and keep records that better reflect new business models and structures. The IoT, sensors in surrounding devices and robots, and wearable monitoring devices could allow the recording (automatically or manually) of real-time observations or incidents, including OSH exposures, directly into an OSH management system and online OSH records and provide access to 'moment of need' information. AI could be used to analyse this information alongside historical data and provide advice directly to the worker and/or employer. Effective strategies and systems would be needed to ensure that the large quantity of data generated is handled ethically, ensuring privacy and good use of data, in particular medical records.

Demonstration of compliance: constant monitoring with mobile ICT-ETs could be used to demonstrate compliance with OSH regulations or as evidence during investigation of incidents or any alleged breach by the defendant, investigator or regulator. VR or AR could also be used as evidence in a court case to allow members of the jury and/or the judge to explore the site of the incident and see a demonstration of what the OSH investigator/regulator (or defendant) believes happened. AI algorithms, using big data, could be used by companies to achieve very accurate assessment of risks and develop effective prevention measures.

3.6 Skills, knowledge and information

New skills and training needs: increased use of and advances in ICT-ETs could lead to new skills being needed by workers to give them access to good-quality jobs. Workers, as well as needing to know how to use the technology, will need to have the relevant skills for the new ways of working that ICT-ETs bring. Workers are likely to need to be self-reliant, flexible, adaptable, resilient to changing jobs frequently, culturally sensitive and competent to work across multiple disciplines. Furthermore, they are likely to need to have interpersonal skills suitable for collaborating virtually, and to have the necessary skills to manage their workloads in a way that is healthy and safe. The approach to education and training may, therefore, need to be different, less academic and fact-based and more about developing personal skills and how to learn, exchange knowledge and cope with change.

Lifelong learning will be essential, as some skills are likely to have short currency and high value, depending on the pace of technological change and the frequency with which workers change jobs. Workers will, therefore, need to be able to learn quickly and then learn again and again.

Self-directed online learning: the changing business models and nature of work caused by ICT-ETs could mean that workers have to take more responsibility for their own learning and training needs. Some online work platforms, for example, have claimed that they have been hesitant to offer training and development opportunities, concerned that this might be interpreted as the platform acting as an employer. ICT-ETs facilitate access to learning and training and allow them to take place on a little and often basis, rather than their being occasional and of long duration. Online learning resources can more easily be designed to allow workers to tailor them to their needs, choosing how they use them and working through them when it is convenient and at their own pace. AI could also be used to assess learners' needs (learning style as well as current level of knowledge) and automatically tailor the resources to meet them. However, it might be difficult for workers to identify relevant and good-quality training when faced with what could be an overwhelming choice. This could result in workers' behaviour being based on inadequate OSH training. Effective strategies and systems are likely to be needed to enable workers to cope with the amount of information available without becoming overwhelmed.

Knowledge transfer: a dependence on ICT-ETs for communication could lead to a loss of social skills or the development of different ones. Either way, this could have a negative impact on social interaction and transfer of (OSH) knowledge between workers, particularly from different generations. If workers feel unable to interact, for example because they are being monitored or because of work intensification, this could prevent valuable informal transfer of knowledge. However, it could also prevent workers picking up 'bad' OSH habits from one another. Furthermore, ICT-ETs can also facilitate new and rapid means of knowledge transfer (e.g. through social media and online work associations), although it may be difficult to assure the quality of the content. Together with the changes in the way workers seek and use information, this could provide an opportunity to engage and inform the self-employed and independent workers, as well as micro- and small enterprises.

Task deprivation and de-skilling: increasing automation of work and processes will result in some workers' roles becoming supervisory only, monitoring processes that rarely go wrong; and widespread algorithms and AI management will mean that workers will receive an instruction for each work step or merely respond to signals. The tasks left to workers will require lower levels of expertise and experience. This could result in workers becoming less and less able to solve problems when they arise and lead to a greater likelihood of human errors. If the use of AI becomes widespread for decision-making, workers could become dependent on it and cease to be able to make decisions themselves. Jobs could lose content and variety, barely require workers' initiative and become less satisfying. This could cause boredom and loss of concentration (cognitive underload) and generate stress, as well as leading to a de-skilling of the workforce.

Corporate memory: ICT-ETs are driving frequent job changes, remote work and the growth of a dispersed, workforce. This could mean a loss of OSH corporate memory and culture, with workers ceasing to know or understand the OSH reasons for doing things in particular ways. The IoT could allow workers to access 'moment of need' training and information, which, if used effectively, could be used as a means of capturing the 'corporate memory' on OSH. However, this could also create an overdependence on electronic information such that knowing where to find information could become more important than remembering information. This might be an issue if, for some reason, it was not possible to access the information, it was corrupted or it was not up to date.

4 Conclusions

The emergence of new technologies, such as the IoT, AI, big data, cloud computing, collaborative robotics, AR, additive manufacturing and online platforms, has a profound impact on the world of work. Although the spread and prevalence of the application of ICT-ETs are currently varied across Europe and across different sectors and socio-economic groups, ICT is becoming an integral part of nearly all sectors, rather than a sector of its own. There is evidence that over the next decade there are likely to be significant and accelerating changes in relation to ICT-ETs, which will considerably change the nature and organisation of work across Europe as well as enable new forms of work and employment status. This will have the potential to create business opportunities, including stimulating increased productivity and growth in Europe, with the possibility of growing inequality in the benefits and disadvantages experienced by workers. There could be significant losses in medium-skilled jobs and major gains in higher-skilled jobs, with concerns about a ‘race to the bottom’ in employment standards. There will also be major changes to the nature of work and the distribution of jobs between sectors. The workforce will be more diverse and dispersed, frequently changing jobs and working online, rather than being present in person. This will all give rise to both challenges and opportunities, including OSH ones.

It is difficult to predict these changes, so scenarios of the future are a valuable tool. The four scenarios produced in this foresight project allowed to identify new and emerging OSH challenges relating to how ICT-ETs could change automated systems, work equipment and tools used; how work is organised and managed; business models, hierarchies, and relationships; the characteristics of the workforce; responsibilities for managing OSH; and the skills, knowledge and information required to work.

Each scenario (in annex) presents different challenges and opportunities for OSH, partly influenced by the pace of change, levels of investment in OSH research, governance styles and social norms. The challenges that are likely to be present in all four scenarios, although their extent and impact may vary, are:

- the potential for automation to remove humans from hazardous environments, but also to introduce new risks, particularly influenced by the transparency of the underlying algorithms and by human-machine interfaces;
- psychosocial and organisational factors that will become increasingly more important because ICT-ETs can drive changes in the types of work available; the pace of work; how, where and when it is done; and how it is managed and overseen;
- increasing work-related stress, particularly as a result of the impact of increased worker monitoring made possible by advances in and the increasing ubiquity of wearable ICT-ETs, 24/7 availability, blurred boundaries between work and private life, and the online platform economy;
- increasing ergonomic risks due to the increase in online working and the use of mobile devices in non-office environments;
- risks associated with new human-machine interfaces, in particular related to ergonomics and cognitive load;
- the increase of sedentary work, a risk associated with obesity and non-communicable diseases such as cardiovascular diseases and diabetes,
- cyber-security risks due to an increase in the interconnectedness of things and people;
- increasing numbers of workers treated (rightly or wrongly) as self-employed, and who could fall outside existing OSH regulation;
- changing business models and employment hierarchies due to increased online and flexible working and the introduction of algorithmic management and AI that have the potential to disrupt current mechanisms for OSH management;
- the algorithmic management of work and workers, AI, monitoring technologies, such as wearables, together with the Internet of Things and Big Data may lead to a loss of workers’ control over their data, issues of data protection, ethical issues, information inequality with regard to OSH, and performance pressure on workers;
- workers lacking the necessary skills to be able to use ICT-ETs, cope with change and manage their work-life balance;
- more frequent job changes and longer working lives.

From an OSH regulatory perspective, there is therefore a potential confluence of factors whereby the use of ICT-ETs drives rapid changes in not only the technologies used at work but also the nature of work, business structures, employment status, hierarchies and relationships; the combined impact of these changes could challenge existing mechanisms for managing and regulating OSH.

Digitalisation therefore opens the door to an increase in OSH challenges, in particular of an ergonomic, organisational and psychosocial nature, that need to be better understood and managed. However, it also offers new opportunities to reduce some OSH risks or better manage them. Technology in itself is neither good nor bad; maintaining a balance between the challenges and the opportunities presented by ITC-ETs and digitalisation will depend on the proper application of the technology and on how it is managed.

Examples of OSH strategies that emerged from the discussions in the various workshops held as part of this project and that could help to mitigate OSH challenges related to digitalisation include:

- the development of an ethical framework for digitalisation and codes of conduct;
- a strong 'prevention through design' approach that integrates a user/worker-centred design approach;
- collaboration between academics, industry, social partners and governments on research and innovation in developments ICT-ETs/digital technologies to properly take account of the human aspects;
- the involvement of workers in the implementation of any digitalisation strategies;
- advanced workplace risk assessments, using the unprecedented opportunities offered by ICT-ETs, while also considering the full range of their possible impacts in terms of OSH challenges, as identified in this foresight project;
- a regulatory framework to clarify OSH liabilities and responsibilities in relation to new systems and new ways of working;
- an adapted education system and training for workers;
- the provision of effective OSH services to digital workers.

The scenarios produced in this project (in the annex) were tested in workshops using a futures technique known as policy wind-tunnelling. This successfully demonstrated that they can be used to:

- help inform policy-makers so that they can take appropriate account of changes related to digitalisation, the use digital technologies and the impact on work and OSH when making decisions to shape the future to achieve safer and healthier workplaces;
- stimulate discussions that incorporate multidisciplinary perspectives about the actions that can be taken today to influence what happens in the future;
- test policies to make them more resilient to the impact of future changes to work as a result of innovation in and the application of digitalisation and ICT-ETs.

The four scenarios (in the annex) have been shown to be a valuable tool for analysing future OSH challenges and opportunities. However, they are not forecasts and the future for OSH for different sectors and regions will contain elements of each of the scenarios in a combination that cannot be predicted. Using the scenarios to develop and test future strategies and policies should reduce risk and help maximise the potential opportunities.

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Annex: Scenario descriptions

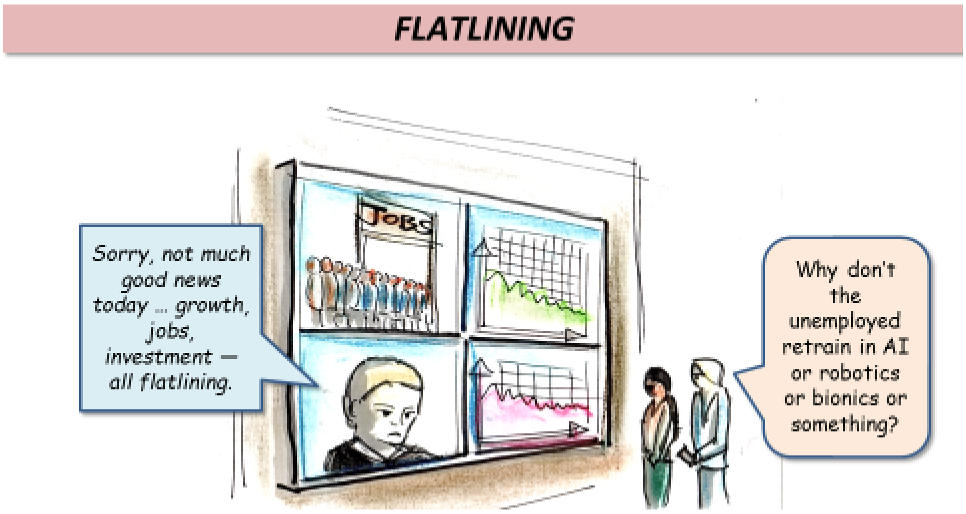
Scenario 1 — Evolution

(Low levels of economic growth and technology application / High levels of governance and supportive public/worker´s attitudes)

Europe in 2025

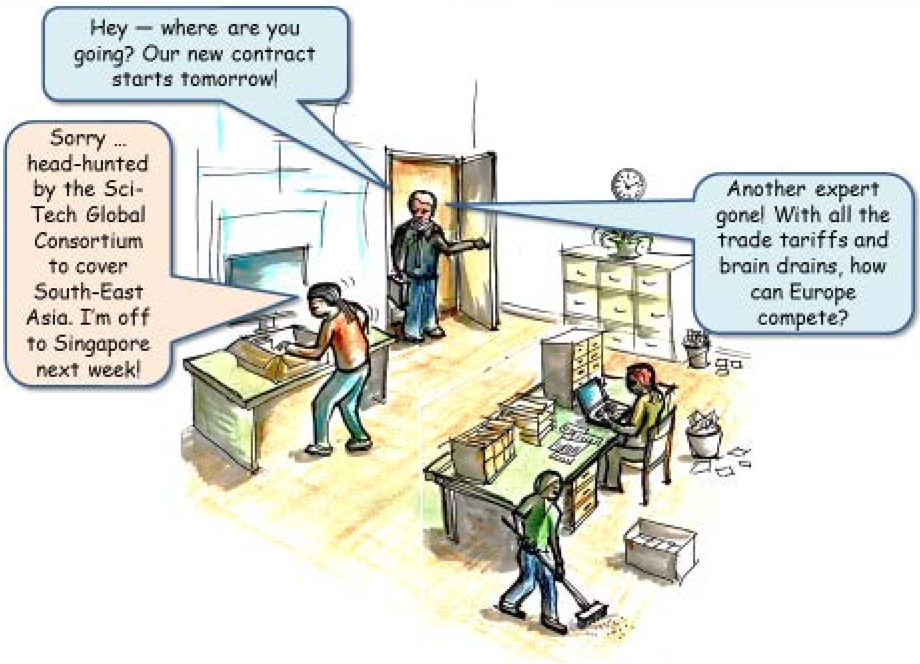
During a decade of low economic growth, the governments of Europe have sought to regain the trust of the voters and maintain social cohesion by focusing on workers' rights, social welfare, health and social care, and education. Employees, workers' representatives, business leaders and governments have worked together through social dialogue to build a consensus on the benefits of the exploitation of ICT-ETs at work. There is a mix of participation and trust management on the one hand and command and control on the other. This approach has been successful insofar as it has helped to maintain public confidence in government and new technology.

The slow pace of economic growth means that there have been limited funds for government and business investment in building the physical and research infrastructure required to support new technologies. Exploitation of these technologies has therefore been constrained, despite the acceptance of the potential benefits.



There have been continuing levels of relatively high unemployment and a loss of confidence in the benefits of international trade. In response to popular concerns, Europe seeks to protect its economies through strict trade and migration policies. However, there is global competition for highly skilled people who can work in a rapidly changing world driven by technological change, which has led to a 'brain drain' of people moving to faster-developing economies.

BRAIN DRAIN



There is a mix of workplace innovation and more traditional work organisation, human resource management and labour relations. In some places, groups of people or local governments have formed their own micro-economic communities of interest and local enterprises. This is patchy, but where it has happened it is a positive response to the problems affecting Europe as a whole, and offers potential examples for others to follow.

PRINTER JAM

By 2025, the richest few have increased their share of the total wealth. Most other people will be relatively poorer, with young people and middle-income workers particularly badly affected by the low economic growth. Although public sector jobs have been maintained, pay is generally poor, except in those areas where people have taken joint action to protect themselves and foster local micro-economies.

GDP growth remains low throughout the period, averaging around 1 % per annum. Businesses have been looking to survive and build a more secure future, and ICT investment is focused on areas where costs are lowest or where profits are highest. There are some parts of Europe that continue to do better than others because they started from a stronger position in terms of ICT infrastructure, investment, skills and adoption. There have not been the necessary Europe-wide strategies and investments to bridge the gaps, so they are widening.

Europe is not seen as a leader in new technologies. The speed of adoption of new technology, which is much lower than in the USA and parts of Asia, means that the rate of change in the labour market has been relatively low. Only about 10 % of jobs have disappeared, but about 40 % have been moderately changed by support from new technology. Real wages have fallen.

This relatively slow rate of change to work helps to maintain a sense of social solidarity, meaning that there is plenty of work for nurses and carers and in the public/state sectors.

The combination of the exodus of young potential high earners and new efforts to constrain immigration means that population projections are now pointing to a reduction in Europe's total working-age population, with further negative implications for GDP growth.

Technological change

The application of new technology and skills has been slow and left mainly to the big international corporations, to motivated individuals or to local initiatives. The low levels of GDP growth and governments' focus on protecting 'old' jobs and maintaining social cohesion mean that a relatively low priority is given to research and development of new technologies. Global corporations continue to invest, but do so in the context of their own business strategies. Existing technology, which is seen as a more reliable and safer investment, is more widely diffused across sectors, whereas the pace of introduction of new technologies is quite slow.

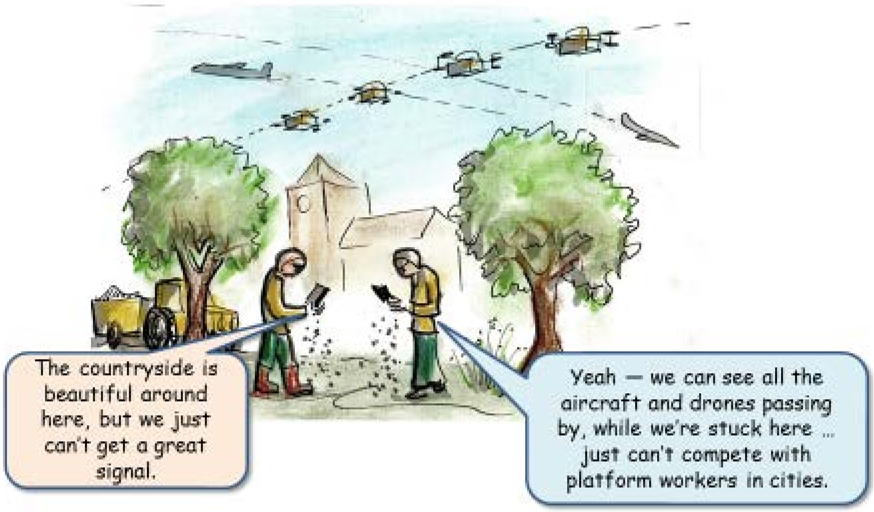
There has been relatively slow development in cutting-edge technologies, such as AI, that drive the Internet of Things (IoT). 'The use of basic AI and voice control interfaces has increased moderately, but more advanced AI and human-machine interfaces (e.g. eye-tracking, gesture and direct brain to computer interfaces) are used only where they will significantly reduce costs. Examples include the management of more complex process and distribution systems. The majority of robots are still mainly undertaking repetitive tasks. Robots working collaboratively with humans or undertaking more complex tasks requiring greater dexterity are limited in number.

Additive manufacturing is beginning to disrupt traditional manufacturing industries and create new business models, including small start-ups.

Cyber-attacks have increased and are a serious threat, as it has not been possible to finance the increasingly high levels of investment needed to counter them.

The use of online work platforms has steadily increased during the decade, particularly where micro-economic communities exist. 5G broadband has been rolled out across the urban areas of the EU, but access in most remote regions is still limited. As a result, some people in more remote areas have been excluded from the growth in mobile and home working and the online labour market.

RURAL BYPASS



OSH environment

The priority for the private sector is staying in business and for the public sector it is reducing and dealing with the issues associated with unemployment. Governments support workers' rights and work with the social partners to ensure that OSH is seen as important, using a consultative approach to work within the constraint that there are limited funds and resources for OSH regulation, research and training. The increase in the numbers of self-employed and online platform workers has removed a significant proportion of workers from regulatory oversight.

There are pockets of good OSH practice, but the loss of management jobs has fundamentally changed employment hierarchies and worker relationships, which can be detrimental to good OSH management. The tendency for existing technologies to be widely diffused, rather than for new technologies to be rapidly adopted, means that OSH hazards and their prevention are generally well known. The manageable pace of change means that OSH regulation is generally able to keep up and there are opportunities for OSH hazards to be designed out and for best practices to be shared before the technologies to which they apply are in widespread use. Social media is also used to disseminate information on OSH issues.

A gradual but patchy increase in levels of automation, use of robotics and use of AR and VR removes some people from hazardous working environments. However, some of these technologies may not be well maintained owing to businesses' constrained finances and/or understanding of the risks. Connected robots/machines could also be vulnerable to cyber-attacks that could cause them to malfunction in a hazardous way.

There is a risk of work-related stress due, for example, to being monitored at work, working alongside robots or, in some sectors, job insecurity. However, wearable technology is also used to help individuals monitor and manage stress.

Scenario 2 — Transformation

(High levels of economic growth and technology application / High levels of governance and supportive public/worker´s attitudes)

Europe in 2025

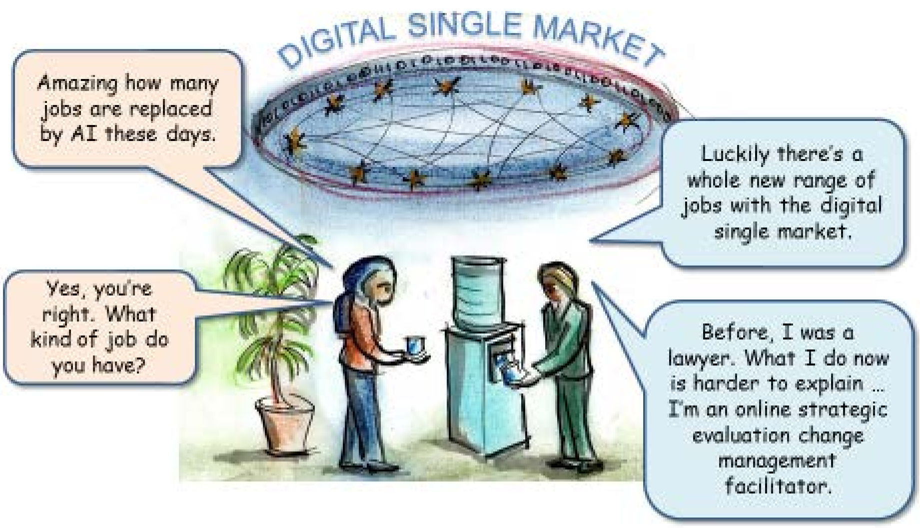
The political and social landscape of Europe has undergone a transformation, becoming one that is more collaborative, consensual and ethical. Policy-making is evidence-based, responsive and resilient. Under this new 'social contract', acceptable behaviour is reinforced through social norms and values.

An increasingly connected, environmentally and socially aware public embraces new technology. Workers (and people more generally) use ICT very effectively to create radical new and innovative ways of organising labour so that, in general, no group is particularly disadvantaged. Mechanisms are available to make governments accountable over a wide range of issues, including the regulation of new technology, online privacy, healthy and sustainable work practices and care for the environment. This creates, among most, a high level of trust in policy-makers, and, in general, an acceptance of new technology. Society is also less discriminatory and more equal, as ICT supports workers irrespective of their demographic (e.g. age or class).

Political alliances, established during the successful implementation of the European Digital Single Market, have resulted in governments across Europe working well together. Governments have embraced the efficiencies offered by ICT-enabled technologies and have found innovative ways of regulating new technologies and working patterns. They have the necessary funds and the knowledge to support sound investments in infrastructure, cyber-security, education and training. This enables ongoing technological change and economic growth of 3 % to be sustained.

The labour market is characterised by frequent changes in the type and nature of jobs available. During the past 10 years, 50 % of jobs have fundamentally changed or disappeared, with many new jobs being created. It is common for workers to have several jobs that fit around their personal lives. There is a complete blurring of work and personal life, with people moving almost seamlessly between one and the other. The majority of workers are capable of protecting their work-life balance, which is supported by Artificial Intelligence (AI) supervisory algorithms built into work interfaces. People also change jobs frequently and with ease, and often continue to work healthily into their 80s. Average life expectancy is 100.

DIGITAL SINGLE MARKET



Unemployment remains generally low owing to widespread good-quality skills among workers, innovative job search tools and new jobs replacing lost ones. Workers' disposable income is generally good, with less disparity between most people. This has created high levels of migration into Europe.

There has been a fundamental change in the underlying principles, structure and control of the internet, including the creation of a digital version of the Geneva Convention. Despite this, cyber-security is an increasingly important and challenging job.

The approach to education and training has been transformed. Human-trainer-led teaching is blended with high-quality interactive Massive Open Online Courses (MOOCs), which are widely available. Quality is assured through accreditation by online worker cooperatives, employment associations and trade unions. Workers, employers and governments all recognise the importance of lifelong learning. Good-quality ICT skills, as well as interpersonal skills, are, therefore, kept up to date across the wide demographic of workers.

TARGET PRACTICE

There is an expectation that people will comply with social norms driven (in part) by insurance and employment implications. Most workers are comfortable with this. For those who are not, it has led to a feeling that they have lost their sense of identity, as they are rarely completely free from being assisted and monitored by AI algorithms, which record attendance, performance and productivity. This has created an underclass of people living on the fringes of society, who don't want to be permanently monitored by ICT-ETs, are 'disconnected' and have lost access to many work opportunities and services that rely on ICT.

The pace of change (technological change and changes in ways of working) is moderated by the need to reach consensus among the social partners, which can sometimes slow down decision-making.

REFORM FOR REFORMERS

Technological change

5G broadband was rolled out across Europe some time ago, including in rural areas. The Internet of Things (IoT) is widespread, such that most devices at work and at home are smart and connected.

The use of basic, narrow AI is part of many aspects of people's personal life and work, and most people work in teams supported and advised by AI systems. This helps workers to be more productive, by removing the routine aspects of jobs. For example, health workers are provided with patient information and a likely prognosis by an AI system. Workers are generally monitored and directed by learning AI systems, which help to manage stress, promote well-being and encourage safer, more productive working practices. These AI systems assess a range of data from the worker, including physiological data collected through wearable devices.

Artificial general intelligence (AGI) is beginning to replace higher-skilled jobs across a range of sectors. In some areas of work, AGI is recognised as being better at data analysis and running processes and systems than humans. These AGI machines now make decisions and act upon them without human supervision or intervention. However, there are some concerns around how much control AGI machines have and how they make decisions.

Empathy algorithms are used to tailor the nature and format of advice according to the varying needs of different users.

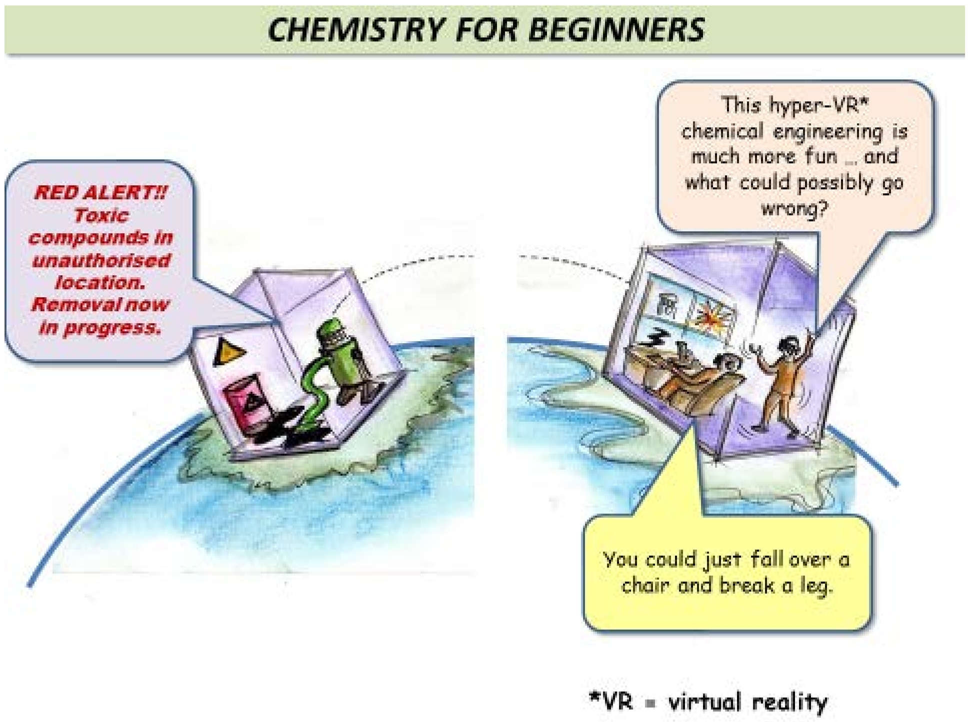
Interfacing with ICT (and other people remotely) is more natural and immersive. There is widespread use of voice recognition, eye tracking and gesture control. The use of direct brain-to-computer interfaces, while not widespread, is no longer seen as niche.

Additive manufacturing has created new business models, such as bespoke local on-demand manufacturing.

Self-driving autonomous cars and other means of transport (including drones) are common and car ownership is low.

There are significant numbers of fully autonomous robots that can undertake complex tasks, including those requiring high dexterity.

'Lights out' manufacturing is quite common in several industrial sectors; many factories are fully automated with no or minimal remote human supervision or intervention.



OSH environment

Good OSH is a priority for all social partners, driven by ethics and recognised as good for a sustainable society and business. This has created a culture of continuous improvement, common standards and effective self-regulation. Social norms promote good OSH management along with safe and healthy behaviour on the part of workers.

The new social contract means that there are trust, transparency, shared values and openness between governments and social partners, which encourages collaboration on OSH. There is also a preference for a consensual, evidence-based approach to decision-making, with governments made accountable by well-coordinated direct action by social partners. Work organisation mirrors this, generally following a participation and trust management regime. This has allowed innovative partnership, workplace innovation, and ICT-based approaches to regulation to be implemented.

There is funding for good-quality OSH research, with access to large quantities of relevant data as a result of the widespread use of wearables and from the IoT. Consequently, OSH tends to be built into ICT enabled technology and work processes. Therefore, on the whole, there is resilience to the moderately rapid pace of change (technological change and changes in ways of working). However, a consensual approach can occasionally lead to a lack of efficiency and an overly precautionary approach. Regulation can also sometimes lag behind the introduction of new technology.

Social norms can cause stress/anxiety from the pressure and/or need to conform; some individuals worry that they are not able to perform or behave well enough to meet societal expectations. The pressure to conform can also sometimes lead to ‘group-think’, such that emerging risks are missed.

Organisations and regulators, in general, have the knowledge and skills to manage OSH effectively. The working environment in Europe attracts and retains motivated, experienced and highly skilled workers. This, along with the open intellectual property movement and good-quality, innovative approaches to training and knowledge transfer, mitigates the impact of workers having several jobs and changing them regularly.

However, changes in employment patterns and hierarchies can mean that there is a lack of clarity about who is responsible for OSH, particularly where work is done via online platforms or where workers have AI bosses. Some workers may also fall outside formal regulation because of their employment status or because their location is hidden behind an online platform. Most people work short-term contracts for different companies around the world, or do small jobs or tasks through online platforms.

Generally, people work alongside AI systems or ‘cobots’, and many are supervised, assessed, coached managed and monitored by AI. This can put excessive cognitive load on some individuals. Others suffer stress/anxiety due to the loss of control or responsibility and peer support at work or are concerned about how much they are monitored.

There are not many fixed places of work, and the realistic nature of VR and AR mean that most people work from home, in shared communal spaces or in public places. Most work meetings are held in virtual reality and, while this improves efficiency and reduces travel costs, some feel a lack of real social interaction and support. Homes, public spaces and means of transport have, in general, evolved to be more worker-friendly from an ergonomic perspective. Human-machine interfaces are generally more ergonomic, but new ways of interfacing may result in new cognitive, voice, visual and MSD risks.

Increasing levels of automation and use of robotics remove many workers from hazardous physical, chemical and biological working environments. AR and VR are used for immersive training and to support maintenance tasks, which can often be done remotely; this also contributes to removing workers from hazardous environments, but can cause cognitive issues and disorientation between the real and virtual worlds and occasionally accidents happen. Where people need to work in hazardous environments they are protected by smart PPE that can alert users to exposure to hazardous substances and tailor advice to the needs of the user. In addition DNA profiling can be used to screen out workers who are susceptible to certain chemicals or allergens.

The use of autonomous vehicles, bionics and exoskeletons enables an ageing population to continue to work. However, their use may cause loss of bone or muscle density and/or joint flexibility.

Good cyber-security and ICT reliability are essential because of the number of online smart devices and dependence on networked ICT systems for many work activities; if hacked, these systems could cause hazardous malfunctions.

Despite this, technology is, on the whole, very reliable and work processes are generally safer. However, when something does go wrong it can take time to realise that there is a problem and workers will have little or no experience on which to rely when deciding how to manage the situation (because technology rarely goes wrong). This can be exacerbated by the fact that many work processes are remotely supervised by just a few workers, who may have little to do most of the time.

People are generally better able to balance personal and work-related demands due to the highly flexible nature of most work. In addition, AI supervisory algorithms are built into work interfaces to prevent unhealthy working practices. However, stress can still be an issue for some people because of the temptation to work intensely; the blurring of work and private life; increased task complexity; being continually monitored; the expectation to conform; and the loss of human interaction at work. As a consequence of automation, robotisation and AI, some workers may also suffer from stress due to task deprivation, for example not having enough to do, their job being monotonous or their job not requiring them to use their cognitive skills.

Scenario 3 — Exploitation

(High levels of economic growth and technology application / Low levels of governance and resistive public/worker´s attitudes)

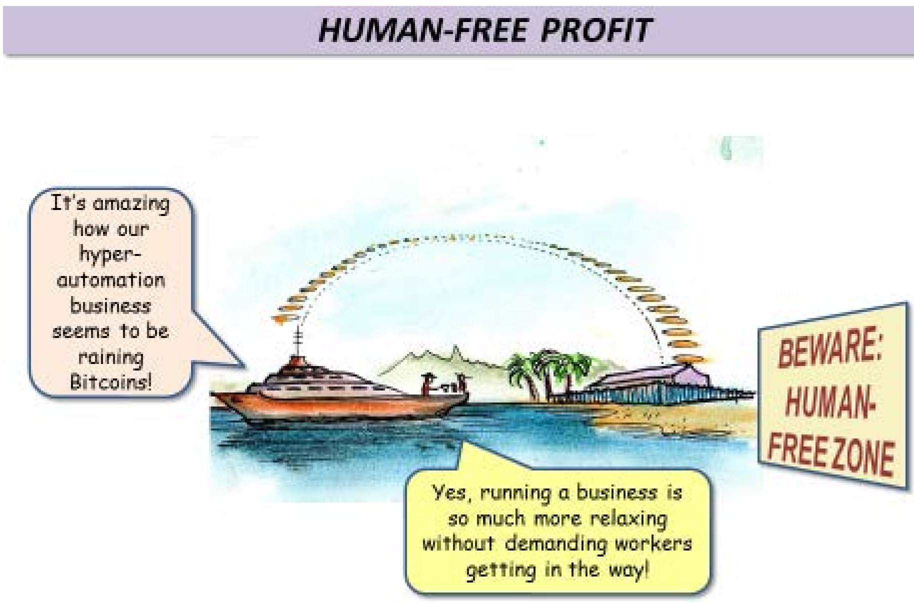
Europe in 2025

Annual economic growth has risen during the past 5 years to about 3 % of GDP, with increased business investment in research and development, infrastructure and capital assets. Market forces and rapid technological change lead to enforced adaptation by the workforce. During the last decade, the social partners and governments have generally failed to work together and have lacked the resources to ensure that regulatory frameworks keep up with the rapid pace of changes in ICT-ETs and the changes they have triggered in relation to (flexible) employment, working arrangements, the nature of work and work location. This has included an inability to modernise the collection of taxes, starving governments of the necessary funding for education, skills, infrastructure, and research and development.

ICT skills are funded where there is an immediate need or where skills cannot be brought in through online platforms or offshored. Businesses are mostly doing well and seek to maintain their positions by investing in research and development to maximise technology exploitation, primarily in the areas that yield the quickest and greatest profits. However, disruptive ICT-ETs can put companies out of business quite suddenly, despite national governments' interventions to try to protect their workers' jobs.

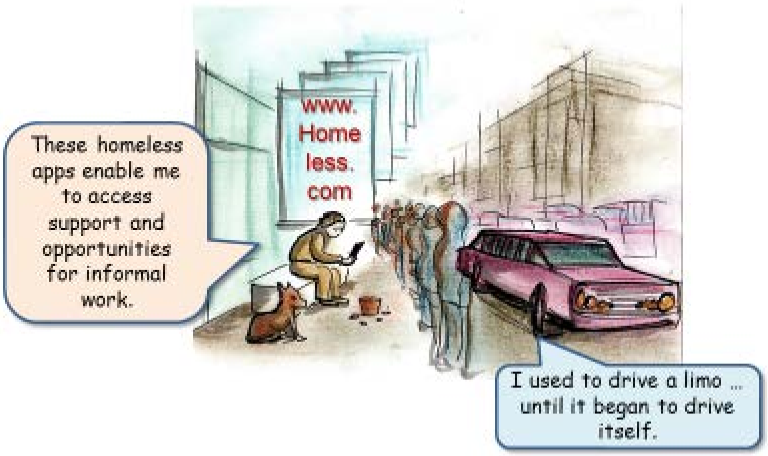
Rapid advances in ICT have had a widespread and profound impact on work. There is an increasing rate of change in the European labour market. The economy is dominated by increased freelancing, zero-hours contracts and short-term contracts (the so-called gig economy). Many people work for at least five employers at any one time, are enrolled with a number of online platforms and frequently change jobs. About 60 % of jobs have fundamentally changed or been lost. Of these, around 40 % of jobs have been lost because of the automation of routine and repetitive work activities. The societal benefits of work are not valued and only about 10 % of jobs are newly created. The available work is primarily unskilled, with only a small proportion of partly standardised high-skilled work.

There are very high levels of unemployment and much greater inequality between the high and low paid. Workers' interests and their training are lower priorities, as it is easy to buy in skills as required. What jobs there are are generally unstable and insecure in nature, and work is often challenging and intense.



There is a ‘digital divide’ between the ‘haves’ (highly skilled individuals who compete for the best jobs) and the ‘have-nots’ (unemployed or in precarious employment). There has been a decline in public trust and workers’ rights, and a lack of government leadership. Those still in work feel threatened by the ongoing rapid pace of ICT developments. There has been a continuing decline in trade union membership and a resulting lack of collective bargaining power. By 2025, workers’ discontent is high and there is ongoing unrest. Protests, including direct action, coordinated and mobilised via social media, are common.

WORKERS ARE EVERYWHERE



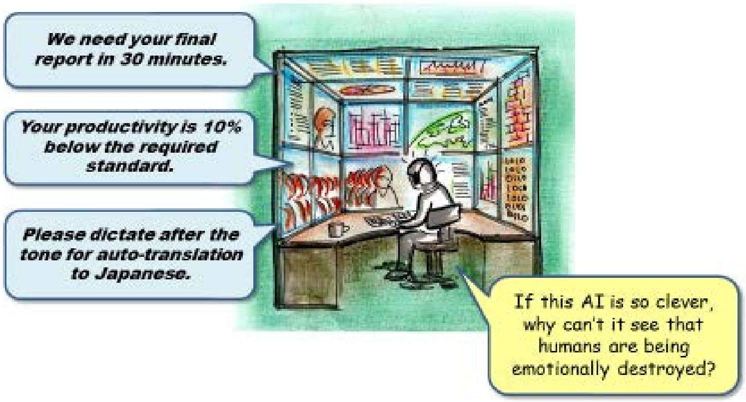
As a result of significant ICT skills gaps towards the beginning of the decade, businesses attempted to upskill the workers needed to use advanced ICT-ETs. This means that there are opportunities for less wealthy EU countries to benefit from the ICT revolution. Increasingly individuals use widely available Massive Open Online Courses (MOOCs) to upskill themselves. This leads to a rise in social mobility for some. However, the demand for high-level ICT skills still outstrips supply, so there are high wages available for those with the best skills. Job opportunities are increasingly dependent on having good ICT skills. Creative/artisan and interpersonal skills are also highly valued. However, use of online training also means that wider skills, for example social skills, can be poor. High value is attached to education and training for those who can afford it or borrow money to pay for it. Face-to-face training is primarily available to only the most affluent workers.

Technological change

There is limited choice for workers in this scenario; technology will be ‘done to you’ rather than ‘be there for you’.

Advances in AI and robotics are ubiquitous in the workplace. Businesses have realised the improvements AI can bring to productivity and efficiency, and systems have now been widely adopted to direct, monitor and assess worker performance and productivity. Management is usually of a command and control nature, overseen by AI supervisors.

PRODUCTIVITY PROBLEMS

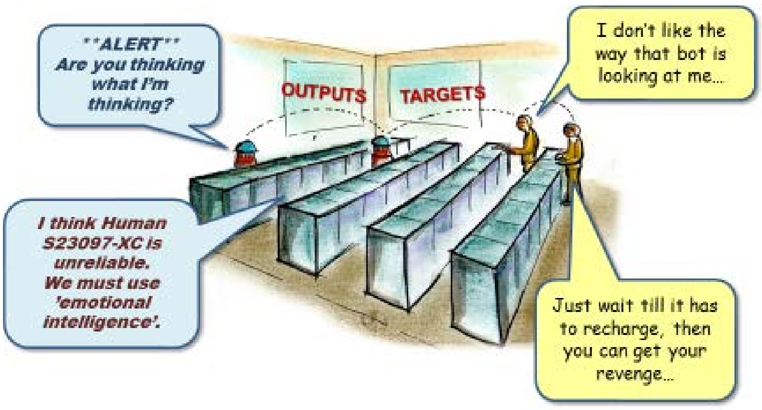


Robots and computer algorithms now carry out the majority of routine and repetitive tasks. Skilled professional jobs have also been significantly affected. Robots commonly work collaboratively with humans and can undertake increasingly complex and powerful tasks. Biomechanical devices, such as exoskeletons, are commonly used in workplaces, for example in care work, maintenance and logistics. However, there are issues around the security and control of biomechanical devices, particularly smart devices that are connected to the Internet of Things (IoT).

Interfaces using voice recognition, eye tracking and gesture control are common in some sectors, and there has been early adoption of direct brain-to-computer interfaces. Traditional large manufacturing activities have been significantly disrupted by additive manufacturing; small and medium-sized enterprises and start-ups increasingly provide products locally.

The IoT is now part of most aspects of daily life and most workers are monitored constantly online and via IoT-connected wearables. However, there is patchy coverage across Europe, with many rural areas lacking access. Internet profiling of prospective and current workers by businesses, including during their leisure time, is routine (to monitor for a healthy lifestyle, valued because of the link to productivity benefits).

POWER GAMES



Throughout the decade, cyber-attacks have been increasingly common, because of the lack of a robust, coordinated response to the threat from both governments and businesses. This has resulted in a greater loss of public trust. Infrastructure, power and utilities have all been disrupted by cyber-attacks, and this is now part of everyday life.

OSH environment

A lack of government leadership, public trust and dialogue, or support from business, means that regulatory frameworks are generally inadequate and unable to keep up with the rapid pace of change in ICT and working patterns. This is exacerbated by a lack of effective collective bargaining for good working conditions, due to falling trade union membership and limited access to alternative bargaining approaches.

There is patchy investment in OSH research and training and poor access to good-quality OSH information. Workers frequently change jobs, do not have the time or money for quality training, and experience extended periods of unemployment. Employers commonly transfer responsibility for OSH management onto their workers through pseudo self-employment contracts. The precarious nature of work can also create a willingness to accept OSH risks, just to be able to work.

The workforce is dispersed and rarely engaged in a traditional employer-employee relationship. For example, most workers are self-employed, with precarious employment contracts (zero-hour contracts, on-call work, online platform work), often taking multiple and/or short-term jobs. This has a detrimental impact on OSH outcomes. One example of this is the lack of implementation and enforcement of any OSH legislation or health surveillance.

Social media is used to form collectives, which attempt to use their combined power to improve working conditions, with occasional but often limited success. AI ‘assistants’ are also provided by the better online work platforms, to promote OSH information to workers. As a result, there is a considerable contrast between good and bad jobs in terms of OSH.

Increasing levels of robotics and use of automation remove many people from hazardous physical, chemical and biological working environments. However, workers generally have to adjust their speed or position in order to work effectively with collaborative robots. This pressure to perform at the same level as robots can cause stress and MSD issues as a result of poor ergonomics or working too fast.

The combination of new technology and older technology can lead to OSH risks, for example if an individual comes across an older robot and expects it to behave in the same way as an intelligent, sensing collaborative robot.

Some OSH issues are offshored along with the work. However, there is still a need for ‘dirty’ work in some areas that are currently too difficult to automate fully or where human workers are still cheaper. For those working in these environments, there is the potential for exposure to a wider range of, and more chemically complex, materials, for example during manufacture or recycling. New materials are also being used for 3D and 4D printing and bio-printing in small shops and start-ups by owners and their workers, who may have little training in the risks posed by exposure to toxic particles/fumes or explosion/fire hazards.

Technology is increasingly complex and brought to market quickly, which can lead to potentially hazardous design flaws that are difficult to spot. A lack of investment in cyber-security and internet infrastructure also means that work equipment is susceptible to malfunctioning owing to hacking in ways that can cause hazardous situations in the workplace, for example the shutting down of cooling systems used in exothermic chemical processes.

Human-machine interfaces are ubiquitous and some are personalised to the user. However, many are not adapted to the cognitive level or other needs of workers. New ways of interfacing may also result in new cognitive, voice, visual and MSD hazards.

Overall, work-related stress, anxiety and depression are common because of the precarious nature of most jobs, job insecurity, work intensification, working for multiple employers, continual monitoring, working alongside robots and pressure from AI systems to increase productivity (known by some as the ‘digital whip’). Cyber-bullying is also common in many workplaces, across many sectors.

Lots of people, despite their self-employed status, feel ‘owned’ by their ‘employers’, are expected to be available for work at very short notice and suffer from conflicting employer demands. It is easy for individuals to over-work and many workers burn out.

Scenario 4 — Fragmentation

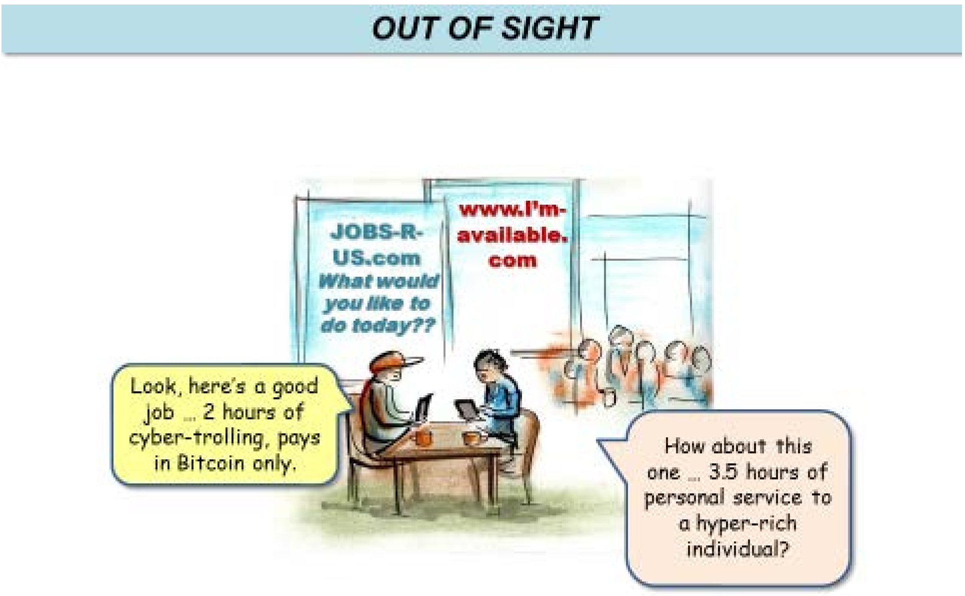
(Low levels of economic growth and technology application / Low levels of governance and resistive public/worker´s attitudes)

Europe in 2025

Europe has endured a decade of low growth and low technological development in most sectors of the economy. There are low levels of social cohesion and most people are motivated by self-interest. The economy is typified by short-termism, low wages, low tax revenues and high inequality. Only those businesses and workers who are the 'fittest' survive. There are high levels of informal work in the grey economy, often based on local or personal relationships, often facilitated by social media.

Ethics have come under pressure, as tax avoidance has become the norm and governments' ability to regulate new working patterns has diminished. Both businesses and individuals working in the grey economy see avoiding tax as 'smart', or at least, sensible. The concept of loyalty to one's company or workforce has virtually disappeared. Traditional models of hierarchical command and control management and human resource management have generally broken down. The lack of tax revenues means there is limited government spending on social welfare and health. Deregulation pressures have led to a 'small state' ethos. There are high levels of unemployment, at least in the formal economy, and many of those in work need at least two jobs to sustain themselves. Job insecurity is widespread, with zero-hours contracts common. The ageing population has no choice but to remain in work longer and older workers tend to have to accept lower value jobs as their previous jobs disappear.

Governments have done little to support innovation. Businesses have exploited developments in technology with a narrow focus on short-term profit, and 'productivity' in the form of the replacement of labour, or by using AI supervisors to drive increased efficiency. In some cases, industrial disputes against automation have actually resulted in its implementation being sped up to restore reliable services to customers. Some well-paid, high-status roles remain, so there is still a segment of society that can afford high-quality personalised services.

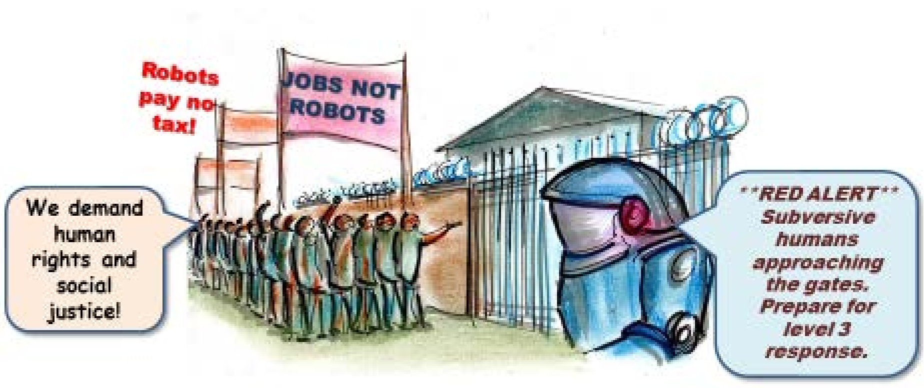


GDP growth throughout the period remains low, at about 1 % per annum at best. Investments by both business and government in research, infrastructure and skills development are generally very low, and incremental improvements are seen as the most cost-effective way of reducing labour costs. However, there have been some significant examples of the successful application of ICT, particularly by the owners of online work platforms to support the gig economy.

Around 20 % of jobs have been lost during the decade, mainly to the automation of low-skilled, repetitive work. Few new (formal) jobs have been created. Most people change jobs frequently as they are pushed out. New job opportunities tend to be lower paid and short term.

Lack of trust that the benefits of new technologies will benefit workers or be spread evenly across the population has led to a high level of resistance to change. While technological change has continued, the rate is, in most cases, steady rather than rapid. More traditional industries (e.g. engineering, retail) continue to exist, but with decreasing profitability. Limited innovation is focused on greater exploitation of both human and environmental resources.

LOCKED OUT



Faith in governments' ability to shape the future has all but vanished and ever fewer people vote or participate in civic society. An 'every person for themselves' attitude prevails, particularly in the formal economy. However, there is still a place for personal contacts and relationships to provide mutual support in some parts of the grey economy. Some see the greater personal freedom and limited state intervention as a positive development.

There is low investment in the maintenance of both equipment and software, leading to more frequent failures, greater numbers of cyber-attacks and consequently even greater loss of public trust.

Low investment in education and training has also created a workforce where only some have the skills to fully exploit advanced technologies. Massive Open Online Courses (MOOCs) are available, but they are of variable quality, so they improve skills only to some extent. Use of online training also means that wider skills, for example social skills, can be poor. All this has combined to hold back innovation in many businesses. The polarisation of society, therefore, continues to increase, with rich individuals and a few successful businesses able to sequester greater shares of national wealth, and a growing underclass turning to increasingly illicit ways of surviving.

Technological change

The wave of technological developments that was in the pipeline at the beginning of the decade has been harnessed for short-term profit but innovation has been limited. Automation has replaced significant numbers of routine repetitive jobs, particularly manual ones in the manufacturing and construction sectors. Drones and autonomous vehicles are becoming fairly common.

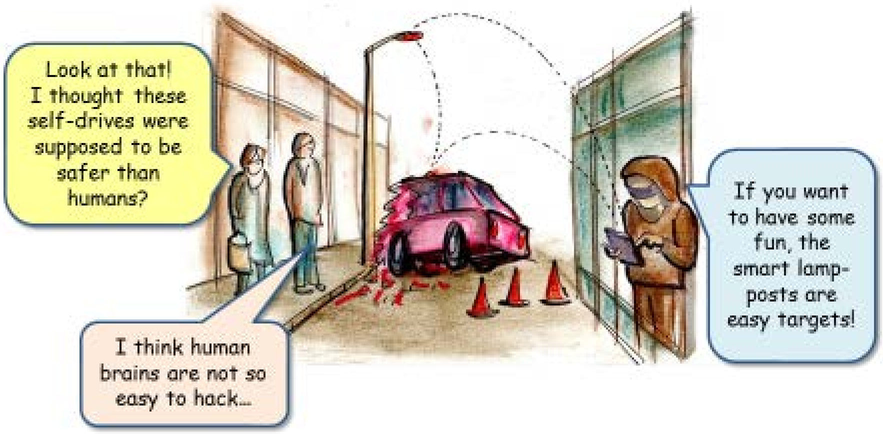
Investment in mobile networks has been limited and 5G is focused on profitable areas, generally industrial areas and cities. The Internet of things (IoT) is now part of many aspects of our daily lives, including work, so we are almost never free from 'supervision.' However, limited investments in networks and cyber-security have led to increased cyber-crime and restricted data sharing.

Monitoring technologies, including through mobile devices, are increasingly used to ensure workers are working as hard as possible, and to remove those seen as not performing well enough.

Additive manufacturing is beginning to disrupt traditional manufacturing industries and create new business models, including small start-ups.

The development of robots undertaking more complex tasks that require greater dexterity has continued but is not widespread. Robots working collaboratively with humans are more widespread and the use of bionics has increased where productivity gains can be made. The effective use of big data has enabled fairly widespread use of basic, narrow AI, which has significantly changed some jobs and replaced routine clerical ones.

SMART CITY FUN



There has been a large increase in online work platforms that provide a wide variety of work, from highly skilled professional work to small, routine tasks. Work is carried out online or offline (but managed online), in varied work locations, and most workers are (pseudo) self-employed. Numerous individuals are on zero-hours contracts and the insecure nature of work (e.g. with workers being called to jobs on a just-in-time basis) means that many suffer from stress and anxiety. Work is often intense, which contributes to both psychosocial and physical disorders. A large amount of the available work is computer-based, which has led to an increase in physical disorders such as MSDs. Some of the online platform work available is in typically dangerous occupations such as forestry. Because most individuals are (pseudo) self-employed, the responsibility for safety and health is transferred from the employer to the worker. Many lack employment benefits such as sick pay.

In addition, a wide range of new online jobs has been created, such as crowdfunding specialists and personal digital curators.

OSH environment

Despite occasional public outcry at disasters, governments struggle to impose or enforce regulations, not least because there are limited tax revenues available to fund enforcement. Indeed, in the name of 'cutting red tape', some regulations have been relaxed and OSH is not well viewed generally. The effects often have a delayed impact, so are not seen for a number of years.

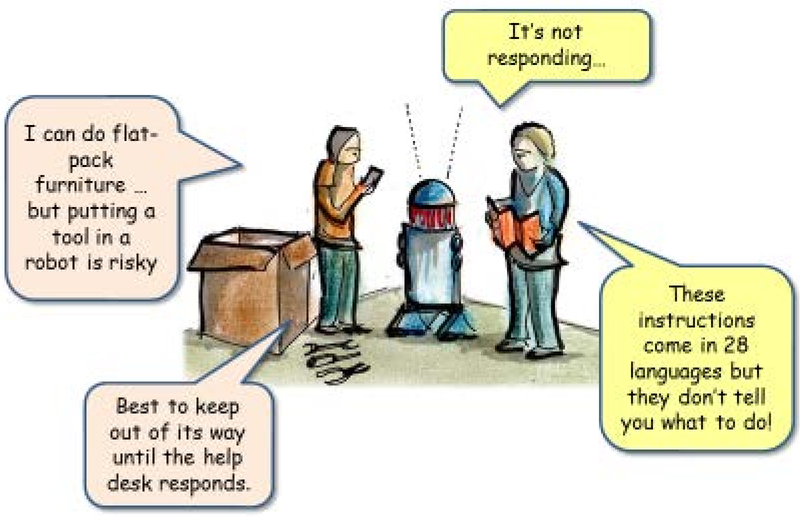
The overall slow pace of change means that in most areas OSH regulation is adequate and little changed, but it can struggle to keep up with pockets of high innovation. This variation across and within sectors makes the transfer of OSH knowledge from one workplace to another more difficult.

The unregulated grey economy is fraught with potential OSH risks and is very difficult to monitor and control. The safety of work processes and the quality of products or advice services cannot be assured, as corners are cut in an attempt to make profits or keep prices low enough to be viable. Extensive sub-contracting also blurs responsibility for compliance with OSH regulations, and responsibility for OSH is transferred to the worker in some sectors. Under-investment, by governments and businesses, in cyber-security has led to more cyber-crime, which can shut down or compromise safety systems.

Companies focusing on short-term profits have consistently under-invested in OSH systems, so the number of equipment failures and the incidence of injuries and work-related ill-health remains high. Organisations invest little in OSH training and many workers have poor access to good-quality OSH information. In addition, workers often experience extended periods of unemployment. Overall, this means that many individuals lack adequate OSH knowledge and work experience, and as a result are at greater risk of harm at work.

A make-do-and-mend culture, with a mix of old and new assets, creates OSH risks arising from the integration of the new with the old, and at the interfaces between the two. The tendency to run old systems until they break down also increases OSH risks.

INSTRUCTIONS NOT INCLUDED



The use of AR and VR has increased for training and to improve productivity. However, there is little new innovation in the underlying technology. The use of these technologies has primarily been to improve the productivity of online platform workers, so instantaneous translation and human interfaces using gestures and eye tracking are fairly widespread.

Small-scale use of additive manufacturing, often outside regulation in the grey economy, increases the numbers of flawed products on the market. Untrained operators are exposed to particulates and hazardous chemicals, for example in backstreet 3D printing operations.

Robotics and automation, commonly in manufacturing but also in the care industry, have improved OSH through reduced exposure of workers to hazardous environments and ergonomic hazards. However, there are also hazards associated with workers interacting with automated equipment, particularly collaborative robots, such as collisions, increased work pace and increased cognitive load. Improved electronic monitoring makes it possible to alert workers to the presence of hazardous substances.

Work-related stress is widespread as a result of extensive job and financial insecurity, poor work-life balance, the lack of predictability in the grey economy, work intensification in some jobs and task deprivation in others. Intrusive workplace electronic monitoring leads to stress and overwork. Some workers may also suffer from stress due to a lack of autonomy and job variation.

Glossary

24/7 — 24 hours, 7 days a week, that is, continuously.
3D printing — a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material; also known as additive manufacturing.
4D printing — 3D printing with time as a fourth dimension, so that the object produced can change form over time in response to a change in environment.
5G — fifth generation mobile networks, providing faster internet connection speeds than current 4G networks.
Additive manufacturing: a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material; also known as 3D printing.
AGI — artificial general intelligence, or strong AI, is AI capable of autonomously applying intelligence to any problem, flexibly performing intellectual tasks in a manner similar to human beings.
AI — artificial intelligence: a machine intelligence that acts as a rational agent, perceiving and responding flexibly to environmental cues to achieve a defined goal or goals.
AR — augmented reality: where real-world views are overlaid with contextual information, usually via a display, sometimes worn over the eyes.
AV — an autonomous (or self-driving) vehicle.
Big data — refers to the potential of new technologies to produce datasets so large and complex that entirely new data processing applications are needed to capture and analyse them.
Bionic exoskeleton — a wearable mechanical outer skeleton that produces or augments human motion, often directly sensing and amplifying its wearer’s movements, improving their strength and abilities.
Bionics — applying knowledge of natural biological processes to the development of mechanical systems and technology, often to replace a person’s missing hands or limbs.
Bio-printing — 3D printing of biocompatible cells and materials into functional living tissues, including bone, heart tissue and multi-layered skin that can be transplanted.
Brain drain — a continuing net loss through emigration of highly skilled and educated people from a particular country.
Burnout — a type of psychological stress, occupational burnout or job burnout is characterised by exhaustion, lack of enthusiasm and motivation, and feelings of ineffectiveness (it may also entail an aspect of frustration or cynicism), and, as a result, reduced efficacy within the workplace.
Cloud (the) — a computing paradigm that provides shared processing resources and data on demand via the internet.
Cyber-attack — a malicious attempt by an individual or organisation to compromise and harm computer networks and systems.
Cyber-bullying — where individuals are bullied through social media.

Deep learning algorithms — refers to a technique involving a family of algorithms processing information in deep 'neural' networks, where the output from one layer becomes the input for the next one.
Digital whip — new forms of discipline and control established by the use of information communication technologies, whereby workers' schedules are set and monitored by a computer, often with an embedded continuous improvement algorithm based on the average time taken by workers to complete specific tasks.
EMF — electromagnetic field: a physical field produced by electrically charged objects that affects the behaviour of charged objects in its vicinity.
Facebook — an online social networking tool.
GDP — gross domestic product: the total value of everything produced by all the people and companies in a country, which is used as a measure of economic growth.
Gig economy — economy based on working in the form of one-off assignments (rather than on a continuous basis), whereby temporary positions are common and (independent) workers are contracted through on-line platforms for short-term engagements
Grey economy — the part of a country's economic activity that is not accounted for in official statistics.
HR — human resources.
ICT — information and communications technology: technology and software that enable users to access, store, transmit and manipulate information.
ICT-ETs — ICT-enabled technologies.
IoT — Internet of Things: the network of physical objects — devices, vehicles, buildings and other items — embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.
IT — information technology, the application of computers to store, retrieve, transmit and manipulate data.
Lights out manufacturing — a method of fully automated production that can run with no human input on site, thus with the 'lights out'.
Micro-enterprise — one that has fewer than 10 employees and an annual turnover or balance sheet total that does not exceed €2 million.
MOOC — massive open online course, an online course aimed at unlimited participation and open access via the internet.
MSD — musculoskeletal disorder: injuries or pain in the body's joints, ligaments, muscles, nerves or tendons that support the limbs, the neck and the back.
Nanotechnology/nanotech — involves the manipulation of matter at a level of magnitude between 1 to 100 nanometres (1 nanometre = 1 billionth of a metre).
Narrow/basic AI — AI that is narrowly focused and only capable of one task.

Open intellectual property movement — a turn towards balancing intellectual property (IP) rights with openness to enable knowledge sharing and innovation across different businesses and organisations while maintaining protection for IP income.
Pseudo self-employment — a situation where employers, to avoid costs such as sick pay or holiday pay, treat as self-employed contractors workers who are really employees.
Remote work — where an individual works remotely from the offices of their employer.
Smart machines — machines that autonomously sense and adapt to changes in their environment or in their own condition, and can communicate with other machines and systems on a network or via the internet.
Social media — a large variety of computer-based tools that allow people or companies to create, share or exchange information, career interests, ideas and pictures/videos in virtual communities and networks; well-known examples are Facebook and LinkedIn.
STEEP — societal, technological, economic, environmental and political: taxonomy used for classifying drivers or trends of change in foresight studies.
Technostress — negative psychological link between people and the introduction of new technologies.
VR — virtual reality, an immersive computer-simulated or multimedia-generated experience that can be multisensory and enables the participant to interact with the virtual environment.
Wearables/wearable technology — networked electronic devices that can be worn, often monitoring and offering a range functions to the wearer, and that can exchange data over the internet with service providers and other devices.
WiFi — a wireless local area network (WLAN) using radio frequencies to allow devices such as personal computers, smartphones and peripherals within range to connect to the network and internet.
Zero-hours contract — a type of employment contract where there is no obligation for the employer to provide minimum working hours or for the employee to accept work that they are offered.

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The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness -raising campaigns. Set up by the European Union in 1994 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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