In partnership

Skills needed for the safe adoption of emerging technologies in engineering

Summary report

The RSA

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This report aims to identify the skills needed for the future of engineering and safe adoption of emerging technologies. It explores how actors in the engineering skills system can work together to ensure that a diverse range of learners and workers are able to develop these skills and thrive in the future of work.

The world of engineering is being buffeted by a number of long-term trends – both demographic and technological – that will impact on the nature, competitiveness and skills needs of the engineering labour market. In parallel, **new and emerging technologies will present both opportunities and challenges** when integrated into engineering practices, and the **safe adoption of such technologies will require specific skills.**

We explore these applications and impacts through **three exemplar technologies**: robotics and autonomous systems (RAS); the Internet of Things (IoT); and hydrogen fuel. We find evidence of **existing skills shortages** both domestically and globally, and **provide recommendations to ensure that long-term future needs are anticipated and catered for.**

Demographic trends in engineering:

- Following broader demographic patterns, **the engineering workforce in the United Kingdom and across more advanced economies is ageing,** with a fifth of UK workers in the sector expected to have retired, or be close to retirement, by 2026. Elsewhere, however, a younger and more mobile workforce is emerging, and **investment in critical infrastructure in developing countries** is driving a higher supply and demand of engineers. These forces **may render the engineering labour market increasingly global, and increasingly competitive.**
- Engineering may be able to **mitigate against the challenges associated with an ageing population** through innovations in health, medical transportation and the built environment, and **will play a critical role in developing countries through the provision of critical infrastructure.**

Technological trends in engineering:

- **Digitisation and the Internet of Things will see increasingly 'smart cities' emerge** with their own engineering requirements, and a **growing demand for high-tech roles** in computer programming and IT.
- **Automation and robotics have the potential to replace jobs that are undesirable and/or dangerous**, but not all displaced workers will be able to easily adapt.
- Decarbonisation will impact sectorally and necessitate **large-scale changes in business models and production processes,** especially around **cement, steel and car manufacturing**. The shift to a more circular economy will likely see **manufacturing jobs supplanted by roles in repairing, recycling and remanufacturing**, with associated skills becoming more important.
- **Net employment impacts from decarbonisation are estimated to be positive, both domestically and globally**; decarbonisation will rely on and generate a number of new engineering jobs and competencies, especially those relating to low carbon electricity generation and heating, including **in manufacturing, installation and maintenance**. However, while **job creation in the UK is expected to be evenly distributed across the country, job losses will be concentrated in specific regions**.

Automation risks to engineering roles and skills

We conduct a novel analysis of skills data to explore the vulnerability of different roles and skills to automation. 'Automation risk' here refers to the role's/skill's vulnerability to automation.

- Our analysis suggests that **engineering professionals are, overall, at a relatively low risk of automation**, but that **related roles may be more affected.**
- **The lowest risk occupations are typically managers, professionals and technicians, while the risk is higher for process, plant and machine operatives, who may also be less able to transition to other engineering roles** owing to their more specific skills and educational backgrounds.
- Separate RSA analysis suggests that there is a **significant sectoral dimension to automation** and that workers in manufacturing will face the most acute challenges, while **construction appears better insulated from these risks** as it is, overall, less routine and requires more discretion.[1]

Emerging technologies: opportunities and challenges

The adoption of emerging technologies in engineering will bring with it new opportunities and challenges. Using **three exemplar technologies** – robotics and automation, the Internet of Things, and hydrogen fuels – we explore potential benefits and issues with regards to **worker safety, environmental safety, and cyber security.**

Worker safety:

- Emerging technologies offer new opportunities with regards to **hazard protection and pre-empting risks**, and by tracking worker wellbeing in hazardous environments. There are, however, **some concerns over the excessive surveillance** that these same technologies could engender, and resultant calls for regulation of employers.
- **'Predictive maintenance'** of machinery promises benefits both for employers – in **reduced downtime and cost** – and for workers – by **reducing the risk of accidents**.

- Robotics offers opportunities **to protect against physical exertion and harm and**

1 Wallace-Stephens, F, Morgante, E (2021) Good work innovations in Europe: reimagining the social contract. [PDF] RSA. Available at: www.thersa.org/reports/good-work-innovations-in-europe-reimagining-the-social-contract

can also remove workers from hazardous environments. However, robots can increase risk if not suitably programmed to work among humans and the operation of such technologies may **increase cognitive strain.**

- **Hydrogen is non-toxic**, meaning that leaks and spills are not harmful to human health. However, it is odourless, can **disperse quickly, and is highly flammable**, which requires careful monitoring and threat detection.

Safety for the environment:

- The coming together of IoT and RAS promises the **more efficient use of resources in a number of production processes** through 'asset-tracking' of equipment and materials, for instance, **as well as in distribution and logistics** through route optimisation, for example. This should reduce energy use and carbon output, though **'rebound' or 'replacement' effects** have been noted, whereby reduced costs lead to greater consumption. The **net result is increased, rather than decreased, resource-use and carbon output.**
- The act of **digitising and automating production and distribution processes can often be carbon-intensive in itself**, and the hardware that this relies on tend to have relatively short lifespans, leading to **increased e-waste** in the environment.
- Hydrogen fuel presents a mixed picture, and a singular focus on this **risks deprioritising wider research and funding into alternative renewable energy sources. At present, hydrogen production is still a high-emitting process**, and it cannot easily or comprehensively supplant fossil fuels. Hydrogen use should be focused on use cases in heavy industries where it is difficult to use cheaper, cleaner alternatives, and where clean hydrogen can use existing infrastructure.
- **Large-scale pure hydrogen transportation would require major restructuring of the existing pipeline to guarantee safety**. Nevertheless, hydrogen presents promise as a **potential store of energy derived from other clean energy sources**, better able to respond to short-term fluctuations in supply and demand.

Cyber security:

- **IoT and RAS open up a number of vulnerabilities within cyber security.** Greater connectedness to the internet and to other devices **increases the 'attack surface'** that hackers can target, and this risk is compounded by a lack of standardisation and regulation.

Key current and future skills in engineering

Our research has allowed us to produce a **taxonomy of the key skills needed now and in the future within engineering**, summarised in the table on the next page. These have been identified on the basis of our horizon scan, analysis of skills data and shortages, and workshops with industry professionals.

It was stressed by industry professionals, however, that attention to emerging skills needs **should not crowd out fundamental, basic engineering competencies** of ongoing importance, such as **assembly, welding and soldering.**

Skills category	Key current skills in engineering	New skills needed for the safe adoption of emerging technologies
Technical: skills relating directly to specialist engineering knowledge and capabilities.	• Designing, testing and evaluating systems, equipment and products • Collecting, documenting and interpreting technical information • Data and statistical analysis • Technical and scientific knowledge development (ie, staying on top of new developments in field)	• Interdisciplinary approaches to work, especially among team leaders • Cross-cutting knowledge of programming languages • Specialist knowledge and tools relating to data analysis and data management • Specialist technical knowledge relating to specific forms of technology • Specific design skills such as computation geometry and circuit design
Digital: skills relating to digital knowledge and capabilities.	• Computer programming • Designing, testing and evaluating digital systems • Using computer aided design tools • Managing and analysing digital data • Using digital tools for automation • Digital literacy	• Knowledge of specific programming languages and proprietary languages • Design skills requiring specialist knowledge of digital tools • Machine learning and deep learning skills to ensure safety and security
Safety: skills relating directly to safety knowledge and capabilities.	• Inspecting equipment and systems • Ensuring compliance with health and safety rules • Ensuring compliance with environmental rules • Formulating safety policy and procedures • Carrying out risk analysis and management	• Safety requirements will be closely linked to digital skills (above) • Competency in real-world testing and experimentation, including 'ethical hacking' to stress-test vulnerabilities • The ability to conduct risk assessments and skills in risk management, as well as more specialist knowledge in relation to specific technologies • Knowledge of how to safely intervene in human-machine interactions • Specialist knowledge with regards to regulatory compliance, certification and documentation processes
Transferable: general skills that could be adapted to other professional contexts, engineering or otherwise.	• Creative problem solving • Leadership • Ethics • Communication • Teamwork and collaboration • Project management	• Systems thinking, analysis and evaluation to integrate new technologies into the industry • Entrepreneurial skills to spot value-adding opportunities • Knowledge of and ability to anticipate sustainability and safety implications • A continued (and currently under-served) need for practical skills (such as assembly, welding and soldering)

Recommendations

Skills shortages are already apparent in the engineering sector, and we note that employers and educators are not yet taking full stock of the changing skills needs brought about by new forms of technology. These challenges will likely be compounded by an increasingly competitive and global engineering workforce. Jointly, these have implications not only for what skills will be needed, but how different actors will need to respond and refresh established practices:

- **Employers** should anticipate spending more on **investment in upskilling/reskilling to fill gaps**, rather than relying on recruiting externally.
- **Governments** should endeavour to **nurture more talent domestically.**
- And **educators** will need to ensure that adequate account is taken of emerging technologies in their curricula, including the **growing relative importance of transferrable and meta-skills** occasioned by these technologies that may currently be overlooked.

Our recommendations are identified through a review of the current and emerging engineering landscape, consideration of emerging good practice, and consultation with industry professionals. They are grouped around three categories: **foundational needs** acquired through primary and secondary education; **professional skills** acquired through more specialist higher/further/professional education; and **organisational cultures and opportunities** instilled by employers within the sector.

Our recommendations are therefore aimed at a **range of actors,** including **government and policymakers, educational organisations, and employers.**

Foundational skills and mindsets – for policymakers, schools and colleges:

- **Safety-related components of the digital, technical and transferable skills learnt in school should be embedded in school curricula.** Schools should adopt a 'safety first' approach to engineering education, rather than seeing this as ancillary to core engineering skills and knowledge.
- **Greater efforts are required to build the pipeline of computing teachers, as well as drawing on capacity and expertise within the technology sector to ensure up to date pedagogy and content.** Digital skills will take on a growing importance, but may be constrained by inequalities in access and teacher shortages.
- **School pupils should be exposed to not only a broader range of disciplines for longer, but also to the practice of combining multiple disciplines.** Our evidence review points to the importance of working across disciplines and of amassing transferrable skills, especially around managing teams with a mix of specialisms.
- **There should be greater investment in transferable meta-skills.** Our novel skills analysis suggests that interpersonal and problem solving skills, among others, might help to smooth transitions and provide security in a more volatile labour market if complemented with more targeted specialist training.

Further, higher and professional training – for further and higher education providers, local and national policymakers:

- **Professional training should embrace agile and lifelong forms of learning.** Technological, demographic and labour market trends all point to the need for greater flexibility in skills-acquisition and recognition. This might include **initiatives like skills passports and digital badging** to reward and recognise continuous learning, more **agile forms of skills provision** such as bootcamps, and partnership-based **local skills improvement plans (LSIPs).**
- **Ensure improved access to upskilling opportunities, especially among underrepresented groups.** Those most exposed to automation risks also tend to be less qualified and to have limited access to training opportunities, and certain demographic groups (including women and people of colour) are underrepresented in a number of engineering professions and subjects. Minimising disruption and filling skills gaps will require improved access to training through **improved outreach, tailored design, and making workplaces more inclusive.**

Organisational culture, support and opportunities – for employers and the sector:

- **Responsibility for safety skills development should rest at an organisational level, recognising the role of culture in determining safety behaviours and incentivising in-house development of skills.** Too often safety is framed as an individual, rather than collective, responsibility.
- **Improve incentives for safety training, for example by making it more accessible and desirable to individuals and organisations. Incentives also need to be strengthened through the role of regulators and CPD requirements to maintain registration.**
- **Build learning and organisational cultures which are open to challenge and agile to change.** Amid ongoing technological change, organisations need to adapt and incorporate changes quickly, and ensure environments where safety concerns can be voiced freely in order to avoid preventable accidents.

How this report adds to the evidence and recommendations landscape

We believe that this research provides valuable actionable insights that take account of the changing context and sector.

Our novel skills data analysis points to **specific skills and pathways to insure against automation-related displacement**. We identify a number of transferrable skills where accreditation might help to smooth transitions from more to less at-risk roles, if supplemented by upskilling in complementary skills.

Our research calls attention to large-scale and long-term changes beyond the world of engineering, that may necessitate more fundamental changes in how the sector can ensure its skills needs are met in the long term. We note that **technological and demographic change mean that established approaches to skills provision may need to become more agile and proactive,** revising not just **what** skills and training are important, but also **how** skills and staffing can keep pace with an increasingly volatile and competitive labour market. For instance, in addition to updating its skills training, the UK will likely need more homegrown talent, and wider routes into the profession to fill vacancies.

As such, we are hopeful and confident that this report constitutes not just a list of ingredients, but a comprehensive recipe for sustained success and safety in the engineering sector.

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8 John Adam Street
London WC2N 6EZ
+44 (0)20 7930 5115

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