MADE SMARTER.

REVIEW 2017

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FOREWORD

PROFESSOR JUERGEN MAIER, CEO SIEMENS UK

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Foreword – Professor Juergen Maier, CEO Siemens

I have been working within the British industrial sector for over thirty years, and have always been impressed with our capabilities as a nation. But, at the same time, I have been disappointed that we haven't reached our full potential and have left too many of the opportunities arising from the Third Industrial Revolution to other nations.

It has therefore been an absolute honour and pleasure to lead the Made Smarter Review, which we hope will form the basis of a sector deal and become a key pillar of the UK's emerging Industrial Strategy. I believe that it can make a real difference in helping the UK take a much more significant leadership role and a much greater slice of the opportunities arising from the Fourth Industrial Revolution.

This independent review, which began in January of this year, has attracted immense enthusiasm and a substantial contribution from the business and academic communities. In ten months, we have engaged with well over 200 organisations across the UK, including small businesses, leading universities, as well as global inward investors from various industrial sectors. It has been a pleasure to work with such an experienced team of industrial leaders.

As a leadership team, we have sought to create a set of proposals that will equip the UK with the means to fully embrace the next industrial revolution. From the outset, we were clear that this review needed to result in some bold and far-reaching recommendations. I believe that, with the publication of this report, we have done so. But I also believe that this review should be seen as the start of a long journey for the UK. Our proposals don't seek to answer every question about how we drive and embrace digitalisation. Rather, they seek to establish the institutional framework and ecosystems that will spur the next generation of domestic technological innovation.

The review covers multiple industrial sectors and, while this has increased its complexity, it has made our analysis comprehensive. The business community believes the recommendations offer a once-in-a-generation opportunity to boost productivity, create new and exciting businesses, generate new jobs, support rising wages, and increase exports.

In the review, we have focused on the following strategic challenges: the increased pace of adoption of industrial digital technologies, the faster innovation of these technologies, and a need for stronger and more ambitious leadership to transform UK industry. As a result, we have developed three game-changing recommendations (plus one support recommendation), which can be summarised as:

- **Adoption**. Build a national digital ecosystem that will be significantly more visible and effective and that will accelerate the innovation and diffusion of industrial digital technologies. This includes a National Adoption Programme to be piloted in the North West, focused on increasing the capacity of existing growth hubs and providing more targeted support. Critical to the success of our recommendations will be the upskilling of a million industrial workers to enable digital technologies to be adopted and exploited through a single Industrial Digitalisation Skills Strategy.
- **Innovation**. Refocus the existing innovation landscape by increasing capacity and capability through 12 Digital Innovation Hubs, 8 large-scale demonstrators, and 5 digital research centres focused on developing new technologies as part of a new National Innovation Programme.
- **Leadership**. Establish a national body, the Made Smarter UK (MSUK) Commission, comprising industry, government, academia, further education, and leading research and innovation organisations, which would be responsible for developing the UK as a leader in industrial digitalisation technologies and skills, with a mandate to develop the UK's own Industry 4.0 domestic and global brand.

We have called our proposals, and the brand for this initiative, "Made Smarter". Ultimately, this is what industrial digitalisation is all about – how manufacturers can start their own industrial revolution by using digital to make things smarter, better, and faster.

I would like to thank the business leadership team who have advised, supported, and committed to our recommendations. I must especially thank the hundreds of you that reached out directly to share your experiences of digitalising your businesses. Some of the most valued contributions came from smaller businesses working at the coal face of the changing technology landscape. I also thank the University of Cambridge and the University of Newcastle for providing academic input, as well as the CBI, the Manufacturing Technologies Association, and the Royal Academy of Engineering for their tremendous support. I also want to highlight key input and resources provided by the Digital and High Value Manufacturing Catapults in support of our work. Finally, special thanks to Accenture for providing the project management resources for this review and for coordinating the input from numerous working groups and pieces of research to bring together our thinking and recommendations.

We have answered the call of government to set out a vision for growth and increased productivity. Industry is committed to working in partnership with government through a sector deal to revive UK manufacturing, and firmly believes that only this combined package of measures, which go beyond business as usual and historical offerings, will achieve the level of ambition needed for the UK to be a world leader of the Fourth Industrial Revolution.

My call to action is now for government and the business community to come together and embrace these proposals. I believe they represent a very positive agenda that we can all get behind, especially in these times of economic and political uncertainty. Focusing on the long-term challenge of the new industrial revolution will bring us together as a nation and make our country more prosperous. I very much look forward to the opportunity of helping the UK take a much stronger role in the Fourth Industrial Revolution as we get to work and take these recommendations forward.

EXECUTIVE SUMMARY

BECOMING A GLOBAL LEADER IN INDUSTRIAL DIGITALISATION BY 2030

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Executive summary

Becoming a Global Leader in Industrial Digitalisation by 2030

This report summarises the findings and recommendations of the Made Smarter Review (previously referred to as the Industrial Digitalisation review), which was announced in the Industrial Strategy Green Paper in January 2017.

With this review, UK industry has answered the call of government to set out a vision for growth and increased productivity across the manufacturing sector by unlocking the potential of Industrial Digital Technologies (IDTs). The review received an active contribution from more than 200 organisations, including the Productivity Leadership Group (PLG), the Artificial Intelligence (AI) and Robotics and Autonomous Systems (RAS) Review teams, and the Additive Manufacturing Strategy Group.

Industry has put forward a set of recommendations that it firmly believes, if delivered as a combined package of measures, will achieve the UK's ambition of becoming a world leader in the Fourth Industrial Revolution by 2030. Delaying action will not only perpetuate the current productivity challenges within UK industry, but erode the opportunity for the UK to be an early adopter of transformational technology.

THE UK OPPORTUNITY FROM INDUSTRIAL DIGITALISATION

Digital technologies are transforming industry. In a 2017 report, the World Economic Forum identified a $100 trillion opportunity for both industry and society through the adoption of these technologies.[1] Each day, around five million devices link up with each other, with the internet, or with both. There are around 6.4 billion data-communicating objects in the world today. And by 2020, this number is forecast to explode to around 20 billion.[2]

Emerging technology breakthroughs in fields such as AI, robotics, and the Internet of Things are significant in their own right. However, it is the convergence of these IDTs that really turbo-charges their impact.

The potential size of the prize is huge. IDTs offer the promise of recapturing the UK's industrial spirit as a nation of 'creators and makers':

- Raising UK productivity and international competitiveness;
- Creating new, higher-paid, higher-skilled jobs that add value to society and positively offset the displacement of poor productivity and poorly paid jobs;
- Strengthening UK supply chains and creating new value streams;
- Addressing regional economic disparities;
- Increasing exports through competitiveness;
- Creating a new vibrant technology market serving UK industry and attracting FDI;
- Improving the resource efficiency of the UK's industrial base, making it more resilient to global resource supply disruptions and reducing its environmental impact through more efficient manufacturing and industrial processes and more optimised supply chains.

[1] Digital Transformation Initiative Unlocking $100 Trillion for Business and Society from Digital Transformation January 2017 in collaboration with Accenture

[2] Industry X.0 Realizing Digital Value in Industrial Sectors- Eric Schaffer 2017

The work undertaken for the Made Smarter Review found that the positive impact of faster innovation and adoption of IDTs could be as much as £455 billion for UK manufacturing over the next decade,[3] increasing manufacturing sector growth between 1.5 and 3 percent per annum,[4] creating a conservative estimated net gain of 175,000 jobs throughout the economy[5] and reducing CO_2 emissions by 4.5 percent.[6] Overall, from the data and evidence collated, we are confident that industrial productivity can be improved by more than 25 percent by 2025.

We are clear that the faster adoption of technology will result in greater investment and in more manufacturing taking place in the UK. For example,

- The automation of manufacturing processes, coupled with real-time process monitoring and re-engineering, can result in radical improvements in cost efficiency and accuracy, allowing work to move back to the UK from low-wage economies and strengthening UK supply chains;
- Technologies such as additive manufacturing can fundamentally change the supply chain, and mean that competitive advantages afforded by high volumes and low labour costs are replaced by advantages like proximity to market and the opportunities to make products unique to each customer.
- These technologies will deliver multiplier effects, creating new businesses and jobs throughout the UK economy. These effects include:
- The potential for new industries and services to be created by harnessing the data and insights flowing from digital technologies, including real-time management of assets such as trains, jet engines or wind turbines;
- The opportunity for the UK to be a leader in the development of digital technologies themselves, in areas of strength such as artificial intelligence, blockchain and virtual reality;
- The need for support for this new economy from new and improved services and infrastructure in areas like cybersecurity, fibre networks, 5G, and remote monitoring.

CAN THE UK BECOME A LEADER IN IDT?

The UK already has a strong combination of leading-edge R&D and a number of high-performing sectors in the application of digitalisation in design, manufacturing, and servitisation. For example,

- Aerospace is already supporting the development and adoption of the specific technologies which will define the industrial digitalisation revolution, including additive manufacturing, collaborative robots, AI, data analytics, and virtual and augmented reality (VR and AR).
- Manufacturers such as Unilever and AB sugar are leaders in the application of IDT to address sustainability. Within the food and drink sector the UK is seen as a global leader in refrigeration monitoring systems via the IoT and in food safety and traceability systems.
- The UK has the strongest AI and machine learning market in Europe, with over 200 SMEs in the field (compared to just 81 in Germany and 50 in both the Nordics and France).
- The UK is investing significantly in key areas of infrastructure like renewables (owing to strong incentivisation in this sector), which provides an opportunity to stimulate the creation of new local supply chains with a high rate of IDT adoption.

[3] ACCENTURE REPORT: 2017 Industrial Digitalisation Review Benefits Analysis.

[4] BCG; Is UK Industry ready for the Fourth Industrial Revolution. Jan 2017

[5] MSR working group report on jobs and the economy

[6] MSR sustainability working group report

But the adoption and application of technology is not consistent across all industrial sectors. Although the UK is well placed to do so thanks to its rapidly growing digital sector, it is not currently capitalising on that potential advantage by applying these technologies in a coordinated and strategic way in an industrial setting.

We see an opportunity for the UK to differentiate itself in this digital industrial revolution. The relatively flexible and competitive UK labour market has allowed many companies to achieve world-class productivity at lower levels of automation. This will provide an even stronger competitive advantage with Industry 4.0 technologies like 'cobots', where humans work in harmony with advanced technologies to create highly agile businesses attuned to the changing needs of their customers.

But, other countries are stealing a march on the UK. There are coherent government strategies in place in most developed countries, for example in Germany (Industrie 4.0), China (Made in China 2025), and the USA (America Makes). So, the UK needs to act quickly if it is to harness the potential of this agenda.

WHAT IS PREVENTING THE UK FROM FULLY ACHIEVING THIS VISION?
The Made Smarter Review has identified three themes which are limiting the UK's ability to achieve its potential:

1. Lack of effective leadership of industrial digitalisation in the UK

- There is no clear narrative setting out what the UK already does well or the significant opportunity for UK industry – and the country – from the faster development and adoption of IDTs;
- There is no cross-sector national leadership providing market-focused strategic vision, direction, and co-ordination, so that the UK can maximise opportunities and set out a clear approach and offer for foreign investors.
- Without that clear vision and narrative the UK is failing to inspire current and future workers with a vision of how they can secure high-quality jobs in a thriving part of the economy.
- The UK has centres of technical expertise, including world-class research centres and the Catapult network, but its capability is fragmented with no coordination for the effective diffusion of these technologies.

2. Poor levels of adoption, particularly among SMEs

- The UK is behind other advanced nations in overall productivity (output per worker), which is in part due to lower levels of adoption of digital and automation technology.[1] This is particularly acute among SMEs.
- One of the identified causes is an ineffective and confused landscape of business support, with no clear route to access help and ambiguity about what 'good' looks like.
- SMEs, in particular, perceive significant barriers to adoption, such as risks around cybersecurity, and a lack of common standards allowing different technologies to connect.
- Unlike other developed nations, the UK's tax system is not targeted enough to incentivise the opportunity.
- Businesses also face a skills shortage, particularly in digital engineering capabilities, and are hindered by a fragmented skills system and a lack of systematic engagement between education and industry.

[1] IFT; World Robotics Report. 2016

3. **Under-leveraged innovation** assets to support start-ups/scale-ups

- The UK is a leader in research and innovation and has started to establish a support infrastructure to develop and commercialise technology. However, these innovation assets are under-leveraged and not focused enough on supporting IDT start-ups, meaning the UK is falling behind in creating new innovative companies and industries.

HOW CAN INDUSTRY AND GOVERNMENT WORK TOGETHER TO ADDRESS THESE BARRIERS?

To properly address these barriers, industry and government should focus their efforts on the same themes. The Made Smarter Review identified the need for the following new approaches, which form the basis of our recommendations.

Stronger leadership – a UK approach

- We want to inspire the UK's next industrial revolution and make it a leader in the creation and adoption of IDTs by providing a clear vision, strategy, marketing, and messaging of the UK's ambition.

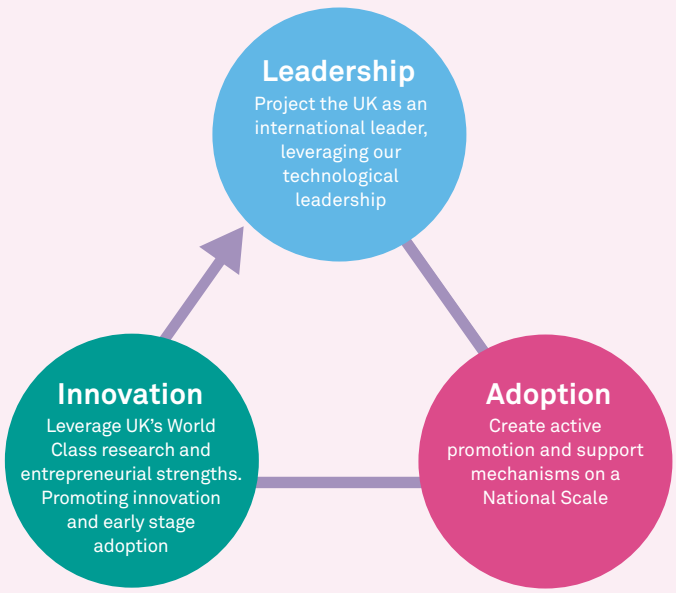
Rapid adoption – raising our game

- We want to see more widespread and rapid adoption of IDTs by manufacturers (especially SMEs), and across their supply chains, through the creation of a significantly more visible and effective ecosystem that will accelerate the innovation and diffusion of the technologies.
- We must upskill our industrial workers in the use of IDTs by standardising and simplifying the way in which quality training and education can be accessed.
- We need to further incentivise IDT adoption by creating clear UK standards for digital industries and targeted fiscal incentives.

Innovation – securing value in the UK

- We need to drive forward a more rapid development and scaling of key IDTs, such as additive manufacturing and AI, and create new IDT companies, value streams and capabilities by leveraging our research strengths and innovation assets.

STRATEGIC GOALS OF THE INDUSTRIAL DIGITISATION REVIEW



In summary, industrial digitalisation is a massive opportunity for UK industry – and the wider economy. But the technologies that underpin it are also highly disruptive, requiring business to be innovative, agile and adaptable. Industry and government will need to work in partnership to provide the infrastructure and ecosystems that can enable manufacturing businesses and their supply chains to maximise these opportunities and be competitive. Get it wrong, and we risk further de-industrialising our economy, and becoming ever more reliant on imports. Get it right, and we will have found the key to rebalancing and strengthening our economy, creating many new, exciting, and well-paid jobs, and leading a renaissance for the UK as a true nation of creators and makers.

OUR RECOMMENDATIONS

3

OUR RECOMMENDATIONS

In this report, we make three game-changing recommendations and one support recommendation. These four recommendations come together as a package and create a strategy for the medium to long term that will ensure that **"By 2030, the UK will be a global industrial leader in creating, adopting and exporting advanced digital technologies, shaping how the world does business"**.

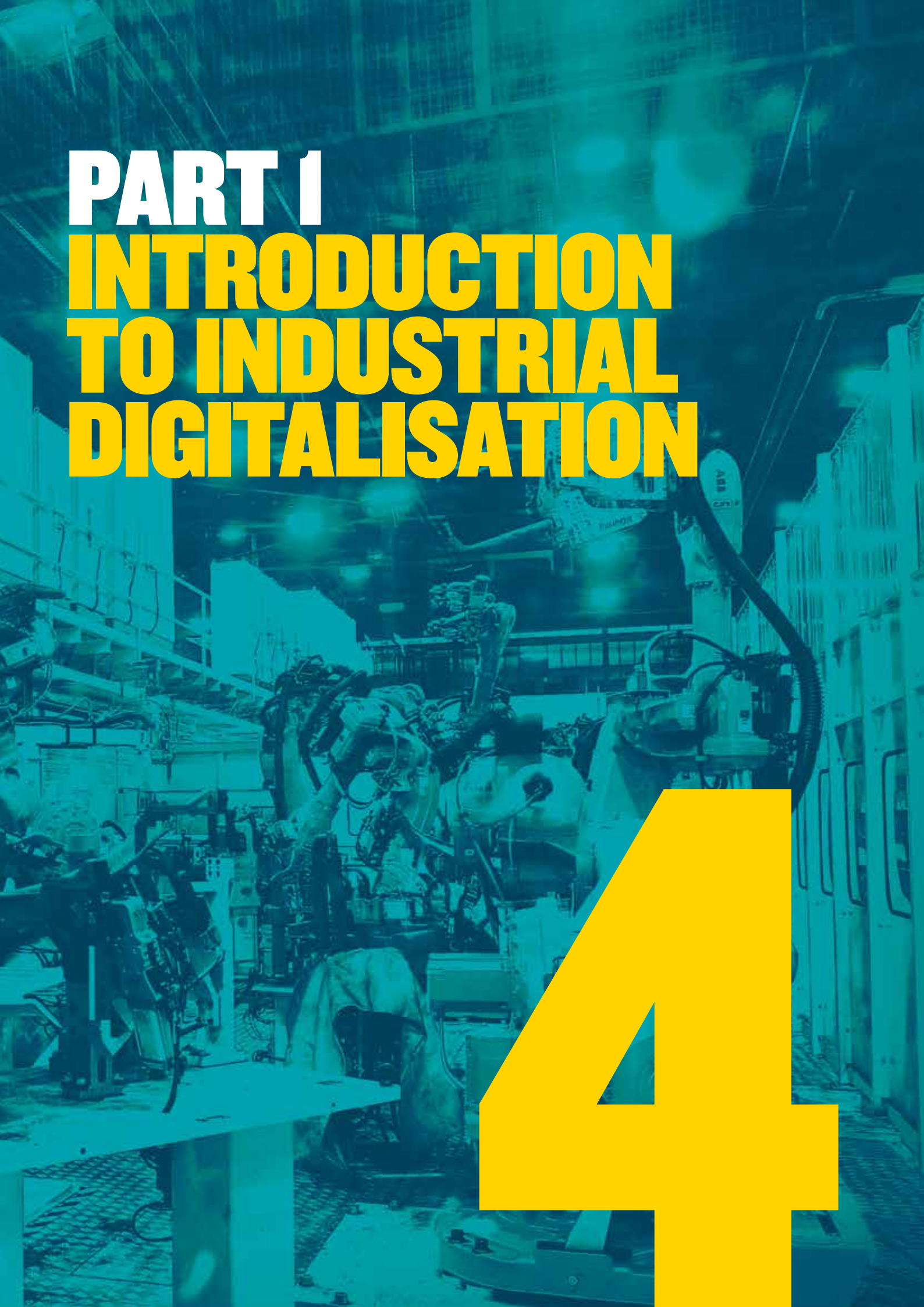
Recommendation	Strategic outcome
Recommendation 1.0 Create a much more visible and effective digital ecosystem to accelerate the innovation and diffusion of Industrial Digital Technologies (IDTs)	
RECOMMENDATION 1.1 **Invest in a new National Adoption Programme (NAP).** This would accelerate the development and diffusion of IDT through focused support to small and medium-sized enterprises in the UK regions. The programme will be owned at a regional level by Local Enterprise Partnerships (LEPs) and delivered by accredited regional partners. Investment will be targeted at strengthening both the capability and capacity of regional advisory services in digital technologies. It will provide kick-start funding for companies to leverage assets and expertise within the ecosystem. It will also increase the mentoring offered by industry and strengthen the interaction with upcoming talent within universities through focused projects and placements.	**North West pilot** • Increase GVA by 15% over a 3-year period – delivering an estimated £70 million benefit. • 20 emerging technology start-ups working directly with industry on new projects. **National rollout** • GVA increase £770 million. • 220 emerging technology start-ups.
RECOMMENDATION 1.2 **Scale the support provided by UK innovation centres through a new national innovation programme.** This would bring together a network of existing distributed Digital Innovation Hubs (DIHs), strategically selected to best serve the challenges of each local business community. It will demonstrate, with industry participation, how the industrial and manufacturing sector can be positively transformed by IDTs.	• 20,000 businesses supported by DIH
RECOMMENDATION 1.3 **Implement large-scale Digital Transformational Demonstrator programmes within the DIHs, co-funded by industry.** These would address both sector-specific and key cross-cutting industry challenges and be focused on delivering tangible results in both productivity and sustainability. The demonstrators would be regionally organised and, together with the National Adoption Programme (Recommendation 1.1), would provide a key accelerator for the diffusion of IDTs especially within SMEs.	• Increase in GVA by £1.2bn • 40 new Digital Innovator spin outs
RECOMMENDATION 1.4 **Drive forward the UK's global IDT research and development leadership.** Create a network of Digital Research Centres (DRCs) to bring together the country's expertise in, initially, five areas: 1. Artificial intelligence, machine learning and data analytics; 2. Additive manufacturing; 3. Robotics and Automation; 4. Virtual reality and augmented reality; 5. The Industrial Internet of Things (IIoT) and connectivity (5G, LPWAN etc.) Each DRC would be tasked with advancing state-of-the-art research and innovation for industrial digitalisation in its technology field. The network of DRCs would build on the excellence and infrastructure in the existing UK science and innovation base and work with the tech developer community to drive UK leadership in the technologies that underpin industrial digitalisation.	• Increase in R&D investment >£400m,

Recommendation	Strategic outcome
Recommendation 2.0 Upskill a million industrial workers to enable digital technologies to be successfully exploited	
RECOMMENDATION 2.1 **Create a single national Skills Strategy and Implementation Group (SSIG) under the governance of the Made Smarter UK Commission (MSUK).** This group would act as a focal point for the engagement of industry and provide a forum for identifying future skills requirements, synchronising and focusing existing initiatives, and ensuring quality and consistency through a kite-marking mechanism.	• 1 million workers re-skilled or upskilled over the next 5 years. • At least 200,000 users completing level 3/ 4 certification per year
RECOMMENDATION 2.2 **Establish a modern digital delivery platform providing scalable, relevant, timely and easily 'digestible' content for upskilling and reskilling.** This would enable all companies, but particularly SMEs, to play their part in the Fourth Industrial Revolution, with incentives and networks in place to drive adoption.	• Delivery of a platform which provides modular, up-to-date, relevant and accessible content for online and blended up-skilling and re-skilling
RECOMMENDATION 2.3 **Establish an incentivised programme, co-funded by industry and government, to improve digital skills capabilities.** Under the guidance of the SSIG (Recommendation 2.1) and using the digital delivery platform (Recommendation 2.2), the programme would take the form of personal training and reskilling allowances which would be targeted at: • Individuals whose jobs are being displaced by automation; • Workers whose skillsets need to evolve to next-generation capabilities (e.g. the use of additive manufacturing technology or artificial intelligence); • Providing leading skills in all organisations (e.g. the digital engineer of the future).	• 100,000 employees enrolled in training incentivisation scheme in year 1.

Recommendation	Strategic outcome
Recommendation 3.0 Inspire the UK's next industrial revolution with stronger leadership and branding of the country's ambition to be a global pioneer in IDTs	
RECOMMENDATION 3.1: **Establish a major national brand campaign, delivered by both government and industry, to significantly increase awareness of how new digital technologies can transform industry.** Delivered within a wider support framework, the campaign would promote the adoption of digital technologies (especially among SMEs), address negative preconceptions that IDT is expensive and risky, and inspire current and future workers with a vision of how they can secure high-quality jobs in a thriving part of the economy.	• Increased awareness of digitalisation in year one (as measured by YouGov poll) by 20% • 36,000 additional manufacturing SMEs accessing support from Growth Hubs
RECOMMENDATION 3.2 **Establish a Made Smarter UK Commission (MSUK).** This would be a national body, comprising industry, government, academia and leading research and innovation organisations, responsible for developing the UK as a leader in IDT. With a chair from industry and a Ministerial co-chair this public–private partnership would provide a market-focused view on IDT priorities, and ensure the faster innovation, adoption and diffusion of IDT to drive maximum value for the UK economy. The MSUK Commission would establish and govern a more visible and better-organised ecosystem that will deliver business transformation through innovation (see Recommendation 1).	• Strong and enduring Industry & Government partnership established providing leadership for Made Smarter
RECOMMENDATION 3.3 **Set up interim Strategy and Support Implementation Groups (SSIGs) to be responsible for the delivery of the MSR recommendations.** These SSIGs would comprise industry, government and academia, and would be accountable to the MSUK Commission.	

Recommendation	Strategic outcome
Recommendation 4.0 Address the key barriers preventing adoption of IDTs	
RECOMMENDATION 4.1 **Implement a Standards Development Programme (including cyber-awareness and best practice) for emerging digital industries to promote the greater interoperability of IDTs.** The creation of standards is known to be an effective way of promoting adoption, by providing confidence and assurance to businesses that use them. This programme would develop both generic and sector-specific standards for IDTs, and would be led by BSI in partnership with industry, the research community, government bodies and regulators. The resulting standards would then be promoted internationally through BSI's membership of CEN, CENELEC, ISO, and IEC.	• Creation and internationalisation of key IDT standards (including 5 priorities identified) by 2020 • Adoption of New Standards >10,000 firms
RECOMMENDATION 4.2 **Implement targeted financial incentives to promote the development and adoption of IDTs.** This would include: • Enhanced capital allowances in the first year of IDT investments, • Broadening the R&D Tax Credit system to include IDT, • An increase in the write-down allowance for specific technologies, and • Working with the British Business Bank to develop policies or programmes to encourage the adoption of IDT and facilitate the financing of suitably qualified projects as appropriate.	• Increased level of investment* in IDT >20%
RECOMMENDATION 4.3 **Develop data trusts to overcome one of the biggest inhibitors in exploiting IDT in manufacturing: a reluctance to share data.** We strongly endorse the recommendations of the UK government's AI review which proposes a government and industry programme to develop data trusts – proven and trusted frameworks and agreements – and ensure data exchanges are secure and mutually beneficial.	• Aim is to develop data trusts in 5 key high value sectors in the first year, which could include Aerospace, Automotive and Pharmaceuticals.

*Additional investment achieved will be determined by the level of incentivisation. The figure quoted is based on evidence from Italy.



PART 1
INTRODUCTION TO INDUSTRIAL DIGITALISATION

4

What is industrial digitalisation?

At its simplest, industrial digitalisation is the application of digital tools and technologies to the value chains of businesses who make things (e.g. in the automotive and construction industries) or are otherwise operationally asset intensive (e.g. power grids and wind farms). These technologies enable the physical and digital worlds to be merged, and can bring significant enhancements to performance and productivity.

We call these technologies **industrial digitalisation technologies (IDTs)**. They come in various forms and various levels of maturity, ranging across artificial intelligence, the Internet of Things, robotics, and analytics. Together, they are driving what is being called the Fourth Industrial Revolution. And it's the integration of these digital and physical technologies into production and logistics that is the key to this revolution. It is this that spurs new businesses to form, increases speed to market, integrates and strengthens supply chains, and realises productivity gains. IDTs are also disruptive, forcing companies to adapt to customer-centric business models, and offer personalised products through mass customisation and enhanced services.

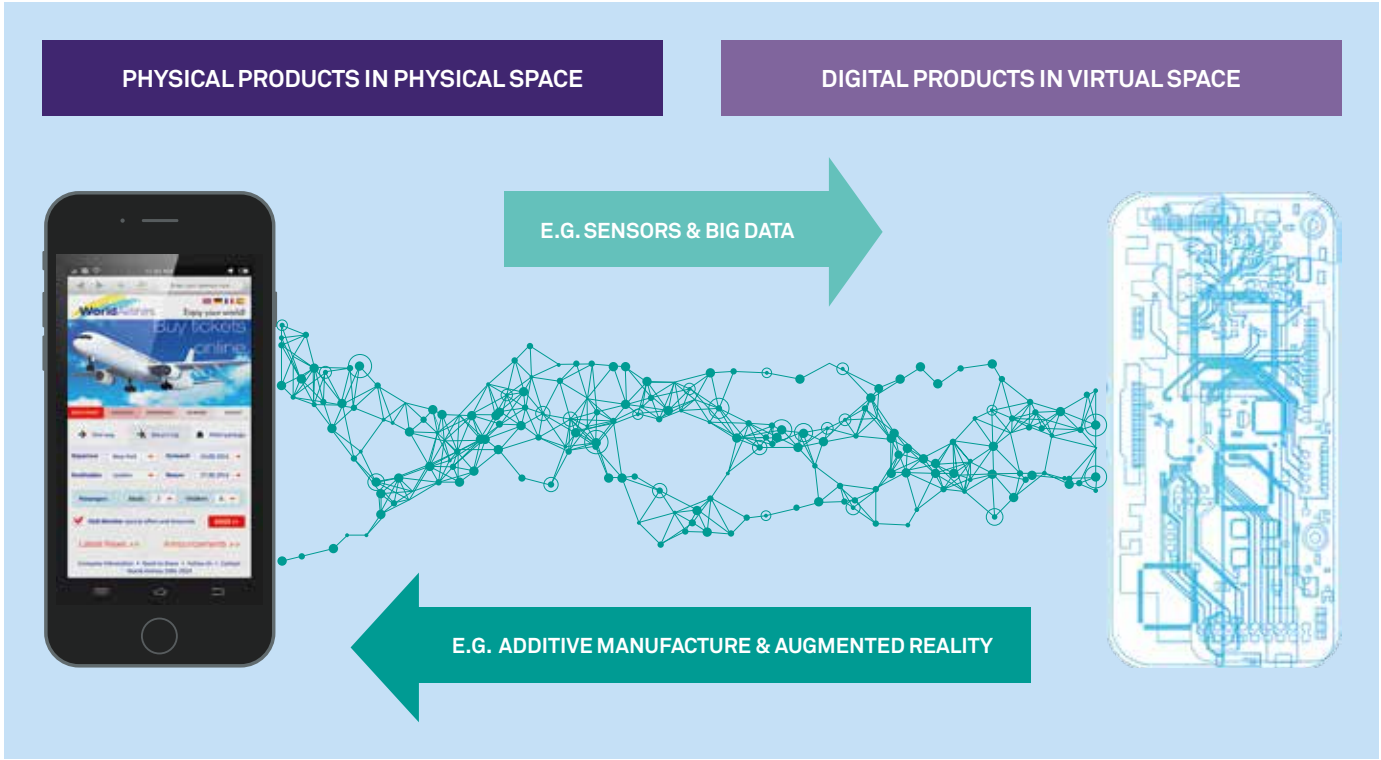


Figure 1

The term industrial revolution is used to signify a significant change in technology that drives a seismic change in industrial processes, output and productivity. The First Industrial Revolution was triggered by the introduction of the steam engine and the mechanisation of manual work in the 18th century, while electrified mass production drove the Second Industrial Revolution in the early 20th century. The Third Industrial Revolution followed more recently when electronics and computer technology began to automate manufacturing and production.

The Fourth Industrial Revolution – also known as Industry 4.0 – is now upon us. It is characterised by a fusion of technologies that are blurring the lines between the physical, digital, and biological spheres. What distinguishes this revolution from its predecessors

is the speed of technological breakthroughs – this has no historical precedent. The World Economic Forum (WEF) has shown that, when compared with previous industrial revolutions, this one is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. And the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.[2] Exploiting technology breakthroughs in fields such as artificial intelligence, robotics, and the Internet of Things is significant on its own. But what really turbo-charges the impact is seeing them work in concert.

WHAT IS THE OPPORTUNITY FROM INDUSTRIAL DIGITALISATION?

IDTs are key to both improving prosperity and reducing the environmental impact of industry. What's more, improved productivity will bring numerous second-order effects. Increased revenues will enable businesses to pay higher wages, which will have multiplier effects on other sectors of the economy. Improved competitiveness will lead to growth, increased sales, greater exports and, thus, increased employment. The cost advantage of low-wage economies will be reduced and, when coupled with the ability to produce ever-more customised products, companies will be encouraged to re-shore activities and locate closer to their domestic markets.

Digital technologies will create new forms of higher-paid employment as many new roles emerge that previously did not exist. Tech City UK estimates that the digital sectors are creating jobs 2.8 times faster than the rest of the economy. The 'tech sector' now represents 6 percent of the UK economy with an estimated GVA per person in the region of £91,800 – well above the UK average. The average advertised salary in digital roles is just under £50,000, 36 percent higher than the national average.

IDTs can improve the resource efficiency of industrial processes. That creates an opportunity to reduce UK resource costs by £10 billion, and offer novel solutions such as improved grid management currently valued at over £2 billion. IDTs can perform a crucial role in developing a resilient UK industrial base that can ride out increasingly frequent disruptions in resource availability, as well as making the UK industrial system more sustainable over the long-term in a post-Brexit context.

The positive impact of IDTs on the UK economy over the next decade could be as high as £455 billion for UK manufacturing,[3] increasing manufacturing sector growth between 1.5 and 3 percent per annum.[4] The effect: a conservative estimated net gain of 175,000 jobs[5] throughout the economy and a reduction in CO2 emissions by 4.5 percent.[6] Overall, from the data and evidence collated, we are confident that IDTs can improve industrial productivity by more than 25 percent.

However, our review addresses more than manufacturing. If we consider the impact on asset-intensive industries such as utilities (e.g. oil production) together with the blurring of manufacturing outputs which are increasingly sold as services, the opportunities for the UK economy are considerably magnified.

[2] The Fourth Industrial Revolution: what it means, how to respond – World Economic Forum

[3] ACCENTURE REPORT: 2017 Industrial Digitalisation Review Benefits Analysis.

[4] BCG, Is UK Industry ready for the Fourth Industrial Revolution, Jan 2017

[5] MSR working group report on jobs and the economy

[6] MSR sustainability working group report

Indeed, digital technologies have the potential to add US$14.2 trillion to the world economy over the next 15 years.[7] The global market opportunity is significant:

- Internet of Things (expected to reach $7.3 trillion by 2017)
- Wearable technologies (expected to reach $70 billion by 2024)
- Big Data and data analytics (expected to reach $32.4 billion by 2017)
- 5G and associated wireless technologies (expecting a 40-fold increase by 2018)
- Robotics (expecting to reach $29 billion by 2018)
- Autonomous vehicles (expecting to reach $28 billion by 2020)
- Advanced manufacturing, building automation (expected to reach $49.5 billion by 2018)[8]

What threats and challenges does digitalisation bring?

Summary box of threats and challenges

UK manufacturing as a share of the UK economy has been in decline over the last two decades. Digitalisation is an opportunity to reverse that trend. But it brings with it a number of threats and challenges, including:

- Competitive threats
- Displacement of manufacturing roles
- Cybersecurity
- Data and privacy
- IP Theft

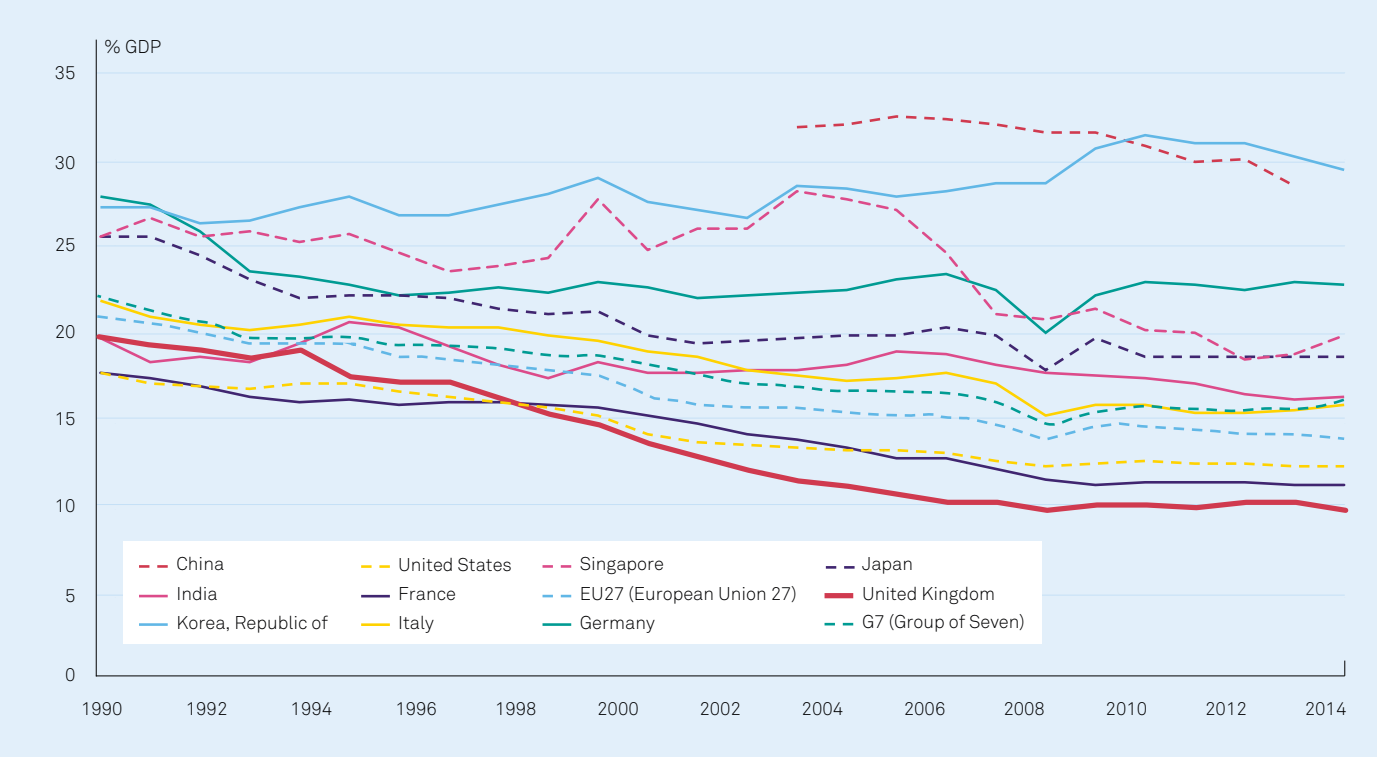
These challenges must be overcome – by industry and government working in partnership – if the UK is to increase its manufacturing growth and productivity in the years to come.

While almost all developed or developing companies have seen a decline in manufacturing as a proportion of their economies in the last two decades, it has been most marked in the case of the UK. Here, manufacturing has fallen from nearly 20 percent of the economy in 1990 to just 10 percent in 2015. And UK manufacturing output, although fairly steady, is still below its pre-recession real-terms peak in 2007.

[7] Accenture, The Growth Game-Changer: How the Industrial Internet of Things can drive progress and prosperity

[8] House of Commons Science and Technology Committee. Digital skills crisis second report of Session 2016-17

MANUFACTURING AS A % OF GDP



Source: UNCTAD International Trade Database

Figure 2

Why has this decline occurred? Outsourcing, a loss of capability, increased use of technology, and international competition have all played their part. Manufactured goods are usually more highly tradeable than services and more vulnerable to competitive pressures. This, combined with higher levels of technological innovation, drives down global prices for manufactured goods – particularly high-volume, mass-produced goods – faster than for services. That, in turn, leads to relatively lower growth in manufacturing sales values compared with services. In practice, it means high-volume, mass-production manufacturing sectors must achieve real growth every year, just to keep their existing share of the overall economy.

Digitalisation offers the promise of reversing this trend. But it brings its own risks. This report explores some of the most challenging:

COMPETITIVE THREATS

Other countries are taking steps to create industrial digital leaders and promote the early adoption of IDTs. This poses a threat to the competitiveness of UK manufacturing.

Changing customer demand requires manufacturers to be flexible enough to produce at both low and high volume while keeping costs low. They can do so by using digital technology to capture and exploit data, leading to highly flexible and reconfigurable production processes, optimised energy management, and end-to-end supply chain efficiency.

Thus digital is quickly becoming the entry standard for competitive companies. Increasingly, manufacturers will need to model themselves on digital exemplars if they want to win new business. Those that fail to do so are likely to be crowded out of an increasingly competitive market.

Digital technology also lowers barriers to entry. As supply chains become more connected and 'transparent', opportunities will open for newcomers to develop their own virtual supply chains. Good ideas with good design can be turned into a market opportunity without the need for expensive capital assets and factory capacity. New entrants, unencumbered by legacy business models and assets, will be able to scale up more cheaply and get their products to market at a faster pace.

Some countries and their manufacturers have already recognised that digital manufacturing can improve productivity and enhance competitiveness. Those that fail to adapt their processes to satisfy ever more demanding customers run the risk of being overtaken by the competition.

THE DISPLACEMENT OF OCCUPATIONS AND THE NEED FOR NEW SKILLS

That IDTs could lead to improved productivity, a safer work environment and improved job satisfaction through the replacement of repetitive tasks is in little doubt. But, while human judgment and decision making will always have a role to play, it is equally likely that IDTs will change, disrupt, and displace some manufacturing jobs.

The UK manufacturing workforce has fallen from a high of 9.1 million in 1966 to 2.7 million today. And the types of jobs that workforce does have changed too. Employees are now more highly skilled, partly as a result of the greater use of technology. The digital revolution is now set to change the nature of those manufacturing jobs even further, especially if the UK is to catch up with its international competitors in the use of industrial robots.

The World Bank reported in 2015 that the UK will need 745,000 additional workers with digital skills between 2013 and 2017 to meet rising demand from employers. It also said that almost 90 percent of new jobs will require digital skills to some degree.[9] The manufacturing sector is not immune to this.

There are concerns from the public, government, and industry about the potential loss of jobs resulting from the digitalisation of manufacturing. According to one US study, up to 47 percent of jobs are at high risk from automation.[10] But there is a great deal of uncertainty surrounding these kinds of estimations. For example, the Made Smarter Review painted a much more positive picture of the effect of digitalisation and the resulting creation of new jobs. The main threat lies in whether the UK can equip manufacturing workers with the new digital skills that they will require in the future.

Increasingly, manufacturers will compete on their ability to create value through the smart use of IDTs. Employees will be hired for knowledge-based production roles, rather than manual work.[11] These changes will come within an already challenging recruitment environment for engineers and software and data scientists. Manufacturers, just like employers in other sectors, should embrace and integrate digital within their business and workforce strategies to both retrain their workforces and create the new digital-focused roles that will support the digital health and competitiveness of the business.

[9] The Effects of Technology on Employment and Implications for Public Employment Services, The World Bank Group, Report prepared for the G20 Employment Working Group Meeting Istanbul, Turkey, 6-8 May 2015

[10] 2013 paper, The Future of Employment

[11] Foresight: The Future of Manufacturing

CYBERSECURITY

Seamless digital communication via the internet, mobile and cloud brings many benefits to manufacturers, but comes with increased security risks. CISCO's 2017 cybersecurity report[12] highlights some of the reasons why manufacturing is particularly vulnerable: legacy equipment or industrial IoT devices built with minimal or no security in mind; gaps between IT and Operations Technology (OT); patchwork architectures increasing risk and vulnerabilities as networks converge; a lack of documented training, processes, and procedures that outline responsibilities and access; and a failure to conduct risk assessments.

The report sets out the resulting impact:

- 28 percent of manufacturers across 13 countries reported a loss of revenue due to cyberattacks in the past year (the average lost revenue was 14 percent).
- 46 percent of manufacturers use six or more security vendors (20 percent using more than ten). 63 percent use six or more products (30 percent using more than ten).
- Nearly 60 percent of manufacturers report having fewer than 30 employees dedicated to security, while 25 percent consider a lack of trained personnel as a major obstacle in adopting advanced security processes and technology.

Many leading manufacturers are implementing multiple levels of security to ensure that they do not succumb to security breaches. But all must recognise the necessity of acting fast to improve the quality of their security infrastructure or risk being exposed to ever more frequent cyberattacks.

DATA AND PRIVACY

Data is currency in the digital age. And that makes manufacturing potentially rich – it generates more data than many other sectors in the economy. The ubiquitous nature of sensors (increasingly available at lower costs) means that data generation and capture is now highly accessible to small and large manufacturers alike. But, as ever more information and instructions are shared electronically – directly between companies or across cloud applications – and saved in different locations, it becomes increasingly challenging to ensure that the information on which decisions are being made is accurate and up to date.

Privacy becomes a greater challenge too. All companies have information they wish to keep secret. But, as value chains become more digitally integrated, information that was previously only available within an organisation might become more readily available to others. The risk of disclosure to unauthorised parties therefore represents an increasing concern to manufacturers.

Data accuracy is another major concern. Greater connectivity could make it more difficult for a manufacturer to ensure its data is not modified by unauthorised parties. So, for example, if information about order quantities or process specifications is altered by a third party, the impact for the company could prove very costly in terms of quality, time, and, potentially, safety.

Risks can also arise if information is not available to the right people at the right time. Any temporary or extended loss of access to key databases can have a major impact, not only within an organisation but also on its clients and suppliers. In the same way that losing access to our emails would interfere with our daily work, a manufacturer losing access to critical data could create serious disruption to the continuity of operations across entire supply chains.

[12] CISCO Midyear Cybersecurity Report (MCR),

INTELLECTUAL PROPERTY (IP) AND DIGITAL PIRACY

Digital piracy is becoming low cost and anonymous. As a result, there is an ever greater risk associated with a manufacturer's IP. Given that IP can constitute more than 80 percent of a single company's value,[13] and is key to competitiveness, it is understandable why it is such a valuable target for theft.

Digitalisation can increase the risk. Because the IP exists as data rather than hard copy information, its loss can easily go undiscovered. In addition, while advanced 3D measurement, digital modelling and rapid prototyping technologies enable improved product and process development, they also facilitate reverse engineering, cloning and the production of counterfeit products.[14]

A manufacturer's approach to IP protection should be considered as part of a wider cybersecurity strategy. The ambition should be to retain a competitive edge while remaining responsive and flexible so as not to stifle innovation.

[13] Ocean Tomo, 2015 annual study of intangible asset market value, 5 March 2015

[14] Foresight: Future of Manufacturing

What is the scope of this review?

Assessing the impact of IDTs on the UK economy, in terms of both creators and adopters, is a very broad endeavour. With that in mind, this review focuses on areas not covered elsewhere (see Figure 3 for an overview). For example, it does not set out to discuss the adoption of digital technologies in health and life sciences which was included within the scope of work being undertaken by Sir John Bell. The review acknowledges various specific studies that are underway, and seeks to contextualise and build on their findings rather than replace them. These studies include the Artificial Intelligence Review being undertaken by Dame Wendy Hall and Jérôme Pesenti, and the work of Digital 4 Industry and the AM strategy.

SCOPE OF THE REVIEW

The scope of the review spans key technologies across the industrial sectors (inlcuding both creators and adopters)

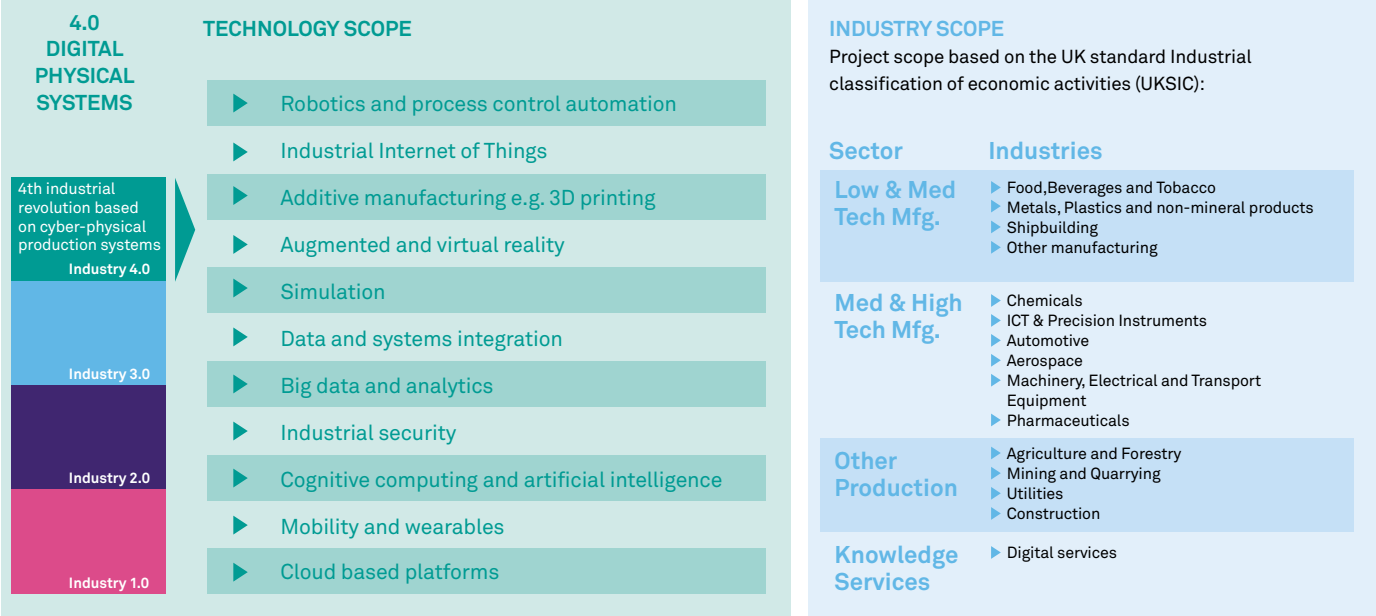


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Figure 3

The review nevertheless considers a broad spectrum of IDTs and a wide view of industrial sectors covering low, medium and high-tech manufacturing and construction. For ease of analysis the IDTs considered have been grouped into the following families:

- Artificial intelligence, machine learning and data analytics,
- Additive manufacturing,
- Robotics and automation,
- Virtual reality and augmented reality,
- The Industrial Internet of Things (IIoT) and connectivity (5G, LPWAN, etc.)

How was the report developed?

The review underpinning this report was led by a diverse group of organisations, including some of the UK's most prominent and established companies, start-ups and research organisations (see Appendix 5). A series of working groups comprising industrial companies were tasked with reviewing the opportunities and challenges of IDTs from a sectoral, geographical or technological perspective (see Figure 4). These focused reviews were used to develop a series of cross-cutting themes which, again, involved wide industrial participation. Our aim was to ensure the recommendations resulting from the review were ambitious and transformational, as well as practical – so they can quickly be turned into action.

TEAM STRUCTURE

200 Organisations mobilised providing sector/technology/regional insight into key themes

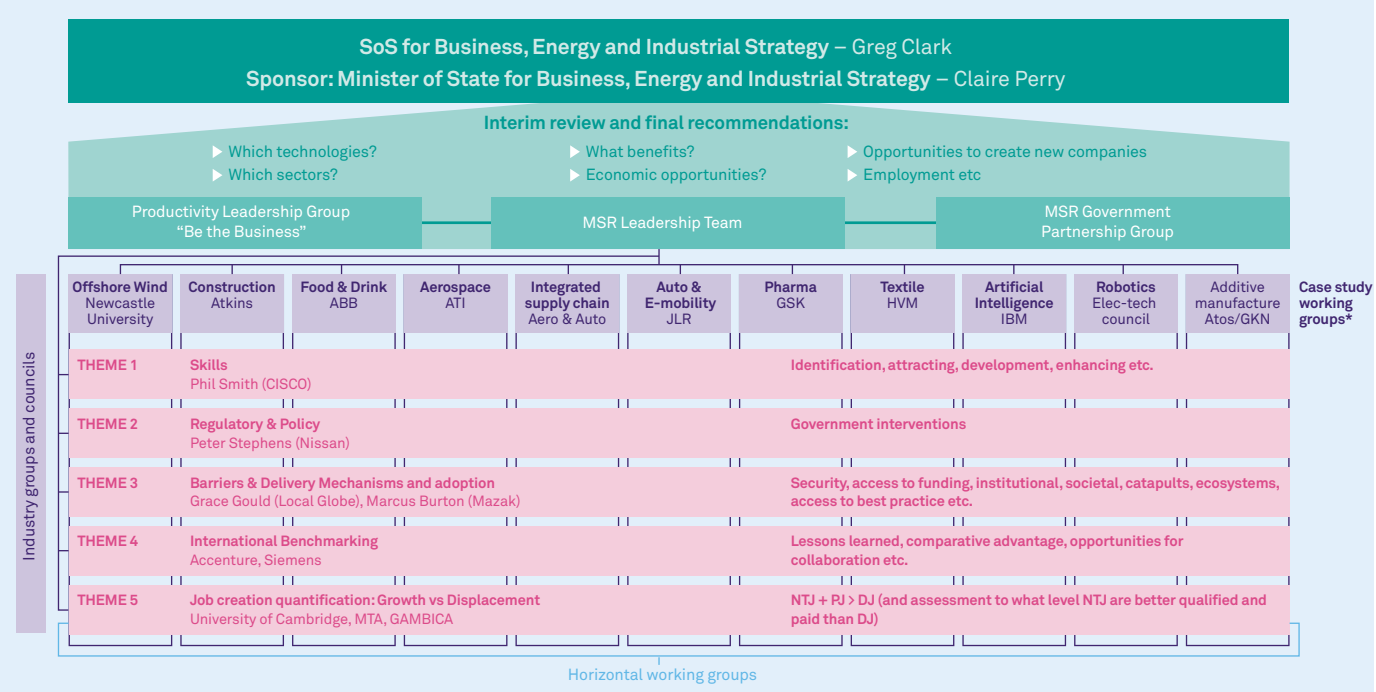


Figure 4

NTJ = Jobs created due to New Technology
PJ = Jobs created due to Productivity Growth
DJ = Jobs displaced

Structure of this report

The findings of the review have been structured to address three simple questions:

1) What are the opportunities for the UK from industrial digitalisation?

In this section we examine why IDT is important to the UK and assess the impact on productivity, jobs and the environment. We ask:

- Can IDT kick-start productivity?
- Will IDT create or destroy jobs?
- Can IDT help create a resource efficient, sustainable and resilient economy?

We review the opportunities to industry of adopting key IDTs and assess how the UK is positioned to lead in their development and exploitation.

2) What is stopping the UK achieving the IDT vision?

In this section we examine the blockers to the UK becoming a leader in the development and adoption of IDT. These are discussed in relation to the key themes identified in the review – leadership, adoption and innovation.

3) How can industry and government work together to address these barriers?

Finally, we examine the actions required to ensure the UK is a global IDT leader by 2030.

PART 2

WHAT ARE THE OPPORTUNITIES FOR THE UK FROM INDUSTRIAL DIGITALISATION?

5

Part 2 – What are the opportunities for the UK from industrial digitalisation?

The UK has a range of strengths which give us confidence that it can realise the opportunities of industrial digitalisation. It has a combination of leading-edge R&D and high-performing sectors in the application of digitalisation to product design and manufacturing. More recently, it has pioneered the use of digital technology to enable servitisation (the shift from selling 'products' to offering 'services').

Aerospace is a good example of the UK's strengths. This sector is already supporting the development and adoption of the specific technologies which will define the new industrial digitalisation revolution: additive manufacturing, collaborative robots, artificial intelligence (AI), data analytics, and virtual and augmented reality (VR and AR).

We can also see UK leadership in the application of IDT to address sustainability in manufacturing – evident in companies such as Unilever, Toyota in Derby, AB Sugar, and in many start-ups around the country. In the food and drink sector, the UK is seen as a global leader in refrigeration monitoring systems via the IoT, as well as in food safety and traceability systems. And a 2015 Accenture study found that UK energy and pharmaceuticals businesses were industry leaders in digitalisation within their sectors.[15]

Additionally, the UK is investing significantly in key areas of infrastructure such as renewables (owing to strong incentivisation within this sector), providing an opportunity to stimulate new local supply chains with a high rate of IDT adoption.

The UK is especially strong in digital and technology and has a thriving start-up ecosystem in IDTs such as AI, blockchain and additive manufacturing. Indeed, the UK has the strongest AI and machine learning market in Europe with over 200 SMEs (compared to just 81 in Germany and 50 in both the Nordic countries and France).

It has a number of successful tech companies which have attracted foreign direct investment, including: ARM Holdings (acquired by Softbank for £24.3 billion who have committed to doubling headcount in the UK), Magic Pony (acquired by Twitter for $150 million), Skyscanner (acquired by Ctrip for $1.7 billion), and SwiftKey (acquired by Microsoft for $250 million). And the UK's FinTech sector is generating huge revenues and attracting large investments (£6.6 billion in revenue and over £500 million of investment in 2015), disrupting established processes and changing the ways that consumers interact with financial services as it does so.

However, the UK is not yet capitalising on its rapidly growing digital sector by applying these technologies in an industrial setting. This needs to change. We see IDTs providing a significant opportunity to the UK's industrial economy. They represent a powerful opportunity to recapture the UK's industrial spirit as a nation of 'creators and makers' by:

- Raising UK productivity and international competitiveness;
- Creating new, higher-paid, higher-skilled jobs that add value to society and positively offset the displacement of poor productivity and poorly paid jobs;
- Increasing exports through competitiveness;
- Creating a new vibrant technology market serving UK industry and attracting foreign investment;
- Improving the resource efficiency of the UK's industrial base, making it more resilient to global resource supply disruptions;

[15] Smart Service Welt – Recommendation for Strategic Initiative Web Based Services for Services

- reducing environmental impacts through more efficient manufacturing and industrial processes and optimised supply chains.

CAN IDTS KICK-START PRODUCTIVITY?

THE PRODUCTIVITY PUZZLE

Productivity is the most important determinant of the standard of living of a nation. Increases in productivity levels are essential to improving economic growth and social prosperity. While productivity growth has slowed in almost all advanced economies since the financial crisis, the UK slowdown has been more severe than elsewhere (see Figure 5). It is now estimated that it takes a UK worker five days to complete what the average G7 worker can do in four days. A recent press article highlighted that UK worker GVA in 2015 was 19 percent lower than the G7 average, and below the USA (29 percent), France (29 percent) and Germany (36 percent).[16]

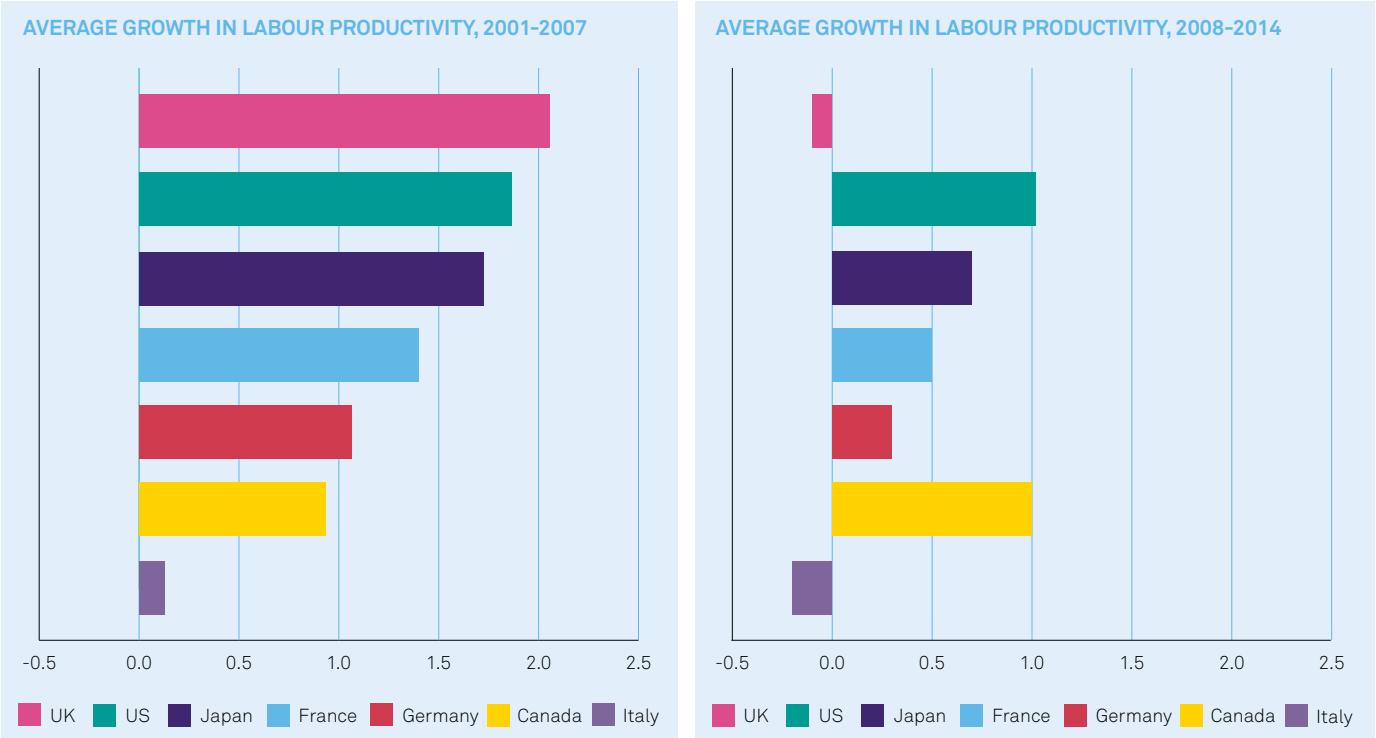


Figure 5

The stagnation of productivity growth in the UK has been the subject of wide-ranging debate and analysis. In stark contrast to our major competitors, UK productivity has failed to recover to its pre-crisis 2008 level. An analysis by the Bank of England[17] identified three possible causes:

1. Low level of investment. The UK has historically under-invested in capital relative to other OECD countries, and the level of investment has not recovered to pre-crisis levels. The UK level of investment between 2010 and 2014 was 16 percent of GDP (compared with 20 per cent for other developed countries).
2. The low interest rate environment has resulted in a low level of business failures, keeping less productive companies in business and therefore lowering average productivity.

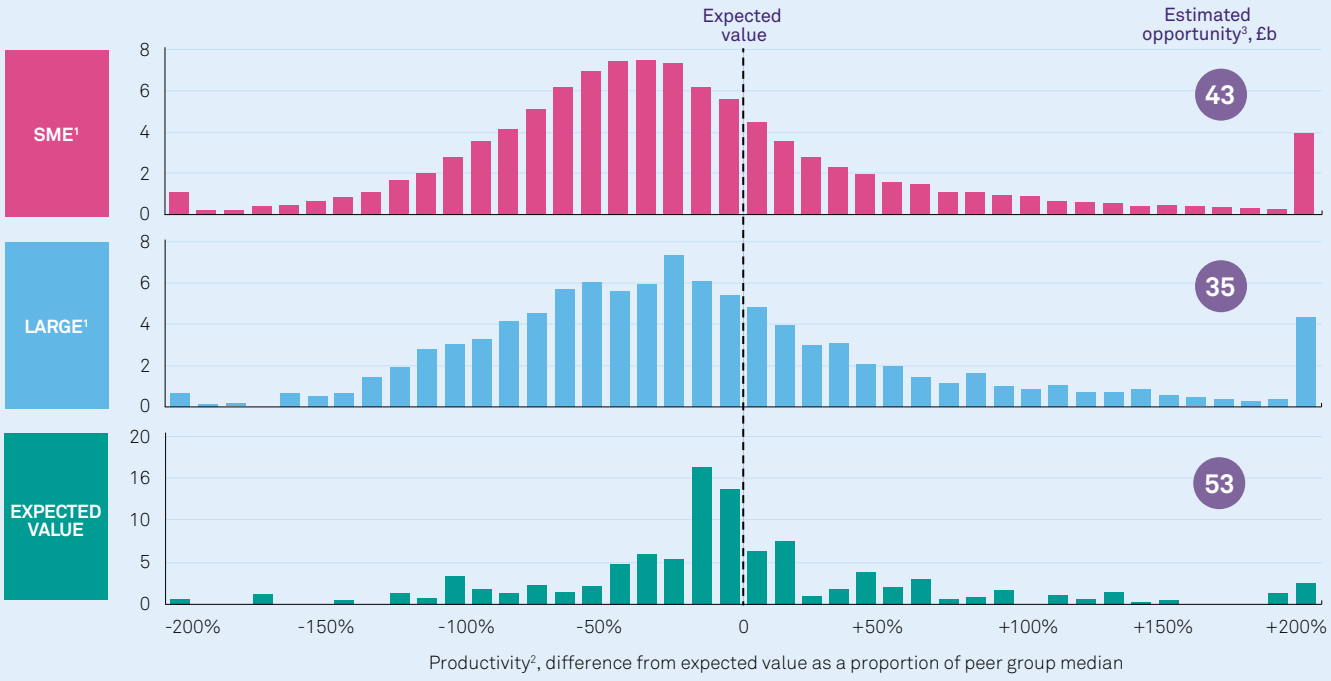
[16] Telegraph 6th October 2017

[17] The UK Productivity Puzzle – Quarterly Bulletin 2014 Q2

3. As output fell, companies retained staff to secure talent amid a skills shortage within the economy.

An analysis undertaken by the Productivity Leadership Group (PLG), with support from McKinsey, shows that while the UK has many high performers, there is a long tail of businesses with below-average productivity. In fact, 75 percent of UK businesses exist within this long tail. This problem is seen across the spectrum: in all sizes of business and in all sectors of the economy. But the long tail of underperformance is particularly acute among SMEs and other businesses with fewer than 5,000 employees (see Figure 6).

DISTRIBUTION OF UK EMPLOYEES BY THEIR EMPLOYER'S PRODUCTIVITY RELATIVE TO THE EXPECTED PRODUCTIVITY FOR A FIRM OF THEIR SIZE IN THEIR SUB SECTOR. %



1. SME =10-499 employees; Large = 500-4999 employees; Very Large = >5000 employees
2. Estimated GVA (EBIT + employee costs) is regressed on a range of variables to control for sub-sector and number of employees using a Weighted Least Squares method (with employee numbers as the weighting). The output of this regression is used to compute and expected productivity, representing the average for a firm of that size in that sub-sector. The residual for each firm is plotted as a percentage of the median productivity for a firm in the same size bracket in the same sub-sector
3. Each company was given a percentile ranking within their group of comparable companies (from the same sub-sector and size category). We then calculated the gains to overall GVA if each company in the bottom three-quartiles increased its performance to match the productivity of the average company ten percentiles above them.

Source: McKinsey analysis using ORBIS (2013 data); OECD (2013)

Figure 6

The PLG report identifies that two-thirds of the UK workforce were employed in underperforming companies and a sizeable gulf exists between high and low performers. Regional differences also exist. Only six of the UK's 63 towns and cities have a higher productivity than the European average, and more than half of UK cities (38) are among the 25 percent of cities with the lowest productivity. Analysis from the ONS, based on GVA per head between 1997 and 2014, supports this finding. It shows the declining contribution of the regions to UK productivity, with the UK becoming more reliant on London and the South East to remain competitive.

This creates a significant opportunity. Addressing the productivity performance of the bottom 75 percent of performers could create around £130 billion in additional GVA each year.[18]

MANUFACTURING IS STILL IMPORTANT TO THE UK ECONOMY

Manufacturing remains vital to the UK. The sector contributes over £6.7 trillion to the global economy. And, while the UK's manufacturing contribution has declined over the past 20 years, it still produces 3 percent of the world's manufacturing output (compared with Germany at 9 percent and the USA and China at 19 percent each).[19] It accounts for 9.8 percent of the UK economy (£162 billion GVA in 2015). The UK is still one of the top ten manufacturing nations in the world (the eighth largest in 2017) and is the third largest in the EU. It employs 2.6 million people directly, and something like 5.1 million across the whole manufacturing value chain. UK exports of manufactured goods totalled £257 billion in 2015 (50 percent of all UK exports). The sector accounts for 70 percent of business R&D and 14 percent of business investment.[20] EY's 2016 UK Attractiveness Survey found that, for every foreign direct investment project in a manufacturing plant, there was a matching investment across the supply chain in areas such as logistics, R&D and sales and marketing.

CAN IDTs DRIVE PRODUCTIVITY IN UK MANUFACTURING?

There is an overwhelming evidence-based consensus that IDTs can provide a step-change in industrial productivity. A 2017 World Economic Forum (WEF) report identified a US$100 trillion IDT opportunity for society and industry by 2025 (WEF report). Studies in Germany estimate that Industry 4.0 – the Fourth Industrial Revolution – can deliver annual manufacturing efficiency gains of between 6 and 8 percent,[21] and the Germany Digital Strategy 2025 (published in 2016) projects productivity gains of up to 30 percent by 2025.[22] A recent KPMG study of the automobile industry found that digitalisation could not only increase productivity (by 3 to 5 percent), but also reduce downtime (by 20 to 35 percent), the costs of poor production (by 5 to 12 percent) and inventory reduction (by 12 to 20 percent), providing a cumulative single sector benefit of £74 billion by 2035.

IDTs can be transformational within all aspects of a business (see Figure 7), including

- Increased labour and resource productivity
- Increased asset utilisation due to reduced machine downtime
- Reduced maintenance costs
- Reduced inventory
- Reduced cost of quality
- Increased forecasting accuracy
- Reduced time to market

[18] Productivity Council Business case – 14th November 2016

[19] Manufacturing International Comparisons, Briefing Paper Number 05809, 18 August 2016

[20] EEF, Manufacturing Ambitions: An industrial strategy for a stronger economy, 2016

[21] Smart Service Welt – recommendations for the Strategic Web-base Services for business

[22] Digital Strategy 2025 – DE DIGITAL

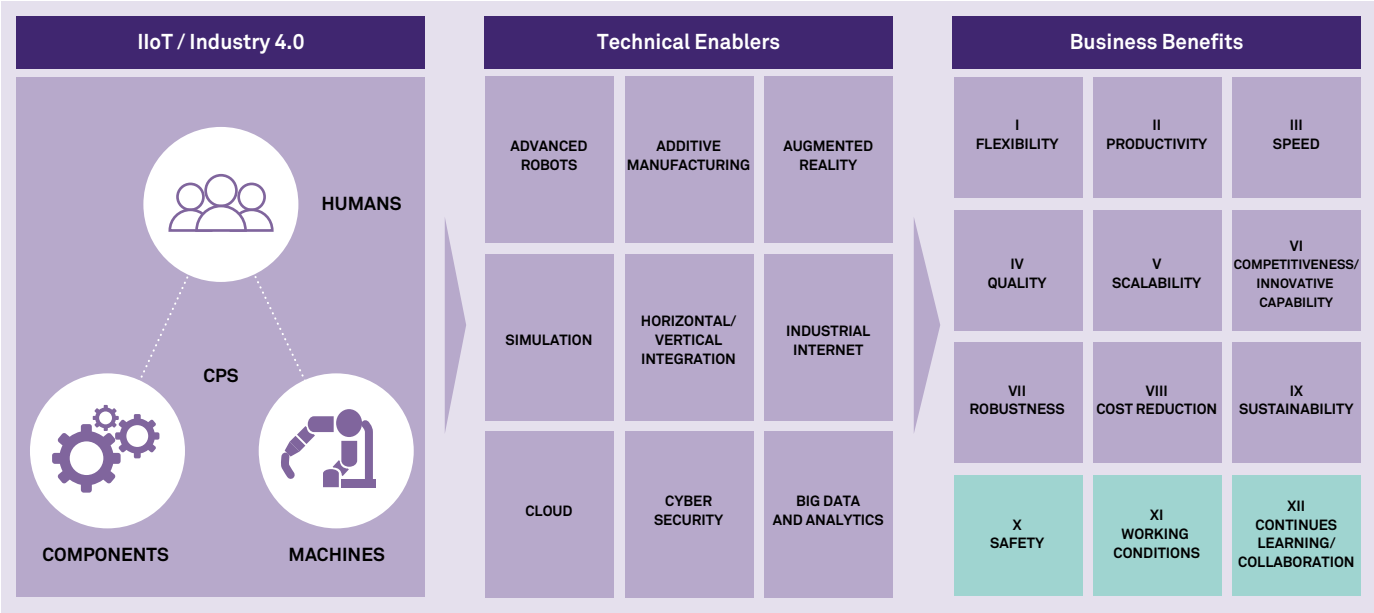


Figure 7

For example, IDTs enable a business to better monitor the health of its equipment and processes. Issues can thus be predicted and fixed before they impact production ('predictive maintenance') which increases asset availability. Considering that 80 percent of a typical maintenance engineer's time is spent undertaking reactive (rather than predictive) maintenance and that machine downtime can be anything between 5 and 20 percent (see Figure 8), the potential impact of this technology is obvious. Our research has identified that predictive analysis can increase operational equipment effectiveness (OEE) by 85 percent.

Factora

PREMIER FOODS

Automotive Chemicals
Food & Beverage
Heavy Industry
Oil & Gas
Power Generation
Other

Asset performance Management
Automation
Brilliant Manufacturing
Cyber Security
Predix

NA
Europe
MENAT
APAC
China

ANALYTICS FOR FOOD MANUFACTURING PERFORMANCE

Breakdown	Action	Solution Architecture	Outcomes
Aging systems, lack of operational insight. **Understand root causes of issues and generate data-driven insights to improve critical processes**	Factora helped connect Premier's machines using GE Historian software to collect process data Factora modeled the processes to visualise what was happening on Premier's production lines Factora performed analyses to understand the correlations and root causes of issues	1 **Develop** advanced analytics using Historian that tie all aspects of production together to maximise manufacturing efficiency 2 **Generate** real-time decision support to empower operators to make critical decisions quickly	20% Overall Equipment Effectiveness improvement Payback period < 2 years Improved process consistancy and higher quality products Decreased raw materials usage

Figure 8

IDTs can transform not only the way products are developed and manufactured, but also the way they are purchased. And that is enabling new services to be offered and new business models to be formed. For example, advances in IDTs, especially in sensor technology, are enabling products to be paid for based on their use through new servitisation models:

- Sensors are becoming smaller and more sophisticated. And much cheaper. In 2014, the average cost for an accelerometer sensor was 54 cents.
- By 2020, component costs will have reduced to the point that connectivity will become a standard feature.
- In the future, sensors won't need batteries. Companies have already begun to build sensors that can function without them.
- Smart sensors are giving objects the power of perception. And sensor-driven computing converts perception into insights – using industrial analytics – that operators and systems can act on.
- Soon, manufacturers will no longer build machines that have only mechanical functions – they will include intelligence as standard.
- The applications that come with industrial machines will be a key means of generating new revenue streams from product–service hybrids.

IDT SHOWCASE FACTORIES

ABB Heidelberg

- Agile manufacturing processes providing real-time visibility into manufacturing processes
- Reduce product cycles, shorten changeover and launch times through off-line programming and virtual commissioning
- Reduce downtime and improve performance through actionable intelligence and advanced analytics on apps
- Improve quality control through data analysis and automation

FESTO Scharnhausen

- Employees cooperate in safe interaction with a flexible robot, which takes over assembly tasks that are ergonomically disadvantageous
- For service engineers, alongside their usual tools, the tablet represents the principal working tool: with the help of an app, they are able to detect and rectify machine faults as soon as possible and directly on-site

SEW Eurodrive

- Mobile handling assistant takes over monotonous jobs in machine assembly and thus lightens the workload of the operator
- Assembly assistants (cyberphysical systems) support the mechanics in their work and carry all the product- and customer-related information with them
- Logistics assistants navigate independently in the room and supply the assembly islands with the correct mount-on components at precisely the right time and transport the finished gearmotors out of assembly to the oil-filling and testing stations and then on to the paint shop

SIEMENS

- Smart Factory in Amberg
- Real time tracking and tracing of everything within the facility
- Recording of all process conditions and parameters
- Integration of data from R&D and manufacturing
- Real time data analytics, proactive data analytics and reporting of results

IDTs BRING BENEFITS TO NUMEROUS INDUSTRIAL SECTORS

Our review analysed the potential benefits of IDT within a number of industrial sectors. Here, we discuss four of the most important: construction, food and drink, pharmaceuticals, and aerospace. The methodology is set out in http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/.

The analysis, involving UK manufacturing companies, as well as academic and industry experts, was based on use cases that highlighted the impact of today's digital technologies within different industrial environments. To quantify the benefit of each use case to both business and society, we used a value at stake analysis framework developed by Accenture in partnership with the World Economic Forum (see http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/).

We found that digital transformation offers huge potential to UK manufacturing over the next decade. For the four sectors studied, a £185 billion value at stake[23] can be expected from IDT, representing 9 percent growth over the baseline. Extrapolating to all UK manufacturing, the cumulative value at stake is estimated at between £313 billion and £455 billion (+10 to 14 percent).[24]

[23] Additional value created to stakeholders though value addition or value migration (see Appendix 3)

[24] Based on extrapolation of Food and Drink, Pharmaceuticals and Aerospace, which together represent 38% of UK manufacturing, to the remaining 62% of UK manufacturing, at either the lowest growth rate (Pharmaceuticals at 10% above baseline) or the highest (Aerospace at 21% above baseline)

THE FOUR INDUSTRIES STUDIED HAVE AN ESTIMATED £185BN VALUE AT STAKE (+9%) OVER THE NEXT DECADE

	VALUE TO INDUSTRY (£ BN)		VALUE TO INDIVIDUALS		VALUE TO SOCIETY
CONSTRUCTION	£88.9	+	Cost savings from construction passed on to individuals Improved living standards	+	365,000 tCO_2e reduction in 2027[1] 105 lives saved over the next decade due to increased health & safety during construction
FOOD AND DRINK	£55.8	+	£2.3bn saved from household spend due to waste reduction 25% increase in customer satisfaction	+	32 million tCO_2e reduction throughout the food supply chain in 2027[1] 27,370 injuries avoided in food & drink production over the next decade
PHARMACEUTICALS	£22.4	+	£1bn of cost savings passed on to consumers 30 minutes per year are likely to be saved per clinical trial patient	+	86,000 tCO_2e reduction in 2027[1] due to efficient manufacturing processes 1,555 accidents avoided in production and 14,804 lives saved from improved dosage accuracy over the next decade
AEROSPACE	£17.5	+	£3bn of cost savings passed on to consumers 69% increase in customer satisfaction 13% increase in job satisfaction	+	63,000 tCO_2e reduction in 2027[1] 15,310 injuries avoided during aerospace manufacturing over the next decade

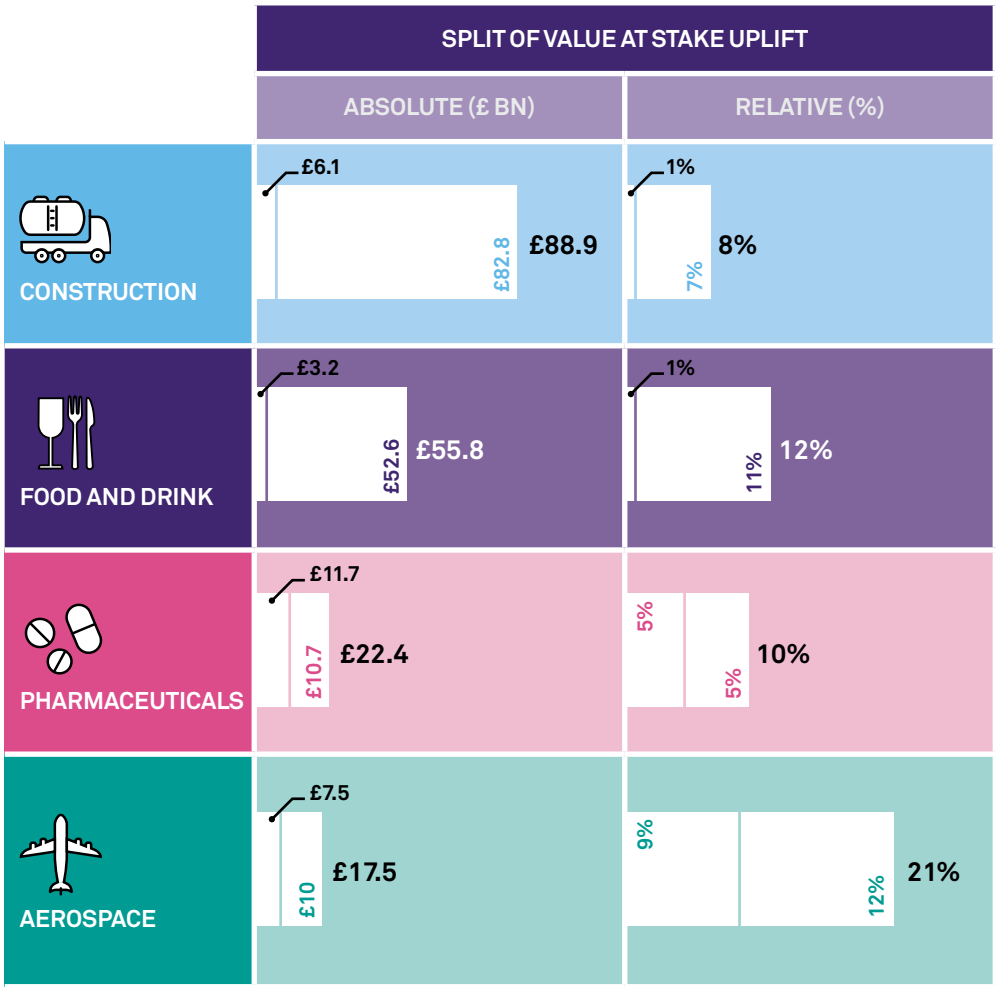
1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Figure 9

It should be noted that, when comparing absolute benefits, each is relative to the size of the industry's output within the UK. So, while the value at stake for aerospace is lower in absolute terms than for other sectors, the relative growth opportunity is the greatest at 21 percent.

Overall, the main contribution to value at stake in this analysis comes from cost reductions. However, significant opportunities for new revenues were also identified, especially in the pharmaceuticals and aerospace sectors. In pharmaceuticals, for example, more than half of the value at stake (£11.7 billion) was estimated to arise from new business models, illustrating the recognition in the sector that digital technologies will be central to future outcome-driven healthcare models.

RELATIVE UPLIFTS DRIVEN BY NEW REVENUE STREAMS SUGGEST HIGH VALUE GROWTH AREAS FOR MANUFACTURE



Cost savings form the largest value at stake in absolute terms

- The majority of growth from digitalisation of the four industries is expected to be from efficiency gains, as opposed to new revenue.
- With an estimated £88.9bn cumulative value at stake over the next decade, Construction has the most significant impact in absolute terms, as the largest industry studied.

However, when looking at the relative value in proportion to each industry, new revenue streams have a more significant impact

- Proportionally, digitisation has a far stronger benefit on new revenue streams within Pharma and Aerospace, with this uplift providing 52% and 43% of the total growth in these, respectively.
- Pharma new revenue streams include integrated patient support and control, healthcare-as-a-service and innovation services
- Aerospace new revenue streams include commercialisation of data and an automated brokerage system among suppliers
- Aerospace has the greatest potential to grow by adopting digital. This is true despite being the smallest industry analysed, therefore, new revenue streams are key for overall industry growth.

Figure 10

We now consider each of these four sectors in detail.

CONSTRUCTION

Our analysis identified £89.2 billion of value at stake in the UK construction sector over the next ten years through the adoption of currently known digital technologies. See Appendix 1 for a point of view on how IDTs will impact construction.

Today, UK construction contributes 6.5 percent (£103 billion) of economic output and 6.2 percent of total employment (2.1 million people). It also represents 20 percent of the total workforce of SMEs across all sectors (BEIS, 2015). But the sector's productivity lags global productivity by over 30 percent, with as much as 98 percent of global infrastructure projects over budget or delayed.

IDTs offer significant opportunities to rectify this. For example, advanced sensors and monitoring can bring a step-change to the sector's ability to plan and monitor works. Currently, significant costs and risks are associated with unknown ground and site conditions which can impact project costs by up to 20 percent (European Commission, 2017). And roughly 40 percent of the UK construction market relates to maintenance and refurbishment. Advanced scanning technologies, including drone mounted LIDAR, DIC and ground-penetrating radar, enable better decisions to be made early in the design process to mitigate risk. And the introduction of smart IoT sensors and advanced composite materials (such as self-healing concrete and polymer

matrix composite materials) will lead to a new approach to maintenance and refurbishment, driving down cost and improving efficiency across the sector.

Additive manufacturing and 'flying factories' (a mobile method of manufacturing outside of a fixed factory) could enable high-precision manufacturing to occur on site and minimise the need to transport bulky prefabricated building parts. Flying factories (and similar innovations) reduce the fixed costs associated with large off-site manufacturing plants.

The economic multiplier effect within the economy could be significant. It is estimated that every £1 invested in construction delivers £2.84 in direct impacts (wage income and profit), indirect impacts (increased productivity in the product and service supply chain) and induced impacts (employment, household income).

Case studies

The **Beck Group** used Building Information Modelling to create 100 visualisations for a church in Seoul. This enabled them to adjust the design of the building to appear curved, but using only flat glass, saving over $1 million on glazing and mullions, and 1,000 hours of design time (https://damassets.autodesk.net/content/dam/autodesk/www/case-studies/sarang-community-church/beck-group-customer-story.pdf).

Construction Robotics, a New York-based start-up, has developed a bricklaying robot called the SAM100, which is being used on job sites across the US. The robot can lay around 2,000 bricks a day, working collaboratively with masons to increase their productivity by 3 to 5 times, while reducing lifting by more than 80 percent (http://www.construction-robotics.com/sam100/).

VALUE AT STAKE FOR THE CONSTRUCTION INDUSTRY IS ESTIMATED TO BE £88.9BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£6.1	• A percentage of cost savings are passed through from the Construction industry to consumers • Living standards will improve due to digital technology enabling higher quality construction	• In 2027[1] digitalisation of Construction could achieve a reduction of 365,000 tonnes of CO_2e due to more efficient manufacturing techniques and smarter monitoring of in-use energy consumption • An estimated 105 fatalities could be avoided over the next decade, through automation of more dangerous tasks
Cost reduction through digitally enabled R&D	£30		
Cost reduction through workflows	£2.6		
Cost reduction through digitally enabled construction and asset maintenance	£28.9		
Cost reduction through automation of labour	£3.8		
Cost reduction due to digitally enabled supply chain management	£8.2		
Cost reduction through resource efficiency	£9.3		
Total value to industry	£6.1 £88.9		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Figure 11

FOOD AND DRINK

We identified a £55.8 billion opportunity for the food and drink sector over the next ten years through the adoption of currently known digital technologies. See Appendix 1 for a point of view on how IDTs will impact the food and drink industry.

The global food sector has sales of over US$8 trillion and is worth five times as much as the automotive sector. It has a compound annual growth rate (CAGR) for consumer expenditure of 6 percent per annum. Food manufacture and distribution consumes 15 percent of global fossil fuels and accounts for 28 percent of global greenhouse emissions. And the sector suffers significant waste, with over 8.4MT of UK food dumped as waste per annum (WRAP, 2017).

Food and drink is the largest manufacturing sector in the UK, contributing over £28.2 billion to the UK economy and employing 420,000 people.[25] The wider food chain generates GVA of £108 billion, employing 3.9 million people (DEFRA 2017) in a truly international industry (£20 billion of exports in 2016). Between 2006 and 2015, the UK food chain grew GVA by 30 percent, exports by 72 percent, branded food exports by 100 percent and food chain employment by 5 percent (DEFRA 2017).

Yet there is potential to grow both the food processing industry and the associated UK food technology sector further (in part by replacing imports of food processing equipment and systems) to exploit the growing global market for food technology.

Within the food processing industry, digital technology provides significant opportunity to:

- improve production efficiency (e.g. through robotics, automation, and connectivity);
- improve traceability by connecting the whole supply chain (e.g. through the IoT, Blockchain, cloud data architectures, and data analytics);
- create more efficient and rapid supply chains (e.g. through intelligent just-in-time delivery, IoT monitoring, and highly connected planning software);
- improve feedback from retailers, consumers and food services (e.g. through automatic supply and demand forecasting systems);
- improve consumer trend monitoring to assist in the development of new products (e.g. through point of sale data analytics and social media analytics).

Automation could increase productivity growth in food processing and wholesaling from 1.4 percent to 3.0 percent per annum. That would increase food chain GVA by 8.3 percent above the underlying trend by 2022. Furthermore, it could reduce greenhouse gas emissions by an estimated 29 percent throughout the food supply chain by 2027 due to efficiencies from digitally managed processes in manufacturing and distribution. There would also be a corresponding reduction in waste management and food waste of 17.6 million tonnes over the next decade, factoring in greater visibility of shelf life.

Case study
Blue Yonder's Replenishment Optimisation is a machine learning tool that automates store replenishment, reducing out-of-stock rates by up to 80 percent without increasing waste or inventory. The tool takes external inputs (such as weather forecasts, holidays or other events that will impact demand) into account to create an accurate model of future demand for different products. This model informs restocking plans, increasing product availability tenfold with 50 times fewer manual interventions. The result: higher profitability with less wastage (https://www.blue-yonder.com/en/solutions/replenishment-optimization).

[25] DEFRA (2017), Agriculture in the UK 2016

VALUE AT STAKE FOR THE FOOD AND DRINK INDUSTRY IS ESTIMATED TO BE £55.8BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£3.2	• £2,266 saving per household due to improved waste management • 25% increase in product satisfaction related to customisation of products	• 32 million tCO_2e reduction throughout the food supply chain in 2027[1], due to more efficient production processes and reduction of waste. This represents a 29% reduction in overall food emissions in the UK • 17.6 mn tonnes of food waste reduced over the next decade • An estimated 27,370 injuries avoided over the next decade from implementation of digital technologies • Potential to reduce the number of food poisoning cases by up to 4.5m through better traceability in the supply chain and monitoring of shelf life
Cost reduction through digitally enabled R&D	£0.5		
Cost reduction through digitally enabled manufacturing and asset maintenance	£13.2		
Cost reduction through digitally enabled supply chain management	£1.1		
Cost reduction through automation of labour	£24.7		
Cost reduction due to increase in resource efficiency	£13.2		
Total value to industry	£3.2 — £55.8		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Figure 12

PHARMACEUTICALS

Our analysis identified a £22.4 billion opportunity for pharmaceuticals over the next ten years through the adoption of currently known digital technologies. See Appendix 1 for a point of view on how IDTs will impact the pharmaceuticals sector.

The sector is one of the UK's most valuable assets, with exports worth £25.8 billion and a projected total global value of $1.2 trillion in 2016. UK data shows the GVA per head for pharmaceutical manufacturing was double that of any other manufacturing sector.[26] It makes a significant contribution to the UK economy and to the population as a whole:[27]

- £11.5 million is invested in the UK each day on R&D;
- 25 percent of all expenditure on R&D in UK businesses is made by pharmaceuticals;
- 107,000 people are employed directly by bio-pharmaceutical companies in the UK;
- Each employee contributes £149,000 to UK GDP every year;
- An eighth of the world's most popular prescription medicines were developed in the UK;
- The sector has a critical role in improving the wellbeing of the UK population and reducing the cost of healthcare.

Yet global competitive pressures, coupled with changes in patient expectations, provide real business challenges for this sector's competitiveness. The UK is in a global race to attract investment and sustain its vibrant and innovative research community and advanced manufacturing expertise.

[26] http://www.abpi.org.uk/media-centre/newsreleases/2017/Pages/PwC-analysis highlights-economic-footprint-of-UK-Life-Sciences.aspx

[27] "Delivering Value to the UK. The contribution of the pharmaceutical industry to patients, the NHS and the economy". API 2014.

How will IDTs impact the sector? Advanced digital design techniques, such as high-throughput testing, robotics, artificial intelligence and Big Data analysis (integrating structured and unstructured data and subsequent advanced analytics) can help eliminate non-viable drug candidate formulations earlier in the development process by better predicting the properties and performance of the target molecule and its formulation. This will streamline product development, reducing the time to market and the associated risks and costs.

Digital technologies will also support the transformation of today's large-scale manufacturing plants designed for blockbuster high-volume medicines. More targeted and outcome-driven healthcare approaches will call for more agile manufacturing processes, such as small-scale production facilities located close to the point of use, autonomous batch and continuous processes with instream quality control, scalable processes, and distributed and additive manufacturing. Furthermore, digital process and plant design will enable the rapid translation of new lab-based processes to commercial production facilities.

The adoption of digital technology in existing and new production facilities will result in significant productivity improvements, expected to be in the order of 30 to 35 percent by 2030. Digitally enabled processing techniques and IIoT plant equipment connected to cloud-based software systems can monitor, predict and control production in real time. Ultimately, that will facilitate greater knowledge generation and robustness, and lead to autonomous production systems for pharmaceutical manufacturing processes. Data captured during production can be used for simulating future plant performance, preventing plant failures and aiding operational decision making. And digital tools using virtual or augmented reality can be used in upskilling and training the existing and future workforces.

By tracking pharmaceutical products throughout the supply chain (using technologies like low-cost sensors, NFC (near field communication), RFID tags, smart labels, printable electronics, integration with microelectronics, real-time data capture, Big Data and analytics) companies will be able to improve shelf-life management and establish clear and accurate demand signals eliminating anything between £10 billion and £15 billion of waste.

The IIoT is giving rise to a smart healthcare ecosystem. The potential for digital technology to help measure, maintain and improve health and wellbeing through preventative approaches and supported health management is considerable. It represents a massive opportunity for the pharmaceutical sector.

Case studies

Lilly has a long-standing focus on the Open Innovation (OI) initiative, based around its OI Drug Discovery (OIDD) platform. The OIDD initiative has enabled the company to access chemistry from both academia and biotechnology companies since 2009 and has proved to be a source of biologically active molecules that significantly complements their internal compound collection. The platform offers testing of compounds in both disease-relevant phenotypic and target-based assays (https://openinnovation.lilly.com/dd/).

Pfizer subsidiary Pharmacia used Computer-Aided-Drug-Design (CADD) tools to screen for inhibitors of tyrosine phosphatase-1B, an enzyme implicated in diabetes. The screen identified suitable compounds with an accuracy of nearly 35 percent, compared with 0.021 percent using conventional methods (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3880464/).

VALUE AT STAKE FOR THE PHARMACEUTICAL INDUSTRY IS ESTIMATED TO BE WORTH £22.4BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£11.7	• 10% of cost savings (£1.1bn) realised through the deployment of digital are expected to be passed on to consumers • Up to 13,854 days per year could be saved for clinical trial patients, due to better tracking and monitoring	• 86,000 tCO_2e reduction in 2027[1] due to more efficient manufacturing processes • An estimated 1,555 accidents could be avoided in production • An estimated 14,804 lives saved, due to a reduction of dosage blunders through personalised medicine
Cost reduction through digitally enabled R&D	£1.3		
Cost reduction through digitally enabled manufacturing and asset maintenance	£5.3		
Cost reduction through digitally enabled supply chain management	£2.3		
Cost reduction due to increase in resource efficiency	£1.9		
Total value to industry	£11.7 £22.4		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Figure 13

AEROSPACE

Our review identified a £17.5 billion opportunity for the aerospace sector over the next ten years through the adoption of currently known digital technologies. Of all the sectors we examined, aerospace offers the greatest potential in terms of both cost reduction and new business models. See Appendix 1 for a point of view on how IDTs will impact aerospace.

Widely considered to be a global leader with a 15 percent market share, the UK's aerospace and defence sector's turnover was £55 billion last year,[28] making a significant contribution to the UK economy and securing over 250,000 high-value jobs. The sector is also one of the most productive in the UK – almost double the national average.[29] And with a forecast market for the civil aerospace sector over the next 20 years predicted at US$6.3 trillion (equivalent to 35,000 new aircraft), and a further US$1.9 trillion forecast in through-life support,[30] the future for aerospace in the UK looks positive.

The sector has a great opportunity to demonstrate leading digital capabilities across the entire lifecycle of product and process. With clear challenges that span multi-tier supply chains, IDT offers a means to satisfy the industry's aspirations for cycle time reductions in the region of 25 to 35 percent and productivity gains across the product lifecycle of 30 to 50 percent.

IDT will support new techniques in model-based systems engineering, as well as the creation and validation of digital twins and the transformation of factories to provide the lean and integrated delivery of new products. IDT will also enable the use of real-time data to dynamically improve in-service product performance, minimise downtime and enhance future products.

[28] https://www.adsgroup.org.uk/wp-content/uploads/sites/21/2017/06/ADS-Annual-Facts-2017.pdf

[29] ATI Analysis of ONS data

[30] ATI Civil Aircraft Market Opportunity Outlook 2016

Furthermore, it will enable a system of virtual certification which will significantly reduce both the time to market and development costs for future products.

In addition, IDT supports an analysis-driven culture which will enable products to be better understood. It will allow the design space to be explored more quickly and with little cost incursion. It offers a more holistic approach that understands product and manufacturing trade-offs and provides engineering with the opportunity to make informed decisions and adopt a highly confident 'right first-time' philosophy.

Future aircraft and services can be developed on the newfound wealth of engineering and asset performance data that IDTs provide. For example, a new Airbus model has around 20,000 individual sensors in its wings,[31] while GE's new jet engines collect 5,000 data points every second.[32]

VALUE AT STAKE FOR THE AEROSPACE INDUSTRY IS ESTIMATED TO BE £17.5BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£7.5	• 30% of cost savings (worth £3bn over 10 years) are expected to be passed on to consumers as the manufacturing process becomes more efficient through the use of digital technologies • 69% increase in customer satisfaction due to personalisation of manufactured products • 13% increase in job satisfaction as jobs will shift to higher value jobs and tasks	• 63,000 tCO_2e reduction in 2027[1] from more efficient manufacturing and production processes as well as better in-use aircraft efficiency • 15,310 injuries avoided over the next decade as a result of improved safety during aerospace manufacturing, through digital tools and analytics
Cost reduction through digitally enabled products, processes and services	£4.8		
Cost reduction through digitally enabled manufacturing and asset maintenance	£4		
Cost reduction through digitally enabled supply chain management	£1.2		
Total value to industry	£7.5 £17.5		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Figure 14

[31] http://www.datasciencecentral.com/profiles/blogs/that-s-data-science-airbus-puts-10-000-sensors-in-every-single, accessed 15 January 2017

[32] http://www.aerospacemanufacturinganddesign.com/article/millions-ofdata-points-flying-part2-121914/, accessed 1 February 2017

EXAMPLES OF TECHNOLOGY DEVELOPED FOR DIGITAL PRODUCTIVITY IMPROVEMENTS

APROCONE (Advanced Product Concept Analysis Environment) is an Airbus-led collaborative project including Rolls-Royce, GKN, CFMS, MSC Software and two universities. The project will develop a highly productive collaborative design environment and associated methodologies that will mean wings and engines can be designed more innovatively and more quickly to meet future market and environmental needs.

MEGGITT M4 (Meggitt Modular Modifiable Manufacturing). Working in collaboration with the AMRC, MTC, Cranfield University and IBM UK, Meggitt leads a programme of work to challenge current value stream conventions by integrating digital tools and enabling multi-component workflows. This ATI-funded project targets productivity improvements and operational excellence through dynamic scheduling, generating simulations and data analytics to predict capacity requirements and performance, and the visibility and traceability of components.

ENABLES (External Network Advanced Build Lifetime Engineering System) is a collaboration between Rolls-Royce, the NCC and bf1 systems (a SME). The technology delivers a near 30 percent reduction in part count, weight reductions, build time/cost savings, and a predicted enhancement of in-service reliability of around 50 percent. It has also fundamentally changed bf1systems's manufacturing capabilities.

AMROCCS (Aircraft Maintenance Repair & Overhaul Configuration Capture System) is a collaboration between various SMEs to develop a virtual reality headset. It aims to reduce the time/cost of maintaining in-service aircraft by guiding locally trained engineers through the repair and maintenance process, reducing the need for specialist repair staff to be flown around the country.

VIEWS (Validation and Integration of Manufacturing Enablers for Future Wing Structures) brought together 13 partners in a £30 million project aimed at reducing the cost of wing manufacturing and assembly by 20 percent and process time by 80 percent. The VIEWS team was led by GKN Aerospace, but included other top-tier industrial partners and four leading UK universities.

Augmented reality. Accenture, as an Airbus Innovation partner, developed an AR supported-worker solution for the fitting of aircraft seats on the A330 final assembly line in Toulouse. Using 'smart glasses' technology, seat fitters are provided with operational instructions and fitting positions as they work. Defects were reduced by 100 percent and costs by 85 percent. And our research indicates that wearables typically increase productivity by 8 percent.

IDTS CAN STRENGTHEN SUPPLY CHAINS

UK manufacturing relies on complex and highly integrated supply chains (see Figure 15). What's more, these supply chains are often spread across numerous countries. And, whether they operate in the automotive, aerospace, construction or food and drink sectors, they must support the 'just in time' models that are critical to efficiency, productivity and competitiveness. This is another area where IDTs can bring significant benefits to UK manufacturers.

SUPPLY CHAIN

Supply Chain Value Transformation & Optimisation

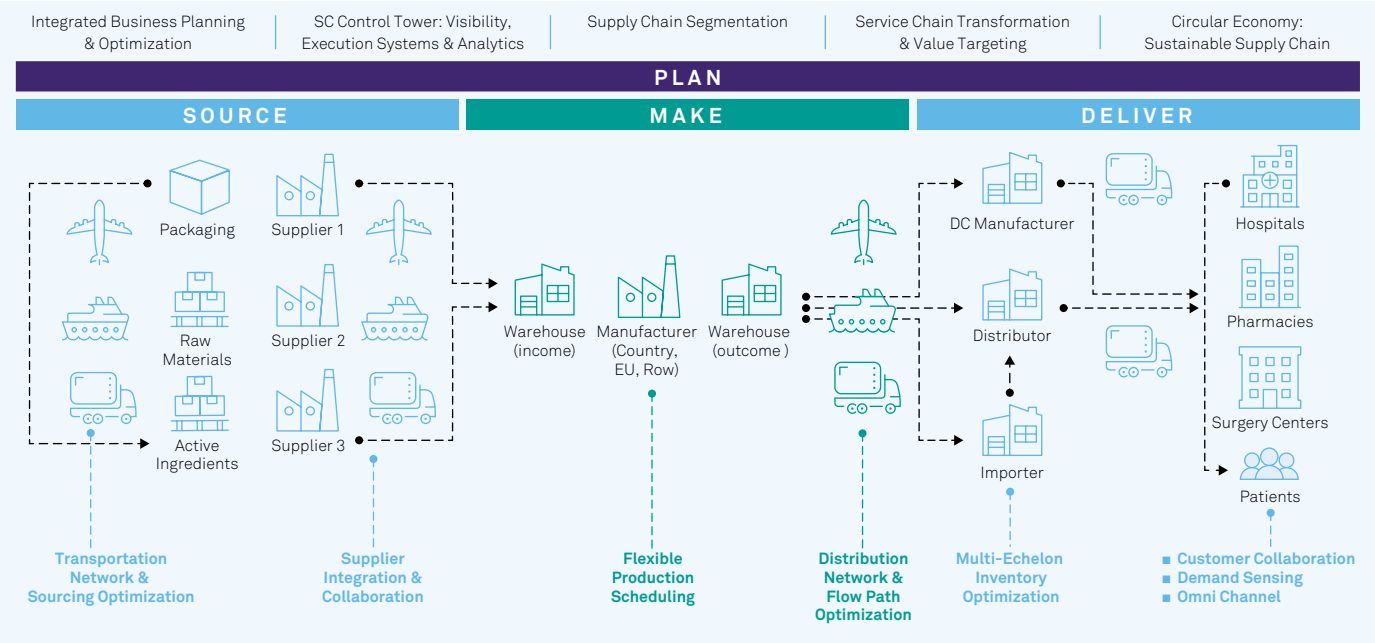


Figure 15

Digitalisation could significantly improve suppliers' output, resulting in £2.6 billion of benefits in the automotive industry alone.

Digitalisation in the UK Automotive Industry, SMMT/KPMG, 2016

By removing delays, eliminating faults, increasing flexibility and improving efficiency throughout the supply chain, manufacturers can make themselves more productive, maintain competitiveness and boost their profits. But effectively managing the supply chain relies on fully understanding how it operates. To do so, data is critical. Indeed, manufacturers have long used data to increase the productivity of their supply chains.

The advent of a wide range of new digital technologies is now enabling new levels of increased connectivity and the more effective use of data. Technological advances mean that more data can now be collected more quickly. And this data can be easily accessed from multiple sites, safely shared between different partners in a supply chain, and more effectively analysed. What's more, these technologies will allow manufacturers to respond to increasing consumer demands for faster delivery and more personalised products. And technologies such as 3D printing have the potential to introduce untold flexibility into production processes.

Taken together, these technologies could revolutionise the way that supply chains operate. They could facilitate a transition from current linear supply chains (with limited use of data and new technologies) to a digitally connected supply chain network driven by connectivity and the rapid use of data. These digitally connected supply chains would be able to respond to feedback instantly and automatically reconfigure themselves according to predetermined rules and algorithms, thereby boosting a manufacturer's efficiency and its ability to cope with temporary disruptions.

TRADITIONAL LINEAR SUPPLY CHAINS

In a digital age traditional linear Supply Chains no longer work...

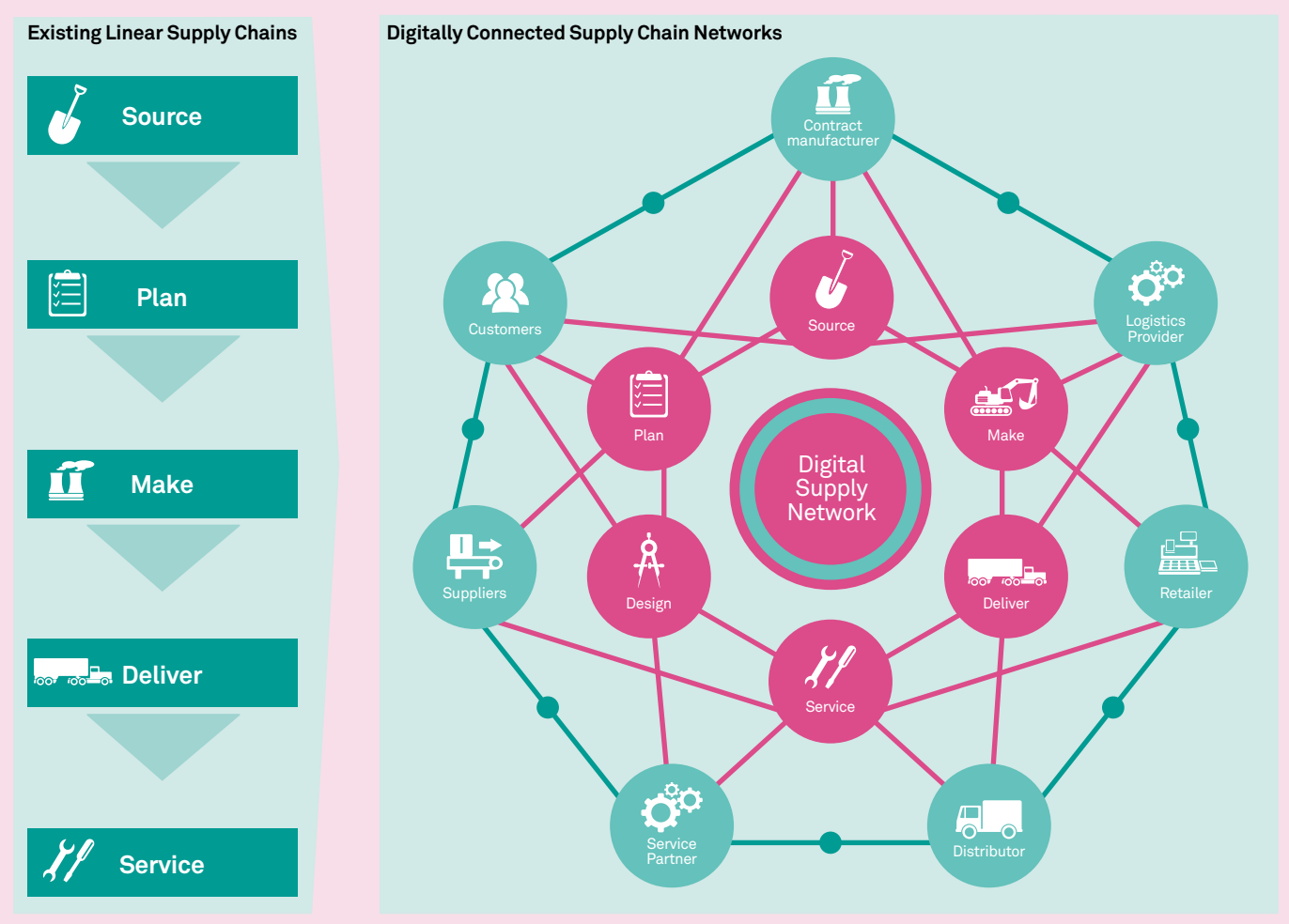


Figure 16

In bringing about this transition, a number of key technologies will be critical:

- Sensors, smart packaging, cloud-based storage and 5G. These will support the introduction of the IoT in supply chains, and will facilitate data collection, traceability and the development of a detailed understanding of a supply chain. Specifically, a network of connected sensors across plants and supply chains will enable asset tracking, condition monitoring, predictive maintenance and anti-counterfeiting solutions.
- Predictive analytics and PLM software. These will support data analysis, and provide flexibility and responsiveness within supply chains.
- Virtual reality, mobile and tablet technology and visualisation tools. These will support more active interaction with data and the real-time operations of a supply chain.
- Cybersecurity, digital trust tools and Blockchain. These will help provide the necessary assurance that connected supply networks are secure.

Will industrial digitalisation create or destroy jobs?

The UK is currently enjoying historically high levels of employment. Official statistics show the present unemployment rate (4.3 percent) is the lowest it has been in over 40 years, while the workforce participation of those aged 16 to 64 is at 75.3 percent – the highest since records began in 1971. The strength of labour market demand is at a near record high, with 768,000 vacancies advertised in the period from May to July 2017.

The impact of the digital economy on employment is already evident. The World Bank reported in 2015 that the UK will need 745,000 additional workers with digital skills to meet rising demand from employers between 2013 and 2017, and that almost 90 percent of new jobs will require digital skills to some degree.[33]

But the effect of IDTs and other technologies on employment is a perennial concern for the public. There is a popular belief that the rapid automation of jobs made possible by these technologies will result in mass unemployment. For example, a 2013 paper estimated that around 47 percent of all US employment is at high risk of being "automated relatively soon, perhaps over the next decade or two".[34] Although the authors did go on to say that "we make no attempt to estimate the number of jobs that will actually be automated, and [we] focus on potential job automatability over some unspecified number of years."

In contrast to this gloomy analysis, our review leads us to strongly believe the net impact of IDTs on employment will be positive. The application of digital technologies within UK industry will increase productivity and revenues, enabling firms to pay higher wages and thus creating multiplier effects on other sectors of the economy. Increased competitiveness will lead to growth, increasing sales, exports and hence employment. Productivity improvements will eliminate the cost advantage of low-wage economies, encouraging companies to re-shore activities and locate closer to their domestic markets. Digital technologies will in themselves create new higher-paid forms of employment as many new roles emerge that did not previously exist, including those in new servitisation business models. What's more, existing roles will be augmented rather than replaced by IDTs, thereby creating more fulfilling and safer jobs.

"The number of weaving jobs increased when automation took place. The number of bank tellers in the US has grown since ATMs were widely deployed"[35]

[33] The Effects of Technology on Employment and Implications for Public Employment Services. The World Bank Group. Report prepared for the G20 Employment Working Group Meeting Istanbul, Turkey, 6-8 May 2015.

[34] Frey, C.B. and Osborne, M.A., 2017. The future of employment: how susceptible are jobs to computerisation? Technological Forecasting and Social Change

[35] Bessen, J.(2015) Learning by doing: The Real Connection between Innovation, Wages and Wealth, Yale University Press

DIGITALISATION LEADS TO JOBS BEING CREATED	
NEW JOBS	New digitally skilled jobs that did not previously exist are created based on the introduction of new technology and techniques. Technology has driven this job creation model for centuries.
GROWTH	Being more productive and competitive, winning additional business leads to need for more of the existing jobs to meet the increased demand.
RESHORING	Digitalisation makes it economically viable to have localised, flexible manufacturing, closer to the market with shorter lead times. Jobs are reshored to the UK from previously low labour-rate countries.
SUPPLY CHAIN	There is a multiplier effect in the supply chain – for every job created in industry, several jobs will be created in product suppliers and service providers throughout the supply chain.
SERVITISE	Digitalisation allows a servitization model, where products are sold as a service with a performance guarantee. In addition to manufacturing jobs, further service based jobs are also created.

Figure 17

THERE IS STRONG EVIDENCE THAT IDTs WILL CREATE JOBS

The potential impact of IDTs on productivity has been clearly identified in this report. Digitalisation-related productivity increases the return on capital employed and will generate after-tax profit growth which can be reinvested. These reinvestments will then create new employment opportunities.[36]

In addition, IDT will provide employment opportunities within new servitisation business models, where the customer pays for 'use' instead of 'ownership'. The classic example is Rolls-Royce's 'Power by the Hour' business model that has worked for many years for a high-complexity, high-value, mission-critical capital good. Other examples include tyre manufacturers who sell tyres on a usage basis.

Various studies have shown a positive correlation between automation and jobs. For example, a 2016 discussion paper for the Centre for European Economic Research found that, "overall, labour demand increased by 11.6 million jobs due to computerisation between 1999 and 2010 in the EU27, thus suggesting that the job-creating effect overcompensates the job-destroying effect".[37] The study found that while routine-reducing technological change decreased labour demand by 9.6 million jobs, it was compensated by product demand and spill-over effects that increased labour demand by around 21 million jobs.

This point is backed up by other surveys. In July 2016, Manpower Group asked more than 18,000 employers from 43 countries across six industries about the impact of automation and digitisation on headcount over the next two years. They found that 83 percent of employers plan to maintain or increase their headcount – and only 12 percent intend to decrease their headcount due to automation.

[36] The Industrie4.0 transition quantified: how the fourth industrial revolution is reshuffling the economic, social and industrial model, April 2016, Roland Berger

[37] Arntz M., Gregory T. and Zierahn U., 2016, The risk of automation for jobs in OECD countries: A comparative analysis. OECD Social, Employment, and Migration Working Papers

When Boston Consulting Group modelled the effect of technology on the German economy, they found that increases in employment depend on the rate of adoption of Industry 4.0 technology. In their base case, where German companies generate additional growth of 1 percent a year due to Industry 4.0 and achieve a 50 percent adoption rate of the technology, robots and computerisation reduced the number of jobs in assembly and production by about 610,000. But this was more than offset by the creation of 960,000 new jobs – a net increase of 350,000 jobs (5 percent). These new jobs come from demand for an additional 210,000 workers in IT and R&D, as well as 770,000 new jobs from revenue growth.[38]

Other studies have made similar findings. In his 2016 paper, Roland Berger estimated that flexible factories, reinvestments and growth in the service sector will create 10 million new jobs in Europe by 2035.[39] A review of the economic impact of industrial robots across 17 countries found that robots increased wages without having a significant effect on total hours worked.[40] And, although the number of manufacturing jobs has been declining for a number of years, Brookings Institution analysts report that countries that invested more in robots lost fewer manufacturing jobs than those that did not.[41] Indeed, a study by Barclays in the UK argues that an investment in automation of £1.24 billion over the next decade could safeguard 73,500 manufacturing jobs and create more than 30,000 jobs in other sectors.[42]

Furthermore, a PwC analysis of data from the US Bureau of Labor Statistics found that the most robotics-intensive manufacturing sectors in the US as a proportion of the total workforce (automotive, electronics and metals) employ around 20 percent more mechanical and industrial engineers and nearly twice the number of installation maintenance and repair workers than other manufacturing sectors – and pay higher wages too. These sectors also tend to have a higher proportion of better-paid production-line workers.[43]

This positive picture was neatly summarised by consultants Deloitte, who argued that "while technology has potentially contributed to the loss of over 800,000 lower-skilled jobs (in the UK) there is equally strong evidence to suggest that it has helped to create nearly 3.5 million new higher-skilled ones in their place".[44]

[38] Man and Machines in Industry 4.0: How will Technology Transform the Industrial Workforce through 2025? September 2015, Boston Consulting Group

[39] The Industrie4.0 transition quantified: how the fourth industrial revolution is reshuffling the economic, social and industrial model, April 2016, Roland Berger

[40] Graetz and Michaels 2015

[41] Muro and Andes 2015

[42] Barclays 2015

[43] PwC 2014

[44] Deloitte LLP 2015

VARIOUS INFLUENTIAL REPORTS

	The Future of Jobs World Economic Forum Jan 2016	The Future of Employment Frey and Osborne 2017	The Global Information Technology Report World Economic Forum 2012	The Skills Revolution Manpower Group Jan 2017	Man & Machines in Industry 4.0 Boston Consulting Group Sep 2015	Automation, labor productivity and Employment Copenhagen Business School 2011
CONS	7.1 million jobs lost globally across all sectors	47% of jobs in USA at risk of being computerised	The report does not estimate specific losses, but a positive net effect	12% of employers will decrease headcount due to automation	Reduction of 610,000 jobs in Germany in assembly and production	-10% employment in the short term if UK automated at highest level
PROS	2 million jobs gained globally across all sectors	The report does not estimate how many jobs could be gained	A 10 point increase in digitalisation score would decrease unemployment by 1%	19% of employers will increase headcount due to automation, 64% will not change headcount.	960,000 new jobs created in Germany – 760,000 due to growth 210,000 in IT/ analytics	+7% employment in the long term if UK automated at highest level
COMMENT	4.7m jobs lost in office administration and 1.6m from manufacturing. The report says "Manufacturing and Production roles are ... anticipated to have relatively good potential for upskilling, redeployment and productivity enhancement through technology rather than pure substitution".	"at risk" is defined as "meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two". This may mean some tasks have the potential to be automated rather than actual jobs lost.	The report estimates 45m jobs created globally by digitalisation from 2007-2011.	The report estimates that the UK will increase employment by 1-10%, compared to a 0-9% reduction in Germany, France, Switzerland and Finland.	The net effect is a 350,000 gain in jobs. The report assumes a scenario of 50% adoption of Industry 4.0 leading to 1% economic growth. A growth of 1.5% would double the additional jobs needed to 760,000.	The net effect is a 7% increase in employment over the long term. The report also estimates a 22% productivity growth in the UK, which is the driver of both short term need for less labour and longer term growth and need for more labour.

Figure 18

IDTs WILL LEAD TO HIGHER-PAID JOBS

As companies increasingly adopt IDTs, they will create a buoyant demand for these technologies – and the employees who have the skills to support them. These new higher-skilled jobs command a wage premium. For example, Deloitte estimates that in the UK, higher-skilled jobs that have replaced lower-skilled jobs pay on average £10,000 more per annum, adding £140 billion to the UK's economy.[45] The 'tech sector' alone represents 6 percent of the UK economy with an estimated GVA per person in the region of £91,800, well above the UK average. Tech City UK estimates that the digital sectors are creating jobs 2.8 times faster than the rest of the economy, and now provide 1.56 million jobs in total, 80 percent of which are based outside of London.[46]

IDTs WILL ALSO CHANGE THE NATURE OF JOBS

Automation will inevitably displace some jobs. However, the impact will not be as great as some predict. A McKinsey report found that the demand for roles involving simple, repetitive, predictable tasks will decrease due to automation. But cognitive and interactive roles are less likely to be replaced. Indeed, the indications are that automation and digitalisation are being deployed alongside human workers to increase their productivity and quality of output. Automation is focused on replacing tasks, not jobs. And that means, ultimately, that it will increase the effectiveness of the worker. When studies take this kind of task-based approach to predicting the effect of automation on employment, they find that only 9 percent of US

[45] Deloitte LLP 2015

[46] TechNation 2016: Transforming UK industries

jobs are in danger of being replaced by digitalisation (compared with the 47 percent figure predicted by Frey and Osborne).[47]

The International Federation of Robotics makes the same point. They say that "robots substitute labour activities but do not replace jobs. Less than 10 percent of jobs are fully automatable. Increasingly, robots are used to complement and augment labour activities; the net impact on jobs and the quality of work is positive. Automation provides the opportunity for humans to focus on higher-skilled, higher-quality and higher-paid tasks."[48]

IDTs should therefore be seen as a positive for employees. They will result in safer workplaces with fewer accidents and less exposure to harsh environments. They will lead to improved job satisfaction through the replacement of dull and repetitive tasks. And they will improve yield and quality through increased accuracy and repeatability. Human judgment and decision making will remain a core part of the workplace.

Cobots (collaborative robots) provide a valuable illustration of how technology is changing the workplace. Low-cost cobots provide a flexible, safe and affordable alternative to fixed automation. They are a particularly positive development for SMEs because they don't require specialist systems integrators and can easily be set up by workers themselves. They can also be quickly adapted to new processes and production run requirements. Companies around the world have introduced cobots into their workforces and by doing so have gained a competitive advantage. They are finding that their human employees can work alongside the cobots to drive intelligent process automation, increase efficiency, and eliminate low value-add activities, releasing those employees to focus on creating customer and business value.

At BMW's US factory in Spartanburg, cobots help fit the company's car doors with sound and moisture insulation, a task that used to cause wrist strain for workers. Canadian electronics manufacturer Paradigm Electronics uses cobots to carry out delicate polishing and buffing tasks on loudspeakers, working with employees who handle the final finish and quality check. These robots have led to a 50 percent increase in productivity, but with no job losses – employees who previously carried out these tasks have been promoted from machine operators to robot programmers.

2.6 million industrial robots are expected to be deployed worldwide by 2019[49]

The value of the collaborative robotics industry is expected to grow to $1 billion by 2020[50]

A 4,800%+ increase in cobot shipments is predicted between 2016 and 2025[51]

[47] Arntz, M., Gregory, T. and Zierahn, U., 2016. The risk of automation for jobs in OECD countries: A comparative analysis. OECD Social, Employment, and Migration Working Papers

[48] IFR 'The impact of Robots on Productivity, Employment and Job April 2017.

[49] https://ifr.org/news/ifr-press-release/world-robotics-report-2016-832

[50] https://www.abiresearch.com/press/collaborative-robotics-market-exceeds-us1-billion-/

[51] https://internetofbusiness.com/iiot-rise-cobots/

In this way, IDTs will shift employment from one occupation to another. Technology has dramatically changed the appearance of numerous industries – and employment opportunities have shifted with the changes. Consider the pre-press industry. This sector dramatically declined with the rise of electronic media. But graphic communications employment opportunities have shifted from the press to the computer and have now joined the fast-developing creative sector.[52] Similarly, as the number of telephone operators has decreased, there has been a corresponding increase in the number of receptionists. And as demand for typesetters has decreased there has been an increase in the need for graphic designers.[53]

Economist David Autor sums up the effect of automation like this: "Automation does indeed substitute for labour – as it is typically intended to do. However, automation also complements labour, raises output in ways that lead to a higher demand for labour, and interacts with adjustments in labour supply. Even expert commentators tend to overstate the machine substitution for human labour and ignore the strong complementarities between automation and labour that increase productivity, raise earnings and augment demand for labour."[54]

"All industries are changing; 65% of today's grade school kids will end up in a job that hasn't been invented yet"[55]

IDTs CAN LEAD TO THE RE-SHORING OF JOBS

Capital investment in digitalisation and automation removes the competitive advantage of low-cost labour. This means the attractiveness of off-shoring to low-cost locations is reduced.[56] And it will enable companies to relocate activities close to significant markets. For example, digitalisation, automation and related technologies such as 3D printing will shift the focus of manufacturing away from mass production and de-localisation. Instead, customisation and flexibility of production will become the watchwords, making it sensible to site manufacturing plants close to the local market. This will only be reinforced in the future as the need to reduce carbon footprints grows.

[52] Sartorius, M.U., 2000. Digitization and Graphic Communication Education: From Print Reproduction to dynamic Image Generation. Journal of Industrial Technology, 16(2).

[53] Why automation doesn't mean a robot is going to take your job. September 2016, James Bessen, World Economic Forum article

[54] Autor 2015

[55] US Department of Labour Study

[56] Man and Machines in Industry 4.0: How will Technology Transform the Industrial Workplace through 2025? September 2015, Boston Consulting Group.

WHAT IS THE LIKELY NET EFFECT OF IDTs ON JOBS IN THE UK?

To assess the impact of IDTs on UK employment, we used the methodology that Boston Consulting Group developed in their analysis of the German economy.[57] Thus, a best-case scenario could be modelled for UK manufacturing.

NOTE:

This scenario assumes that the UK government policy and industry investment levels match the German model. It is not a forecast, but an estimate of the potential gain in the best case.

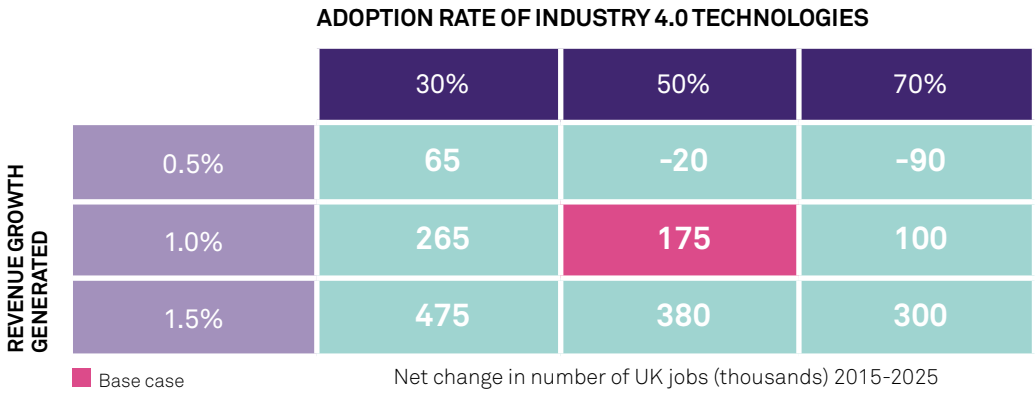


Figure 19

From this analysis it can be seen that, in most scenarios, the net effect is to increase employment, unless higher adoption rates result in low growth. In the base case, the net effect components are:

Jobs displaced	- 295,000
Jobs created through growth	+ 370,000
New jobs created	+ 100,000 (IT, analysts, R&D)
Net Increase	**175,000**

[57] Man and Machines in Industry 4.0: How will Technology Transform the Industrial Workforce through 2025? September 2015, Boston Consulting Group

MTL Instruments Ltd is a UK-based process control company specialising in instrumentation for hazardous and potentially flammable atmospheres – the sort found routinely in the oil and gas, petrochemical and pharmaceutical industries. MTL's electronic products are protected from their harsh operating environments by a combination of electronic design, circuit board coatings, and mechanical housing.

MTL was founded by three entrepreneurial engineers in Luton in 1971, went public on the USM in 1988 and became a fully-listed company on the London Stock Exchange in 1995. It now has sales of over £100 million per annum and is part of multinational electrical group, Eaton Electric.

Back in 1991, MTL had sales of around £18 million per annum and employed approximately 250 people of which 208 were employed in direct production. Its products were mainly assembled manually and, in addition to the production staff in the factory, it also used home workers on a piece part basis, making use of the fine assembly skills of Luton workers who had come from the hat industry.

MTL had a reputation as a technology leader and several tier-one instrumentation and automation companies were looking to incorporate its products into their systems. This threw up two challenges – how to scale up to the required volumes and how to meet their strict quality targets which included "Right First Time" (RFT) performance of 99.5 percent or better (the manual assembly process was yielding an average of less than 95 percent RFT).

MTL management decided to automate the printed circuit board assembly process, acquiring a large pick-and-place machine and moving to surface mount technology for its newer products. The total investment at that time was around £500k. Existing staff were retrained on the new machine and no production positions were lost, although the company did encourage home workers to transition to in-factory work, which most of them did. Over the next two years, output doubled.

By 1995, MTL had grown its sales to around £35 million per annum and had opened a factory in India to make its legacy labour-intensive products. It realised it still needed to increase capacity, so it acquired an adjacent building in Luton and invested in additional

machinery and new robotic sprayers for coating circuit boards. It also further automated its end-of-line test equipment. The company moved to a permanent double-day shift with occasional additional night shift (made up of volunteers from the production staff). Again, no production staff were lost. In fact, additional staff were recruited. And existing staff were retrained on the newly automated plant. Indeed, this retraining indirectly led to several of MTL's production staff later launching careers at companies like Rolls-Royce, or setting up their own consultancy businesses. The number of production staff rose to 312 in 1995 and then to 367 in the following year.

By the end of 2008, MTL's sales had risen to over £100 million and it was acquired by Cooper Industries, a US-based multinational, making the combined operation the largest hazardous area company in the world. This, in turn, became part of the Eaton group in 2012. MTL still manufactures the majority of its products in its Luton factory and continues to invest in automation.

THERE IS NO ALTERNATIVE

As the UK exits the EU and becomes fully exposed to the competitive pressures of the free market, companies will need to focus on productivity to survive. If businesses are unable to stand on their own two feet they will fail, risking entire factories and industry-related supply chains and services. Therefore, the greatest threat to employment is not automation but an inability to remain competitive.

We can learn from history. The UK car industry appeared to be in terminal decline in the 1970s. But it was saved through a combination of direct foreign investment and the introduction of new production techniques and technologies. It has now been transformed into a global leader.

UK AUTOMOTIVE INDUSTRY	1984	2011	2016
Vehicles produced	**1.1m**	**1.3m**	**1.8m**
People employed	**298,000**	**124,000**	**151,000**
Productivity (vehicles/person)	**3,700**	**10,500**	**11,900**

Source SMMT, ONS

Figure 20

Can IDTs create a resource-efficient, sustainable and resilient economy?

THE ENVIRONMENTAL IMPACT OF INCREASED INDUSTRIALISATION

By 2050 we can expect UK manufacturing to produce something like four times as much value add than it does today. But it needs to do so while creating zero waste, creating zero climate change emissions, and using half its current resources (materials and water).

IDTs have a crucial role to play in developing a resource-efficient UK industrial base. The effective adoption of IDTs can help deliver over £10 billion in reduced resource costs – adding both to profits and to the nation's balance of payments through less reliance on imports and increased export opportunities. Recent research from the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability identifies the potentially transformational role of digital technology in the journey towards a restorative, regenerative and net-positive economy.[58]

IDTs also have a crucial role in developing a resilient UK industrial base that can ride out increasingly frequent resource availability disruptions, as well as offering novel solutions to grid management currently valued at over £2 billion. And IDTs are shown to perform a crucial role in any move to make the UK industrial system sustainable over the long term in a post-Brexit context.

The UK already has leading examples of how innovative IDTs can deliver these new capabilities to industry worldwide. They illustrate the UK's potential to be a world leader in exporting IDT for sustainability – and they highlight the potential new companies, jobs and profits that would flow as a result. But these positive benefits are far from guaranteed. Our analysis shows that few organisations are setting resource efficiency or resilience goals for their exploratory use of IDT. Government is yet to prioritise these benefits, nor has it investigated the potential for improved resilience in our energy and resource systems at lower cost than presently.

What is 'sustainable development'? The World Economic Forum defines it as development that increases the living standards of current generations without sacrificing that of future generations. This addresses issues such as economic and resource efficiency, environmental accountability and social equity.

What does sustainability mean for manufacturing? The production of all that is made or manufactured undeniably contributes to modern well-being. But it also contributes to many of the environmental challenges we see around the world today. Industrial sustainability (IS) is the practice and study of how industry responds to current sustainability challenges and eventually becomes part of a larger and fully sustainable system.

A RESOURCE-EFFICIENT NATION

IDTs enable a radical improvement in non-labour resource efficiency. As much as 50 percent of manufacturing costs are in materials, parts, energy and utilities. And these costs have been stubborn at yielding the productivity gains that businesses have seen in their use of labour.

[58] Smart, P., Hemel, S., Lettice, F., Adams, R. and Evans, S. Forthcoming 2017. Pre-paradigmatic status of industrial sustainability: a systematic review. International Journal of Operations and Production Management.

Using benchmarking analytics and the huge quantities of data produced by just a single factory, manufacturers can identify the 'golden moments' where one product can be produced for half the energy or CO_2 emissions of the same product manufactured at a different time. Alternatively, the same data can be used for anonymous comparison between factories. One study estimated that this would yield up to £10 billion extra profit for UK manufacturing by lowering material, energy and utility costs, while simultaneously delivering a 4.5 percent CO_2 reduction for the UK. This kind of 'win-win' opportunity exists if we can rise to the technical challenge of unravelling large and complex sets of data to make sensible comparisons.

IntelliSense (see case study below) is doing just that for the natural resources and mining industry. The company is using AI, the IoT and analytics to identify target energy savings and deliver resource productivity gains for its customers worldwide, while creating new jobs and companies in the UK.

Augmented Reality (AR) is an important part of the drive for productivity. It enables, for example, engineers to see energy, water and waste flows in real time in the factory setting. Engineers can thus bring their traditional skills of productivity improvement to bear against a real cost that was previously only visible in spreadsheets. We can expect this kind of AR technology to eventually lead to improved factory design tools.

INTELLISENSE.IO

IntelliSense.io is a market leader in the Industrial Internet of Things (IIoT), machine learning and AI sector. It provides a range of applications and services through an innovative platform to help eliminate inefficiencies and improve productivity yields in plants, processes and people.

Its platform uses technologies like machine learning and physical models that analyse real-time and historical data to predict and simulate future performance. It also uses virtual sensors based on its customers' data and sensor networks to plug data gaps as well as advanced analytics and automation outputs from statistical, physical and machine learning models. These allow businesses to identify areas for improvement. They can, for example, monitor the quality and safety status of materials during transportation, track the supply chain from end to end, and identify and respond to any bottlenecks more quickly. Reduced performance variability, less unplanned downtime, and the optimised use of resources lead to lower energy consumption and associated costs.

IntelliSense.io delivers optimisation as a service (OaaS) through a combination of software and networks, wherein the IoT platform and Big Data technologies are integrated in ready-to-use software applications.

The company's client base is primarily in capital and asset-intensive industries and it has built substantive partnerships in the natural resources and mining industry. Its customers include one of the largest copper and gold mines in Latin America, which has seen a 55 percent reduction in its variability, and a uranium mining site in Kazakhstan which has seen a 15 percent increase in system efficiency and energy savings and a 7.5 percent increase in yield.

The success of IntelliSense.io is founded on the power of new technology. Older technologies could not continuously manage changing operating environments and did not have the ability to predict the mineral composition of feed. The company's leading technologies, in contrast, significantly benefit its mining customers, where

input materials vary on an hour-by-hour basis and connectivity has been difficult in the industry's often harsh and extreme environments.

Benefits to IntelliSense.io:

- Being a market leader allows it to gain a competitive first-mover advantage and develop more global customers. As the costs of the IoT, data analytics, and AI technology decrease, its profits will further increase.

Benefits to its customers:

- Optimisation is delivered as a service with no CAPEX investment required.
- Deployment is realised with minimal disruption to existing operations.
- Improved business efficiency from the optimisation of production processes reduces energy consumption, water requirements, unplanned downtime, and results in higher yields.
- Lower costs/higher revenue from reduced unit costs can be reinvested or passed onto consumers in the form of lower output prices.
- Enhanced natural resource use.
- Extended equipment lifetime further reduces production costs and waste.
- More stable and secure operations.

Wider benefits to the UK economy:

- IntelliSense.io helps the UK lead in emerging sectors and markets, improving national competitiveness.
- Builds on critical UK industry strengths in the wider IoT market.
- Building international business relationships helps improve trade prospects and exports.
- Contributes towards entrepreneurship, innovation and job creation.

Potential future value:

- The Department of Energy and Climate Change estimates that £293 million of energy savings could be realised among SMEs by making use of Big Data analytics in logistics and transportation alone.[59]
- The latest PwC Global Data and Analytics Survey found that 49 percent of manufacturers expect advanced analytics to utilise assets efficiently.[60]

A RESILIENT NATION

The government report 'The Future of Manufacturing' predicted that the UK would see increasingly frequent and large disruptions – from material availability due to geopolitics, floods, droughts and energy disruptions. IDTs have the potential to mitigate these kinds of disruptions because they enable manufacturers to drive resource productivity and reduce the resources required for each unit of value-add they produce.

Smart energy systems are a clear example of IDT's potential, and the current UK market for such systems is already worth approximately £160 million per year. Open Energi (see case study on the following page) is a growing IDT company using sensors to identify short-term strains on the National Grid and adjust the amount of electricity being consumed by industrial equipment (such as refrigerators or heating systems) for short bursts. These adjustments have

[59] https://www.gov.uk/government/publications/smart-technologies-in-smes

[60] https://www.pwc.com/us/en/advisory-services/data-possibilities/big-decision-survey.html#ToolSpeed

little or no effect on operational processes but perform a service to the grid in helping to balance electricity supply and demand.

Future advances will see IDTs used to connect sets of factories or supply chains, or even local clusters of factories, to deliver grid services such as demand shifting, peak-lopping and frequency response. This represents a £2 billion market in the UK.

Material efficiency can also be enhanced through IDTs. Many factories are potentially able to use other factories' waste as an input material. IDT can predict future waste availability, and its qualities, with a level of accuracy never previously possible. We predict the rise of new UK start-ups offering services to increase this kind of waste exchange. What's more, IDT enables the mapping and analysis of material flows at a national level. This is something that the House of Lords has described as a massively powerful but as-yet unavailable tool for government and sector level planning.[61]

OPEN ENERGI

Open Energi is a UK company using innovative digital technology to connect a range of distributed energy assets and aggregate and optimise their electricity demand in real time. Its service is an example of business model innovation with triple bottom-line benefits.

The company's technology platform is a demand side response (DSR) service that helps the National Grid balance electricity supply and demand in real time. Sensors detect the frequency in the electricity system. If it is higher or lower than the balanced frequency, it will send a request to thousands of IDT devices across the country and ask if they can temporarily increase or reduce power consumption to restore the optimal balance between electricity supply and demand. The responses are aggregated and adjusted in real time, creating a virtual power station, without compromising operational performance. The company's technology also provides an interactive, customisable portal that helps identify energy savings.

One of its largest customers is water company United Utilities, which owns connected assets such as water pumps, motors and blowers at some of its largest wastewater treatment works across the North West. By 2020, the company aims to provide over 50MW of DSR for the National Grid, equating to a reduction of over 100,000 tonnes of carbon for the UK per year.

Open Energi will be launching a new platform in 2017 further utilising AI, machine learning, Big Data analytics and the IoT to deliver data-driven savings and revenues to its customers from multiple markets and services.

Benefits to Open Energi:

- Open Energi is paid by the National Grid for providing demand flexibility. The National Grid's Power Responsive initiative is a stakeholder-led programme designed to stimulate interest in and the adoption of technologies to help balance electricity supply and demand through financial incentives.

[61] House of Lords report on Waste, 2008

Benefits to its customers:

- Revenue: Open Energi distributes part of its revenue from the National Grid to its customers (over 40 in total) in return for sharing their demand flexibility.
- No disruption: the technology functions almost invisibly, requiring minimal behavioural change. The installation process is simple and does not require large input costs.
- Efficiency: through data-based insights into how its customers' processes and equipment are working, Open Energi can identify problems and possible efficiency gains, thereby lowering their customers' production costs.
- Carbon emissions: demand flexibility reduces the National Grid's reliance on fossil fuelled power stations for balancing the grid – thereby cutting carbon emissions in addition to creating a smarter, more resilient and more secure energy system.
- High satisfaction: according to a survey of over 200 businesses conducted by The Energyst, a specialist publisher in the energy sector, 78 percent of DSR users are satisfied with the outcome.[62]

Wider benefits to the UK economy:

- Public good: enables the National Grid to manage peak loads, increase resilience and meet their target of achieving up to 50 percent of electricity balancing via DSR by 2020, accelerating the UK's transition to a cleaner, more affordable and more secure energy system. No upfront infrastructure costs are required and it reduces the need for the National Grid to rely on backup power systems.
- Lower energy bills: the National Grid currently spends just over £1 billion a year on balancing electricity supply and demand. The company predicts that this could double to £2 billion a year within the next five years.[63] Not only does this save the National Grid money, but it also reduces the costs being passed on to consumers.

Potential future value:

- The Association of Decentralised Energy calculated that wider DSR adoption by businesses could reduce electricity costs by £8.1 billion per year and that 16 percent of the UK's peak electricity requirement could be provided by firms shifting energy loads.[64]
- The National Grid estimates that increasing flexibility could deliver up to £2 billion of consumer value per year by 2030.[65]
- 78 percent of survey respondents in the Demand Side Report in 2016 by the Energyst reported that they would or already use revenues gained from DSR provision to offset energy costs or invest in energy efficiency measures. A previous survey suggested that firms could shift around 10 percent of their energy loads with minimal impact on operations. This would save UK energy consumers £600 million by 2020 and £2.3 billion by 2035, equivalent to removing 1,300 diesel engines from service.[66]
- Open Energi estimates that 1.7 million tonnes of CO_2e could be saved per year from dynamic frequency response.[67]

[62] Demand Side Response, The Energyst, 2017

[63] http://www.telegraph.co.uk/business/2016/06/26/balancing-demand-could-cost-national-grid-2bn/

[64] http://www.smartestenergy.com/info-hub/the-informer demand-side-response-could-be-worth-8bn-to-uk-economy-report/

[65] http://www.green-alliance.org.uk/resources/Smart_investment.pdf

[66] Demand Side Response, The Energyst, 2016

[67] http://www.openenergi.com/uk-demand-side-flexibility-mapped/

However, several barriers hinder the wide-scale adoption of these technologies by more companies across the UK. Many companies are confused by the complexity of the technology, processes and structures in the DSR sector. This can, in turn, make it challenging for businesses to evaluate commercial propositions and leads to slow decision making.

Better regulation to enable a level playing field in still a relatively infant industry might be a sensible way forward. The Association for Decentralised Energy is developing a code of conduct for DSR aggregators to set common standards across the sector and establish best practice in the industry.

A SUSTAINABLE INDUSTRIAL NATION

The ultimate goal of the industrial system must be to work with the raw materials that the planet has the ability to offer. Any alternative approach is, by definition, not sustainable.

Many large and small manufacturers, as well as start-ups, are pursuing this ambition with increasing seriousness. Unilever is, for example, hitting its target to send no hazardous waste to landfill across over 230 factories three years early.

Foraging factories are an innovative example of highly sustainable manufacturing. They use similar technologies to the waste exchange factories described above. They can identify which raw materials are likely to become available locally and when. They then search their order books to assess which products to make, and how to adjust the bill of materials for that product to allow it to be made from the waste that is available. This is only possible with the extreme flexibility that IDT automation and process control technology bring. Ecover have, for example, been experimenting with this kind of factory in Mallorca. UK factories are conducting similar experiments out of the public eye.

The UK is already seeing an early wave of start-up pioneers using the power of increasing data availability to find products and materials and re-manufacture them. Sometimes these are the original manufacturers (such as Cummins) who rely on sensors to know when their products are under-performing in the field and then bring them back to the factory to be made good as new. Others are start-ups like RYPE Office who bring office furniture back to original performance using advanced technologies.

The UK creative industry is world-renowned, including many of its niche sustainable industries such as sustainable fashion, sustainable building design, and sustainable infrastructure. Two such examples are in business model innovation and the circular economy, where small UK start-ups are providing advice to global industry on how to innovate their system of value exchange and how to begin the journey to becoming a circular organisation.

Though it is very early to predict the benefits of this drive toward sustainability, IDTs are likely to deliver further reductions in downtime, increases in added value (as fewer resources are used across the system), plus cleaner air and cleaner energy systems. Re-manufacturing, even supported by advanced and flexible automation, is relatively labour intensive and will increase employment directly (by up to 300,000 jobs).

CAN THE UK BE A LEADER IN KEY IDTs?

IDTs will have a potentially transformational impact on UK industry. But they also represent a new and expanding industrial sector in their own right (see Figure 21).

ADVANCED TECHNOLOGIES

Digital enablement of advanced technologies in manufacturing from automation focused robotics and simulation to 3D printing capabilities, with digital driving both hardware and software cost and operational/financial performance improvements.

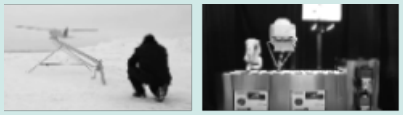
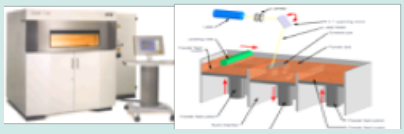
Capability Breakdown	Examples	Interventions
Robotics: Have historically been used for dull, dirty, and dangerous jobs. Now are much less costly, easy to program/train, interactive, working side-by-side with skilled labor. Benefits include increased productivity, increased flexibility, reduced labor, reduced downtime and other operational/personnel costs. **Sensors / "Smart" Products:** Sensing abilities (environmental, vision, audible, proximity, temperature, etc.) and other automations to enable improvements such as identifying and rejecting defects, handling hazardous materials, working in difficult environments (under water, in extreme heat or cold, in dark or dim lighting, etc.). Additionally, sensors are being embedded into products during the manufacturing process that collect serial number level information as its made, that then is extended to the user experience. **Additive Manufacturing / 3D Printing:** 3D printing facilitates mass customization, unlocks new revenue streams through on-demand production, reduces engineering and prototyping cycles, extends support for the long tail for products or parts that consumers buy at low volumes, etc. **Augmented Reality:** In the context of manufacturing and product design, Virtual Reality (VR) digitally simulates a product or environment, often with the user being able to interact and immerse themselves within it. With Augmented Reality (AR) the digital product is projected on to the real world background, rather than a digitally simulated one like with VR.	**Baxter** **Sawyer** **UAV Analytics** **High Speed Sorting**  **3D Printing – Laser Sintering of Metallic Parts** 	• Organizations have realized significant benefits in operational flexibility, throughput and quality. • By implementing 3D printing (additive manufacturing), organizations have successfully reduced the weight of parts by 30-55%, energy use in production by up to 90% and the cost of specialized 3D parts up to 30%. • The usage of augmented reality technology has been shown to shorten the repair time by 1% on average.

Figure 21

Our review analysed five of the most important IDTs to both understand the UK's relative position within their respective industries, and identify any issues that are preventing the UK becoming a world leader in their development and application. The technologies we looked at were:

- Additive manufacturing,
- AI, machine learning, and data analytics,
- Automation and robotics,
- Connectivity (5G, LPWAN, etc.) and the Industrial Internet of Things (IIoT), and
- Virtual reality and Augmented Reality.

For additive manufacturing, AI and automation and robotics, a 'value at stake' analysis was undertaken as part of the research (see Figure 22).

DIGITAL TECHNOLOGIES COULD CONTRIBUTE £454BN (+22%) OVER THE NEXT DECADE

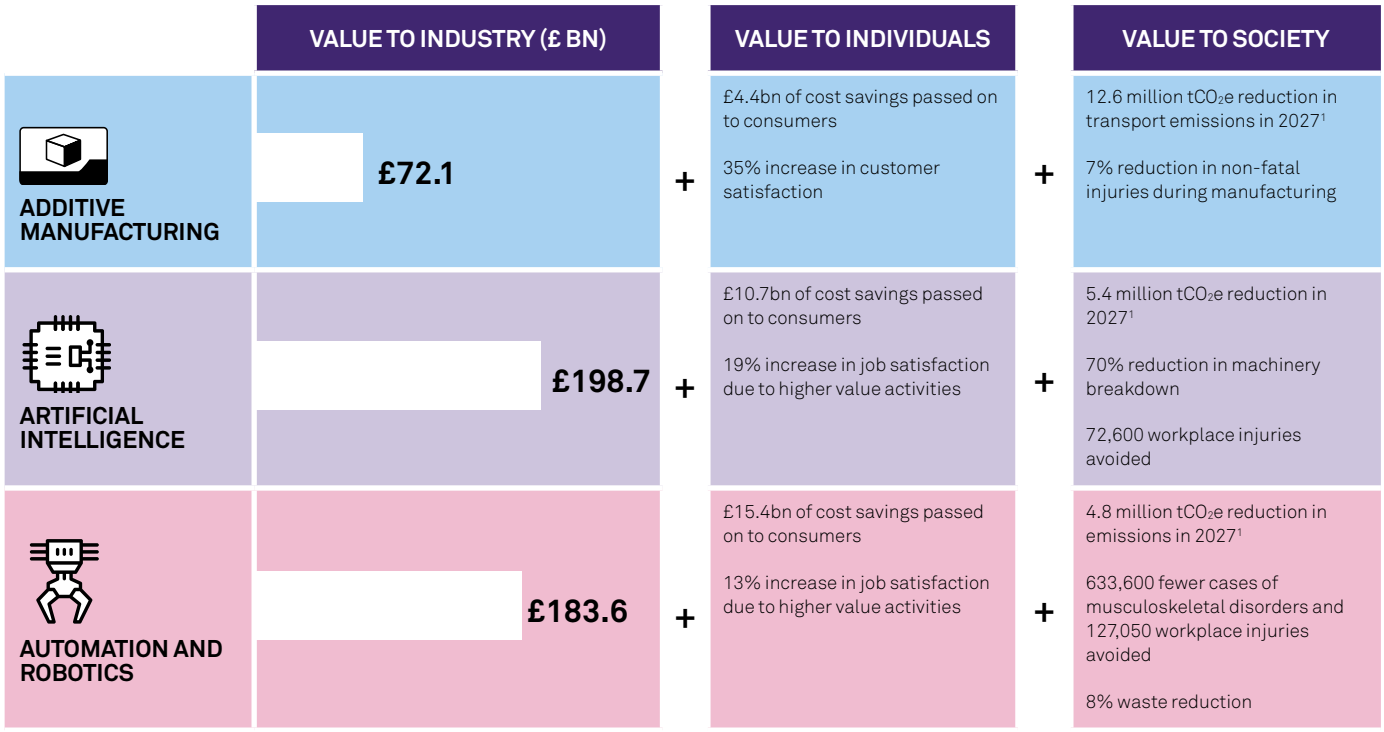


Figure 22

ADDITIVE MANUFACTURING

The application of additive manufacturing technology within UK industry can provide a value at stake of £72.1 billion to the UK economy – with additional benefits for both the individual and society

Additive manufacturing (AM) refers to the successive adding of layers of material using generic "3D printing" machines. It presents an opportunity to radically transform certain manufacturing lifecycles, changing the very limits of what can be physically and economically produced. It disrupts existing concepts of business models and supply chains, bridging the worlds of the digital and the physical. In principle, it allows even the most complex designs to be digitally transmitted for production at the point of demand. AM offers the potential for rapid prototyping, radical design innovation, lower tooling costs, reduced time to market and lower production costs and emissions – particularly for custom/low-volume/high-complexity components.

AM is one of the key enablers of the Fourth Industrial Revolution. While the directly attributable value of AM products and services is currently a modest £300 million (£6 billion worldwide), employing about 35,000 people in the UK, it is experiencing a steady CAGR of around 30 percent. And this growth is expected to accelerate as issues of standards, raw material consistency, IP protection and parts verification are addressed.

The UK is among the world's leaders in the research, innovation and adoption of AM technology for high-performance applications in medicine, aerospace and other industry sectors. The country has a world-class AM machine manufacturing capability, well-established national centres for AM (The Manufacturing Technology Centre), university excellence in AM research, and a relatively small but solid foundation of companies applying AM within product

development activities for prototyping and tooling. Industry is expected to invest £600 million over the next five years, and spend more than £30 million on AM-related research.

Yet many UK companies, especially within the SME community, lack the awareness, resources or confidence to apply AM as a core and integral part of their manufacturing toolkits. A recent global survey conducted by EY revealed that only 17 percent of UK companies have any experience with AM (compared with 37 percent in Germany and 24 percent in China, which have significant government support). Over 50 percent of Chinese and South Korean companies expect to use AM technologies for production parts within five years.

For those UK companies that are using AM technologies, the revenue it generates only accounts for approximately 1 percent of overall company revenue. This compares with 8.8 percent in the USA and a 2 percent average across all countries. It is clear that, in the application of AM, the UK is beginning to lag behind other nations. Those nations, particularly the USA, China, Germany and Italy are seeing AM adoption and growth rates much higher than in the UK largely because they have strategic government investment programmes backing up AM-based industrial strategies. It is estimated that the UK has a window of less than two years to reverse this trend if it is to avoid a serious threat to its status as a top-ten global industrial manufacturing player.

While the number of UK organisations involved in AM is growing, the picture is somewhat disjointed. The 2012 UK Research Mapping Report found that "the manufacturing community in the UK is highly fragmented with organisations only networking through projects rather than through a structured network, community of interest or association".[68] For the most part, UK manufacturing companies (particularly within the SME community), view AM as a somewhat immature technology that may offer benefits in terms of prototyping, but for which the barriers to entry for full production applications are too high.

What is required is a more co-ordinated approach to pull through the UK's world-leading research and innovation to improve process efficiency and material choice, to consolidate critical know-how in design, production and testing, and to de-risk private investment in the supply chain (materials, machinery, software, and skills).

ARTIFICIAL INTELLIGENCE

- The application of AI in industry offers £198.7 billion value at stake to the UK economy between 2017 and 2027.
- The 2016 Accenture report 'Why Artificial Intelligence is the Future of Growth', conducted with Frontier Economics, proposes that the productivity enhancing impact of AI can add £650 billion GVA to the UK, with a productivity level 25 percent higher than would otherwise be the case.[69]

AI, whether in the form of augmented intelligence, cognitive computing, or machine learning, is set to touch every facet of our work and personal lives. And it has the power to radically transform them for the better. The technology's ability to live up to these lofty expectations has only recently become possible with the advent of high-performance cloud computing and widespread connectivity. The vast amounts of data necessary to deliver value from AI are now becoming available in many forms, not least through cost-effective data capture devices and sensors.

[68] UK Research Mapping Report 2012

[69] https://www.accenture.com/lv-en/_acnmedia/PDF-33/Accenture-Why-AI-is-the-Future-of-Growth.pdf

A significant part of AI's economic benefit will come from the combination of AI systems and people, allowing the current workforce to focus on the parts of their job that add the most value. Adding an AI capability also allows the better use of existing capital investments, improving efficiency and quality as well as reducing costs.

AI is expected to change the nature of work by augmenting human skills. But, as with each successive technological revolution, there are fears about its impact – especially around reduced employment. However, the experience of using AI to date supports the view that more jobs (and, what's more, higher-value jobs) will be created than will be displaced (see Figure 19).

The UK has a comparative advantage in developing AI technologies, with a thriving ecosystem of researchers, developers and investors. A CBI survey in May 2017 revealed that AI tops the list of technologies that UK organisations plan to invest in over the next five years. But it also highlights that, while leaders in a number of UK businesses are taking steps to realise the benefits of AI, the slow uptake of others risks creating a divide and leaving many companies behind.[70]

In speaking with UK businesses as part of our review, we found that many are confused by the hype surrounding AI, and a lack of specific information on how the technology can solve specific business problems. Furthermore, those who overcome these initial challenges then find it difficult to build a business case to invest. A lack of case studies makes quantifying ROI and de-risking projects difficult. A gap exists between those who have started to resolve these issues and those who have not. But even the leaders appear to be implementing point solutions rather than making AI investment part of an overall strategy. In addition, businesses raised concerns about how predictable the outcomes from machine learning would be.

Another issue for UK companies is the need to navigate a complex ecosystem of suppliers, customers, academic institutions, government, regulators and other stakeholders. The complexity of this ecosystem acts as a disincentive to the adoption of AI technologies. Businesses also cite the problem of inadequate AI skills. These limitations fall into two distinct groups. The first concerns the skills necessary to understand, develop and deploy AI solutions. The second and potentially larger concern is the ability of the existing workforce to work alongside AI technologies.

Finally, businesses expressed a variety of concerns about sharing and processing data. These range from an understanding of the data an organisation processes, and its value, through issues of protection, security and liability when sharing and processing that data, to the interoperability standards that will facilitate sharing.

AUTOMATION AND ROBOTICS (ELECTECH)

- The application of automation and robotics within UK industry provides a value at stake of £183.6 billion to the UK economy – with additional benefits for both the individual and society.
- Barclays estimates that an accelerated level of investment in robots could raise manufacturing GVA in the UK by 21 percent over ten years.
- Copenhagen Business School identified productivity improvements of 22 percent if the UK invested in automation in line with the best in class for each industry sector.

[70] http://www.cbi.org.uk/news/half-of-firms-expect-ai-to-transform-their-industry/

ElecTech refers to the industrial application of electronics, electro-technical, and embedded software technologies. It is a core part of the digitalisation of manufacturing, providing many essential skills, components, and capabilities. The ElecTech sector is widely regarded as driving some of the greatest innovation and creativity in any advanced economy (source: ZVEI).

Almost every aspect of the digitalisation of industry rests on many different ElecTech technologies, from communications to power subsystems, and from embedded processing for automation and control to intelligent lighting and security systems. Advanced ElecTech computation powers everything from the largest datacentres to the smallest sensors and servos, doing everything from day-to-day computing to accelerating AI-based machine learning, and making every electric motor smarter and self-maintaining. Without ElecTech, industrial digitalisation simply could not happen.

ElecTech is a major sector in the UK, employing more than a million people in over 45,000 companies. Indeed, the UK has one of the strongest intellectual property capabilities in ElecTech in the world. It already attracts significant inward investment from companies like Apple, Google and Amazon thanks to our strengths in ElecTech technologies and early adopters in the automotive, aerospace and creative industries.

Many of the ElecTech technologies essential to the future of automation and robotics have industry leaders here in the UK, including those producing silicon chips (ARM), sensors (Renishaw), AR/VR (Imagination), AI (GraphCore), power (Dynex Semiconductor) and communications (5GIC Surrey and CSR, now part of Qualcomm).

The UK already has world-leading research institutions in robotics, in fields as diverse as healthcare, subsea autonomous vehicles and vacuum cleaners. Groups such as the Edinburgh Centre for Robotics, Sheffield Robotics, Bristol Robotics Lab, and Imperial College's Hamlyn Centre are all recognised as significant contributors and innovators in global robotics research.

Furthermore, the UK has some highly innovative robot companies. These include the Shadow Robot Company (artificial hand robots), Peak Analysis and Automation (laboratory robots), Engineered Arts (human-emulating interactive robots) and Tharsus (warehouse robots for Ocado and others). Dyson is an example of a consumer goods company investing tens of millions into robotics for household appliances. And automotive multinationals, such as Jaguar Land Rover and Nissan, have already seized on the benefits of robots as a key part of their automation strategies in the UK.

However, overall uptake of manufacturing automation in the UK is disturbingly slow compared to most other developed nations. The UK has only 33 robots per 10,000 employees (compared with 93 in the US and 170 in Germany) (source: IFR). What's more, the gap is widening. Germany invests 6.6 times more than the UK in automation, although its manufacturing sector is only 2.7 times the UK's in size (source: ZVEI). The key reasons for this are public perception, lack of ambition, aversity to risk, shortage of skills, and finance.

The design, deployment and support of robot-based manufacturing systems has been embraced by most G7 countries such as Germany, France, Italy and the US, as well as powerhouses such as China (see Made in China Appendix 2) and South Korea. They see it as a key to increasing productivity. They recognise that automation changes the underlying economics of manufacturing, enabling them to create high growth and better productivity, and enabling their factories to make more competitive products – whether cars, furniture, food or clothing.

CONNECTIVITY AND THE INDUSTRIAL INTERNET OF THINGS

- The IoT is predicted to generate up to $11 trillion in value for the global economy by 2025.[71]
- The IoT will bring 67,000 jobs to the UK by 2020.[72]
- Adopting the IoT on an industrial level (the IIoT) could boost the UK economy by £352 billion by 2030 (Accenture).
- IIoT expenditure is expected to reach around $500 billion by 2020 (from $20 billion in 2012).
- The IIoT could create $15 trillion of global GDP by 2030.[73]

The Industrial Internet of Things (IIoT) brings together a number of technologies to drive more informed, faster business decisions for industrial organisations. It combines cutting-edge machines, advanced analytics and a plethora of devices that connect with each other through communication technologies. That connectivity allows the data collected by those devices to be monitored, exchanged and analysed to deliver valuable insights for industrial companies.[74]

The IIoT allows traditionally non-digital companies to build a data footprint through sensors and the monitoring of equipment and machinery. This data footprint then allows new business models to develop and provides greater opportunities for the digital sector to work closer with industry.

To make this happen, a connectivity infrastructure is needed to underpin the factories of the future. From Low Powered Wide Area Networks (LPWAN) to next-generation 5G internet, improved connectivity is essential in utilising the technologies that underpin the Fourth Industrial Revolution. 5G is estimated to enable US$12.3 trillion of global economic output by 2035.[75] LPWAN will allow connectivity at a much lower cost and increased reliability when compared to traditional mobile connectivity (3G, 4G, etc.). That will reduce the cost overheads for manufacturing SMEs and ensure reliability for IIoT networks across geographically wide and often hard to reach parts of factories.

Manufacturers also need to become more aware of cybersecurity strategies and increase investment in the prevention of cyber-attacks.

The UK is home to a rapidly growing community of companies developing and commercialising IoT component technologies, products and services. The UK government has invested significantly in the connected technologies sector through the £32 million of funding awarded to the IoTUK programme in the 2015 Budget. IoTUK is a national initiative designed to support IoT development and uptake in the UK, through applied research, demonstrating the technology at scale, attracting international investment and supporting small companies.[76]

[71] Unlocking the Potential of the Internet of Things by James Manyika et al. http://bit.ly/2eRn6X8

[72] AS Big Data Internet of Things http://bit.ly/2nr38sm

[73] "The Growth Game Changer" by Mark Purdy and Ladan Davarzani, https://accntu.re/2mHhAb

[74] "Everything you need to know about the Industrial Internet of Things" by GE Digital http://invent.ge/2eqfX43

[75] IHS Economics / IHS Technology "The 5G economy: How 5G technology will contribute to the global economy" 2017 http://bit.ly/2rWtnta

[76] The IoTUK programme includes academic research (PETRAS), hardware accelerators (StartUp Bootcamp and R/GA), large-scale demonstrators (CityVerve and two NHS Testbeds) and dissemination models to increase take-up rates (Future Cities Catapult and NHS England). The Digital Catapult provides co-ordination, SME acceleration and amplification services to the programme.

IoT research is also vibrant in the UK, with much of it driven by universities. As part of the IoTUK programme, the start of 2016 saw the launch of PETRAS, a new IoT research hub for the UK,[77] underpinned by a £9.8 million grant from the Engineering and Physical Sciences Research Council (EPSRC),[78] and boosted by partner contributions to approximately £23 million, which will research many of the challenges facing IoT developers – including issues around ethics, privacy, trust, reliability, acceptability and security.

The IIoT is also crucial in driving efficiencies via analytics. More than two-thirds of analytics professionals believing industrial analytics will be fundamental to business success by 2020 – and 15 percent think that it is already crucial today. Those professionals expect predictive and prescriptive maintenance of machines (79 percent), customer/marketing related analytics (77 percent) and analysis of product usage in the field (76 percent) to be the most important applications of industrial analytics over the next three years.[79]

VIRTUAL REALITY AND AUGMENTED REALITY

- Goldman Sachs Global Investment Research estimates a potential VR and AR user base of 6 million engineers in the US, Europe and Japan.
- A global market of $80bn by 2025.[80]
- VR in the UK entertainment and media industry alone will reach a value of £801 million by 2021, making it the fastest-growing and largest VR industry in EMEA.

Virtual reality (VR), which immerses users in a computer-generated world, and Augmented Reality (AR), which overlays digital information onto the physical world, are already reshaping existing ways of doing business and have the potential to increase productivity in engineering and manufacturing. Already widely adopted by the retail and marketing sectors, manufacturing is now driving AR's enterprise adoption.

In a recent report, PwC identified nearly 500 UK companies or institutions who have adopted or invested in VR or AR in the past year. However, this is only the start. The UK hosts a number of notable companies in the industrial VR/AR field, including Autodesk, Virtalis, and Eon Reality, and it is this applied sector in which much of the future industrial value lies. For example, the construction industry is exploiting the technology to leapfrog and modernise the whole sector through rapid training and increased quality, efficiency and safety of workers. The Construction Leadership Council believes that through digital technologies – mainly AR and VR – there is immense potential to transform the industry.[81]

ImmerseUK (a UK national body launched in 2016 and supported by InnovateUK) is bringing together the community of industry developers, researchers, government bodies and end users to support the UK in becoming the global leader in the application of immersive technologies – including high-end visualisation, VR, AR, haptics and other sensory interfaces. This mixed community promotes interaction between industrial sectors and incubates innovative solution development. It also allows manufacturers to have direct access to technology start-ups which may not currently have engineering and manufacturing users for their products.

[77] http://www.petrashub.org

[78] http://www.epsrc.ac.uk

[79] Industrial Analytics 2016/17 by Knud Lasse Lueth et al. http://bit.ly/2li6PM1

[80] Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform, Goldman Sachs Global Investment Research, 13 January 2016

[81] A New Reality: Immersive Learning in Construction, October 2017

This connection between solution providers and end users will be key to promoting the UK as a leader in the development and use of applied visualisation.

VR and AR are already being used by manufacturers to support the development of complex assemblies, planning for the maintenance of equipment and products, the provision of remote expert support, as well as higher quality assurance and increased productivity. For instance, when the UK division of the Hosokawa Micron Group looked to improve its productivity, this innovative powder processing company decided to couple its market-leading equipment and services to the world of Virtual and Augmented Reality, and then to further harness this to data analytics. The result has been to transform a business whose revenue and growth had appeared to be plateauing to one with a target operating income rarely seen in the industry.

Other users of VR and AR include companies like BAE Systems who are using technology developed by the video games industry to build warships for the Royal Navy more cheaply and efficiently, and, in the process, directly support the aspirations of the National Shipbuilding Strategy.[82] This defence and aerospace company has started to employ 3D VR, allowing engineers and sailors to "walk" through life-sized computer-generated versions of the ships they are working on.

It is in these potential scenarios, from validating design (VR), to virtually prototyping manufacturing processes (VR), to validating assembly procedures (VR/AR) and delivering operational support (AR) where true value will be obtained. The strategy 'fail fast, but fail virtually' and provide a 'many to one' support through the adoption of Virtual and Augmented Reality is where true productivity gains can be made.

[82] National Shipbuilding Strategy: The Future of Naval Shipbuilding in the UK, September 2017

PART 3
WHAT IS STOPPING THE UK ACHIEVING THE IDT VISION?

6

Part 3 – What is stopping the UK achieving the IDT vision?

Our review identified three key themes that are preventing the UK becoming a leader in IDT. These are adoption, innovation and leadership. We now consider each of these themes in turn.

ADOPTION

- The UK is behind most developed countries in overall productivity (output per worker), which is in part due to lower levels of adoption of digital and automation technology.[83] This is particularly acute among SMEs.
- Another potential cause of this productivity lag is an ineffective and confused landscape of business support for IDTs, with no clear route to access help and ambiguity about what 'good' looks like.
- SMEs, in particular, perceive significant barriers to IDT adoption, such as risks around cybersecurity, a lack of common standards allowing different technologies to connect, and access to funding to support investment.
- Businesses also face a skills shortage, particularly in digital engineering, hindered by a fragmented skills system and a lack of systematic engagement between education and industry.

International studies have identified that UK Industry is less prepared than many of its leading competitors to exploit the opportunities of the Fourth Industrial Revolution. The Boston Consulting Group found, for example, that only 9 percent of UK respondents had made large progress, compared with 11 percent in France, 13 percent in China and 14 percent in Germany – and the variation was greater when intermediate progress was considered.[84] The EU Digital Transformation Index 2017 placed the UK 11th in an EU ranking of digital readiness, citing the UK strengths as its entrepreneurial culture, e-leadership and access to finance, while scoring it low for skills, infrastructure, and the integration of technologies.[85]

The digitalisation of industrial production requires the diffusion of key IDTs. However, many businesses lag in adopting the technologies. For example, the adoption of cloud computing, SCM, ERP, and radio-frequency identification (RFID) applications by firms is still much below that of broadband networks or websites. European Commission data for 2015 shows a very low proportion of UK companies using ERP systems to share data internally and enhance productivity. At 17 percent of all enterprises, this is around half the EU average. The problem is concentrated in companies with fewer than 250 employees, although large companies are still 20 percent lower than their EU counterparts.[86] Nevertheless, it is these advanced ICTs that enable the digitalisation of industrial production. The EU Digital Intensity Index (DII), a micro-based index measuring the availability of twelve digital technologies to businesses, places the UK 14th.[87]

Our review identified a number of reasons for this low level of adoption, including a lack of awareness of IDT availability and opportunities (see Figure 24). The net impact is low levels of investment, poor levels of productivity, and ageing capital stock.

[83] BCG, Sprinting to Value in Industry 4.0, Dec 2016

[84] BCG, Is UK Industry ready for the Fourth Industrial Revolution?, Jan 2017

[85] Digital Transformation Scoreboard: European Commission 2017

[86] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_bde15dip&lang=en

[87] For the Digital Intensity Index see the Digital Economy & Society Index (DESI), http://digital agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/visualizations

When BDO and the Institute of Mechanical Engineers interviewed UK manufacturing companies in 2016, they found similar results. Only 8 percent[88] of respondents had a good understanding of Industry 4.0 or industrial digitalisation processes, despite 59 percent of them recognising that the Fourth Industrial Revolution will have a big impact on the sector. A third of reported companies had invested no money in automation systems and Industry 4.0 related technology in the preceding 24 months and a quarter had no plans to invest in this area in the next two years. Perhaps most notably, 44 percent cited a lack of understanding as the main reason they are not currently investing.

This failure to adopt IDT is affecting the UK's productivity. According to the Bank of England,[89] around a third of UK businesses have experienced no productivity increase since 2000 – and for every frontier company, there are two or three pushing down the average. This lagging productivity is in part due to a long tail of companies that have not adopted IDT at scale. And it is particularly acute among industrial SMEs. A recent Boston Consulting Group study found 21 percent of UK industry had no Industry 4.0 goals, more than double the size of the equivalent "tail" in France or Germany.[90]

The UK industrial structure is based on a small number of large organisations who have the capacity and capability to provide leadership in digital adoption. However, 99.4 percent of UK companies are SMEs, with limited capacity and capability to adopt digital. Industrial SMEs frequently lack the information, expertise and skills, training, resources, strategy and, moreover, the confidence to adopt new technologies. And suppliers and private consultants can face high transaction costs in trying to diffuse digital technologies into these businesses.

The SME sector provides significant growth opportunities. There is more opportunity to address productivity disparities between "the best and the rest".[91] The McKinsey Global Institute estimates that 55 percent of potential productivity gains in developed countries comes from catching up to best practice, whereas 45 percent comes from pushing the frontier outwards. This could even be more pronounced in the UK due to its relatively high proportion of SMEs.

The CBI suggests that improving growth in manufacturing subsectors could boost the economy by as much as £30 billion by 2025, creating over 500,000 jobs across UK regions. Enhancing the UK's domestic supply chain could also create sustainable semi-skilled and skilled manufacturing jobs across the UK, rebalance regional disparities in earnings, and reduce the industry's reliance on international supply chains.

The Institute for Manufacturing has identified that UK supply chains remain relatively weak. For instance, only around 40 percent of the parts used in vehicles assembled in the UK are sourced domestically. And, overall, only around half of manufactured parts used in the UK are sourced domestically, compared with 90 percent in services. Low UK activity in a number of sectors has contributed to a long-run trade deficit which, despite a remarkable increase of service exports over the last few years, still stands at around £30 billion.

Most other developed countries have active government interventions to promote leadership and the adoption of IDT within their industrial bases (see Figure 23). For example, Germany has Industry 4.0, the USA have 'America Makes', China has 'Made in China 2025', France has 'Industrie du Futur', Sweden has 'Smart Industry (SE), Switzerland has 'Produktion der Zukunft',

[88] BDO; INDUSTRY 4.0 REPORT June 2016

[89] Haldane, A. G. (2017), Productivity puzzles, Speech given at the London School of Economics, 20 March 2017.

[90] BCG, Is UK Industry ready for the Fourth Industrial Revolution?, January 2017

[91] New Industrial Capabilities for New Economic Growth A Review of International Policy Approaches to Strengthening Value Chain Capabilities, University of Cambridge

Italy has 'Piano nazionale Industria 4.0', Spain has 'Industria Conectada 4.0', and Japan has its Robot Strategy (RRRC, 2015). What's more, in July 2017, China outlined a development strategy to become the world leader in AI by 2030.[92]

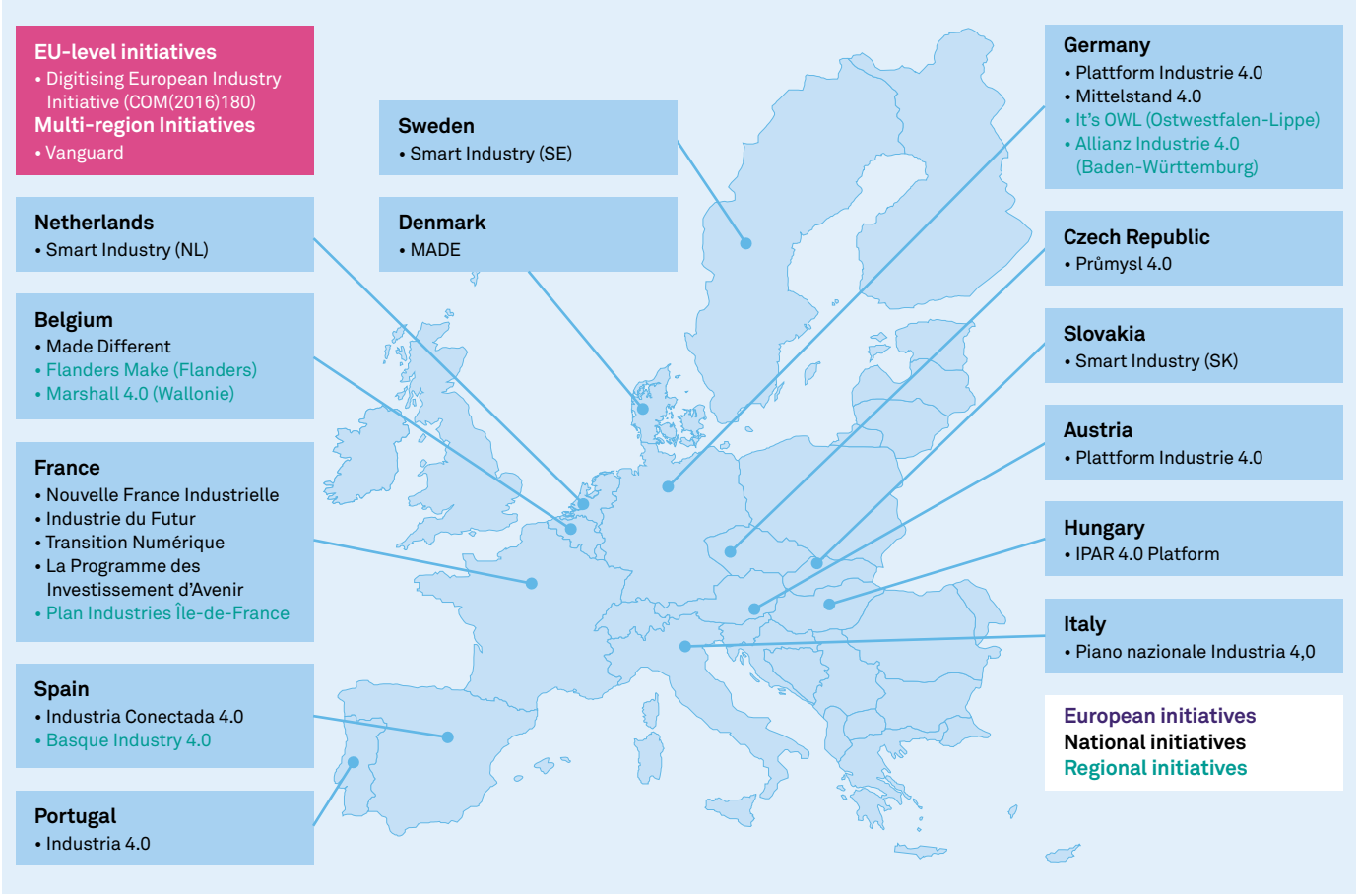


Figure 23

At the European level, there are Digital Innovation Hubs within Horizon 2020, where around €500 million is programmed over the period 2016 to 2020, including initiatives such as I4MS and SAE. Incubators are being set up under the Big Data PPP, and activities such as pilot lines in nanotechnology and advanced materials under the NMBP work programme are underway, as well as a network of technology centres providing services to SMEs in advanced manufacturing for clean production under the INNOSUP work programme. Other initiatives include a catalogue of competence centres in key enabling technologies, a pan-European advanced manufacturing support centre assisting SMEs in transforming their organisations for the factory of the future and setting up learning networks of factory of the future companies. See Appendix 2 for an overview of international interventions.

At national level, several EU member states have launched initiatives relating to the digital transformation of industry, some with a policy focus, others more concerned with research and innovation. Around ten policy-level initiatives or platforms are already active, and more are planned. Examples include Mittelstand-Digital Competence Centres in Germany and Fieldlabs in the Netherlands.

[92] Economist, 29 July 2017, AI in China

WHAT ARE THE BARRIERS TO ADOPTION?

As part of our review, we surveyed manufacturing companies and held workshops to identify the key barriers to IDT adoption (see Figure 24). We found concerns about:

- Cybersecurity,
- Slow internet connection speeds,
- Legacy equipment,
- Limited understanding of technologies and their potential opportunities,
- Loss of IP,
- A lack of trusted advice,
- A perception of high cost and risk of IDT deployment,
- Most importantly, a lack of skills.

Many small firms often have difficulties in implementing organisational change. They usually have limited resources, including a shortage of skilled personnel. This scarcity of technical skills can often result in a lack of awareness about the productive potential of ICTs. A recent study on the impact of digital change on skills and employment in Germany suggests that the "ability to plan and organise, to act autonomously", combined with company-specific and occupation-specific working experience, are crucial for the successful digital transformation of businesses.[93]

The findings of our review reinforce results from other surveys. For example, the Lloyds Bank 2016 digital index reported that the highest barriers to adoption were the lack of skills (15 percent), no relevance to the business (14 percent), and concerns about security (14 percent).

Other studies have found businesses citing a lack of time, resources and low priority,[94] and technology lock-ins,[95] often due to the use of proprietary solutions, as well as a lack of (open) standards. A World Economic Forum executive survey (WEF, 2015) confirms that this lack of interoperability ranks among the top three barriers to IoT adoption (after security concerns, but before uncertainty in the return on investment). Furthermore, there is evidence that most data generated by sensors does not reach operational decision makers due to interoperability issues (McKinsey Global Institute, 2015).

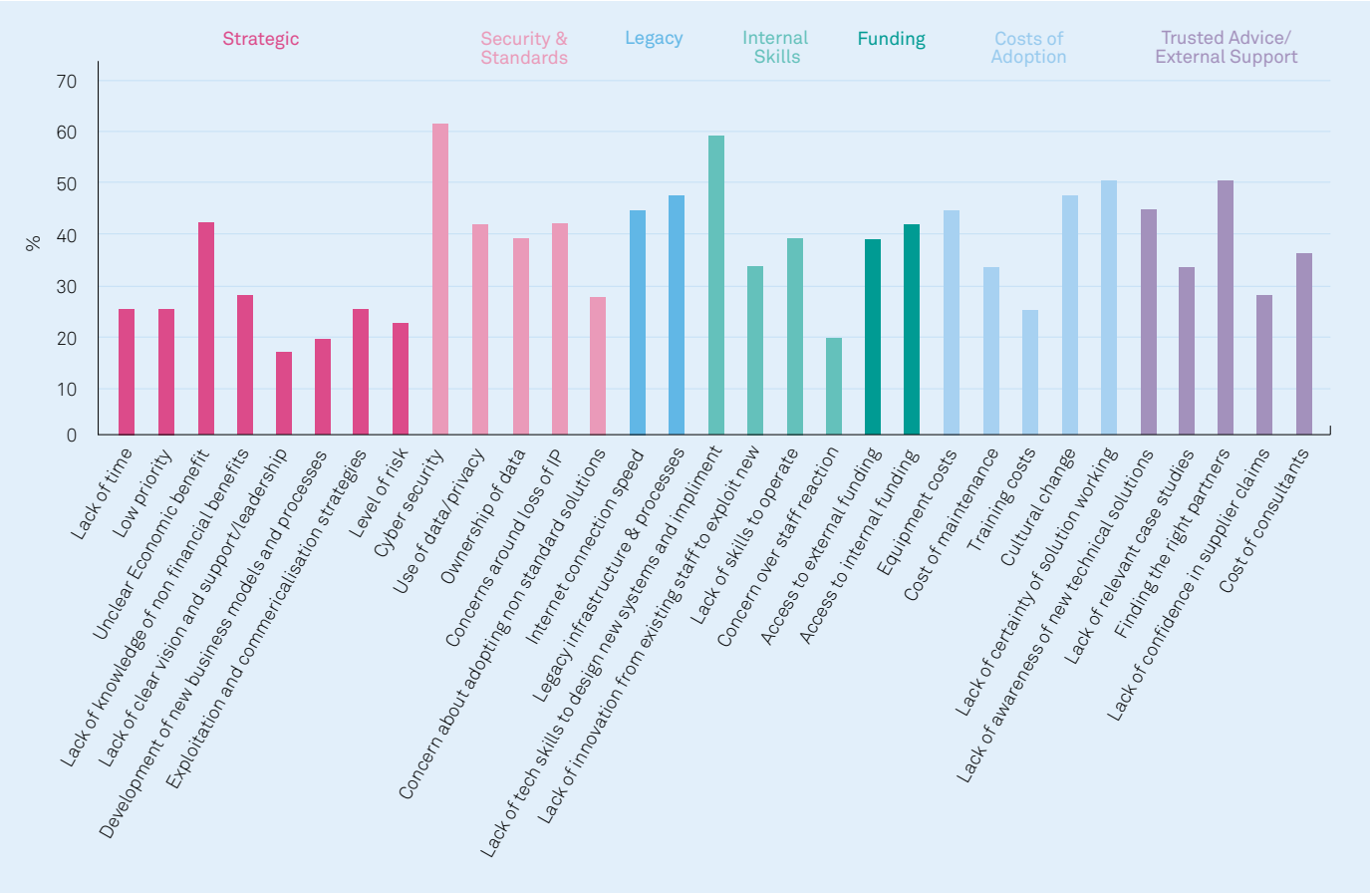
[93] Hammermann and Stettes, 2016

[94] State of Digitisation in UK Business - Strategic Labour Market Intelligence Report David Mack-Smith, James Lewis, Mark Bradshaw - SQW

[95] The Next Production Revolution – Implications for Government and Business - OECD

INDUSTRIAL DIGITALISATION

Survey finding implied 7 key barriers to industrial digitalisation, with cyber security voted top barrier



BARRIERS

- **Skills shortages**
- **Limited industry 4.0 understanding**
- **Limited access to innovation**
- **Poor infrastructure**
- **Perceived cost**
- **Limited empirical evidence**
- **Weak data security & legislation**

Figure 24

Skills

The greatest barrier to IDT adoption is the lack of skills. There is already an identified shortage of digital skills in the UK economy, and the demand for these skills is projected to increase. It has been predicted that, within 20 years, 90 percent of all jobs will require digital skills. This means that approximately 16.5 million people in the UK are going to need to be skilled to become 'digital workers' and 'digital makers'. Yet, there are 10.5 million people currently lacking basic online skills, the majority of whom are aged over 55, and many of whom are working in sectors where digitalisation will be crucial to keep the UK competitive internationally.

The pace of change unleashed by digitalisation means that around two-thirds of children in primary school today will work in jobs which do not even exist yet. The nature of employment is also continuing to change. The days of working for a single employer have ended. Individuals will have a number of careers over their working lives and will need to continually reskill to be relevant in the marketplace. There is a need to develop a culture of lifelong learning and

reskilling, such as the Singapore "skills future program". And there is a need to improve visible career pathways for adults, such as those in the US (Van Horne et al 2015).

While young people will acquire basic digital skills by default because of digital's pervasive nature, to be truly employable more advanced skills are required. Digitalisation will offer real benefits to older workers and to the sectors where there are larger concentrations of such workers. This group must acquire basic and then more advanced digital skills specific to their sector and nature of work in order to remain employable as technology advances. And, because around two-thirds (65 percent) of the workforce of 2030 has already left the education system, the UK cannot rely on the education system to satisfy industry's demand for digital skills in the short to medium term. In an industrial sector which employs around three million workers, this means that two million people will potentially need to be upskilled or reskilled in the workplace.

Technology can help make more efficient use of existing workforces. In construction, for example, the World Economic Forum has mooted that innovations which are already commonplace in the automotive sector, such as human-robot collaboration and exoskeletons, could make working in the sector less physically demanding and thus better suited to an ageing workforce. So, although in the longer term these sectors do need an influx of younger talent, in the immediate to medium term the looming skills crises could be averted by using existing workers more efficiently. This carries added importance because improvements in workforce efficiency would positively impact the UK's productivity. And lagging productivity is a key drag on the UK's economic performance.

The skills shortage is particularly acute in industry, where there are shortages of engineers, especially at the higher technical levels (e.g. Level 4/foundation degree equivalent). If the UK is going to lead in the new and emerging IDTs it needs enough people with the skills to support them, either within current businesses or as pioneers at start-ups.

For example, additive manufacturing (discussed in the preceding part of this report) is an area in which there is potential for the UK to lead. The technology is still to be adopted on a wide scale by industry, but it is consistently being refined, with 'print' times falling and techniques becoming more sophisticated as more materials are brought within scope. UK industry is investing heavily in additive manufacturing research and prototyping, but insufficient skills in its use among the wider workforce could hamper more widespread adoption in manufacturing processes. And it could prevent start-up enterprises and market disruptors from launching in the UK, despite its relatively flexible approach to innovation.

Even in the face of this skills shortfall, employers continue to underinvest in skills development. Employers in the UK spend half as much on continuing vocational training as the EU average (Eurostat 2010). Employer investment per employee in training declined by 13.6 percent for each employee in real terms between 2007 and 2015 (Dromey and McNeil 2017). Declining employer investment would be concerning at the best of times, but it is all the more so at a time in which public investment in skills for those in work is being cut. The adult skills budget was cut by 41 percent between 2010/11 and 2015/16 (Foster 2017), and the criteria for access to funding have been tightened.

The stop–start nature of government education policy has resulted in a confusing landscape. Different conditions are applied to available funding. The system is difficult to navigate and there is a fragmented offer for employers and individuals alike. Policy changes, caused in part by political change and frequent changes of Ministerial responsibility for skills, has been identified as one key cause of this fragmentation (Institute for Government, 2017).[96]

[96] https://www.instituteforgovernment.org.uk/publications/all-change

There is currently no overarching body which focuses on digital engineering and represents industrial demands and requirements. And there are, at present, no national skills standards for digital engineering, and no National Occupational Standards (NOS) to underpin industrial digital job roles on a UK-wide basis. There are also no Standard Occupational Codes (SOC) for these roles, which means they are not accounted for individually in government data banks such as the Business Register and Employment Survey (BRES). This results in a lack of understanding of industry skills standards and the specialist training available, and leads to under investment in skills. The existing skills system and the training provided is focused on job requirements for today, not for the future. There is a lack of expertise within higher education, further education and schools to support employer needs.

Cybersecurity

Without data security it will be particularly difficult to convince SMEs that digitalisation of their businesses is the way forward. Only 22 percent of EU citizens have complete trust in internet companies, for example. And, as noted above, 28 percent of manufacturing organisations reported a loss of revenue due to one or more cyber-attacks in the past year (the average lost revenue was 14 percent). According to IBM's Cyber Security Intelligence Index, manufacturing was ranked as the third most frequently hacked industry in 2017. It is a tempting market for cyber-attackers, with systems regarded within the sector as "weak by design as a result of a failure to be held to compliance standards". The industry also suffers almost 40 percent more 'security incidents' than average.[97] The UK manufacturing sector is particularly at risk. According to research from EEF, almost half (46 percent) of manufacturers have failed to increase their cybersecurity investment in the past two years (with 56 percent of this number being small manufacturers). What's more, 20 percent of manufacturers have not made their employees aware of cyber-risks in company policies, as little as 56 percent say that security is given serious attention by their board, only 36 percent have an incident response plan in place, and just 24 percent monitor cyber-threats through business KPIs.[98]

Standards

Standards have been proven to drive productivity growth, as evidenced by recent research papers.[99] They promote the adoption of technologies by companies, both by resolving interoperability issues and by supporting knowledge diffusion. Industrial digitalisation is a relatively new area for standardisation, reflecting the increasingly complex and interdisciplinary nature of technological systems, and, to date, the lead has been taken by countries that have already established their own national programmes in support of digital manufacturing (for example Industrie 4.0 in Germany[100] and the Industrial Value Chain Initiative in Japan[101]). However, there are gaps in what has been proposed, and the current international standards activities do not reflect the priorities of UK industry.

The importance of setting global standards was described by the Government Office for Science in their report Technology and Innovation Futures. They said "acting as a standards setter is one of the government policy levers that can support emerging technologies by using insights from living labs to develop UK standards – setting the global agenda by 'showing, not telling'".[102]

[97] Security Trends in the Manufacturing Industry, 2017, IBM Security https://ibm.co/2yaH2PK

[98] EEF Cyber Security Survey Results 2016, http://bit.ly/2kAFr0u

[99] See, for example, https://www.bsigroup.com/LocalFiles/en-GB/standards/BSI-standards research-report-The-Economic-Contribution-of-Standards-to-the-UK-Economy UK-EN.pdf and http://www.iioc.org/the-economic-value-of-standards/

[100] http://www.plattform-i40.de/I40/Navigation/EN/Home/home.html

[101] https://www.iv-i.org/en/

[102] https://www.gov.uk/Government/uploads/system/uploads/attachment_data file/584219/technology-innovation-futures-2017.pdf

Open standards have been derived for the construction sector, including COBie and IFC, but these are applied with varying degrees of success. Within construction, estimates of productivity gains of between 15 and 20 percent associated with whole life costs of the project have been achieved through modest investment in standards by the UK government (NBS 2016).

Financial incentives

SMEs are risk averse. And they see investment in innovation as a risk that might greatly affect their financial performance and even jeopardise their survival. Digitalising business processes will require innovation, investment in process design, investment in physical assets, software, and technology integration. It calls for behavioural change. And the taxation system is a proven mechanism to alter behaviour.

However, the UK's tax investment incentive system is not targeted enough. Research by Bond and Xing has found "very robust evidence" that more generous capital allowances (for equipment in particular) can help tip investment decisions over the line. It also found a positive link between the 'present value' or worth of capital allowances and investment as a proportion of GDP in G7 countries.[103] Other countries, such as Germany, Poland and Italy, are now offering specific incentives to invest in IDTs (see Appendix 2 and the Italian example below). And in France, the government has introduced an exceptional depreciation scheme for the purchase of industrial robots for SMEs to depreciate 140 percent of the value of their investment.

THE ITALIAN APPROACH

Industra 4.0 was a key pillar of the Italian 2017 Budget in recognition of its productivity potential. Carlo Calenda, Italy's Minister of Economic Development, set out a goal of "replacing half of the investment in innovation that's been lost since the start of the [economic] crisis".

The budget provided €11 billion of government investment, comprising hyper-depreciation (250 percent) and tax shields, the setting up of Digital Innovation Hubs with the help of local branches of the Italian CBI (confindustria), increases in R&D tax credits, and fiscal and economic measures to increase the competitiveness of Italian SMEs.

Results reported to date

- 14.7 percent growth in industrial production machine orders for the third quarter of 2017 compared to the same quarter in 2016 – however domestic demand was up 68.2 percent

Pros

- Non-sectorial, horizontal approach
- Big media bang when it was launched – the Italian industrial base is widespread and had been waiting for something like this for some time
- Likely to be combined with tax credits on training and retraining employees on Industry 4.0 related skills in the next government budget

Cons

- A punctual measure, which might go into next year's budget but could remain a one off – thus truncating its potential benefits
- Digital Innovation Hubs are taking a long time to set up – by the time they are ready, the measure might already be over

[103] Race to the Top: developing a Corporation Tax regime to support sustainable growth CBI Policy Briefing #3

Business support

When it comes to supporting SMEs overcome the barriers to IDT adoption, our review revealed that they found the support landscape is confusing, geographically differentiated (there are 133 different schemes available within Cheshire alone, defined by post codes), subject to short-term, initiative-driven change, focused on employment in detriment to efficiency, and reliant on European funding (e.g. the ESIF operational programme 2014–2020) which will cease in the near-term future. Due to a lack of UK direction, individual regional bodies have developed their own localised strategies. For example, LCR 4.0 in the Liverpool City Region is delivering targeted digital manufacturing support to 300 manufacturing SMEs over three years.

The quality of support programmes provided to SMEs varies throughout the regions, which adds to the confusion. In addition, the gap created by the dissolution of the Manufacturing Advisory Service has not been bridged within some regions.

Summary

In summary, our review identified the following blockers to IDT adoption:

- The support landscape is confusing, geographically differentiated, and subject to short-term, initiative-driven change.
- Companies lack understanding of where they stand in comparison to their peers and of how they can start their digitalisation journey. Nor do they understand if funding is available to de-risk their investment.
- The quality of advisory support provided to SMEs varies throughout the regions due to lack of skills in IDT.
- Specialised technical and market knowledge is costly and, as a result, not all businesses have the basis for making informed technology investment decisions.
- There is no recognised independent source of advice about what IDT solutions are available and which are appropriate to adopt.
- Many SMEs have a low absorptive capacity to update production processes and undertake the development of new products.
- In addition, many SMEs do not have the time, capacity or funds to partner with universities or research and technology organisations.
- SMEs are risk averse and see investment in innovation as something which could greatly affect their financial performance – and even jeopardise their survival.
- Access to state-of-the-art research, engineering expertise, and equipment is not typically readily available.
- Businesses also face a skills shortage, particularly in digital engineering capability, hindered by a fragmented skills system and a lack of systematic engagement with industry.
- Some larger firms underinvest in their supply chains due to fear of helping competitors.
- Larger companies are not exploiting the creativity and agility of small, research-intensive manufacturers which could be a source of innovation.
- Lack of SME involvement in innovation activities impacts the long-term competitiveness of advanced manufacturing sectors that require continuous innovation and kick-start funding.
- Technology companies find it expensive to deal with large numbers of SMEs.
- Businesses lack knowledge of the potential of new technology adoption, particularly when relevant technologies originate in other sectors.
- The high level of legacy infrastructure due to a low level of investment in capital equipment, the adoption of new technologies, and process improvements.
- A lack of standards and interoperability.
- Concerns over data breaches and cyber-standards.
- Sharing of information resulting in a loss of IP.

INNOVATION

The UK is a leader in research and innovation and has started to establish a favourable supporting infrastructure to develop and commercialise technology. However, these innovation assets are under-leveraged and not focused enough on supporting both IDT and start-ups, meaning the UK is falling behind other nations in creating innovative new companies and industries.

Our review found that the current industrial R&D environment is uncoordinated. As such, there is a significant duplication of effort. The number of spin outs from universities and research institutions into manufacturing is too low. And there is a lack of help for researchers to directly engage with industry and inspire them to see new business opportunities. There needs to be a better connection between manufacturers and research institutions to ensure they develop solutions to real-world challenges.

An OECD study on the implications for policymakers in supporting the Fourth Industrial Revolution[104] identified three significant international trends. Firstly, international studies have identified that, in addition to their core activities related to technology research, research institutions are also increasingly carrying out a range of complementary innovation activities. These complementary activities include: advanced skills development, access to specialised equipment and expert advice (particularly for SMEs), the provision of test beds for new production processes and products, and stakeholder engagement and network formation. In addition, some institutions, in collaboration with economic development agencies, use their technical capabilities to attract foreign direct investment and support regional development. A positive UK example is the investment by McLaren in a new manufacturing facility on the Sheffield technology park near to the Advanced Manufacturing Research Centre (AMRC). Singapore's Institute of Manufacturing Research (SIMTech) is another good example of an institution that has built on its core research function to provide a broader range of complementary innovation functions. And in the USA, the Information Technology and Innovation Foundation (ITIF) have proposed taking a small percentage of all federal R&D funding and putting it towards 'technology commercialisation activity' – for example, capacity building grants, accelerators, proof of concept stages and other common pitfalls around commercialisation.

Secondly, in addition to basic research, the real benefits of IDTs come when they operate together. And, in realisation of this fact, countries are redesigning major programmes, institutions and initiatives to tackle increasingly complex manufacturing R&D challenges. This includes widening the scope beyond basic technology research and placing a greater emphasis on new research partnerships and links to pursue synergies between research actors and engage a greater variety of manufacturing stakeholders. It also includes investing in new innovation infrastructure to assemble the combination of tools, equipment and facilities required to meet tomorrow's production needs.

Thirdly, production technologies, manufacturing systems, and industry sectors are all converging. It is this convergence that is likely to drive the next production revolution. In designing research programmes and initiatives, policymakers need to be aware that the convergence is opening new manufacturing R&D opportunities and challenges. It is increasing the scope for innovation in manufacturing and creating more diverse ways in which value can be captured from it. The European Commission's research programmes addressing so-called 'multi-KETs' (multiple key enabling technologies) are examples of explicit efforts to pursue new manufacturing R&D opportunities driven by convergence (see further Appendix 2).

[104] The next Production Revolution – Implications for Government and Business OECD

One approach adopted within the European Union to address these issues is the creation of Digital Innovation Hubs (DIHs). Presented as part of the Digitising European Industry Strategy (DEI)[105] with a goal of providing industry access to technology and experts, these Hubs:

- Enable the leveraging of assets by wider industry (including SMEs),
- Increase the emphasis on commercialisation,
- Widen the scope of development programmes to address complex industry problems necessitating the integration of IDT technologies,
- Build a broader innovation architecture,
- Form networks across industry sectors, academia and research organisations,
- Increase the spin out of start-ups,

The overall objective of this initiative is to ensure that any industry in Europe – whether big or small, wherever situated, and in whichever sector – can fully benefit from digital innovations to upgrade its products, improve its processes and adapt its business models for the digital age.

It was noted by the DEI strategy that some research institutions were providing their expertise and access to advanced facilities to industry and that private companies (large and small) have useful products and services for the digitalisation of processes, products and services. It was also noted that incubators and accelerators existed to help start-up companies grow and scale and that cluster organisations, industry associations representing individual companies, were already playing an important role with respect to sector-level innovation. Furthermore, investors are already providing access to finance and local authorities are aware about the importance of innovation and are developing their smart specialisation plans. But the view was that these initiatives have been sporadic and uncoordinated.

The Digital Innovation Hubs are different because they will bring all these actors together within a particular region and develop a coherent and coordinated set of services to help companies (especially small companies or enterprises from low-tech sectors) that have difficulties with their digitalisation. They 'speak the language' of SME businesses, understand their needs and bridge the cultural gap between them and innovators. They offer a one-stop-shop that is more than just technology focused. They provide a holistic view of digitalisation as a company-wide transformation process which enables companies not just to identify technical solutions but to finance and nurture innovations to a level that they may actually be implemented – and contribute to improved competitiveness.

LEADERSHIP

- Although the UK has leading-edge R&D and some world-class sectors in the application of digitalisation, there is no clear narrative setting out what we already do well and the significant opportunity that exists for UK industry – and the country – from the faster development and adoption of industrial digital technologies.
- This means our strengths are not recognised internationally, reducing potential inward investment. And we are failing to inspire current and future workers with a vision of how they can secure high-quality jobs in a thriving part of the economy.
- We have centres of technical expertise in, for example, the Catapult network. But capability is fragmented with no single hub coordinating each technology to provide a focus.

The rapid emergence of digital technologies has transformed some areas of consumer services, from music and video streaming (Spotify and Netflix) to finance (challenger banks

[105] Roundtable on Digitising European Industry: Working Group 1 - Digital Innovation Hubs

and cryptocurrencies) to the shared economy (Uber and Airbnb). But UK industry has been relatively slow in understanding the significant opportunity that it affords.

This is partly down to a lack of national leadership. A 2016 report by PwC found that the biggest challenges for UK firms in adopting IDT remain a lack of digital culture, talent, and clear digital operations vision. There is no national strategy or organisation that stands as a point of contact for IDT leadership. Market information about the opportunities available through the industrial adoption of digital technologies has been mixed and confusing. This lack of clarity and cohesion makes it difficult for the long tail of industrial companies to recognise the benefits of IDT adoption.

There is currently no coherent, centralised and easily accessible model for business engagement. Nor is there a recognised source of independent advice about IDT. But creating one would help overcome the barriers to more widespread IDT adoption. Such a resource could provide leadership, distribute information, support the development of management skills and coordinate commercialisation support.

This is needed because the slow adoption of ID technologies, especially among SMEs, is largely due to a lack of information and poor management practices. According to the Engineering Employers Federation, nearly a third (31 percent) of manufacturers or their members understand or are familiar with the concept of the Fourth Industrial Revolution. Less than half (42 percent) were unfamiliar, the remaining being undecided.[106]

In Germany, almost half the companies in the manufacturing sector (46 percent) use Industry 4.0 applications, while another 19 percent have specific plans to implement them, according to a recent Bitkom survey of 559 industrial companies with more than 100 employees. Thus, nearly two-thirds of German industrial companies are already active in the Industry 4.0 sector. It is logical to assume that a common brand unifying the ecosystem helps to encourage this level of uptake and builds trust in the technology.[107]

In the US, where the 'industrial internet' is a mainstream and common brand, 53 percent of manufacturers said adopting Industry 4.0 is a priority. Respondents in cost-sensitive industries like semiconductors, electronics, oil and gas are the most eager to move forward – 80 percent of these businesses say Industry 4.0 is a priority.[108]

At present, there is no unifying national brand or campaign for industrial digitalisation in the UK. There are varying overlapping initiatives to raise awareness – either from trade associations (notably EEF)[109] , from regional institutions like Liverpool 4.0[110] or from NDPBs such as Innovate UK.[111] This mirrors the same fragmented ecosystem that this review is also addressing.

Contrast the UK position with Germany Trade and Invest (GTI), which is responsible for driving digitalisation by owning, developing and coordinating the Industry 4.0 brand, which is promoted nationally and internationally.[112] In fact, most developed economies have national campaigns to actively promote the adoption of digital technologies in industry. See, for example, the description of Made in China 2025 and America Makes in Appendix 2.

[106] EEF Manufacturing Ambitions Survey 2016

[107] Bitkom; Industry 4.0. June 2016

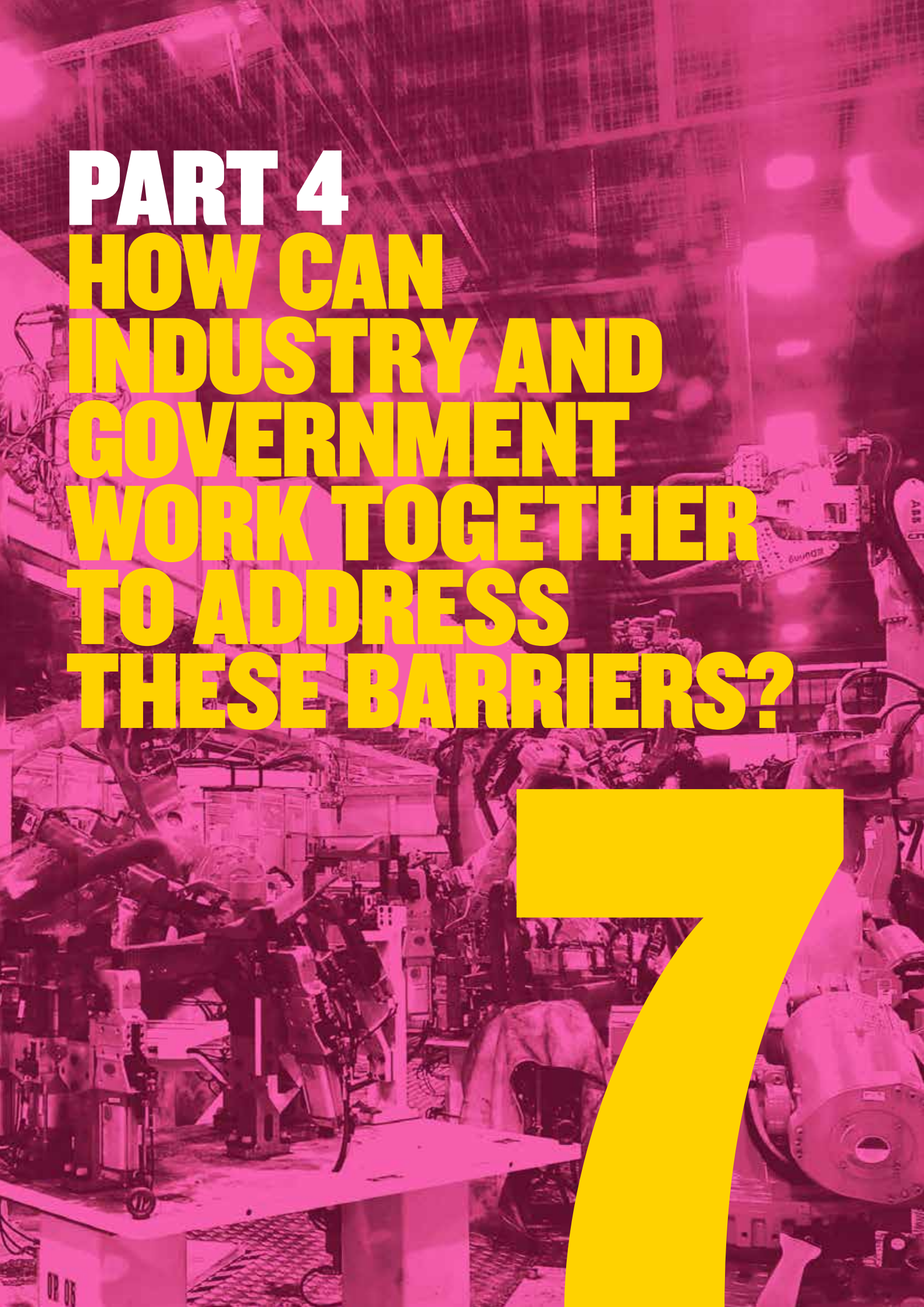
[108] BCG; Sprinting to Value in Industry 4.0, Dec 2016

[109] EEF: The 4th Industrial Revolution (4IR): A primer for manufacturers 2016

[110] http://lcr4.uk/

[111] https://innovateuk.blog.gov.uk/2017/03/28/what-does-the-fourth-industrial-revolution-4ir-mean-for-uk-business/

[112] https://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/industrie-4-0



PART 4

HOW CAN INDUSTRY AND GOVERNMENT WORK TOGETHER TO ADDRESS THESE BARRIERS?

7

Part 4 - How can industry and government work together to address these barriers?

Our review has identified the three key themes of adoption, innovation, and leadership which are preventing the UK from achieving its vision of being a global leader in the development and adoption of IDT by 2030.

In partnership with government, academia, research organisations, and industry, we are proposing the following three recommendations to resolve the issues we have identified (we are also proposing a fourth supporting recommendation which addresses enablers).

ADOPTION AND INNOVATION. The UK needs to adopt IDT faster, especially within small and medium-sized companies. This can only be achieved through the coordinated leveraging of UK expertise and assets; a focus on solving large-scale industry problems; and targeted support to address barriers to adoption of which the lack of skills is the major issue.	Recommendation 1 Create a significantly more visible and effective ecosystem that will accelerate the innovation and diffusion of IDTs Recommendation 2 Upskill a million industrial workers to enable digital technologies to be deployed and successfully exploited Enablers Implement a series of enablers to address key barriers to adopting IDTs
LEADERSHIP The UK needs co-ordinated, market-focused IDT leadership at a national level.	Recommendation 3 Inspire the UK's next industrial revolution by providing stronger leadership, branding and messaging of the UK's ambition to be a global pioneer in IDTs

These recommendations come as a package. Together, they are intended to establish the right conditions for the UK to become the global leader in industrial digitalisation by 2030.

This part of the report describes how our recommendations would be realised (see also Figure 25 for a depiction of the framework we envisage). Broadly, implementation would comprise:

- A national Made Smarter UK Commission, underpinned by two key implementation bodies responsible for skills and technology.
- A National Adoption Programme aimed at SMEs to increase the uptake of IDT.
- Regionally distributed Digital Innovation Hubs focused on technology diffusion, adoption and commercialisation.
- Focused IDT research centres with the goal of keeping the UK at the forefront of global R&D activities in IDT.

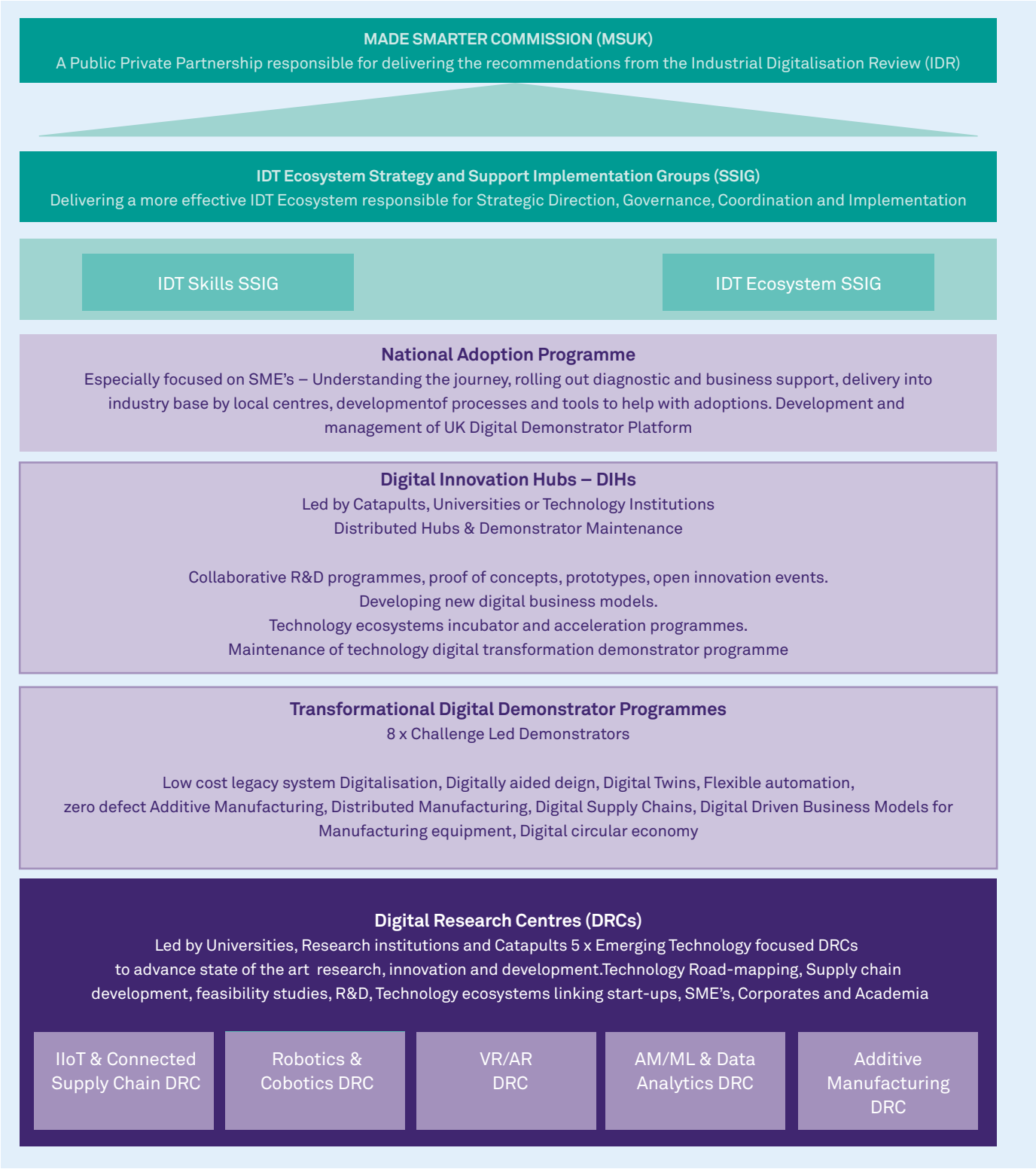

MADE SMARTER COMMISSION (MSUK)
A Public Private Partnership responsible for delivering the recommendations from the Industrial Digitalisation Review (IDR)
IDT Ecosystem Strategy and Support Implementation Groups (SSIG)
Delivering a more effective IDT Ecosystem responsible for Strategic Direction, Governance, Coordination and Implementation
IDT Skills SSIG
IDT Ecosystem SSIG
National Adoption Programme
Especially focused on SME's – Understanding the journey, rolling out diagnostic and business support, delivery into industry base by local centres, developmentof processes and tools to help with adoptions. Development and management of UK Digital Demonstrator Platform
Digital Innovation Hubs – DIHs
Led by Catapults, Universities or Technology Institutions
Distributed Hubs & Demonstrator Maintenance
Collaborative R&D programmes, proof of concepts, prototypes, open innovation events.
Developing new digital business models.
Technology ecosystems incubator and acceleration programmes.
Maintenance of technology digital transformation demonstrator programme
Transformational Digital Demonstrator Programmes
8 x Challenge Led Demonstrators
Low cost legacy system Digitalisation, Digitally aided deign, Digital Twins, Flexible automation, zero defect Additive Manufacturing, Distributed Manufacturing, Digital Supply Chains, Digital Driven Business Models for Manufacturing equipment, Digital circular economy
Digital Research Centres (DRCs)
Led by Universities, Research institutions and Catapults 5 x Emerging Technology focused DRCs to advance state of the art research, innovation and development.Technology Road-mapping, Supply chain development, feasibility studies, R&D, Technology ecosystems linking start-ups, SME's, Corporates and Academia
IIoT & Connected Supply Chain DRC
Robotics & Cobotics DRC
VR/AR DRC
AM/ML & Data Analytics DRC
Additive Manufacturing DRC

Figure 25

Recommendation 1

Create a significantly more visible and effective ecosystem that will accelerate the innovation and diffusion of IDT

Urgent action is required to unlock the opportunities of IDT and diffuse the technologies across UK industry. This action must address two principal needs:

1. To increase the entry of new business into the market, and grow businesses which become carriers of new technology. OECD research over recent years has highlighted the role of new and young firms in net job creation and radical innovation (OECD).

2. To implement productivity-raising IDT in established companies. An important issue is that small companies tend to use key technologies less frequently than larger companies. In Europe, for example, 36 percent of surveyed companies with 50 to 249 employees use industrial robots, compared with 74 percent of companies with 1,000 or more employees (Fraunhofer, 2015).

Any policies in this area must avoid simply focusing on the predictable early adopters. These tend to be multinationals, high-technology start-ups, or the small number of companies already using technology. Instead, policies must target the larger number of 'harder to reach' SMEs and avoid focusing on restoring lost manufacturing jobs. It must be understood that upgrading the ability of manufacturing communities to absorb new production technologies will take time (five to ten years, or more). That is why programmes to diffuse IDT need to be resourced with the longer term in mind (OECD).

Recommendation 1 calls for a significantly more visible and effective ecosystem that will accelerate the innovation and diffusion of IDTs. This can be realised in four ways:

1.1 Establish a new National Adoption Programme to support SME adoption.

1.2 Create a network of Digital Innovation Hubs to demonstrate the transformational potential of IDTs.

1.3 Implement large-scale Digital Transformational Demonstrator programmes to address sector-specific and cross-cutting industry challenges.

1.4 Make the UK a global leader in IDT R&D by bringing together expertise in Digital Research Centres.

NATIONAL ADOPTION PROGRAMME

Recommendation 1.1
Invest in a new National Adoption Programme (NAP) to accelerate the development and diffusion of IDT through focused support to SMEs in the UK regions. The programme will be regionally owned by Local Enterprise Partnerships and delivered by accredited regional partners. Investment will be targeted at strengthening both the capability and capacity of regional advisory services in digital technologies. It will provide kick-start funding for companies to leverage assets and expertise within the ecosystem and will involve increased mentoring from industry, as well as stronger interaction with upcoming talent within universities through focused projects and placements.

We are recommending an ambitious new National Adoption Programme (NAP), which will be delivered by industry and government, with a goal of **increasing and accelerating the development and adoption of IDTs** by manufacturing SMEs and across supply chains within the UK regions.

The proposed operating model would be proven through a six-month pilot project in the North West of England prior to its rollout to other regions. There are two principal reasons for the pilot. Firstly, it will enable action to commence quickly rather than wait for a programme to be formulated at a national level. Secondly, it will refine and de-risk the overall programme, and create assets (training material, processes, etc.) to facilitate wider deployment.

The goals of the NAP would be to:

- Increase SME engagement by a factor of 10. This would equate to
  - 3,000 SMEs engaged in the pilot programme (with 1,000 receiving intensive support),
  - 33,000 SMEs engaged during the rollout (with 11,000 receiving intensive support).
- Increase the number of manufacturing SMEs accessing research, innovation and catapult centres.
- Increase collaboration between university students and SMEs.
- Enhance supply chain competitiveness through the application of digital technology.
- Increase the number of new start-up companies.

As part of the sector deal, **industry and academia will provide:**

- Active support to companies within their supply chains, peers and start-ups.
- Support for the upskilling of supply chains in conjunction with the growth hubs.
- Access to facilities and showcase events to see IDT in action.
- Access to case studies and training materials.
- Access to interns and student placements from universities, raising awareness of career prospects in SMEs and raising the absorptive capacity of participating SMEs to drive innovation.
- SME mentoring by leading industrial organisations.
- Leadership to manufacturing champions networks.
- Leadership to peer networking.
- Access to business problems and data and support for co-development with start-ups.
- Support for the upskilling of existing advisory services.

Government will:

- Invest in the local advisory service by:
  - Recruiting additional IDT advisors to provide specialist support across the region to both SMEs and existing advisory staff (including support for upskilling);
  - Training/upskilling of existing advisors;
  - Administrative support for the scheme;
  - IDT awareness and engagement events for SMEs.
- Fund an SME IDT adoption and innovation 'kick-start' scheme which would provide specialist interventions to de-risk proposed investments and new product development.

STAKEHOLDER	ROLE
Government	Enduring policy framework and funding
LEPs/Growth Hubs	Coordination, account management
Professional bodies	Trusted advisor – promote, provide awareness
Accountants and banks	Trusted advisor – promote, provide awareness
Industry	Leadership, mentoring/support, promotion, provision of training, case studies, datasets
Peers	Support, experience, case studies
Academia	Graduate short-term industry programme, knowledge-transfer programmes, delivery of projects
Digital Innovation Network	Access to demonstrators/technical experts
Be the Business	Provision and management of the digital engagement platform
Third-party advisors/private sector	Specialist advisory services accredited by LEPs

While initial investment will be required during the first three years of the programme, an exit strategy will be developed to reduce reliance on central funding as IDT awareness increases and the digital innovation support network becomes more visible.

The NAP would establish a common UK framework which builds on best practice initiatives (such as Liverpool LCR 4.0) and prior learning, incorporating the strengths of previous support interventions such as the Manufacturing Advisory Service. It will complement and reinforce existing regional support structures, rather than adding new layers, and provide the necessary focus on IDT. The successful transformation will involve the engagement and coordination of a very broad stakeholder group (see the table above). Only through the collective coordination of the energies of this group, channelled through a common transparent and easy-to-navigate process, will the NAP's goals be achieved.

Why the North West of England?

The North West is one of the UK's largest regional economies. It also has the greatest manufacturing output, producing 9 percent of the UK's total exports, with activity in a wide range of industrial sectors such as aerospace, automotive, chemicals, biomanufacturing and agriculture. It has a higher proportion of workers in low-paid employment than the national average. In 2012, GVA per job in the region was £39,210 compared with £45,100 for the rest of the country. Underinvestment in the North West's infrastructure, skills base and business support and innovation networks, has left much of the region struggling to compete in a rapidly advancing global economy.

The region has a recognised strategy recently reinforced in the Science Innovation Audit: "To establish a Northern Powerhouse Advanced Manufacturing Innovation Corridor in which the widespread adoption of Industry 4.0 and the embracing of innovation, transformational skills and management, internationalisation, coupled to talent development and retention in the region, drives productivity growth to world-class levels".

The region contains a range of different local authorities operating different administrative models, which will prove the operational flexibility of the NAP. The regional organisations involved in business support work collaboratively and have actively supported our review and are motivated and ready to support the pilot programme.

What's more, the region is the initial pilot area for the 'Be the Business' initiative which is recognised as the umbrella productivity initiative in which IDT is a key enabling capability.

Ultamation

Ultamation, an award-winning company based in the Liverpool Science Park, specialises in home automation solutions that are used to manage heating, lighting, energy, security and audio/video. Ultamation offers high-quality, bespoke services from initial concepts, through design and installation to handover of the completed project with the client. They base their success on being able to offer their customers something unique.

Ultamation are therefore always looking for ways to integrate new technologies. The potential applications of augmented reality (AR) sparked excitement among the team, for example. They started exploring an AR-based control interface which could cover numerous applications, including smart homes and commercial meeting spaces.

The Virtual Engineering Centre (VEC) worked with Ultamation to create a prototype which could control connected devices in a smart home setting. The interface allows users to interact with multiple devices by holding up a smart phone or tablet to face their appliances, or even simply interesting features around the home. The application will recognise objects such as a TV and can trigger the relevant menu for the controlling functions like power, volume and channel selection.

Ultamation is delighted with the work completed and has sought professional advice for the potential patent application of their AR control interface. The prototype has been handed over to the Ultamation development team, who have since enhanced the application with emerging AI technologies. The company is very excited about the potential of this AR technology, and will look at introducing it in future projects.
http://lcr4.uk/lcr4-case-studies/

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THE NAP DIGITAL JOURNEY

Figure 26 provides an overview of the 'digital journey' that we envisage the NAP delivering. It comprises four stages: Connect, Engage, Participate, and Champion.

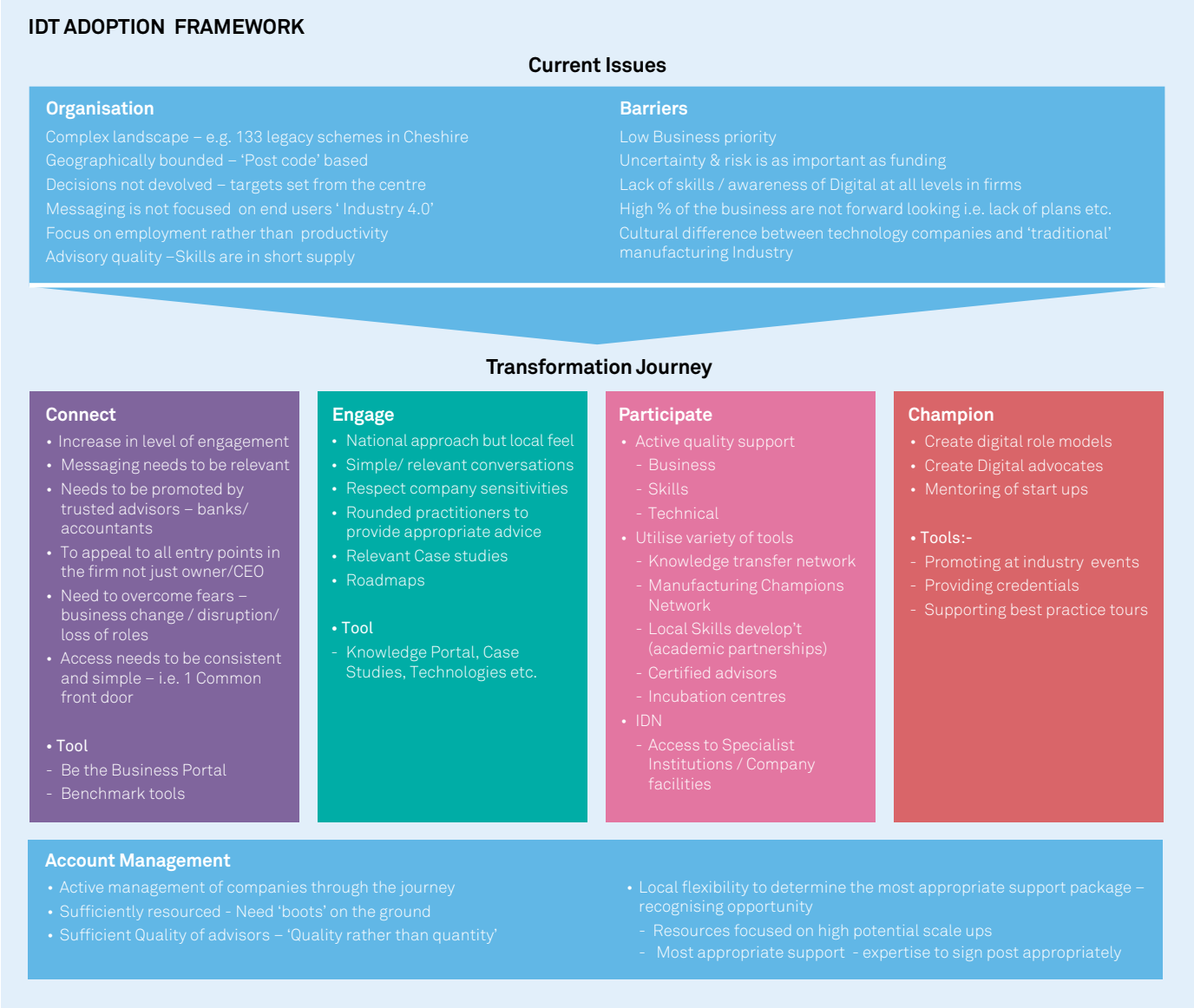


Figure 26

Connect

Promoting awareness and stimulating engagement with the SME community is critical to IDT adoption. Our review found that a poor understanding of the opportunities, an incorrect perception of costs and technical/security risks, as well as a lack of impartial advice and a lack of resources were hindering adoption.

One of our key recommendations is a national campaign to increase awareness of not only the opportunity but also the ease of adoption and availability of support. The messaging will be clear, understandable and relevant. Awareness will be supported by promotion from trusted advisors, such as accountants/banks, industry trade bodies/councils, and professional bodies.

Online enquiries and guidance will leverage the 'Be the Business' digital platform to promote awareness, identify points of contact and provide initial diagnostic tools.

Engage

Beyond promotion and awareness, additional incentivisation is required to achieve the level of SME engagement that will lead to a meaningful impact on industrial output. Targeted kick-start funding has been demonstrated to be an effective mechanism to motivate companies to engage. This provides SMEs with the opportunity to partner with specialist accredited advisors (funding between 10 and 30 days) such as a university or research institution. They can help engage, for example, on a technology feasibility study, or the analysis of technology transfer. This de-risks IDT adoption and new product development and provides the SME with unprecedented access to skills and assets. For example, Ultamation (see case study above) would not have been able to develop its innovative new AR product without leveraging the world-class facilities and expertise available at the Virtual Engineering Centre.

Kick-start funding incentivises SMEs and academia/support organisations to come together, and results in longer-term relationships. The benefits of the scheme are that companies know there will be dedicated and tailored support, as well as access to world-leading technology, and this will act to de-risk investment. Example schemes include LCR 4.0 which has actively assisted 52 SMEs in six months, delivering a mix of productivity improvements and new product development, and an ERDF assist programme which engaged 526 companies in the creative and digital industries promoting technology fusion.

One of the keys to engagement will be to invest in impartial guidance and support for SMEs on their digital journeys. The level of effort and timescales required to connect with the large and diverse SME community should not be underestimated. However, there have been exemplar programmes which provide the necessary learning. Wave 2 Growth Hubs (W2GH) was a £32 million programme which funded 15 growth hubs across the UK, engaged 67,000 businesses, directly supported 5,700 businesses, created 4,100 jobs, and leveraged over £75 million in private investment.

The proposed programme will have locally agreed targets and the discretion to tailor programmes/support levels for SMEs according to the nature of the problem being addressed and level of opportunity and absorptive capacity of the organisation.

Participate

NAP advisors will convert engagement into participation. With support from industry, the Digital Innovation Hubs, and research and academic partners, the NAP will have a number of levers to pull in helping SMEs adopt IDTs. These will include:

- Access to specific capabilities promoted via the Digital Innovation Hubs (for example, specialised manufacturing equipment for prototype development or production manufacturing).
- Access to academic research assistants.
- Technology demonstrators.
- Access to case studies/training materials.
- Access to specialist technical resources within the Digital Innovation Hubs.
- Access to interns/student placements from universities, thus raising awareness of career prospects in SMEs and raising the absorptive capacity of participating SMEs to drive innovation.

- SME mentoring by leading industrial organisations.
- A manufacturing champions network.
- Peer networking.
- Third-party accredited specialist suppliers.
- Access to technology start-ups for co-product development.

Specific examples of SME support projects in the pilot region include The University of Central Lancashire's Innovation Clinic which brings industry and academic expertise together with state-of-the-art facilities and technology to provide support at all stages of the product development process. Lancaster University's Centre for Global Eco-Innovation (CGE) provides in-depth R&D support to help SMEs develop new eco-innovative products, processes and services for global markets, with a strong focus on advanced manufacturing. And the Lancashire Forum, delivered by Lancaster Management School (LUMS), develops a network of like-minded SMEs, better equipped to embrace innovation as a driver of productivity and growth within their businesses.

Champion

Through the successful adoption of IDTs, the NAP will create advocates for digital adoption. This will add momentum to the programme and increase the capacity of the network to support a greater number of SMEs.

HOW DO OUR PROPOSALS ADDRESS THE BARRIERS TO IDT ADOPTION?

The following table sets out how our recommendations address the barriers to IDT adoption that we have identified.

BARRIER	PROPOSED SOLUTION
The support landscape is confusing, geographically differentiated, and subject to short-term, initiative-driven change. Companies lack understanding of where they stand in comparison to their peers and how they can start their digitalisation journeys. Nor do they understand if funding is available to de-risk their investment.	Harmonised single national framework, clear signposting, route map supported by consistent messaging and advice.
The quality of advisory support provided to SMEs varies throughout the regions due to lack of skills in IDT. Specialised technical and market knowledge is costly and, as a result, not all businesses have the basis for making informed technology investment decisions. There is no recognised independent source of advice about what solutions are available, and which are appropriate to adopt.	Investment in skilled IDT advisors and upskilling existing advisors, supported by a network of excellence within the innovation network.
Many SMEs have a low absorptive capacity to update production processes and undertake the development of new products. SMEs do not have the time, capacity or funds to partner with universities or research and technology organisations. SMEs are risk averse and see investment in innovation as something which could greatly affect their financial performance – and even jeopardise their survival. Access to state-of-the-art research, engineering expertise, and equipment is not typically readily available.	Access to kick-start funding, student placement programmes, industry mentoring and Digital Innovation Hubs.
Businesses also face a skills shortage, particularly digital engineering capability, hindered by a fragmented skills system and a lack of systematic engagement with industry.	Targeted training programmes, access to training platform, access to expertise in Digital Innovation Hubs.
Some larger firms underinvest in their supply chains due to fear of helping competitors. Larger companies are not exploiting the creativity and agility of small, research-intensive manufacturers which could be a source of innovation. Lack of SME involvement in innovation activities impacts the long-term competitiveness of advanced manufacturing sectors that require continuous innovation and kick-start funding. Technology companies find it expensive to deal with large numbers of SMEs.	Industry commitment through the sector deal. Challenge programme demonstrators which encompass supply chains. Digital Innovation Hubs will provide a conduit between technology providers (start-ups) and manufacturers (SMEs).
Companies lack knowledge of the potential of new technologies, particularly where those technologies originate in other sectors.	Comprehensive knowledge of cost-effective solutions, like the $700 Raspberry Pi connection kits being developed in Japan (see Appendix 2 – Industrial Value Chain initiative (IVI)).
The high level of legacy infrastructure due to a low level of investment in capital equipment, the adoption of new technologies, and process improvements.	Opportunities developed and shared within the Innovation Network, through IDT advisors, supported through the online platform.
A lack of standards and interoperability. Concerns over data breaches and cyber-standards.	Cyber-awareness and standards programme proven through demonstrators.
Sharing of information resulting in a loss of IP.	Establishment of data trusts.

Air Quality Research

Air Quality Research Ltd (AQR) cleans fluids using a sustainable, environmentally friendly and cost-effective approach. The company develops novel, chemical-free, energy-saving products for controlling bacteria and reducing chemical contamination, providing safe fluids for use in the home and in industry. To clean water as effectively as possible, AQR needs to ensure that all stages of its processes operate efficiently and correctly and all equipment is safe and well managed.

AQR was interested in how a computational fluid dynamics (CFD) analysis could examine issues concerning fluid flows and suggest to AQR where improvements in its own processes could be made. But AQR lacked sufficient digital skills to undertake the CFD work.

The Virtual Engineering Centre (VEC) helped AQR investigate a number of different designs which would optimise its cleaning process and enhance performance. Using simulation, the VEC demonstrated the importance of digital skills and which potential changes to product design could be made. Testing different designs through a digital platform allowed for quick, easy and cost-effective changes to be made without the costs and resources required for a physical prototype. In just one hour, the VEC completed work for AQR that would have normally taken between 3 and 4 days.

AQR is conducting field trials to assess the design's performance in the disinfection of rainwater and industrial wastewater, ensuring this is then made into safe re-useable water in the most cost-effective and regulatory-compliant manner possible. Once all testing has been completed, AQR will be able to confidently take their improved product design to a supplier to manufacture and then straight to the market.

Through better testing and by minimising the product-to-field time, AQR feels confident in bringing a more successful product to fruition. The new product can also be applied to many other elements, and AQR is now considering how their process can clean milk – which could replace the larger equipment the dairy industry currently uses. http://lcr4.uk/lcr4-case-studies/

LCR4.0
Together for Manufacturing.

EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND

Digital innovation assets in the North-West pilot region

The Advanced Manufacturing & Automation Centre (AMAC) in Blackburn delivers training and apprenticeships for the manufacturing and engineering industries. Edge Hill University's £13 million tech hub, the CAVE (Computer Augmented Virtual Environment) provides cutting-edge facilities and systems to students and businesses. The Collaborative Technology Access Programme (cTAP) is a £11.4 million capital investment at Lancaster University that will provide industry with managed access to state-of-the-art technology facilities, equipment and expertise commercially unavailable elsewhere. And the Engineering Department at Lancaster University, through its knowledge exchange team, Lancaster Product Development Unit (LPDU), offers physical resources and the expertise of academics, students and engineers.

The recently opened Academy of Skills and Knowledge is a £15.6 million investment by BAE Systems at Samlesbury, providing the aerospace industry with the skills to continue engineering and manufacturing military aircraft. The University of Central Lancashire's (UCLan) Engineering Innovation Centre (EIC), is a £40+ million project developing the region's capabilities in engineering, which will work with local SMEs and primes within the advanced engineering and manufacturing sector. The proposed North West Advanced Manufacturing Research Centre (NWAMRC) is an industry-focused centre of excellence for innovation, product development and manufacturing skills for Industry 4.0, led by Sheffield University's AMRC, part of the High-Value Manufacturing Catapult.

The University of Manchester (UoM) School of Computer Science is among the largest and most highly rated research schools in the UK (4th in the Research Excellence Framework 2014), with major strengths in Big Data, artificial intelligence and novel computer architectures.

And the UoM's Data Science Institute brings together more than 250 Big Data researchers from across the university, with strengths in data analytics, machine learning, statistical inference, numerical algorithms, information management, and cybersecurity (particularly cryptography). UoM is also a lead partner in the N8 High Performance Computing Centre which operates Polaris, one of the 250 most powerful computers in the world.

Sci-Tech Daresbury has over 1,200 people onsite, including more than 400 scientists, working in fields such as accelerator science, high-performance computing, simulation and data analytics and sensors and detectors. It operates large-scale facilities used by many UK universities and, increasingly, by industrial companies like IBM, Unilever, Bentley Motors, and BAE Systems. It includes STFC Daresbury Laboratory, the Hartree Centre, the Virtual Engineering Centre, the Cockcroft Institute, 3M Buckley Innovation Centre (3M BIC), and more than 100 high-tech companies employing over 500 people in areas such as advanced engineering, digital/ICT, biomedical and energy and environmental technologies. These companies vary in size, from start-ups, to more mature SMEs, to international corporates such as IBM and Lockheed Martin. About one in six are global multinational companies.

The Hartree Centre, at Daresbury, is one of the world's most powerful supercomputing and data analysis infrastructures, and a leader in the Big Data revolution. It is helping UK industry gain a competitive edge by harnessing the power of Big Data, analytics, visualisation and data-centric cognitive computing. Since 2013, it has received £172 million in government investment plus £200 million from IBM to establish a R&D programme that will create the next generation of data-intensive systems – bringing

people and skills together with technology to support business developments. The Centre also has a long-term partnership with Unilever to support its R&D processes.

The Virtual Engineering Centre, is an established industry-focused impact centre for digital innovation, research and digital skills development. The Centre comprises a multidisciplinary team of engineers, computer and artificial intelligence scientists and industrialists supported by academics at the University of Liverpool. It provides expertise and digital facilities to a broad range of sectors to help them develop their digital strategies, supporting product and process development to increase global competitiveness. Key industry partners include Bentley Motors, Aston Martin, JLR, Airbus and AMEC Foster Wheeler, Rolls Royce, EDF, Sellafield (energy), and Hitachi Rail, as well as a number of utility-focused organisations. The Virtual Engineering Centre is leading the LCR4.0 project supporting over 300 SMEs in the adoption and development of Industry 4.0 technologies, for growth and new product generation. In partnership with the Hartree Centre, the Virtual Engineering Centre offers a unique UK facility combining expertise and easy access to the latest transformational digital technologies, including virtual test frameworks for collaborative innovation (e.g. BEIS digital nuclear reactor design, high-performance computing, cognitive computing and Big Data analytics).

Sensor City is a collaboration between the University of Liverpool and Liverpool John Moores University and is a flagship University Enterprise Zone. It enables industry and academic partners in a range of sectors to translate their innovative sensor concepts into commercially viable solutions. It provides technical expertise, business support and an international platform needed to collaborate, fund and promote sensor solutions to a global market. Positioned at the intersection of industry and academia, Sensor City facilitates connectivity and fosters progress, helping partners capitalise on the growing sensor revolution.

The 3M Buckley Innovation Centre (3M BIC) is a wholly owned subsidiary of the University of Huddersfield. It is a state-of-the-art building offering a one-stop shop for businesses that want to experience dynamic growth through its bespoke, innovation-led business model. The 3M BIC promotes business growth and open innovation, and facilitates business-to-academia collaboration. Technical, professional, academic, and business support go hand in hand. SMEs get a foot in the door to the Centre's own capabilities, as well as its main partners, the University of Huddersfield and NPL North of England, and associated businesses, tenants, and network members.

MADE SMARTER UK DIGITAL INNOVATION HUBS

Recommendation 1.2

Scale the support provided by UK innovation centres through a new national innovation programme. This would bring together a network of existing distributed Digital Innovation Hubs (DIHs) with additional investment to underpin targeted MSUK activities and interventions to demonstrate how the industrial and manufacturing sector can be positively transformed by IDTs. The DIHs and their spokes will be strategically selected to best serve the challenges of local business communities. The MSUK Commission will be responsible for the selection and governance of the MSUK innovation activities delivered by the DIHs and local spokes to ensure maximum impact.

Through a National Innovation Programme, we will seek to create a world-leading innovation ecosystem for IDTs in the UK which will promote disruptive technologies in an industrial setting. We will do this through a targeted coordination and leveraging of existing resources and assets in academia, research organisations, government laboratories (NPL), Catapults, and industry. This will create a network of 12 connected, regionally distributed Digital Innovation Hubs (DIHs) based on regional needs, characteristics and industrial specialisms, which will be readily accessible by SMEs (see above for a list of the assets identified in the North West of England). The National Innovation Programme will be coupled with the National Adoption Programme, offering businesses a suite of support and innovation mechanisms relevant to the current stage of their digitalisation journeys.

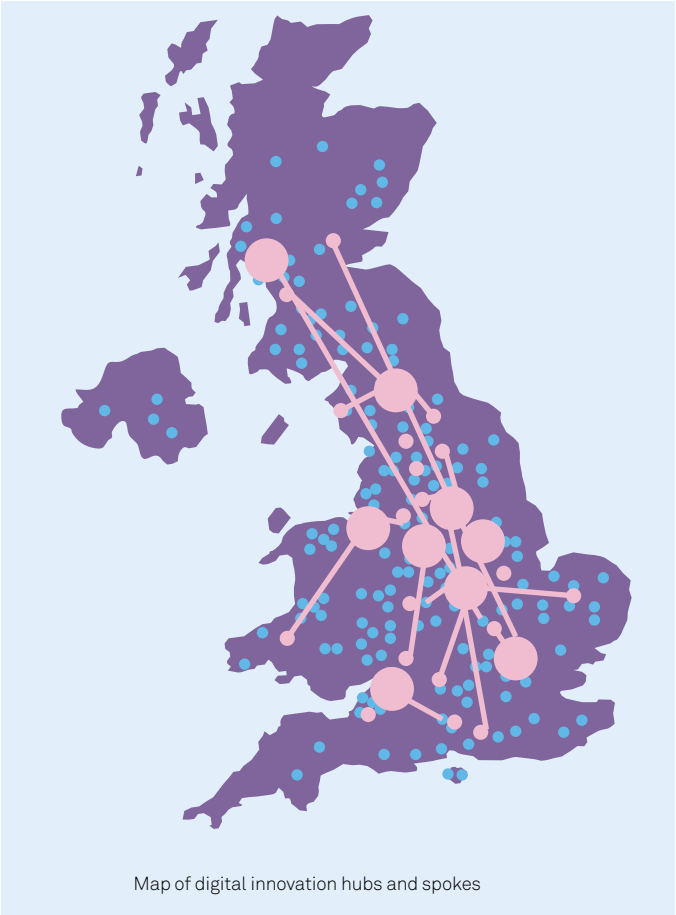
LEVELS OF SUPPORT	CUSTOMER PROFILE	VALUE PROPOSITION	KEY DELIVERY PARTNERS
LEVEL 1 – Understanding the Journey	I don't know what this is all about, it feels like a sales pitch from large corporations and I don't understand the benefits I don't know what this means for me or whether it is even relevant	EXPLAIN, DIAGNOSE, SIGNPOST Awareness raising Diagnostic tools Signposting and brokerage KICK START FUNDING	National Adoption Programme Digital Innovation Hubs & Local Spokes
LEVEL 2 – Planning and executing my Journey	I know what to do, but I need to understand the area in more detail I know what to do, but how do I justify investment? Even if I justify it, there is still a lot of risk involved! I am now in an evolutionary journey, but now I want to be disruptive and I don't know how	DEMONSTRATE, INTEGRATE, DERISK, ADOPT Live demo visits Digital Business Models Transformational Demonstrator Framework CATALYST FUNDING	Digital Innovation Hubs
LEVEL 3 – Evolving the ecosystem	have a vision of what I want to do long term but I don't know if the required technologies are being created I have a vision of what I want to do long term but there is not an ecosystem available to support it	ADVANCE, CREATE, SPIN-OUT Technology Roadmapping Feasibility projects Technology ecosystem incubator and accelerator INCUBATION FUNDING	Digital Research Centres (DRCs)

Figure 27

The DIHs will operate regionally, on hub and spoke models, connecting and harnessing the existing ecosystem to ensure that any UK business has access to expertise, either locally or via the network depending on the business challenge. There will be strong links between regional Hubs to facilitate access to additional facilities. For example, a SME may require access to industrial specialisms from another region, fill missing competences, or collaboratively develop new services and tools to address sectoral issues.

Technology developers and users will come together with the DIHs to integrate, test, demonstrate and diffuse IDT. This could, for example, be coordinated by Digital Catapult (including its regional centres across the UK) and the High-Value Manufacturing Catapult, with input from other members of the Catapult network. Furthermore, the spokes will be built upon – incorporating a number of existing institutions and networks from existing universities, manufacturing and industry research hubs and innovation institutions.

The projects within the DIH programme will address key challenges and opportunities identified by business. They will develop a cohesive national capability and infrastructure that demonstrates how the industrial and manufacturing sector can be positively transformed by digital technologies, while addressing long-term business drivers.



Map of digital innovation hubs and spokes

Figure 28

The DIH programme will be built with industrial technology users from the current manufacturing base and innovators from the tech sector and will be underpinned by multiple integrated digital technologies. Its activities will include collaborative R&D programmes (in partnership with the Digital Research Centres), proof of concepts, prototypes, open innovation events, developing new digital business models, technology ecosystem incubator and accelerator programmes and competitions, as well as the maintenance and development of the Transformational Digital Demonstrator programmes (see following pages). The DIHs will provide a meeting point for the technology and manufacturing communities, providing real industry challenges for the tech community to address, as well as demonstrations of the applications of IDTs, to accelerate diffusion among the industry base.

This will help companies beginning their Made Smarter journeys understand the following:

- Which companies work in the application area they have identified and where can they see the technology being applied?
- Are any of these demonstrators being applied in the same industry sector they work in, or are they from other sectors?
- Is there a clear articulation of the barriers that the demonstrator had to overcome, and of the benefits that have been derived?
- What alternatives were considered and why was the final solution chosen?
- From where did the company get their advice and funding?

While the DIH network will connect and leverage capabilities from existing infrastructure, it will also create new capacity and new services that will ensure an agile interface for both technology users and developers in line with the pace of change of IDTs and the markets within which they are being exploited. The emphasis will be on the support of start-up businesses with funding through the catalyst programme.

In summary, the 12 regional DIHs will:

- Operate on a hub-and-spoke model, with national coordination through the Hubs.
- House a network of physical IDT demonstrators. The National Adoption Programme (see previous page) and the MSUK platform (see following page) will steer businesses to appropriate technology demonstrators where off-the-shelf solutions have been integrated in innovative ways. These will be embedded in DIHs as interactive demonstrators, or in industry partners as real use cases. The demonstrators will help businesses understand how a suite of digital technologies can address their own business challenges or opportunities. It will also identify where the solution providers are not satisfying market demand. The identification of these gaps will drive research challenges for the Digital Research Centres (see below).
- Accelerate the pace of technology adoption in industry by defining, integrating, developing and de-risking novel digital technologies for businesses. This mechanism will be funded through catalyst project funding available to manufacturing SMEs to support the testing and de-risking of their digitalisation action plans with delivery and innovation partners.
- Support the development, management and engagement of 8 Transformational Digital Demonstrator programmes.
- Provide a meeting point, offering SMEs or start-up technology businesses the chance to create demonstrators and a platform to share their solutions with the wider manufacturing community. 'Pit stops' will be held, where manufacturing businesses can present their challenges to technology businesses who will develop innovative solutions.
- Establish a web platform to signpost innovation and demonstrators that will connect to the MSUK leadership campaign. Build and curate virtual demonstrator content enabling businesses to explore facets of IDT applications online.
- Map emerging technology start-ups and scale-ups for inclusion in the web platform.
- Offer deep-dive live demos and workshops, providing a deep-dive into a specific area, including a live demonstration of a relevant solution, face-to-face in-depth conversations with experts, and the opportunity to scope the project of the participant's choice. These will be developed with the DRCs.
- Support digital business models which can be used to build baseline models of current production systems and to evaluate potential future scenarios, including the implementation of future digital solutions. These models have the capability of making an impact assessment of the KPIs and of calculating ROI for a particular implementation. As a result, SMEs will be able to better justify their investment in their digitalisation journeys.
- Support projects such as the AI4ME (Artificial Intelligence for Manufacturing and Engineering programme), an initiative led by CFMS Ltd. AI4ME brings together a multi-sector grouping of OEMs with industrial challenges to be addressed by the AI community. The OEMs' committed funding will be matched by the National Innovation Programme to contract AI start-ups and SMEs to develop solutions for these critical sectors. AI4ME offers a unique vehicle to develop the AI supply chain and raise collective awareness within UK industry.

DIGITAL INNOVATION HUBS - DEMONSTRATE / DERISK / ADOPT

Barriers to adoption :

- Recognition of opportunity and ROI as a barrier
- Risk of integrating and adopting emergent technology
- Risk of poor interoperability and cyber security

What providers and organisations can help me digtialising?

What have my peers and others in my sectors done and what benefits did they gain?

How can I exploit emergent technology to address business challenges and create new business opportunities?

Where can I see it in action?

Where can I get support to reduce the risl in development and implementation of new digital solutions?

Where can I explore the risks and opportunities associated with cyber security and interoperability?

Understand

- Single entry point to system irrespective of location, size or sector
- Access online app to navigate relevant demonstrators and providers; sector, size, technology, geography.
- Virtual demonstrators on line
- Physical demonstrators distributed nationally.
- Access relevant industry use cases
- Access technology demonstrators with a range of applications
- See the technology in action in real world applications

Signpost

- For mature market ready technology signpost to approved providers
- Support in navigating complex market place and pick suitable providers
- Use vouchers to launch projects
- Mentoring for integration projects

Explore

- Interactive technology demonstrators
- Integration of multiple technologies to solve sector relevant challenges
- Assess technologies at range of price points; full factory to single machine analysis.
- Work with engineering teams to understand best fit for your business
- Demonstrate ROI
- Bring digital tech businesses together with manufacturing businesses
- Signpost to DTNs for specifc technology development

Derisk

- Safe environment to integrate and test technology
- Test relevant solutions in neutral space using existing assets
- Scale up solutions to be factory ready
- Financial support for projects- banks
- Incubators for technology start ups
- Create demonstrators for emergent technology from DTNs
- Access to training and skills support

Account Management

- Active management of companies through the journey
- Standardised national response and experience irrespective of entry point
- Signposting tailored for company need based on diagnostic and DRL assessment
- **Start with business need and seek technology solutions**

Figure 29

DIGITAL TRANSFORMATIONAL DEMONSTRATOR PROGRAMMES

Recommendation 1.3

Implement a programme of large-scale Digital Transformational Demonstrators, co-funded by industry, aimed at both sector-specific and cross-cutting industry challenges and focused on delivering tangible results in both productivity and sustainability. These Demonstrators will be regionally organised and will, together with the National Adoption Programme, provide a key accelerator for the diffusion of IDTs, especially within SMEs.

Through consultation with industry and analysis of value chains, a series of strategic cross-sector opportunities for business transformation have been identified. Eight Transformational Demonstrator programmes will therefore target the key barriers and enablers associated with these opportunities. These programmes will use IDTs to build a system of innovative solutions and platforms around real-world scenarios, to demonstrate what is possible in each area. They will also create mechanisms to drive adoption across the UK and will develop paths for accelerated exploitation.

The Demonstrators will be housed within the regional DIHs (see previous page) and will help businesses understand how IDTs can address today's business challenges within the factory environment. The programme will demonstrate how sectors and supply chains can be transformed, and value generated in new ways:

- Demonstrating the digitalisation of legacy systems (data collection, data analytics and value quantification).
- Using digital for future propositions (to develop new products or services) with use cases that companies can use to generate their own business cases.
- Driving horizontal integration (the digital thread from design to manufacture to in service to end of life) and vertical integration (from data to actionable insight) to unlock productivity.

The Demonstrators will be industry led, using the challenges of key UK manufacturing sectors to demonstrate the transformative opportunities that can be unleashed by IDTs.
The consultation undertaken during our review identified those challenges as being:

- Digitalisation of legacy systems for different industrial scenarios, including data collection, data analytics and value quantification.
- Enabling smart factories powered by AI to achieve right-first-time quality, and optimising operational efficiency through data acquisition, storage, analysis, interpretation, and action.
- Driving horizontal integration through supply chains, including enabling and securing the digital thread, driving collaboration but also protecting commercial interests.
- Reducing time to market, streamlining and connecting the design and manufacturing processes and enabling design capability through 'digital twin' architectures.
- Flexible operations to enable the agile adoption of higher product variability or customisation models.
- Advanced automation and digitalisation of the food manufacturing sector to demonstrate reduced waste, increased productivity, and transition to a high-skilled workforce.
- Servitisation to demonstrate how the digital thread of data, from design to manufacture to in-service use, can create new insights and support new ways of generating value from products and IP. The Demonstrator will explore servitisation of assets ranging in value and will include production equipment, with special emphasis on through-life engineering.

- Enabling circular economy cycles through data flows, enhancing the sustainability of manufacturing value chains, and reducing their impact on non-renewable resources.

A Demonstrator will be developed for each of these eight areas. The result will be a portfolio of national capabilities, infrastructure and assets that can act as a 'sandpit' for the future adoption of technology and further innovation. Connectivity, interoperability, security, intelligence and autonomy will run across each of the Demonstrators. And each will follow the same structure, with a phase of definition and partner engagement, a phase of development and a phase of industrial transfer, testing, adoption and exploitation.

The Demonstrators will address industry challenges that will be clearly defined in the Industrial Strategy Challenge Fund (ISCF). These could be sector cross-cutting, such as "how do we use IDTs to double productivity in manufacturing processes at the same time as halving the environmental impact?". Or they could be sector-specific, such as, for the food and drink sector, "how do we halve the amount of waste and increase productivity by 30 percent through increasing the level of automation, while creating more jobs than we displace?" (see further below).

These key industry issues will be addressed by using data as a valuable asset and enabling better connected supply chains, advanced automation (for example, in the food sector), interoperability standards and cybersecurity. A series of business-led feasibility projects will be executed around each of the Demonstrators, enabling a 'plug and play' approach with businesses and the innovation community to evolve the live demonstrators and test and de-risk technology solutions that can be directly transferred into industry. At the same time, feasibility projects will create a better environment for involving start-ups and scale-ups, accelerating the commercialisation of relevant technology and setting clear paths for exploitation.

Food and Drink Demonstrator

To demonstrate, via sub-sectors of the food and drink industry, the key digital technologies that have the potential to transform the food supply chain. The challenge will demonstrate step-changes in business productivity, reduce food waste, and show how digital technology can develop new business models for the food industry.

The project will:

1. Develop and demonstrate novel/advanced robotic technologies applicable to the food industry, especially soft robotics which offer new routes to solve many industry issues.

2. Deploy and integrate multiple digital technologies to deliver improvements in resource efficiency and real-time optimisation of process plant operations, including the challenge of operating legacy/mixed technology assets.

3. Develop a digital solution to meet increasing demands for traceability and standards through a complex value chain. Current systems tend to have low digital connectivity which brings inefficiency, costs, and can be a barrier to entry for new entrants.

4. Improved supply chain management which better aligns demand and supply to remove over-production and waste.

GOAL	TECHNOLOGY	SPECIFIC SECTOR CHALLENGES
Food manufacture 1. 25% > Productivity - labour and resource efficiency (including emissions reduction) 2. High-value Employment 3. Safer working environment 4. Technology uptake	• Robotics and automation • IoT • AI and machine earning • Simulation/digital twinning/ optimisation	• Non-structured environment • High product variability • Food grade environment • Technology affordability • Legacy assets • Health and safety • Upskilling • Process optimisation – minimise resources
Food traceability 1. Reduced food incidents 2. Product quality 3. Increased competition	• Cloud • Data analytics • Blockchain • IoT • Smart packaging	• Compliance • Inefficiencies – paperwork • Fraud • Reduced barriers to entry • Self-life visibility • Quality increase
Waste and emissions 1. Over-production 2. Matching supply and demand	• Cloud • Data analytics, AI • Blockchain • IoT	• Efficient fulfilment through a complex supply chain • Price instability • Optimised logistics

Other sector impacts:
Novel advanced robotics demonstrations will address challenges relating to availability of low-skilled labour and poor labour productivity for adjacent manufacturing sectors including: **Textiles, General engineering, Aerospace.**

Demonstration of connectivity of legacy equipment will enable productivity and quality gains to be realised without wholescale capital investment, driving benefits for multiple sectors including: **Textiles, General engineering, construction.**

Data traceability and access to data analytics to track logistics and democratise supply chains will also drive agility, productivity, quality and new market opportunities in the following sectors: **Automotive, Pharmaceuticals, Textiles.**

A NATIONAL IDT RESEARCH AND DEVELOPMENT PROGRAMME

Recommendation 1.4

Drive forward the UK's global IDT research and development leadership by bringing together the country's expertise in networks of Digital Research Centres (DRCs) in, initially, five technology areas: AI, machine learning and data analytics; additive manufacturing; robotics and automation; VR and AR; and the IIoT and connectivity (5G, LPWAN etc.). Each DRC will be charged with advancing state-of-the-art research and innovation for industrial digitalisation in its field. The network of DRCs will build on excellence and infrastructure in the existing UK science and innovation base, and work with the tech developer community to drive UK leadership in the technologies that underpin industrial digitalisation. Strategic direction and coordination will be provided by the Made Smarter UK Commission.

A network of Digital Research Centres

A national research and development programme will be committed to keeping the UK at the forefront of global R&D activities in IDTs. It will bring together the UK's IDT expertise by creating networks of specialist Digital Research Centres (DRCs), each focused on a particular technology. These DRCs would accelerate the development of their respective technologies to fulfil market demand. It is in this space that transformative developments would be achieved, both in technological solutions and in the development of new business models.

This new R&D ecosystem will emphasise industry challenges, and will initially focus on five technology families, although we recognise this arrangement will need to evolve in line with advances in the technology:

1. AI, machine learning and data analytics;
2. Additive manufacturing;
3. Robotics and automation;
4. VR and AR and visualisation; and
5. The IIoT and connectivity (5G, LPWAN etc.)

Each DRC will be charged with advancing state-of-the-art research and innovation for industrial digitalisation in its field. The DRCs will build on excellence in the existing UK science and innovation base and will work with the Digital Innovation Hubs (see above) through collaborative R&D with the tech developer community to drive UK leadership in the technologies that underpin industrial digitalisation. A number of candidate organisations have been identified (see below).

The goals of the DRCs will be:

- To significantly increase the number of spin-outs from universities and research institutions.
- To create a more joined up and targeted research agenda that ensures the leading UK research institutions collaborate, avoid duplication of effort, and align with the needs of industry.
- To position the UK at the forefront of global IDT R&D, and continuously innovate while feeding this innovation back into industry.

- To enable leading technology developers in key areas to build a strong position for UK IDTs.
- To accelerate the capabilities of the UK's world-class science base into industry.
- To advance the state of the art in the manufacturing application of core IDTs.

The DRC networks will be co-ordinated by the SSIG (reporting into the MSUK Commission), which will:

- Coordinate R & D across multiple universities and research centres (including the High-Value Manufacturing Catapult centres).
- Allocate funding on key projects and programmes.
- Organise collaborative events and workshops across universities, industry and relevant manufacturing organisations.

The DRCs' activities

The DRCs will each drive and deliver the research agenda within their technology domain, and will also undertake the following activities:

Technology road-mapping. Each R&D area will build on the work of the EPSRC Network Plus Connected Everything, with priorities determined through an expert steering group. The areas likely to be targeted include: security, reliability/trustworthiness, sensors and networking, advanced simulation and visualisation, and the capture of current manual skills. The road-mapping activity will include the definition of long-term industrial challenges and the definition and management of a research pipeline accordingly.

Supply chain development. Supply chain mapping will be conducted across the five technology areas to identify gaps in UK supply chains, growth opportunities for UK businesses, and the elements of the value chain that can anchor most value in the UK. Particular support will be provided to businesses developing technology platforms or integration solutions. These businesses could carve out a new ecosystem in the UK of 4IR system integrators where the value add is embedded in control systems, software, and integration rather than in hardware.

Feasibility studies. Also in line with the activities currently driven by EPSRC Network Plus, funding will be provided for feasibility studies to accelerate the execution of the research pipeline defined by the DRCs.

Research and innovation programmes. An Innovate UK competition will be created to advance the state of the art and accelerate research pull-through. Businesses developing technology solutions will seek funding and collaboration through these programmes. Next-generation technology demonstrators will be harvested as outputs of the research and innovation projects run with the DRCs. This will refresh the offering of the Digital Innovation Hubs as the state of the art is advanced. Technology demonstration will be a stipulation of innovation funding awards to industry and DIHs.

Technology ecosystem incubator and accelerator. When solutions are unavailable, either in a technical or a financial sense, engagement with the digital innovation community comes into play through direct industry pull. Within these areas, the DRCs will encourage and promote cross innovation and collaboration between industry, universities, start-ups and scale-ups to spark innovation and solve real world problems directly with challenge owners. This activity will also foster the creation of new spin-offs and start-ups, creating a safe environment for experimentation and initial development as well as supporting the development of success stories that can kick-start successful commercialisation. It is at this level that the greatest risk (and greatest potential gain) would be encountered. Therefore, funding routes for this level of activity would not only be through national support programmes, but also through investors (either business angels or banks) with incentives to promote UK 'stickiness'.
An Incubation Funding scheme will enable tech developers and start-ups to prototype, test, and explore applications for new technology offerings. Funding will be made available to support incubation projects with businesses working closely with the Digital Innovation Hubs.

The DRCs' technology scope

The five technology themes identified by our review are the pillars from which industrial digitalisation in the UK will be delivered. Each DRC will cover one of the five themes. The following table describes the challenge and scope of each in more detail.

Description	Challenge	Scope
Artificial Intelligence & Machine learning		
AI systems are capable of accelerating, enhancing and scaling human expertise by enabling greater understanding of data, by making considered arguments and recommendations and by 'learning' over time. In manufacturing and industry it can be utilised for predictive analytics (e.g. predicting when equipment / tools may need maintenance), analysing and optimising processes through data collected across the supply chain and production lines including enabling a closer relationship with the consumer.	One main challenge for AI concerns the design of learning algorithms that can work with extremely large data sets that come from a wide variety of sources in a wide variety of formats. In order to effectively benefit industry there needs to be readily available and labelled data sets for AI/ML researchers and innovative technology companies to utilise to train their algorithms to be more accurate and useful to the end user.	There needs to be development of different algorithm structures which are scalable, which can 'learn' and which can use collaborative techniques on a number of input methodologies and file types. The AI/ML network will look to facilitate access to manufacturing data sets via challenge owners, providing data test beds for AI/ML researchers and innovators to utilise to train their algorithms for the future and develop new business models and opportunities.
Robotics and Automated Systems		
Robotic and automation systems are capable of mimicking and enhancing the abilities of humans to provide greater levels of throughput, repeatability and productivity. Systems that include advanced cognition, perception and human robot collaboration allowing complex manufacturing tasks to be carried out more productively than humans alone.	The principal challenge for Robotics and Manufacturing is to ensure that robotics are more widely adopted by developing technologies & implementation processes that our simpler, more cost effective and provide higher levels of autonomy and coloration with other machines and humans whilst developing the UK skills base in these areas.	The network will enable the development of low cost, advanced perception, cognition, autonomy and collaborative technologies (cobots).
Visualisation / Immersive Technologies		
Advanced Visualisation enables the effective communication of data, concepts and ideas to enable greater productivity, reduce risk, improve quality and optimise production. This can include CAD design through to the adoption of immersive technologies (Virtual, Augmented & Mixed Reality) for digital twins, training and virtual prototyping.	In advanced visualisation, the biggest challenges are interoperability between, and within, hardware and software platforms and the amount of manual intervention required to deploy content effectively while being scalable. There is also a need for standardisation. Furthermore, connectivity to enable VR/AR devices, along with the effective collection of data from across the factory floor is essential in creating beneficial and accurate virtual environments for activities such as training and digital twins.	There needs to be support for the development of either standards or smart interfaces to enable seamless interoperability while at the same time enabling automated publishing of content that is fit for purpose. The network will focus on enabling test beds for immersive technologies, promoting opportunities for challenge owners to provide data to help build future use cases and opportunities to connect immersive technology researchers and innovators to manufacturers to test new business models and use cases of the technology across the supply chain.
The Industrial Internet of Things and Connectivity		
The Industrial Internet of Things (IIoT) can be used in the form of sensors on equipment across the supply chain to provide real-time data that can be utilised to a wide variety of technologies across manufacturing, from machine learning to digital twins and visualisation / informatics for more effective analytics. In addition, connectivity infrastructure as a whole including 5G and Low Powered Wide Area Networks, along with interoperability can enable the development of capabilities on the factory floor while reducing overheads and optimising processes. Distributed Ledger Technologies (Blockchain) can also be utilised to promote broader opportunities for more localised and personalised manufacturing.	The Internet of Things, 5G & Next Generation Internet, Low Powered Wide Area Networks and Cyber Security sit as the underpinning technologies of Industrial Digitalisation. Data intensive technologies such as VR/AR, AI/ML etc. will require suitable connectivity technologies to provide the means for time-critical cost efficient data collection from IoT across manufacturing environments and the supply chain, while effective security will be crucial to mitigate against risks. The challenge will be to ensure manufacturers have this infrastructure in place to utilise IDT across the board for the future.	With partnerships and collaborative exercises such as Pit Stops and competitions across the public & private sectors and academia, Industry led challenge test beds in LPWAN and 5G (taking into consideration security challenges) and the dissemination of grant funding opportunities from the ICF, Innovate UK and the EPSRC – the Connected DRC will help build the capability for leading edge innovators and researchers to test their technologies and ideas in a real world industry setting and solve challenges / explore new opportunities across the supply chain (from interoperability, IIoT, autonomous vehicles, Distributed Autonomous Manufacturing and).
Additive Manufacturing		
Additive Manufacturing (AM) also known as 3D printing is where are objects are created laying one layer on top of the other until a 3D object is created. The technology has so far mostly been used for rapid prototyping and rapid tooling but is now being used to manufacture end use parts. It is transforming the way some of the UK's best known companies manufacture their products and has the potential to put the UK at the forefront of global manufacturing.	AM is an essential ingredient for globally competitive HVM and is a strong driver for accelerating digital manufacturing (Industry 4.0) into all levels of the supply chain. In the last 5 years it has become a serious contender for mainstream manufacturing, with application potential in all major industrial sectors. The world's largest flight-tested aerospace AM part was made recently at the MTC Catapult Centre for Rolls-Royce; this is the 1.5 metre front bearing housing ring vane for the Airbus A380 engine. Mainstream automotive companies are planning to exploit how the novel designs and material properties offered by AM can simplify assembly, improve productivity and improve speed to market.	The DRC will offer a coordinated AM research programme (including an Innovation and Knowledge Centre), as well as a Catalyst (Research and Innovation) programme, a programme of CR&D calls tailored to strategic priorities, Phase 2 investment in National Centre for Additive Manufacturing (hub & spokes), the definition of AM skills, support for the development of the Expert UK AM User Group, and will establish and run a national help/contact point for businesses who are new to AM.

Potential candidates for Digital Research Centres

Artificial Intelligence, Machine Learning, Data Analytics DRC
Turing Institute, University College London, University of Cambridge, Imperial College London, University of Sheffield, University of Southampton, University of Birmingham, Loughborough University, University of Manchester, University of Bristol, University of Warwick, University of Oxford, Heriot- Watt University, University of Surrey, University of York, University of Edinburgh, Newcastle University, Hartree Centre, University of Strathclyde, NPL.

IIoT and Connectivity DRC (5G, IoT, Cybersecurity)
University of Warwick, University of Oxford, Lancaster University, University College London, Imperial College London, Cardiff University, University of Edinburgh, University of Bristol, University of Surrey, University of Southampton, IoT UK.

Robotics and Automated Systems DRC
Cranfield University, Middlesex University, Heriot-Watt University, Imperial College London, Kings College London, London South Bank University, Loughborough University, Middlesex University, Newcastle University, Sheffield Hallam University, RAS Network, University of Bristol, The Advanced Manufacturing Research Centre, The Manufacturing Technology Centre, The Advanced Forming Research Centre.

AR, VR, and Visualisation DRC
Sunderland University, Newcastle University, South Bank University, University of Bath, Bath Spa University, Cambridge University, Sussex University, Ulster University, Queens University Belfast, Northumbria, Ravensbourne University, York University, Bristol University, University College London, Queen Mary, Sheffield University, Edinburgh Napier University, Southampton University, The Advanced Manufacturing Research Centre, The Manufacturing Technology Centre, Warwick Manufacturing Group, Design Engineering & Test Centre, Immerse UK.

Additive Manufacturing DRC
Bournemouth University, University of Edinburgh, The University of Nottingham, The Manufacturing Technology Centre, The University of Sheffield, University of Loughborough, The University of Strathclyde.

HOW WILL A BUSINESS MAKE USE THE NEW IDT ECOSYSTEM?

Figures 30 and 31 show the digital journeys that we envisage businesses undertaking in the new ecosystem, whether they are an industrial SME that wants to investigate whether IDT can address its particular business problem, or an innovator that wants to further develop/ commercialise its ideas and products.

INDUSTRIAL SME ADAPTION & INNOVATION JOURNEY

Figure 30

IDT INNOVATOR DISRUPTION JOURNEY

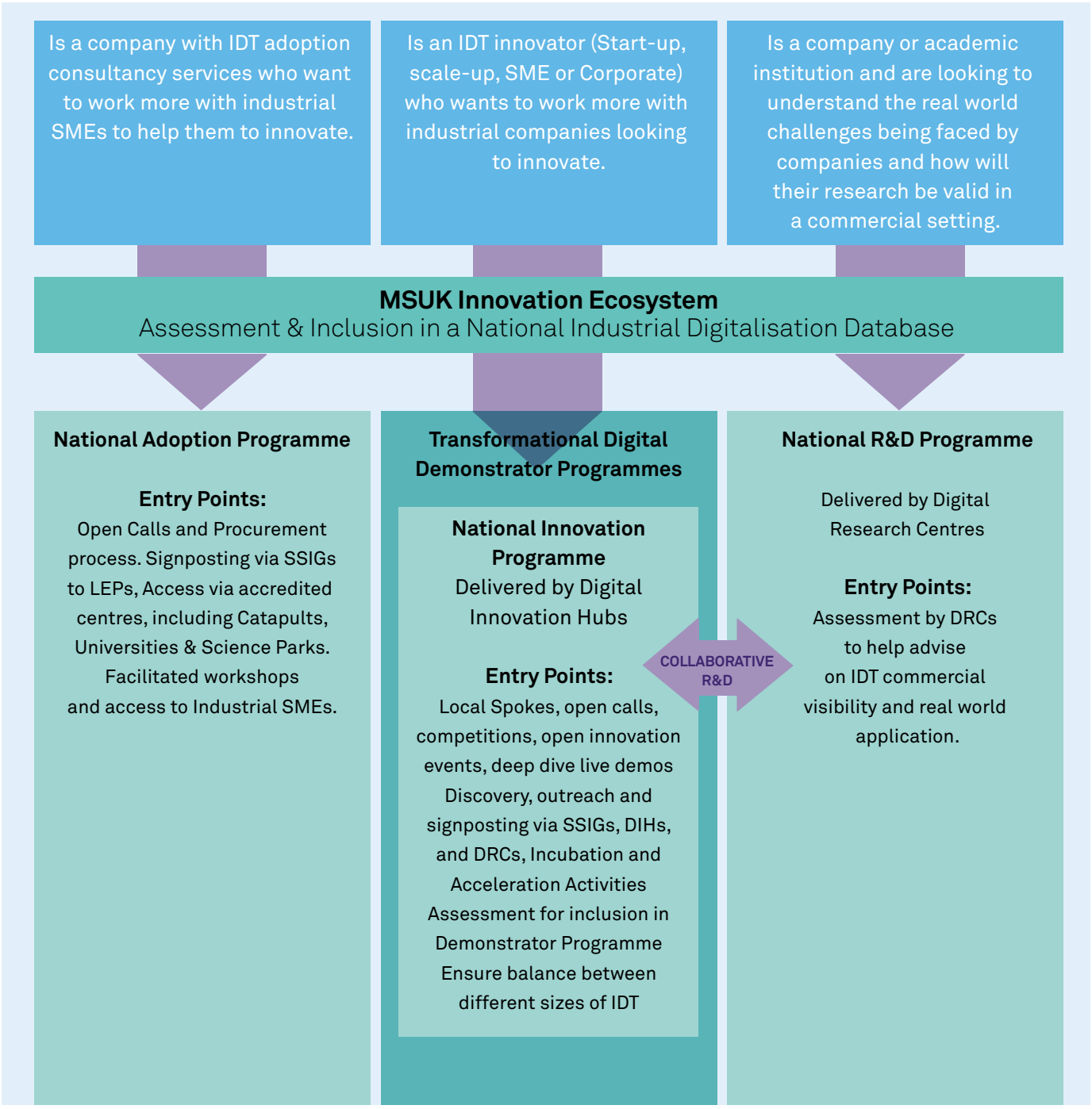


Figure 31

Recommendation 2

Upskill a million industrial workers to enable digital technologies to be deployed and successfully exploited

A lack of digital skills has been identified as the most significant barrier preventing the UK achieving its goal of being a world leader in IDT. The immediate priority is thus for industry and government to work together to increase the level of IDT skills in the existing workforce. This will be achieved through:

- Increasing investment and uptake in skills acquisition.
- Better identifying future skills requirements.
- Improving the provision of and access to quality training to support those future skills.
- Creating an agile skills development system able to respond to rapidly changing market needs.
- Creating a culture of lifelong learning and more visible career pathways for adults.

Our review has set an ambitious goal to reskill and upskill a million workers over the next five years. Its focus, although not exclusively, will be on SME workers (who represent a third of industrial sector employees) through the better coordination of IDT-related skills initiatives and institutions. As such, we are proposing a number of recommendations which both recognise the new technical and professional education system currently in development and are built wherever possible on existing organisational infrastructure and capabilities, in particular the following:

- The Institute of Coding
- The upcoming Institutes of Technology
- The National College Programme
- The National Re-Training scheme
- Apprenticeship programmes
- The wider further and higher education system
- Other bodies and programmes with local and sometimes national capabilities

For example, a full apprenticeship programme may not always be suitable for upskilling workers in emerging technologies. However, apprenticeships have been made a skills policy priority by government and the apprenticeship brand is one that carries currency with employers in industry. Therefore, Modular Apprenticeships, with modules covering new technologies and soft skills, may be more appropriate. These would add up to a full apprenticeship, including the award of a full apprenticeship certificate, following the end-point assessment of learners to establish their competence. Modules on emerging technologies could also be developed which could plug into existing apprenticeship standards – this is already happening in Scotland and this example should be monitored by the UK government and other devolved governments for its effectiveness.

"To stand in the way of automation and industrial digitisation may make King Canute smile, but would be a singular disservice to employees as other competing economies are already highly active in this area. Instead we need to retain existing employees' skills and experience whilst augmenting with relevant industrial digitisation knowledge. Without a central co-ordinating body for skills and some targeted retraining and reskilling incentives, many of our supply-chain SME will inevitably be left behind – this would be to the detriment of the larger supply-networks in which they operate and to the economy as a whole."

Andrew Churchill, Managing Director, JJ Churchill Ltd

A NATIONAL SKILLS STRATEGY AND IMPLEMENTATION GROUP

Recommendation 2.1

Create a single national Skills Strategy and Implementation Group (SSIG) under the governance of the Made Smarter UK Commission (MSUK). This will act as a focal point for the engagement of industry and provide a forum for identifying industry's future skills requirements, synchronising and focusing existing initiatives across established bodies and stakeholders, and ensuring quality and consistency through a kite-marking mechanism.

We propose a central coordinating body for industrial digital skills, in the form of a Made Smarter Skills Strategy and Implementation Group (SSIG), to promote good practice and innovation in skills development through an open partnership of employers and their representatives (e.g. professional institutions), universities, private training providers, experts in online learning delivery, and professional bodies. The SSIG would also work in collaboration with regional and local agencies (e.g. Local Enterprise Partnerships, Skills Development Scotland, etc.).

"Promoting partnerships between employers, universities, private training providers and professional bodies (whatever the dialogue) is bound to be productive, and setting and maintaining standards for quality of training is essential for movement of qualified people across companies and industries."

Eric Michels, HR Business Partner, SEE

The SSIG would focus on maximising the opportunities offered by reskilling existing workers and would coordinate the numerous organisations making up the education ecosystem. Its key activities would include:

- Providing the mechanism for the early identification of emerging skills requirements and feeding these into the education/skills system.
- Working with industry and training providers to ensure the dynamic development of training to address current and future needs.
- Ensuring quality and relevance for users through an industry-led kite-marking programme.
- Mapping and guiding users to the resources available by simplifying the engagement process.
- Signposting existing capabilities, e.g. apprenticeships, the Institute of Coding, Institutes of Technology, national colleges, and employer-provided capabilities.
- Sharing best practice through the coordination of stakeholders and contributors.

"CloudNC is an artificial intelligence company focused on bringing autonomy to the machining industry. We are delighted to see that the Made Smarter Review has resulted in these excellent and practical skills intervention suggestions. Implementation will be an essential first step in retaining competitiveness in manufacturing over the coming decades. We endorse them fully."

Theo Saville, Chief Executive Officer of CloudNC

As IDTs will have an impact on the skills mix and profile of each part of the United Kingdom, it is imperative that there is a UK-wide, national response. That response must ensure that individuals and employers in all corners of the UK are able to take on the skills needed to make the most of the opportunities opened up by Industry 4.0.

The SSIG will therefore work with the different regions and nations within the UK, focusing attention on the particular skills, and the particular levels of skills, that local employer demand requires within local labour markets. It will ensure equality of access to good-quality training resources and national sharing of best practice through the online platform (see Recommendation 2.2 on the following page) and will enable individuals and employers to acquire the right skills irrespective of geographical boundaries or borders.

Regional labour market data and intelligence, gathered and collated by the SSIG, will be used to ensure that local approaches to the skills challenges presented by industrial digitalisation are properly coordinated. The SSIG will work with Local Enterprise Partnerships (LEPs) to ensure their skills strategies are directed at the right skills priorities at the right levels. It is envisaged that material at all requisite skill levels, from GCSE/Standard Grade Level up to Master level, will be made available through the online platform, with individuals and employers then signposted to the training they need by LEPs and by other local stakeholders.

The Skills Matrix

A Skills Matrix for industrial digitalisation, produced by SEMTA and its members in the course of the development of this report, provides an accurate snapshot of current and known future skills needs (see below). However, the inherently unknowable nature of how an industrial revolution will develop, and its impact on the skills profiles of those working in industry, means that reviewing and refining the Skills Matrix will be crucial. This role should also be overseen by the central coordinating body.

The Skills Matrix was compiled from interviews with and survey responses from a number of organisations, including Airbus, Atkins, EEF, JLR, and Toyota. It reflects the skills identified by those employers as being required in an age of industrial digitalisation at each level. However, it should be noted that under each technical level not every skill identified will be needed by every individual, and that particular combinations of skills will be required depending on the role, level and employer organisation. Some of these technical skills already exist within the workforce. Others will be new skills that will need to be developed. The Skills Matrix is by no means a definitive view on skills but is intended to stimulate further debate and discussion in this area. It can be used in many ways, including identifying employee reskilling and upskilling opportunities and recruitment requirements.

The Matrix has been divided into three sections:

- Mature skills that are widely used in many organisations
- New skills that are currently used in a limited way or in a few organisations
- Emerging skills that will be required for future industrial digitalisation.

TECHNICAL SKILLS
(not all will be needed at each level)

MATURE SKILLS – ALREADY EXIST AND USED						
	LEVEL 1	**LEVEL 2** Semi –skilled Intermediate Apprenticeship	**LEVEL 3** NC/ND (Engineering Technician) Advanced Apprenticeship	**LEVEL 4** HNC/HND/FD (Incorporated Engineer) Higher Apprenticeship	**LEVEL 6** Bachelor's degree (Incorporated Engineer) Degree Apprenticeship	**LEVEL 7** Master's degree (Chartered Engineer)
Programming software			✓	✓	✓	✓
Mechatronics			✓	✓		
Processing of data			✓	✓	✓	
Material and production skills		✓	✓			
Process skills		✓	✓			
Electrical engineering/systems			✓	✓	✓	
Electronics			✓	✓	✓	
Maintenance, servicing, and further development of the system (robotics)		✓	✓			
Mechanical and plant engineering		✓	✓			
Product design				✓	✓	✓
PLC Programming				✓		
Specify, install and setup control systems hardware				✓		
Value Stream Mapping and LEAN principles			✓	✓	✓	

SKILLS CURRENTLY USED IN A LIMITED WAY

	LEVEL 1	LEVEL 2 Semi –skilled	LEVEL 3 NC/ND (Engineering Technician)	LEVEL 4 HNC/HND/FD (Incorporated Engineer)	LEVEL 6 Bachelor's degree (Incorporated Engineer)	LEVEL 7 Master's degree (Chartered Engineer)
Computer network skills				✓	✓	✓
Data science			✓	✓	✓	
Rapid prototyping – CAD software, 3D printing, advanced injection moulding			✓	✓		
Robotics – software and programming skills and engineering ability				✓	✓	
Data interpretation/mining – plus making use of Big Data and infomatics			✓	✓	✓	
Optimisation, monitoring and controlling of processes			✓	✓	✓	
Industrial networks control systems (HMIs, SCADA etc)				✓		
Proportional hydraulics (PLC controlled)			✓	✓		
Systems Engineering				✓	✓	✓
Data management/leadership				✓	✓	

NEW/EMERGING SKILLS – NEED FOR FUTURE

	LEVEL 1	LEVEL 2 Semi –skilled	LEVEL 3 NC/ND (Engineering Technician)	LEVEL 4 HNC/HND/FD (Incorporated Engineer)	LEVEL 6 Bachelor's degree (Incorporated Engineer)	LEVEL 7 Master's degree (Chartered Engineer)
Computer security software skills			✓	✓	✓	✓
Artificial intelligence				✓	✓	✓
Using virtual and augmented reality				✓	✓	✓
Human–machine interaction (HMI) skills					✓	✓
Predictive analytics			✓	✓	✓	✓
Automation technology			✓	✓		
Microsystems technology			✓	✓		
Appreciation of digital technologies	✓	✓	✓	✓	✓	✓
Intelligent application of digital technologies			✓	✓	✓	
Digital leadership				✓	✓	✓
Digital creativity (creation of product digital twins, creation of production line digital shadows)					✓	✓
Interface management/leadership				✓	✓	
GENERIC SKILLS	Complex problem solving, critical thinking, creativity, people management, change management, coordinating with others, emotional intelligence, judgement and decision making, service orientation, negotiation, cognitive flexibility (Source: WEF) Sense-making, social intelligence, novel and adaptive thinking, cross cultural competence, new media literacy, transdisciplinarity, design mindset, cognitive load management, virtual collaboration (Source: Future of Work 2020, Institute for the Future) Customer relationship management – crucial if benefits in vertical integration are to be involved. Creation of new business models at a more senior level					

GENERAL DIGITAL SKILLS
(Source: Eight Digital Skills we must teach our children, WEF)

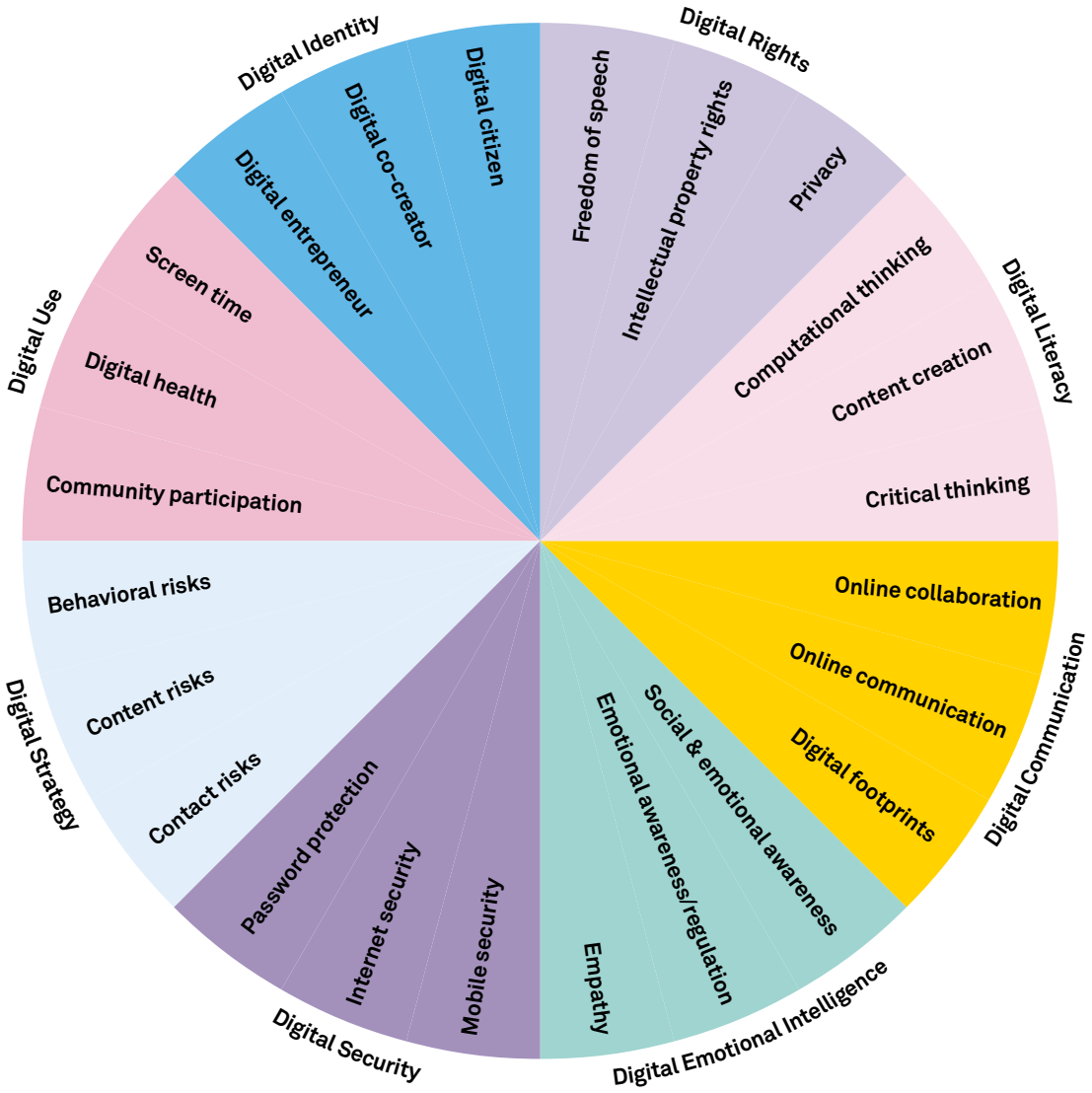


Figure 32

AN ONLINE DIGITAL PLATFORM FOR LEARNING

Recommendation 2.2

Establish a modern digital delivery platform, providing scalable, relevant, timely, and easily 'digestible' content for upskilling and reskilling. This would enable all companies, but particularly SMEs, to play their part in the Fourth Industrial Revolution, with incentives and networks in place to drive adoption.

We propose an online 21st century digital learning platform to improve access to quality IDT training. With a goal of achieving at least 200,000 completed user certifications each year to 2022, this would lead to at least one million of the three million workers currently employed in industry being upskilled in new and emerging digital technologies to meet industrial need.

The platform will adopt or adapt an individual platform (or a set of platforms), such as Futurelearn or the IET online platform, to provide an accessible, customised and relevant set of online modules which could be used as part of a learning pathway to reskill and upskill workers.

The platform will be accessible on a UK-wide basis to employers of all shapes and sizes. It will be populated from industry-provided and certified competence- and capability-based content which will be freely shared with the education and skills system as required. Content will be regularly updated and targeted at the skills in most demand in the most relevant sectors. It will provide short-form, modular resources, that are industry supported and quality assured through a kite-mark. The platform could be used as a standalone resource or in blended form in environments such as diffusion centres, further education colleges, higher education institutions, university technical colleges and schools. The training provided would contribute to qualifications, accreditations and, potentially, apprenticeships. What's more, the uptake of the platform's content would act as a demand signal to the rest of the education system about the nature of current and potential future skills requirements.

"Airbus is already working on the competencies and opportunities digitalisation will bring to our business and the ecosystem we operate within. This initiative will definitely help us, but more importantly our supply chain, with the skills needed to address the challenge of Industry 4.0. It is vital that we not only nurture these skills for the next generation but that this initiative succeeds to ensure the competitiveness of the UK."

Mark Stewart, General Manager and HR Director, Airbus

Why an online platform?

The provision of online learning is the most cost-effective way to scale the provision of reskilling resources. And the rate of change of IDT demands dynamic, user-driven, regularly updated content at pace – something which an online platform can deliver.

Recent policy developments in skills innovation have tended to focus on institutions with geographical bases, such as University Technical Colleges, National Colleges and the new Institutes of Technology. These will continue to have great value. However, a wave of nationally transformative technological change, in the shape of Industry 4.0, requires a nationally accessible platform to supplement and compliment these physical bases.

The capability and uptake of online learning, either standalone or blended with physical facilities, is increasing at pace. The 2016–17 Learning Benchmark Report from Towards Maturity highlights an increase in the use of learning technologies, with e-learning and live online learning seeing the highest rise (88 percent and 89 percent respectively). Furthermore, it predicts that in the next two years there will be even more of a shift away from face-to-face training, citing, for example, a rise in the use of virtual classrooms from 39 percent to 69 percent.

The rapid nature of technological change means that access to the training needed to harness new digital technologies must be similarly rapid. The national nature of the skills challenge presented by the adoption of digital technologies presents a golden opportunity to develop an effective mechanism for spreading new skills quickly throughout industry. This need for speed means that the most sensible delivery mechanism is online.

Collating training resources online has a number of other advantages. It provides for truly UK-wide access on equal terms across regions and nations; it offers an easy way for those seeking training to search through what is available and find the training which best suits their needs; and it makes the kite-marking and quality assurance process, along with usage monitoring for the central coordinating body, simpler and quicker.

Using a digital online platform to access to kite-marked resources would ensure the cost of operation could be kept low – through the elimination of a need for an additional bricks-and-mortar presence and for staff to deliver training. Online access would ensure that individuals using the platform could study at the right pace for them and their employers. It would provide an easy way for employers and individuals to check progress, to identify any difficulties in study, and to work to address them. For those lacking in the digital skills needed to access online training, employers would be signposted to physical locations where their workers could complete the free basic digital skills training that will be offered by government.

The digital diffusion of training in new digital technologies would eliminate geographical disparities in access, an issue which has been evident in the operation of the National Colleges programme. It would ensure that leaders and managers in industry are aware of where to signpost workers and where they themselves can access training in new technologies (this is an issue of critical importance given that just 28 percent of industrial leaders have a ‘very good’ awareness of what Industry 4.0 entails (Oracle, 2016)). Barriers to access for smaller employers and individuals would also be eliminated – any individual with an internet connection would be able to use the online platform and have instant access to learning resources provided by industry and kite-marked by the central coordinating body.

It is envisaged that, as the platform develops and awareness of it increases, learning undertaken through it could be integrated with other forms of study to produce a blended learning approach. Training providers could integrate modules and short-form courses accessed through the platform into their own course offerings. Materials could also be used as part of an immersive learning approach or, in future, integrated into apprenticeship and T-Level programmes. The completion of online learning through the platform could then be accepted as evidence of an individual's progress. In the case of apprenticeships, such self-study could count towards the 20 percent off-the-job training requirement, a step which would also ease industrial employer concerns about the financial viability of using apprenticeships to upskill existing workers.

The platform could also be used to ensure knowledge of new technologies is absorbed by those working for institutions such as colleges, Institutes of Technology, schools, and private training providers. With training accessed through the platform all bearing a Made Smart kite-mark, trainers would have full confidence that the knowledge they are absorbing is both relevant to industry and up to date. In doing so, the online platform will be key to ensuring that the sustainability strategy can be successful.

"The development of our engineers is business critical to Jaguar Land Rover, ensuring continued innovation and technical excellence in the delivery of premium cars and all-terrain vehicles. The Technical Accreditation Scheme is our innovative and progressive approach to skills growth, making the most of the excellence of our university partners in delivering cutting edge education."

Jo Lopes, Head of Technical Excellence, Jaguar Land Rover

It is important to recognise that existing platforms (such as FutureLearn and the IET) should be used for this provision. It is also important to note that we already have commitment from several companies (Cisco, Accenture, ATOS etc) to provide content and support for this platform, such that the content is kept current and owned/curated by the appropriate industry experts. The content is likely to be short form, rapidly iterated, user rated and highly current. It will continuously evolve as the needs of industry emerge.

It is vital that the data derived from this platform about demand for courses, their uptake, and success, as well as their content and quality, is continuously monitored and used as a demand signal not only for the further development of the platform but also made available to higher and further education and schools as a strong signal of the skills and job types needed for the next generation. It is also envisaged that the modular content itself will be made available to those institutions as applicable to minimise their overhead and to ensure currency.

INCENTIVES TO RETRAIN AND RESKILL

Recommendation 2.3

Establish an incentivised programme, co-funded by industry and government, to improve digital skills capabilities. Under the guidance of the SSIG and using the digital delivery platform, this would take the form of personal training and reskilling allowances targeted at:

- Individuals whose jobs are being displaced by automation
- Workers whose skillsets need to evolve to next-generation capabilities (e.g. the use of additive manufacturing technology or AI)
- Providing leading skills in all organisations (e.g. the digital engineer of the future)

We are proposing that retraining/reskilling is incentivised to address the weak demand from employers (currently half the EU average), to encourage organisations to train workers in the next generation of IDT skills, and to engender a culture of continuous workforce development and reskilling.

Although the costs of training will not be onerous, for a smaller employer or for an individual, they could nonetheless act as a disincentive - especially when it is considered that those most urgently in need of reskilling are those earning lower wages and therefore least likely to have the disposable income needed to invest in their own skills.

We are therefore proposing that the training costs for using the online platform (see above) are shared between the employer and government. The costs of the employer's contribution could be offset through a skills equivalent of the R&D tax credits for money spent on reskilling and upskilling, and the government could explore flexibility in the use of the Apprenticeship Levy, including apprenticeship vouchers which are unspent within 24 months by those employers which pay the levy.

The programme would be targeted at SMEs and those workers whose jobs are most likely to be affected by technology, particularly lower-skilled jobs involving repetitive tasks that are more vulnerable to automation. Workers at lower skill levels are also relatively less likely to have the wherewithal to seek out and access training for new skills. In industry, many of those workers have been actively put off formal learning by their experience of academic education.

Initially, training will focus on the following areas of priority identified by this review, and will be available at Level 3, Level 4-6 and Level 7:

1. Cybersecurity,
2. AI and machine learning,
3. The IoT and data analytics,
4. Additive manufacturing,
5. Robotics and automation.

For example, cybersecurity skills are essential in ensuring that digitalised industrial workplaces are able to operate without being compromised by internal and external threats to their online systems. Smart factories face many of the same challenges as other systems connected to the internet, including cyber-espionage, hacking and malware, in addition to wider issues around supply chain security and the security of the IoT. The research shows that the number of cybersecurity roles advertised in the UK was the third highest globally. As a result, employer demand exceeded candidate interest by more than three times, according to Indeed, resulting in the biggest skills gap of any country in the world, bar Israel. The Indeed survey shows that Britain's cybersecurity skills gap has grown by 5 percent in two years, a tally exceeded only by Brazil and Canada.[113]

Data analytics are an integral part of smart manufacturing and thus a hallmark of Industry 4.0. Big Data is set to become increasingly important to UK industry as more of the physical labour involved in the manufacturing process is undertaken by machines and the role of humans shifts towards analysis of the process. An accurate and considered interpretation of the data produced by intelligent systems in smart factories is crucial in ensuring that they operate efficiently and that issues in the manufacturing process are identified and resolved.

"Cybersecurity, Artificial Intelligence, Additive Manufacturing and Data Analytics are growth areas for skills in all industries and skills shortages across the UK are well documented. Given the scale of the challenge, all companies, large and small, need support from government, particularly at the higher and advanced levels."

Eric Michels, HR Business Partner, SEE

Training would be delivered, in part, using the online platform we recommend (see above). This would also provide an effective means by which to demonstrate that the allowance was being spent appropriately. However, the allowance could also be used to fund other forms of training in emerging technologies where deemed appropriate (for example, continuous professional development certified short courses, or courses carried out at further education institutions or private training providers). Kite-marking these courses and organisations will ensure that training allowances are used to the greatest effect.

[113] http://www.independent.co.uk/news/business/news/cyber-security-skills-gap widen-supply-demand-expertise-uk-companies-it-a7529986.html

Recommendation 3

Inspire the UK's next industrial revolution with stronger leadership and branding of the Country's ambition to be a global pioneer in IDTs.

A MAJOR NATIONAL BRAND CAMPAIGN TO RAISE AWARENESS OF IDTS

Recommendation 3.1

Establish a major national brand campaign, delivered by both government and industry, to significantly increase awareness of how new digital technologies can transform industry. Delivered within a wider support framework, the campaign would promote the adoption of digital technologies (especially among SMEs), address negative preconceptions that IDT is expensive and risky, and inspire current and future workers with a vision of how they can secure high-quality jobs in a thriving part of the economy.

We are proposing a major national brand campaign – Made Smarter – to significantly increase awareness of industrial digitalisation and how new technologies can transform the productivity of the manufacturing and production sector. This would also promote the growth of a new wave of technology businesses across the UK. The campaign would be industry led and delivered by the Made Smarter Commission (see below). Its objective is therefore to transform perceptions and, in turn, generate real behavioural change in the marketplace. It would thus aim to:

- Increase the number of manufacturing SMEs accessing support from Growth Hubs.
- Increase the number of manufacturing SMEs using research, innovation and catapult centres.
- Increase the adoption of digital technologies, especially among smaller enterprises.
- Raise the profile of UK manufacturing and engineering.
- Raise awareness of the UK brand and approach with international investors and collaborators.

We have designed the blueprint for a campaign and brand to go live as early as January 2018. See overleaf for example concepts currently undergoing market testing.

NB Campaign imagery and content is provisional and shown for illustration purposes only.

Through our consultation with more than 200 companies, we have identified a fundamental lack of awareness and understanding about digital technologies across the industrial and manufacturing sectors in the UK. This is borne out by research such as the BDO report summarised in the previous section. The MSR leadership team believes that the scattered support network for manufacturing, combined with a lack of a coherent national brand for UK digitalisation, has contributed to market confusion and poor adoption rates, particularly among the SME base.

Thus, in the context of industrial digitalisation, the UK is currently witnessing market failure through the lack of a national technology brand and campaign. Industry has the propensity to only invest in brands of its own, where a product or solution is being marketed for its own interest. Indeed, industry will typically only invest in a new brand that will promote its own marketing objectives or perhaps that of similar companies. A lack of technological neutrality means industry has not self-organised to market a national strategic digital adoption strategy. Individually this makes sense – business must use its own resources to market its own products successfully to make a return. But collectively it misses the bigger picture – that creating a national brand that drives exports, inward investment and greater uptake of new technologies, leads to greater gains in the long term. This is why governments across the world have intervened in their own markets to create national technology brands. The UK has done this before more broadly, notably with the Great Campaign which created 10,000 new jobs and secured incremental economic revenues of £2.7 billion for the UK, comprising:

- £1.77 billion from international and domestic tourism;
- £720 million from trade and foreign direct investment; and
- £228 million from international education.[114]

[114] Civil Service Quarterly, Cabinet Office 2017

How will the campaign be delivered – and by whom?

The goals of this review are closely linked with the aims of the Productivity Leadership Group (PLG), a business campaign aimed at improving the UK's enduring productivity problems by making measurement more easily accessible and establishing best practice.

Our recommendations in this review form part of the PLG's aspiration for business to be at the forefront of improving the UK's productivity. Evidence demonstrates that increasing the use of digital technologies in industry would make an important contribution to that aspiration. The PLG will therefore work in close collaboration with the Made Smarter UK Commission (see below) in the planning and execution of this marketing campaign, as part of the PLG's wider 'Be the Business' movement which was launched in June 2017. The campaign would ultimately be the face and brand for the Made Smarter UK Commission, which would be accountable for its delivery.

A NATIONAL MADE SMARTER UK COMMISSION TO MAKE THE UK A WORLD LEADER IN IDT

Recommendation 3.2

Establish a national body – the Made Smarter UK (MSUK) Commission – comprising representatives from industry, government, academia and leading research and innovation organisations, responsible for developing the UK as a leader in IDTs. With an industrial chair and a Ministerial co-chair, this public–private partnership will provide a market-focused view on IDT priorities, ensuring their faster innovation, adoption and diffusion to drive maximum value to the UK economy. The MSUK Commission will establish and govern a more visible and better organised ecosystem that will deliver business transformation through innovation (see also Recommendation 1).

Recommendation 3.3

Set up interim Strategy and Support Implementation Groups (SSIGs) to be responsible for the delivery of this report's recommendations. These would comprise representatives from industry, government and academia, and would be accountable to the MSUK Commission.

With funding from both industry and government, we will establish an exciting and more coherent IDT ecosystem, built on the foundations of the existing infrastructure, initiatives, institutions and networks that make up the UK's innovation community.

The Made Smarter UK Commission (MSUK) will be a national body dedicated to developing the UK as a leader in IDTs. It will be a public–private partnership between industry, government, academia and leading research and innovation organisations, providing a market-focused view on IDT priorities, ensuring their faster innovation and adoption to drive maximum value to the UK economy. The MSUK Leadership Board will take oversight, strategic direction and responsibility for the delivery of the recommendations in this report, and sustaining activity over many years. It will establish and govern a more visible and better organised ecosystem by aligning industry, government and other stakeholder views on IDT, which will deliver business transformation through innovation.

The MSUK ecosystem will be structured around a Governance and Leadership Board, two Strategy and Support Implementation Groups (SSIGs) and three national programmes:

1. National Adoption Programme
2. National Innovation Programme
3. National Research and Development Programme

The two SSIGs will be responsible for the delivery of our key recommendations relating to skills and ecosystem delivery. They will consist of two small teams responsible for coordination, communication, implementation and tracking of KPIs across the ecosystem to maximise value and impact. The SSIGs will effectively bring together all the below dimensions into one coherent whole, promoting collaboration across the MSUK initiative and helping to communicate activities of the MSUK ecosystem externally:

1. IDT Ecosystem SSIG - Responsible for the governance, strategic direction, coordination, and implementation of the evolving ecosystem that will support the faster innovation and adoption of IDTs.
2. IDT Skills SSIG - Responsible for the governance, strategic direction, coordination, and implementation of the skills recommendations that will upskill a million employees in the field of digital engineering.

The goal of the MSUK Commission would be to break down the barriers we identify in Part 3 of this report:

- The slow adoption of IDT technologies, especially among SMEs, due to a lack of information and poor management practices. According to BDO and the Institute of Mechanical Engineers, only 8 percent of manufacturing companies interviewed in 2016 understand industry 4.0 or digitalisation. 44 percent cited a lack of understanding as the main reason they are not currently investing.
- The lack of a coherent, centralised and easily accessible model for business engagement or recognised source for independent advice in the field of IDT. Such a resource would provide leadership, distribute information, support the development of management skills and coordinate support for commercialisation.
- A lack of leadership – a 2016 PwC report found the biggest challenge for UK firms in adopting IDT remains a lack of digital culture, talent, and clear digital operations vision. There is no national strategy and organisation that stands as a point of contact for IDT leadership. The lack of national leadership was recognised in Germany in their 2016 Digital Strategy 2025 which proposed the creation of a Digital Agency (see Appendix 2).

Support recommendation – Implement a series of enablers to address key barriers to adoption of IDTs

ENABLER: STANDARDS

Recommendation 4.1

Implement a Standards Development Programme (including cyber-awareness and best practices) for emerging digital industries to promote the greater interoperability of IDTs. The creation of standards has been demonstrated as an effective way to promote adoption, by providing greater confidence and assurance. This programme would be led by BSI working with industry, research communities, government bodies and regulators to address both generic and sector-specific standards. The resulting standards would then be promoted internationally through BSI's membership of CEN, CENELEC, ISO, and IEC.

Our review identified a need to create clear standards for the adoption of digital technologies by UK industries and supply chains. This will maximise the impact of the demonstrators and adoption programmes we recommend by enabling the diffusion of knowledge across industry. It will also de-risk investment in digital technologies and lead to the development of global standards in areas of UK strengths.

The programme would be led by BSI working with industry and other parties acting in Communities of Interest (CoIs) to address both generic and sector-specific standards. The work programme would consist of standards development, implementation, and internationalisation. BSI, in partnership with NPL, will create an agile standards development programme that enables good practice to be deployed in demonstrators and adoption programmes. The resulting standards will be made available by BSI, and promoted internationally through its membership of CEN, CENELEC, ISO, and IEC.

The programme should be co-funded by government and industry. Industry will participate in workshops, sharing best practice and developing use cases. Each CoI will produce a standards roadmap setting out priorities and a work programme, and then enter a delivery phase where the outputs are produced. Additionally, the CoIs will work with the demonstrators and adoption activities to pilot the standards and feed knowledge back into the standards programme. Industry support, in the form of time commitment from companies as well as shared expertise and knowledge, will be provided.

This activity will be managed by senior experts who will set the digital industrial standards strategy, working within the governance of the Make Smarter UK Commission. Members will come from a range of industry sectors, as well as the research community, government bodies and regulators.

The priority standards already identified include:

Guide to the use of data in manufacturing supply chains.

- Interoperability standards: to accelerate and strengthen the digital connection of UK manufacturing supply chains.

Guide to establishing a framework for collaborative relationships in supply chains.

- Collaborative product design standards: to identify and capture best practice in digital design within industry.

Specification for security-minded management of digital manufacturing processes (addressing Cyber Security issues).

Guide to establishing the precision and accuracy of connected sensor measurements in a network.

- Governance, security, and assurance of data standards – to address concerns with cybersecurity and provide confidence in data used to demonstrate product safety and performance assurance derived from digital models including virtual certification.

Vocabulary for the design and delivery of through-life engineering services.

- Service innovation standards: to establish good practice that will help manufacturing companies implement novel service offerings.

The creation of standards drives productivity growth, as evidenced by recent research papers.[115] Industrial digitalisation is a relatively new area for standardisation, reflecting the increasingly complex and interdisciplinary nature of technological systems, and to date the lead has been taken by countries that have already established their own national programmes in support of digital manufacturing (for example, Industrie 4.0 in Germany[116] and the Industrial Value Chain Initiative in Japan[117]). However, there are gaps in what has been proposed, and the current international standards activities do not reflect the priorities of UK industry.

The importance of setting global standards is described in the Government Office for Science in their report Technology and Innovation Futures. They said, "acting as a standards setter is one of the government policy levers that can support emerging technologies by using "insights from living labs to develop UK standards – setting the global agenda by 'showing, not telling'".[118]

Our proposed programme focuses on opportunities for the UK to lead the creation of standards in areas of strength for the UK manufacturing sector, such as service innovation and use of digital information in the design process.[119] The creation of international standards in areas of UK strength will help UK companies exploit competitive advantage in international markets, as described in a recent paper by Gregory Tassey of the University of Washington:

"The realization of competitive advantage will only be achieved if (1) individual economies identify and invest in industries within the broader global supply chain where they can achieve comparative advantage, (2) a technical infrastructure, largely based on standards, is developed and implemented to ensure efficient product portfolio development, production, and commercialization for each economy's selected strategy, and (3) the standards infrastructure is uniform across all economies involved in the global supply chain."[120]

BSI, as the UK member of the European and international standards bodies CEN, CENELEC, ISO and IEC, has a strong track record of getting UK standards recognised as international

[115] See, for example, https://www.bsigroup.com/LocalFiles/en-GB/standards/BSI-standards research-report-The-Economic-Contribution-of-Standards-to-the-UK-Economy UK-EN.pdf and http://www.iioc.org/the-economic-value-of-standards/

[116] http://www.plattform-i40.de/I40/Navigation/EN/Home/home.html

[117] https://www.iv-i.org/en/

[118] https://www.gov.uk/Government/uploads/system/uploads/attachment_data file/584219/technology-innovation-futures-2017.pdf

[119] BSI (2017). Acceleration of digital innovation by UK manufacturing supply chains. The role of standards.

[120] Tassey, G. (2017). The Roles and Impacts of Technical Standards on Economic Growth and Implications for Innovation Policy, Annals of Science and Technology Policy: Vol. 1, No. 3, pp. 215–316. Available from: http://dx.doi.org/10.1561/110.00000003

standards. Globally recognised standards such as ISO 9001 (quality management), ISO 14001 (environmental management) and ISO 27001 (information security) all started as BSI standards. Recently, BSI has taken an international lead in innovative technologies such as smart cities and Building Information Modelling (BIM), where the UK standards have been adopted across the world and contributed to the UK's international reputation for expertise in these areas.

Furthermore, the National Physical Laboratory (NPL) is the UK's National Measurement Institute, and is a world-leading centre of excellence in developing and applying the most accurate measurement standards, science and technology available.

Standards enable the adoption of technologies, both by resolving interoperability issues and by supporting knowledge diffusion:

- Interoperability: Open, vendor-neutral standards allow the development of plug-and-play capabilities that reduce the time taken to integrate new technologies, products, data and systems. They also help reduce the risk of technology lock-in, thereby encouraging investment and de-risking the adoption of new technologies.
- Knowledge diffusion: standards can support technology transfer by establishing a common vocabulary, and common methods of characterisation and testing, performance specifications, processes. This allows the market to coalesce around a shared expectation of what good looks like. This is described in a paper published by the Institute for Manufacturing at Cambridge University:

"The case studies [in additive manufacturing, smart grids and synthetic biology] also suggest that standards not only support information and knowledge diffusion, but also help mediate between innovation activities and between actors. The standards in the case studies not only help structure and communicate necessary information, but also facilitate its generation (for example, testing in additive manufacturing) and structure how it is communicated both 'forward' to downstream and 'back' to upstream innovation activities (for example, how to describe system elements in synthetic biology). This supports standards as a mechanism for aligning and coordinating innovation activities."[121]

Only by having clear standards will the current uncertainty be removed. The goal is to remove the critical barriers of interoperability as part of the wider objective to increase the adoption of IDTs in the UK.

ENABLER: FINANCIAL INCENTIVES

Recommendation 4.2

Implement targeted financial incentives to promote the development and adoption of IDT. This would include:

- Enhanced capital allowances in the first year of IDT investments,
- Broadening the R&D Tax Credit system to include IDT,
- An increase in the write-down allowance for specific technologies, and
- Working with the British Business Bank to develop policies or programmes to encourage the adoption of IDT and facilitate the financing of suitably qualified projects as appropriate.

[121] Featherston, C., Ho, J-Y, Brévignon-Dodin, L., O'Sullivan, E. (2016). Mediating and catalysing innovation: A framework for anticipating the standardisation needs of emerging technologies, Technovation 48-49, pp. 25–40. Available from: http://www.sciencedirect.com/science/article/pii/S0166497215000772

As part of our coherent set of policy interventions we propose new financial incentives to clearly signpost to companies the importance of adopting digital technologies and address SMEs' risk concerns about their scale and available resources.

Access to finance (in the form of loans) may not be as critical a barrier to IDT adoption as the challenges faced by companies in understanding the new technology, developing the skills required, and having easy access to significant demonstrators of the technology or support from advisors. However, as an element of an industrial strategy to encourage companies on their digital journeys, having an 'access to finance' element has been proven to have a positive effect.

A tax policy in itself, however, is not sufficient to overcome the significant barriers to adoption that have been identified. But it becomes relevant once the initial barriers to adoption have been overcome and an organisation is ready to invest.

> The CEO at GKN created a central investment fund for the purchase of cobots to encourage adoption across the business. Internal operating units could request a cobot based on a simple justification. The investment did not sit on the business units balance sheet. The uptake has been very strong and while some projects inevitably failed, the net effect has been positive. The company now has a greater understanding of the technology and it is delivering benefits through the application in areas that were never initially considered.

The recognition by the government of the special nature of IDT and its importance for future national prosperity is an important message that it can give through the tax system:

1. Investment and tax
Increased depreciation allowance for IDT: special recognition should be given to the different nature and depreciation rates of IDT. It is therefore proposed to increase the writing down allowance for specific technology.

We recommend a study to identify the optimum level. The current level is 18 percent, however it could be as high as 40 percent.

Enhanced capital allowance for first year of investment in IDT: there should be a First Year Allowance or Enhanced Capital Allowance for defined technologies similar to that used for certain categories of energy-saving equipment. This would give a specific benefit to companies investing in IDT at an early stage in the project. Research by Bond and Xing has found "very robust evidence" that more generous capital allowances for equipment in particular can help to tip investment decisions over the line and that there is a positive link between the 'present value' or worth of capital allowances and investment as a proportion of GDP in G7 countries.[122]

We recommend that there should be a business-led team to define the technologies that would qualify and that this could be part of the strategic role of the Digital Technology Commission.

[122] Race to the Top: developing a Corporation Tax regime to support sustainable growth CBI Policy Briefing #3

2. Direct support/grants/loans
Widen the scope of the successful R&D Tax Credit system to include IDT integration: R&D Tax Credits are recognised as an effective mechanism for providing direct support to companies undertaking R&D.

The scope of these R&D Tax Credits should be widened to include IDT that is innovative and new for a specific organisation, even if the technology has been applied elsewhere. This may require more work on definition, marketing and promotion targeted at IDT to gain the traction required and may not require any fundamental changes in policy.

3. Develop financial support/advice for IDT through the British Business Bank
There should be recognition of the special importance of IDT and that the British Business Bank should be engaged to have policies or programmes designed to encourage the adoption of IDT and facilitate the financing of suitably qualified projects as appropriate.

4. Introduction of a SME Kick-Start Funding scheme to support IDT adoption
Targeted kick-start funding schemes have been demonstrated as an effective mechanism to motivate companies to engage. They offer SMEs a small financial incentive (10-30 days) for partnering with a university or research institution for R&D assistance, a technology feasibility study, the analysis of technology transfer, etc. This incentivises SMEs and academia/support organisations to come together and results in longer-term relationships. The benefit of the Kick-Start Funding scheme is that companies know there will be dedicated and tailored support and it will act to de-risk investment. This scheme is to be closely coordinated with the Digital Innovation Hubs and the National Adoption Programme described earlier.

ENABLER: ACCESS TO DATA

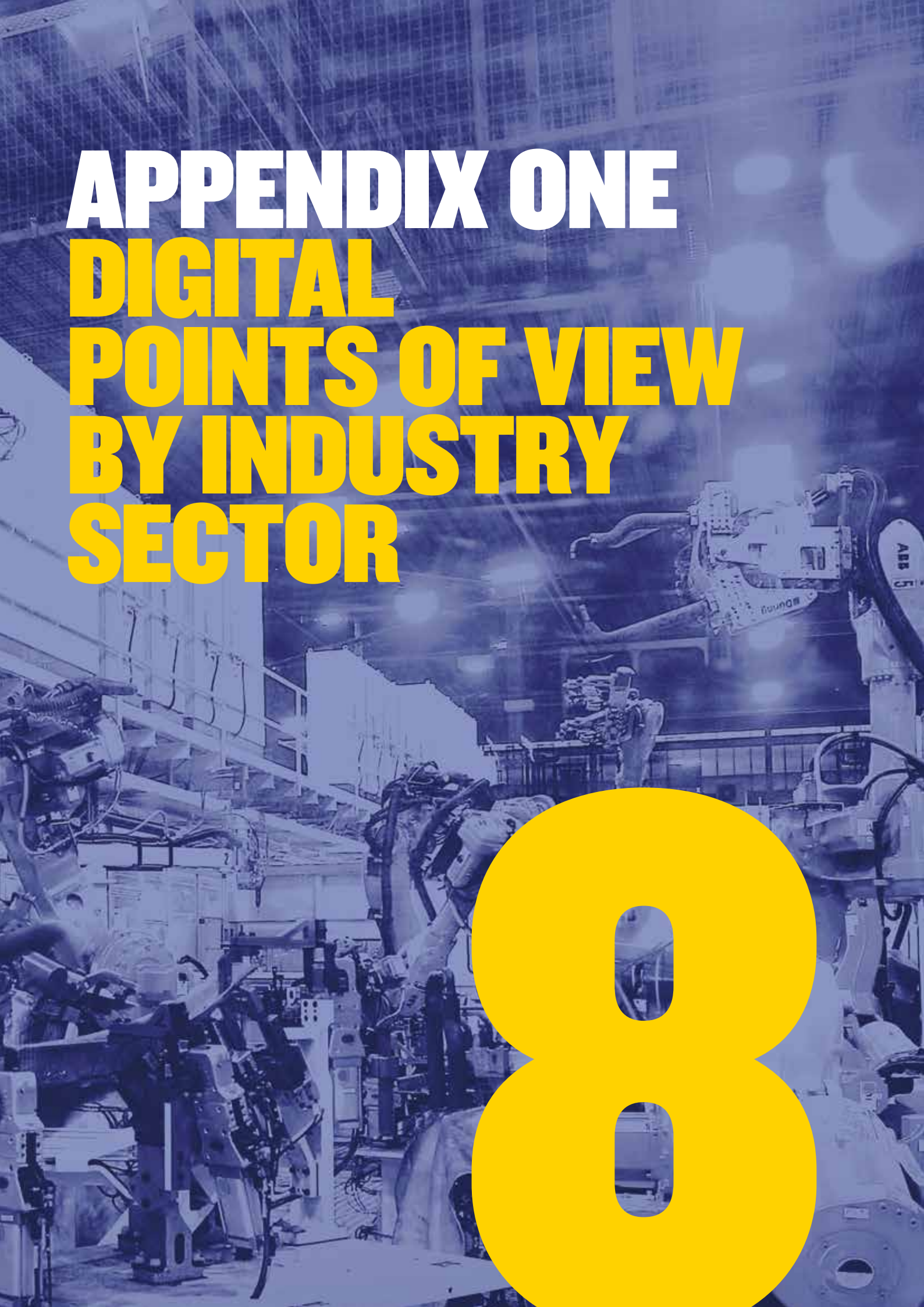
4.3 Recommendation

We strongly endorse the recommendations of the AI review which proposes that government and industry should deliver a programme to develop data trusts – proven and trusted frameworks and agreements – and to ensure exchanges are secure and mutually beneficial.

A reluctance to share data within the manufacturing context was identified as a significant inhibitor to the exploitation of IDT. We strongly support the recommendations from the Artificial Intelligence review which would see government promoting greater access to data. This includes:

- Supporting industry in a programme to establish data trusts – proven and trusted frameworks and agreements – and to ensure exchanges are secure and mutually beneficial.
- Government encouraging the publication of information in machine-readable formats, and increased access to information by re-examining the ability to access wider materials that are currently protected by copyright, where the application of AI and/or data analytics learning would not be in breach of copyright.

As part of the sector deal, the Made Smarter SSIG (see above) will work with the AI review to further define the actions required to establish data trusts, and gain access to publicly available information (or anonymised data) where it could be used in the public good.



APPENDIX ONE
DIGITAL POINTS OF VIEW BY INDUSTRY SECTOR

8

AEROSPACE

Realising Digital Opportunities for Aerospace

Aerospace Technology Institute

Realising Digital Opportunities for Aerospace

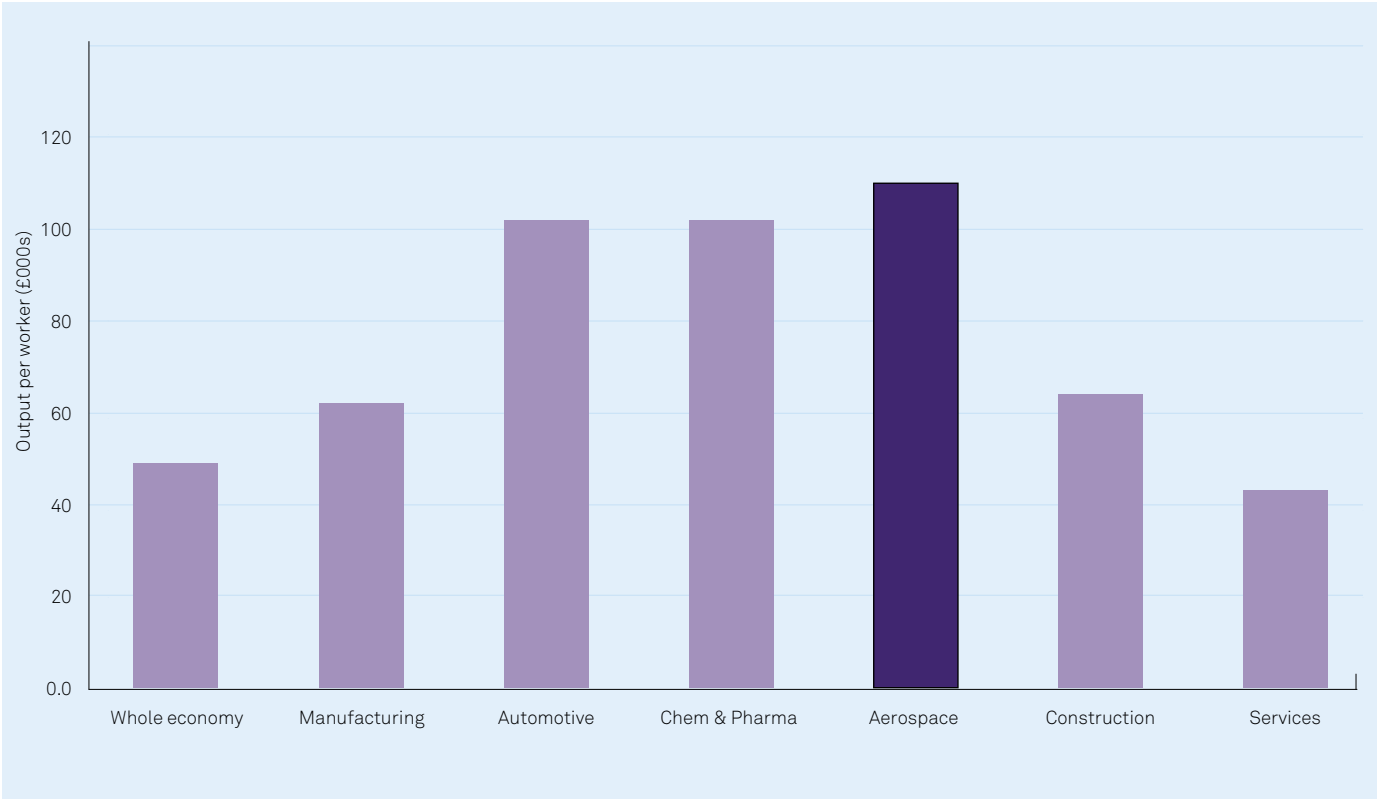
Aerospace Technology Institute

Aerospace

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

The UK is a global leader in aerospace with the second largest presence worldwide. The sector is a major contributor to the UK economy with a turnover last year of £55bn[165] , supporting over 250,000 high-value jobs with a productivity level at almost double the national average[166]. It enjoys a projected ~90 percent growth in sales over the next 20 years, and full order books. The forecast market for civil aerospace globally over the next 20 years is predicted at US$6.3 trillion, equivalent to 35,000 new aircraft. A further US$1.9 trillion is forecast in through-life support.

UK PRODUCTIVITY BY SECTOR



Source: ATI Analysis of ONS (2013-14)

Aerospace is a mature, highly regulated sector. It has high barriers to entry, but disruptive new entrants are nevertheless entering the sector. Current capability in the UK is wide-ranging technologically and regionally, largely clustered around OEM and tier one suppliers. Much of the UK's capability however rests on successful investments in technology made in the 1970s and 80s.

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

Digital technology presents transformational opportunities for products and processes, from concept to disposal. It will also be essential in helping the UK improve its productivity and capability to the extent necessary to maintain its competitive position as the second largest aerospace sector in the world.

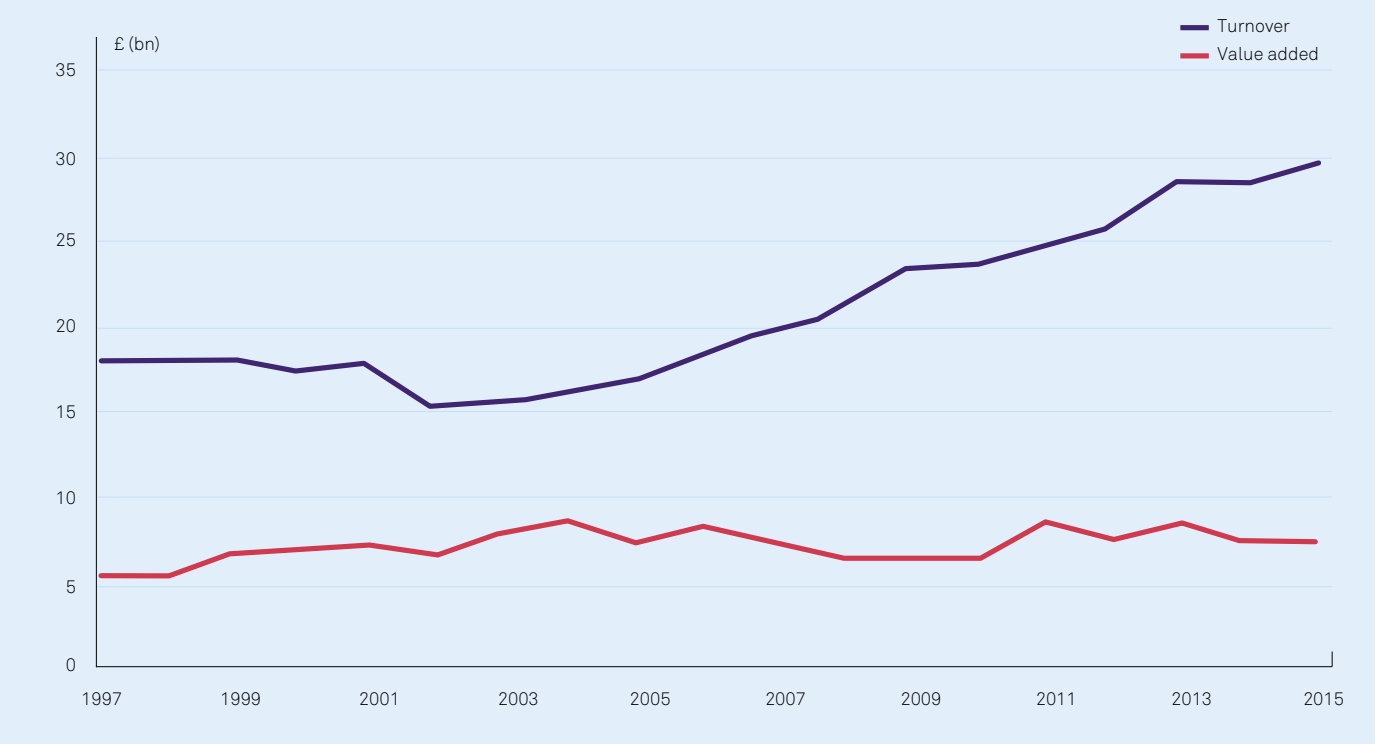
[165] https://www.adsgroup.org.uk/wp-content/uploads/sites/21/2017/06/ADS-Annual-Facts-2017.pdf

[166] ATI Analysis of ONS data

Sector trends published by the Office of National Statistics (ONS) highlight a divergence between UK aerospace turnover and gross value added (GVA). Between 2002 and 2015, turnover grew by over 5 percent per year, while value added remained almost flat (albeit with some significant fluctuations during the period). This trend implies that, against a steady increase in aircraft and engine orders, the UK is capturing a lower share of product value.

One explanation for this is an increase in overseas sourcing, perhaps due to capacity, price or quality issues, as identified in a recent UK aerospace supply chain study carried out by the Department for Business, Energy and Industrial Strategy (BEIS)[167].

UK AEROSPACE ECONOMIC ACTIVITY (£ BN)



Source: ATI Analysis of ONS data

To remain competitive, the UK needs to establish clear leadership on advancing the digital agenda, support innovation, and increase adoption.

A national effort to increase digital capability across the supply chain would radically enhance the competitiveness of UK aerospace companies and wider industry.

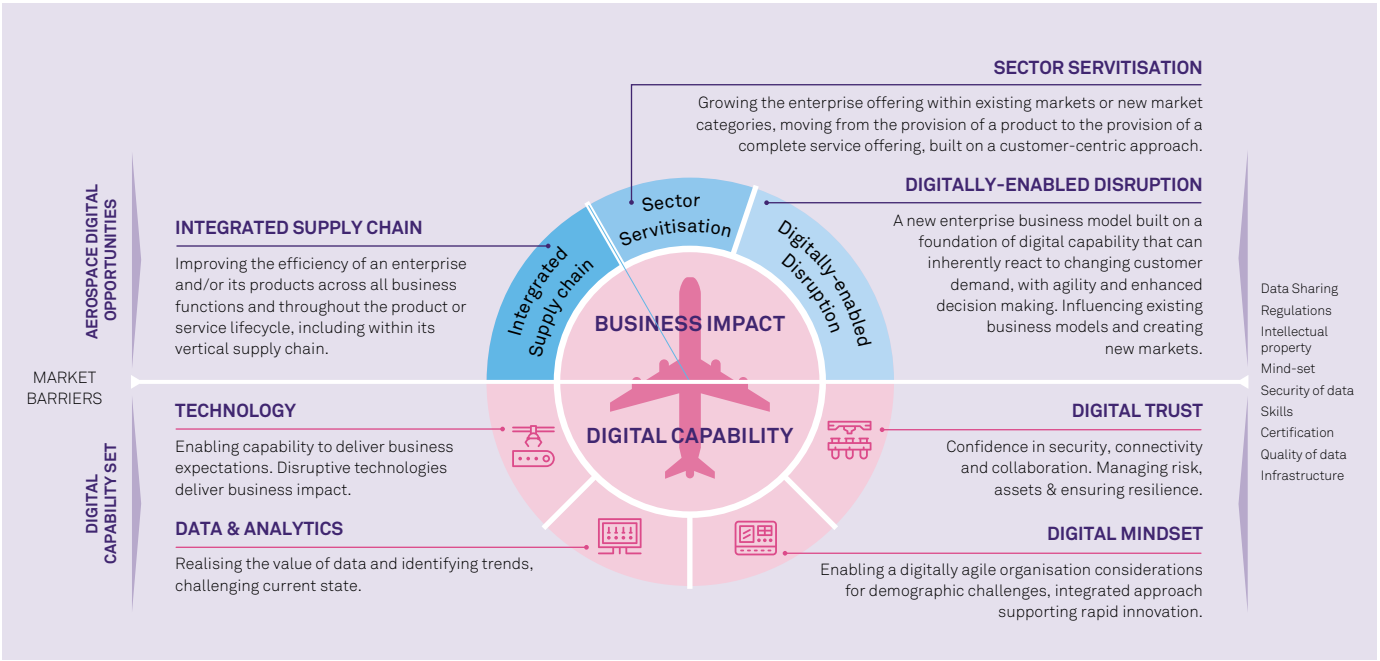
Key areas should include developing a digital workforce, the exploitation of a fully integrated information environment, the development and exploitation of digital assets to enable business model transformation, and maximising productivity.

[167] bis-16-310-aerospace-supply-chain-study

Digital technologies can enable radically new business models and platforms, such as electric-powered urban air mobility. These new offerings will depend on a "system of systems" approach to manage safely the complex interactions of air vehicles within urban environments and airspace. In turn, this will demand high speed digital connectivity, fully autonomous vehicle architectures and complex airspace management.

More needs to be done to secure the future of UK aerospace, as investment has lagged that of other major aerospace nations, particularly in digital infrastructure (e.g. 5G networks and utility services such as HPC), and high-value design capabilities (the combination of competencies required to conceptualise, define, integrate and test whole aircraft and their complex systems).

A DIGITAL FRAMEWORK FOR AEROSPACE



Leadership and Ambition

Aerospace provides a great platform to demonstrate how digital developments challenge multi-tier supply chains across the entire life cycle of product and process. For example, the sector is presently targeting ambitious challenges such as cycle time reductions of 25-35 percent and productivity improvements across the product life cycle of 30-50 percent.

Innovation, Creation and Implementation

Aerospace can provide excellent examples of the radical potential of emerging digital technologies:

- End-to-end integration – improving productivity through capturing and exploiting data
- Enhancing the capability of supply chains through connectivity
- Digitising legacy systems
- Providing the possibility of virtual certification
- Developing propositions for new products and services
- Using artificial intelligence to support decision-making, design, fabrication and operation of future aircraft, including urban air mobility platforms.

Adoption at pace

Aerospace is not new to digital technologies. An aircraft is a cyber-physical system, its performance predominantly automatically controlled and optimised by software. Digital technologies are widely used in design (e.g. model-based definition) and in manufacturing (e.g. robotics). Key emerging technologies such as additive manufacturing have been qualified for flight status, but with limited deployment. Benchmarking existing capability against an objective view of what could be achieved is fundamental to wider adoption.

Recent Accenture analysis [http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/] predicts that the application of digital transformation across the product life cycle could generate an additional £17bn in added value to the sector over a ten year period. This represents a 20 percent increase in value add to the sector.

One potentially dramatic development would be to prove the concept of virtual certification of aircraft. This would directly impact time to market, improve product awareness and provide the UK with a leading role in the future digital aerospace sector. It would drive the development of a raft of cutting-edge capabilities such as compliant model-based systems engineering, and validating mechanisms for digital twin technologies; it would set the requirements for future design, manufacturing and through-life validation, and inspire the development of new products and services across the supply chain.

The complexity of wide-scale adoption of digital transformation should not be underestimated, however. It will fundamentally change many sectors. It will ensure faster product development and more dynamic business models, enable a more integrated supply chain (or extended enterprise) characterised by data sharing and a collaborative product development environment. For UK aerospace, adoption will pose a dramatic challenge to the incumbent supply chain.

BARRIERS TO DIGITALISATION

The aerospace sector has high technological and regulatory barriers to entry. These factors, along with the pace of aircraft development, are often cited as restricting change and impeding the application of digital technology.

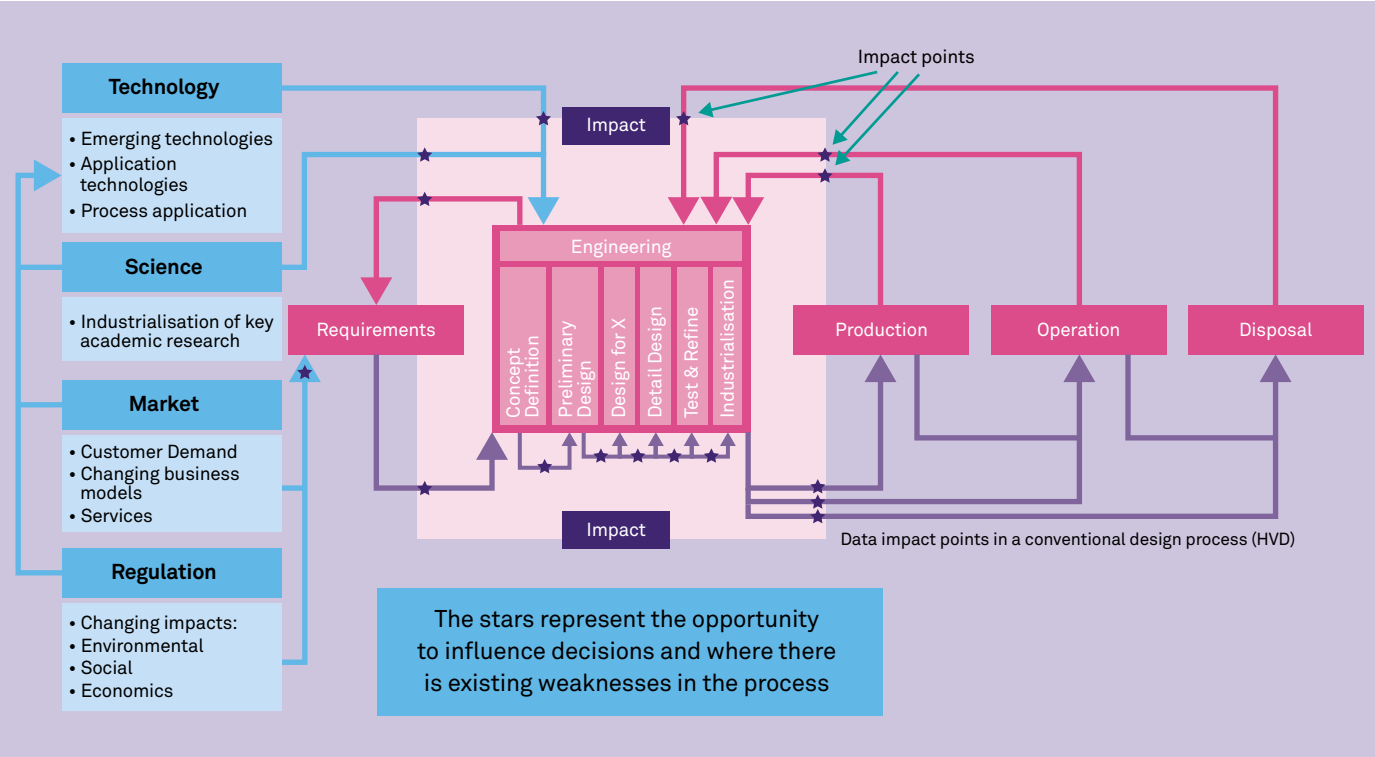
A recent ATI survey found that most within the sector identify IP protection, data sharing and cyber security as the biggest barriers to transformation. However, those outside the sector "looking in" cited culture to be the biggest barrier. Some of the responses received are examined below.

Data Sharing, Intellectual property and Interoperability

Certification standards require masses of data to be collected during the life of a component or whole aircraft. Current commercial constraints limit access to data, in turn restricting its applicability and value. Today, a very small proportion of data collected is analysed; companies are reluctant to share, concerned by the lack of controls and standards in place to protect their interests, such as embedded intellectual property. Demonstrating the benefits of sharing data could significantly help support engagement and standardise commercial data sharing across the supply chain.

Standardisation and interoperability of data represents a fundamental barrier to productivity and wide scale adoption of digital transformation. The interoperability of legacy systems generates additional work, increases risk and stifles innovation. For example, in product design, translating model files between various CAD tools required for detailed design (such as CFD, FE analysis, and DFMA tools), may introduce inaccuracies, restricting the fidelity of the analysis. This inhibits multi-disciplinary design optimisation, is not conducive to iterative

design, and limits the ability to certify products virtually. Improving this would lower the high cost of certification and improve productivity significantly, including that of supply chain companies which currently support the multitude of software versions required by their customers.



Governance & Standards

There is a lack of awareness of the approaches required to integrate data across the supply chain. Some standards exist for specific challenges (such as STEP translation and digital certificates). A novel approach is required. Industry working groups are looking to establish the standards needed to support the adoption of digital technology, identifying gaps and adapting existing standards.

Demonstrating the elements involved in creating a digital communication framework (or "digital thread") to bring together separate manufacturing processes across a supply chain, would illustrate the benefits of data sharing and the standards necessary to create a robust system, encouraging wider adoption. It would also help identify and evaluate the potential data handling terms for future contracts, also facilitating adoption.

Security

The advent of a connected world increases the need to safeguard intellectual property. Cyber security is an international multi-sector challenge that aerospace should not consider in isolation. The financial sector is the established leader in this field, and has pioneered block chain technology as one of the most secure methods of cyber protection, ensuring that the provenance and privacy of assets (finance, data, IP, ownership, etc.) are upheld.

Additive manufacturing (AM), enabled through digital technology, can demonstrate some of the challenges around how data is created, registered and delivered to a third party that could be in another country. For aerospace, AM represents some significant challenges: ensuring that product design has not been tampered with during delivery and translation, and confirming that data is retained only for the duration of the process and subsequently destroyed to prevent fraudulent duplication. Once manufactured, the validation of the product requires verification prior to integration potentially for flight.

Culture

Aerospace consists of very few companies at the top level, providing little opportunity for the supply chain to change its business model. The lack of data transparency and opportunity to change is largely driven by not quantifying the value of the data collected. Airlines are also beginning to recognise this. Many are changing the commercial terms for purchasing or leasing aircraft, recognising the opportunity to sell data to the most appropriate source where the biggest return can be realised. There is a lack of skills and knowledge to generate value and insight from data. Digital capabilities alone will not provide the solution; exploiting new digital technologies is predicated on an understanding of the physics that supports the engineering solutions. A multi-disciplinary approach is essential.

Within the supply chain there is a lack of commercial consistency. Lower tier companies are bidding for build-to-print configurations on one to two year contracts. This often means that significant changes to productivity through digital technology cannot be realised as finance can be difficult to justify.

Digital adoption does not need to be expensive; digital requirements can be quantified through familiar verification and validation models. The value of data needs to be demonstrated; businesses need to understand how existing capabilities in design and manufacturing could be adapted (e.g. through digitising legacy systems) against a known budget, so that the business case for adoption can be realised.

ACTIONS TO ENABLE DIGITALISATION

The UK's industrial digitalisation agenda needs to be ambitious and look beyond a short-term horizon. Through the analysis carried out in this study, the following key themes have been identified to provide direct impact and value to aerospace and its supply chain.

Delivering a Digital Workforce

Future competitiveness will be rooted in digital skills and knowhow, and the culture required to succeed in a digital world. It is therefore essential to map out the transition needed from today's workforce to that of tomorrow. Aerospace will need to adopt state-of-the-art cross-sectoral approaches to underpin its core engineering skills. The high-skilled, high-value jobs of tomorrow will require the understanding of, and ability to operate across, numerous disciplines. This will redefine the domain of engineering, and enable manufacturing to be carried out in autonomous and robotic factories, slashing cycle times and driving up productivity.

Digitalisation also offers a huge opportunity to encourage diversity as roles are not restricted by the traditional roles such as engineering and IT performed today. The future workforce will possess a broad core understanding, supplemented by expertise in emerging themes such as visualisation, big data and HPC in evaluating scenarios, and cognitive systems to maximise design, manufacturing and through-life performance.

Exploiting a fully integrated information environment

Leveraging shared information can enable the extended enterprise concept to advance in the UK, improving productivity in the supply chain. The benefits of this approach include: dynamic scheduling, improved product quality through high fidelity measurement, and enhanced prognostics. Seamless integration of data can reduce non-value-added tasks, remove barriers to entry, enable innovation in a safe environment, and enable multi-partner product development through, for example, creating a fully collaborative digital twin shared by supply chain partners.

A fully integrated information environment requires a consistent national approach. Certainty in design data exchange, non-repudiation, governance and validation of strategic partnerships are all key considerations.

Exploiting Digital Assets and Enabling Business Model Transformation

Quantifying the value of digital capability in a collaborative environment, measuring the real value of data and demonstrating the possibilities available will make an immediate impact on the adoption of digital technology. Demonstration programmes should illustrate tangible intervention at an appropriate scale, from minor, inexpensive sensors that enhance awareness, through to a fully integrated supply chain that supports the factory of tomorrow. Each example should validate the level of investment required and quantify the benefits of adoption.
In addition to promoting adoption by the supply chain, this approach would support a more collaborative and competitive landscape, and offer the opportunity to explore how exploiting data can lead to new business models.

Companies need to begin their digital journey with practical steps; adapting legacy systems to the digital world is therefore a priority.

Maximising Productivity

End-to-end integration, interoperability and processes that support a future vision are required to realise the opportunities presented by digital technology.

For aerospace, virtual product and process certification provides a focal point. Vast productivity improvements can be achieved through a holistic, analysis-driven culture that utilises data from all areas of the product and process life cycle. Achieving this will support a right-first-time approach, a more efficient and productive use of resources, reduced costs, improved quality and a more integrated and competitive supply chain.

AUTOMOTIVE

Building an agile, productive and sustainable manufacturing supply chain that will enable UK automotive sector to lead the world in next generation personal transportation

Automotive

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

The UK automotive sector has enjoyed unprecedented success in recent years. Car manufacturing is now at its highest level since 2005, exports are stronger than ever and the UK can boast an increasingly competitive supply chain, with cars built in Britain now having over 22% more UK content than they did six years ago.

The automotive industry is a vital part of the UK economy. In 2015 it accounted for more than £71.6 billion turnover and £18.9 billion value added. With some 169,000 people employed directly in manufacturing and 814,000 in over 2,000 companies across the wider automotive industry.[168]

The UK produced 1.7 million cars and commercial vehicles and almost 2.4 million engines in 2015, the highest production level since the recession in 2007. The output level is expected to reach 2.0 million vehicles by 2021[169]. The UK remains the second largest vehicle market and fourth largest vehicle manufacturer in the EU. It is also the second largest premium vehicle manufacturer after Germany.[4]

However, currently the automotive sector is experiencing a period of unprecedented change. Driven by global megatrends such as CO2 reduction, air quality improvement and exacting safety requirements, vehicles are becoming increasingly electrified, autonomous and connected. This disruptive transformation is happening rapidly and in itself represents a significant opportunity for companies that are flexible and can develop new products and business models quickly e.g. servitisation. In turn, many of the developments provide the foundations for integration into the wider challenge of personal mobility. Digitalisation is the prime enabler.

Innovation in product and manufacturing technology is a cornerstone of the automotive sector. Since the invention of the first assembly line, the automotive sector has proven itself to be excellent at industrialising and adopting new process and product technologies. The sector is characterised as global and extremely competitive. As a consequence, there is an unwavering focus on cost, pace and efficiency. In product development this has driven the rapid development and widespread adoption of digital tools for design, modelling and simulation; iterative optimisation now happens virtually, followed by the minimum number of physical verification tests. In manufacturing it has led to the implementation of highly automated processes. Overall this has enabled the sector to become very productive. In contrast with the UK cross-sector position or even manufacturing as a whole, the UK automotive sector is the most productive in Europe*. In 2015, the automotive sector achieved a real GVA per job figure of £111,900 (twice the national average). This leadership position brings with it the challenge of remaining one step ahead, especially in light of BREXIT.

The technologies associated with the 3rd Industrial Revolution (e.g. electronics, IT and automation) are ubiquitous across the automotive sector (especially OEMs and tier 1s), and are utilised from research and development through to manufacturing and beyond, creating a solid foundation for the adoption of the next wave of connected, digital technologies. Consequently, the automotive sector is well positioned to become a vanguard in regard to the implementation of digitalisation throughout the supply chain, subsequently sharing the learning to accelerate and de-risk adoption across the UK. Specifically, the main opportunity for growth and productivity gains, as well as helping to make the UK capable and attractive for re-shoring,

[168] http://www.automotivecouncil.co.uk/wp-content/uploads/sites/13/2015/11/1511-Automotive-Council-UKIC-Report.pdf

[169] http://researchbriefings.files.parliament.uk/documents/SN06152/SN06152.pdf

lies with the digitalisation of Small or Medium Sized businesses (those employing 0-249) people that make up 99% businesses in the UK*.[1]

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

The global automotive industry is faced with growing customer demand for shorter lead times and high degrees of personalisation, leading to increased manufacturing complexity and greater pressure to establish smart, responsive supply chains; things have come a long way since Henry Ford said "You can have any colour you want, as long as it's black".

For decades, there has been major competition in the global supply chain from businesses in countries with low labour costs which has led to significant hollowing out of the UK supply chains. In the UK, although the proportion of local content has grown significantly, the UK automotive sector currently runs a trade deficit of around £18bn. The UK cannot win this "race to the bottom" and needs to find alternative ways to add value; digitalisation presents an excellent opportunity. That said, it is possible to increase the proportion of local content through the rigorous application of "right-shoring" techniques. There are five levers that can address this:

1. Continue to close the gap between UK sales (2.7m) and UK production (1.7m) – the trend to 2m production is a critical success factor
2. Continue to support/promote the premium/luxury/niche sector to provide more value in the cars we build and export versus the value of imports
3. Support the development of new technology supply chains in conjunction with the Technology working group – this is a major initiative being led by the APC with support from AIO and HVMC
4. Continue to support the growth of UK local content, at all levels in the supply chain, to displace parts imports, through both domestic organic growth and FDI through the AIO
5. Continue to support the development of capability for the UK supply chain to successfully increase exports

The key opportunities for digitalisation are based on the activities and technologies shown in the table below:

Digitalisation activities	Key technologies
Collect, store and transmit data	Sensors and tracking (e.g. RFID) Communications interface & standards (enabling cyber physical digital transfer) Cloud based storage and service models 5G
Analyse data	Predictive Analytics PLM Software
Interact with data	Virtual reality Mobile/Tablet/Watch Visualisation tools (e.g. Tableau) Crowdsourcing (e.g. sentiment analysis)
Produce digitally	Additive manufacturing techniques (e.g. 3D printing) Advanced Robotics (e.g. collaborative robots & cyber physical systems) MES software
Protect data	Cybersecurity & digital trust Blockchain

Specifically, they can be summarised as:

Complexity and connectivity

The technologies underpinning industrial digitalisation will enable the automotive sector to add numerous features and functionality into the product, whilst simplifying the powertrain and increasing visibility in the supply chains that will deliver next generation vehicles.

Data will have greater value if shared through supply chains, but this will raise challenges around security and ownership of data. To derive value from the data derived from greater connectivity context and data processing will be required to generate actionable insight. Such examples will be necessary to demonstrate the return on investment of technology and to articulate the business opportunity to encourage businesses connect across supply chains. The notion of assigning value to data and making this tradable may help to drive market behaviour and appropriate business contracts. One advantage of greater connectivity would be within the business; digitalisation of cross functional teams from design and manufacturing.

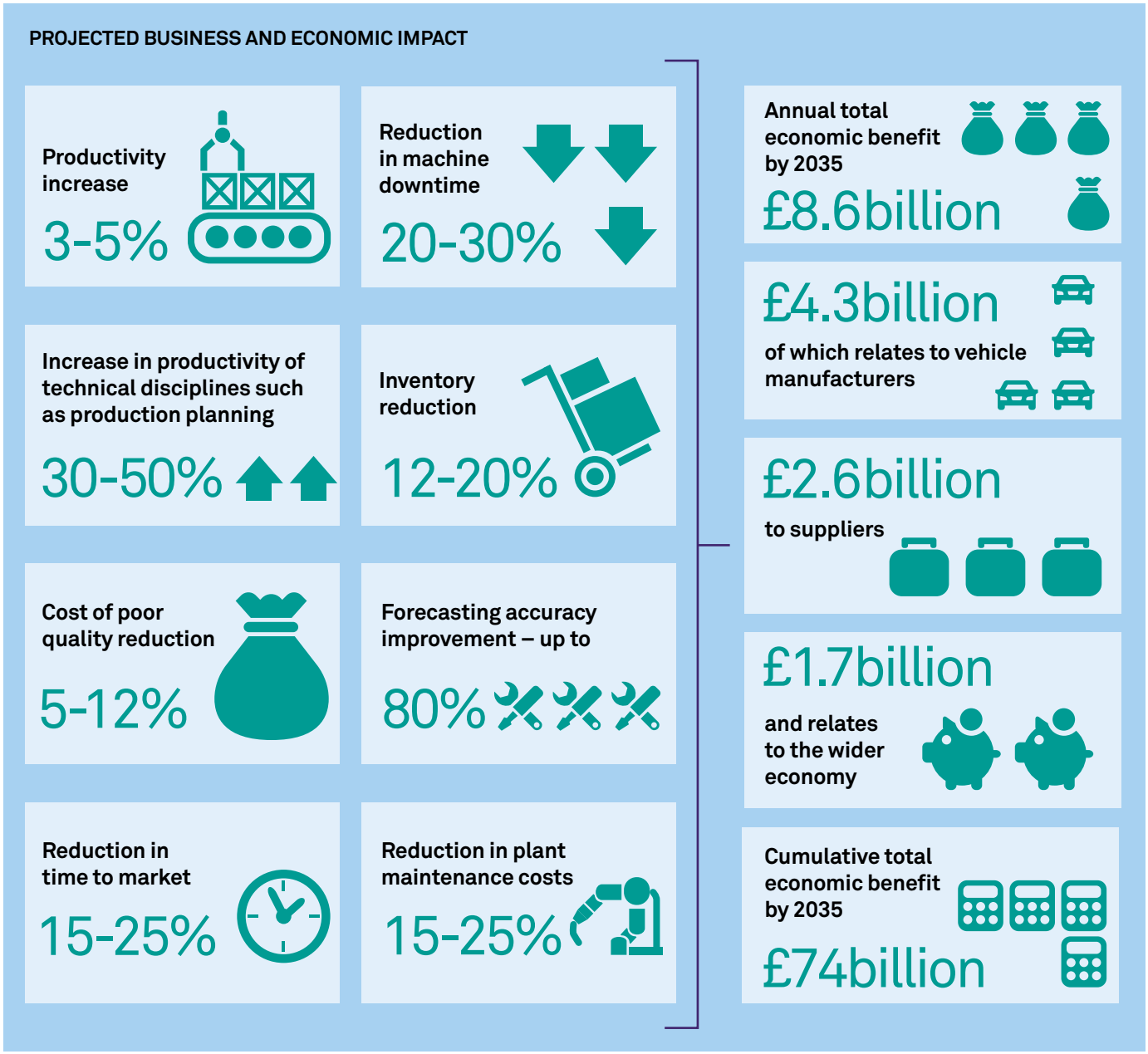
Transformation – Fit for Purpose

To deliver business transformation in the automotive sector we must remain impact focused, not technology driven. We seek the business and sector challenges where digital manufacturing technology can address the business needs and open up new opportunities. This means selecting fit for purpose technology to meet the need which may not always be the most advanced solution. The state of the art should be advanced in parallel.

There is a need to lead and educate the community on what of what technology is available and how to apply it. This includes providing the skills to the user manufacturing community and imparting knowledge to business leaders. Sharing best practice within the automotive sector and from without will help to identify opportunities and catalyse investment. Where have solutions been found for similar problems? There may be a role for OEMs to lead their supply chains as well as peer to peer learning.

Whilst there are well established technology providers in the market with existing corporate relationships there is a need to connect the digital technology community and start ups to the automotive industry. This is where much of the opportunity will be realised. The technology could be classified by the business challenge it addresses; e.g. data visualisation and AR/VR for decision support and guidance, digital twin for process execution, control and improvement.

The projected business and economic impact can be summarised as follows:



BARRIERS TO DIGITALISATION

Many vehicle manufacturers, while recognising the importance of digitalisation, had only initiated a series of pilots so far. Some suppliers, notably SMEs have not started any significant digital pilots. Manufacturers and suppliers both forecast substantial benefits from digitalisation including productivity gains, shorter lead times more personalised vehicles and enhanced services for customers. A key barrier to implementation was found to be a lack of knowledge and the necessary skills to design and execute a company-wide digital strategy. Another key barrier is the trust needed between supplier and manufacturer to share data electronically. SMEs identified funding for investment as a concern.

Skills

- Becoming/remaining an intelligent customer.
  - Awareness levels are low and clarifying the mechanisms to drive digitalisation.
  - Decision making on investment and technology selection is complex and uninformed.
  - Lack of human resources strategies for digitalisation.
- Recruiting the right people.
  - Attraction of fresh digital talent and engagement in horizontal innovation;
  - Dynamic evolution of job roles, skills and expertise due to rapid technological change;
  - Digital skills needed for both skilled and unskilled labour;
  - Job role changes to exploit human potential in creative / value added activities.
- Changing working styles and culture.
  - Flexible working.

Supply Chain, production and assembly

- How can we best configure our supply chain assessing the digital maturity of suppliers, identifying weak links and using technology to improve supply chain capability?
- How do we get better visibility within our supply chain, making it more dynamic by sharing data securely and improving compatibility?
- How can we optimise logistics through real-time insights using technologies such as tracking?

Within the Factory

- What technologies will have the biggest impact on productivity, agility and people's jobs?
- How can I quickly reduce the time to rectification and the amount of firefighting?
- How do I break down the organisational silos?
- How do I best configure cross-functional teams e.g. to improve connectivity between design and manufacturing to create additional efficiencies?
- How can I automate process execution with the associated verification and analysis?
- How do I embed and maintain a digital thread throughout the product lifecycle?

Automotive Specific Opportunities

- How do we achieve the integration and interoperability of legacy equipment, reducing the complexity of the process and avoiding point solutions?
- How do we create the internal ecosystems for technology development?
- How can we reduce the risks and make it easier to access and plug in external technologies from SMEs?
- How can we gamify production to bring competitive engagement of workforce?
- How do we unearth new business opportunities through exploring application of affordable digital technologies?

- What would the digital thread for through life ownership of autonomous vehicles be configured and managed? How is data ownership attributed? How do we guarantee the provenance of the data?
- How can we safely test and verify new technologies within the factory without risking production? How do we create configurable, representative 'sandpit' environments to trial technologies away from the factory?

ACTIONS TO ENABLE DIGITALISATION

The UK automotive sector is in a leading position and consequently is well positioned to realise the comprehensive adoption of digital technologies. As a result it presents a tremendous opportunity as THE place to demonstrate digitalisation to the wider UK industry.

The recommendations can be grouped into four priority areas:

Demonstrators

- Show what's possible and share experiences by creating a community of practice based on a comprehensive network of open-access digital demonstrators, supported by implementation case studies, which are relevant to organisations at any stage in the digitalisation journey, have a clear business case and measureable and validated business impacts.
- Accelerate the adoption of digital technologies through open-access 'sandpit' environment(s), enabling organisations to trial new technologies, perform test implementations, overcome integration challenges, train staff, amongst others, without fear of negatively impacting series production.

Wholescale Supply Chain Implementation

- Establish the ground truth of the current state of adoption of digital technologies through the roll-out of a diagnostic tool for assessment of the digital maturity of companies in the supply chain and nationally of the manufacturing sector.
- Following an assessment of digital maturity, accelerate business impact by signposting organisations to additional resources/support and assist them in the creation of a tailored roadmap and action plan.
- Ensure that a future connected supply chain is resilient and secure by advancing the knowledge and awareness of cyber security through SME vouchers for cyber audits.

Skills

- Ensure that digital skills training is available to support the UK labour force, both re/up-skilling the existing workforce and embedding the requisite skills in people entering the labour market.
- Broaden awareness and foster opportunities for new business and contract models that are frequently enabled by digitalisation.

Standards

- Facilitate or create standards for interoperability
- Define best practice approaches to cyber security for companies in the manufacturing sector

The opportunities identified above align well with the findings of previous work carried out by Automotive Council, SMMT etc and could be delivered by utilising the existing network of expertise such as the Digital Catapult, High Value Manufacturing Catapult, CESAM or others. This would help to prevent duplication and also presents an opportunity to leverage current infrastructure for test beds and demonstrators by improving the connectivity between them.

CONSTRUCTION

Transforming the UK construction industry by ensuring digitalisation at scale to realise productivity increase, creation of highly skilled jobs and increased UK export opportunities

Construction

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

High quality social and economic infrastructure is vital for economic growth and improved quality of citizens' lives (ICE 2016). An inadequate supply of infrastructure has caused the UK's global economic competitiveness to erode to 7th in the world, with inadequate infrastructure the second most problematic factor (WEF, 2016). For the UK, the construction industry contributes 6.5% (£103Bn) of economic output with 6.2% of total employment for 2.1m people. It also represents 20% of the total workforce of SMEs across all sectors (BEIS, 2015).

Globally, 98% of infrastructure projects are over budget or delayed, with an average of 80% over budget and at least 20 months late. Construction's productivity is also lagging global productivity by over 30%. If constructions productivity is improved to average global productivity, it would pay for 50% of the total demand of infrastructure (McKinsey, 2015).

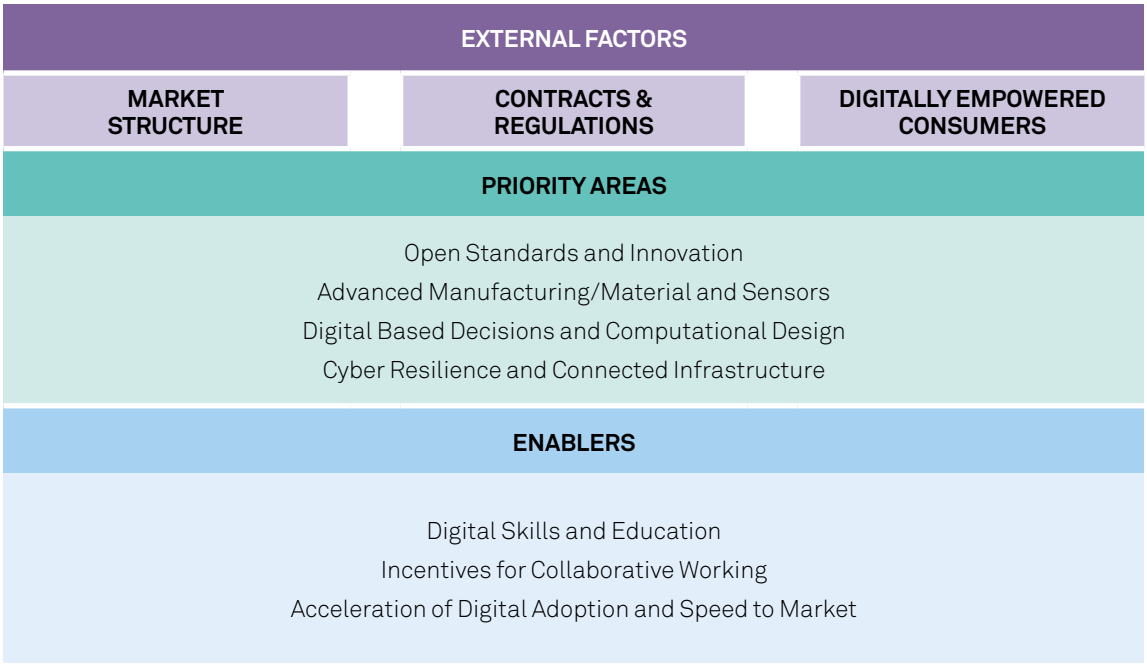
These statistics show that the construction industry plays a unique role in the global economy and cannot be compared easily to other industrial sectors. There have been many UK industry reports spanning 70 years that highlight the dysfunction of construction; from Simon (1944) to Latham, (1994) Egan, (1998) Wolstenholme (2009) and Farmer (2016).

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

Key issues that have hampered the sector include low investment in innovation and skills, and lack of aggregated demand generating scale, making technology adoption difficult. It is estimated that £1 invested in construction delivers £2.84 in direct (wage income and profit), indirect (increased productivity in the product and service supply chain) and induced (employment, household income) impact. It is also estimated that 92p of every £1 is retained in the UK, and delivers a return of 56p to the Exchequer (therefore, estimated net investment is 44p).

Looking forward, the industry may experience a 50% reduction in employment as new technologies are implemented (BIM2050, 2015). There may also be disruption in the structure of traditional professional disciplines, from linear, siloed career paths, towards a 'T-shaped' portfolio professional career path (dotBuiltE™, 2017). However, in context of technical skills, there is a labour supply gap in construction (CITB 2016). This may be exacerbated by the UK exiting the European Union.

The scale of the opportunity is in both the unique nature of construction (its size and vital role in the economy) and its potential to be a high value digital industry that is the foundation of a digital economy. Digitalisation will enable the sector to deliver services cheaper, faster and smarter (Construction 2025, 2013).



BARRIERS TO DIGITALISATION

These potential areas for digital disruption in construction require support from the following underpinning cultural and educational aspects to enable this step change in the construction industry to occur.

Digital Skills and Education

We have already mentioned the shift of traditional professional disciplines from siloed career paths to 'portfolio professional' career paths. This means the education of professionals will need to become more vocational and be supported by digital learning platforms. The traditional skills of the sector will need to be augmented, with areas such as material science, data analytics and information management becoming key.

The industry needs its institutions to embrace the future of their professions and ensure their certification of courses (such as degrees) are brought up to date to capture the need of the modern professional. We also need institutions to manage their bodies of knowledge to support the standardisation of methods and procedures to support progressive firms to continue to support the systemisation of services into digital service models. (shown in image above, adapted from Susskind 2015).

Incentives for Collaborative Working

There are no established commercial structures or vehicles to incentivise collaboration in construction. The existing contracting framework requires trust between parties and an altruistic approach to information generation and exchange. In many cases, suppliers are expected to generate information to the advantage of others with no real recourse for remuneration for that value generation.

The standards for BIM such as PAS1192-2&3 provide a framework for construction buyers and suppliers to specify the information needed between project stakeholders. They provide the ability for construction buyers to specify a digital asset that can be contracted against. However, the use of these standards is not commonplace in the market and are incorrectly perceived as an additional cost to delivery and operations.

Acceleration of Digital Adoption

The speed that research is commercialised is accelerating through the 'triple-helix' partnerships of academia, start-ups and industry (Nature, 2016). This model of open innovation has become functional in many sectors, but construction is yet to fully embrace partnerships with academia in terms of digital services and business model innovation.

As an industry, we need to ensure that this industrial cycle is not as damaging to the environment as previous cycles. Positive disruption (Nature 2011) includes the environment in the economic means of production. The previous cycles of industrialisation have seen great financial gain at the cost of the environment in terms of pollution, and linear consumption of raw materials that have failed to be recycled appropriately.

ACTIONS TO ENABLE DIGITALISATION

To address these external factors in the context of the construction industry, this report focuses on four priority areas for industry and government with a view to potential sector deal creation.

Open Standards and Innovation

Applying British Standards is worth £8.2bn to the UK economy. Furthermore, 28% of annual growth in GDP, 34% in productivity gains and £6bn of exports is attributed to applying standards (Cebr, 2015).

The application of standards is a key driver in delivering digital information platforms in the construction sector, also referred to as a 'single source of truth'. To integrate the flow of information through the design, building and operation of the built environment, standards need to be developed and applied on a market level to achieve the benefits seen in sectors such as automotive and aerospace design.

Standards for Building Information Modelling and The Smart Cities Framework are being integrated under the Digital Built Britain Programme (a UK Government initiative) to generate a market capacity for a digital construction sector.

Open data standards have been derived for the construction sector, including COBie and IFC, but these are applied with varying degrees of success. Estimates of productivity gains of between 15-20% associated with whole-life cost of the project have been achieved with modest investment in standards by the UK Government (NBS, 2016). The investment into Digital Built Britain will yield positive outcomes for construction firms and enable the market capacity for digital information.

Open innovation enables larger companies to restructure their research and development to collaborate with start-ups and universities to develop new technology. This method of R&D can reduce costs by as much as 50% (Grove, 2008).

Advanced Manufacturing, Sensing and Monitoring

Advancements in technology can introduce a step-change in the construction industry's ability to plan and monitor works. Currently, significant cost and risk are associated with unknown ground and site conditions which can impact project costs by 20% (European Commission, 2017), and roughly 40% of the UK construction market relates to maintenance and refurbishment.

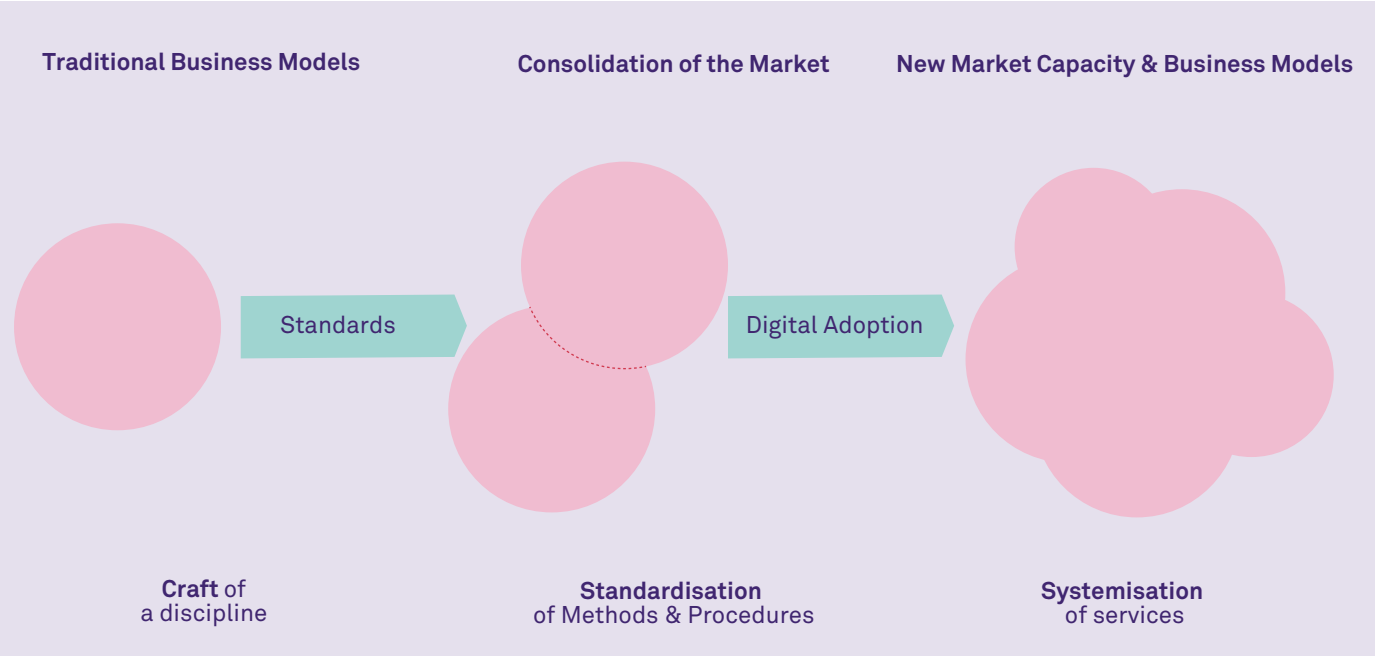
Through use of advanced scanning technologies, including drone mounted LIDAR, DIC and ground-penetrating radar, better decisions can be made early in the design process to mitigate risk. Similarly, the introduction of smart IoT sensors and advanced composite materials (such as self-healing concrete and polymer matrix composite materials) will lead to a new approach to maintenance and refurbishment, driving down cost and improving efficiency across the sector.

Additive manufacturing, and 'flying factories' (a mobile method of manufacturing outside of a fixed factory), could enable high precision manufacturing to occur on site and minimise the need to transport bulky prefabricated building parts. Flying factories (and similar) reduce the fixed-cost associated with large off-site manufacturing plants.

Digital Based Decisions and Automated Design

With almost infinite computing power and data storage coupled with the rapid expansion of network bandwidth, better decision making can be enabled in construction through integration of big data sources, and automation of traditionally expensive, time-consuming design activities.

Through the application of technologies such as machine learning and distributed ledger technology (DLT) to the traditionally analogue design process, mass efficiencies can be realised. Parametric tools can allow for rapid testing of design solutions against site constraints and requirements, helping to ensure that the built environment satisfies the client brief and becomes more user-centric. By reducing the burden of later stage design changes, overall cost fluctuation can be reduced, helping to achieve greater programme and cost certainty than previously realisable.



The application of DLT (the technology behind Bitcoin) can enable the financial incentivisation of collaborative working. Currently, the construction industry is required to be almost altruistic in its information production and sharing. The commodification of construction information via DLTs could transform the market of professional services. More simply, DLTs can be used to turn traditional paper contracts into automated computer code that can distribute payment automatically when work is complete. This also has a strong potential to 'rewire' the market.

Cyber Resilience and Connected Infrastructure

Increased connectivity in infrastructure creates opportunities to cut costs of operations and reduce the response time to major incidents as information can be collected in an instant, and the most efficient solution for the entire system derived. Realising 'system of system' interdependencies in the built environment through connected infrastructure can help to improve the value of current built stock, as well as maximise the impact of newly constructed interventions.

The recent attack on the UK's National Health Service by hackers using a 'cyber weapon' called WannaCry (FT, 2017), demonstrated the disruption that is caused by poorly managed digital infrastructure. Connected infrastructure can be targeted by similar cyber weapons and there is a vast difference in consequences between impacting patient records and train signalling systems. The impact of cyber security breaches on large infrastructure systems could be vast, therefore incorporation of such defence technology into new infrastructure is essential.

REFERENCES

1. Built Environment 2050, BIM2050, Construction Industry Council, 2014
2. Business Population Estimates for the UK 2015, Department of Business, Innovation and Skills, 2015
3. Construction 2025, UK Government, 2013
4. Construction Industry: Statistics & Policy, House of Commons Library, 2015
5. Career progression in the construction industry, CITB, 2016
6. Grove, M. (2008). OPEN INNOVATION 2.0. The Open Source Business Resource
7. ICE Autumn Statement Submission, ICE, 2016
8. Instrumental City: The View from Hudson Yards, Places Journal, 2016
9. NBS Report, The National Building Specification, 2016
10. Portfolio Professionals in the digitised Built Environment, dotBuiltEnviornment™, Reading University, 2017
11. Positive disruption, Nature, 2011
12. Technology transfer: The leap to industry, Nature 2016
13. The Construction Productivity Imperative, McKinsey, 2015
14. The Economic Contribution of Standards to the UK Economy, Centre for Economics and Business Research, 2015
15. The Future of Employment: How Susceptible are Jobs to Computerisation? Frey & Osbourne, Oxford University, 2013
16. The Future of The Professions: how technology will transform the work of human experts, R Susskind and D Susskind, Oxford University Press, 2015
17. The Global Competitiveness Report, World Economic Forum (WEF), 2016
18. The UK Collaboratorium for Research on Infrastructure and Cities (UKCRIC), University College London, 2017
19. Understanding and Monitoring the Cost-Determining Factors of Infrastructure Projects, European Commission, 2017
20. What is WannaCry and how can it be stopped?, Financial Times, May 2017

FOOD & DRINK

Digitalisation will secure the future of food supply chains

Food and Drink

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

In the UK the Food Chain generates food and drink sales of over £200billion per annum. Globally the industry is worth over $8trillion and growing at 6% per annum, or nearly $500billion per annum in increased sales as a combination of more people and as consumers 'trade up' to convenience, added value products and food service as wealth increases - the UK is a World leader in adding value, traceability and provenance in the food chain.

Food and drink processing is the largest manufacturing sector in the UK, contributing over £28.2billion to the UK economy and employing 420,000 people.[170] The wider food chain, from farm to fork, generates GVA of £108billion, with 3.9m employees (DEFRA 2017) in a truly international industry, with £20billion of exports in 2016. From 2006-'15 the UK food chain increased GVA by 30%, exports by 72%, branded food exports by 100% and food chain employment grew by 5% (DEFRA 2017).

The return on investment from Industrial Digitalisation (ID) in the UK food chain includes five main economic opportunities:

- Improved UK food chain productivity - the increase in UK core food chain productivity through adoption of ID enabling the sector to replace imports, leading to sector growth;
- More competitive UK food exports - the increase in UK core food chain productivity through adoption of ID enabling the sector to grow exports, leading to sector growth;
- Increased adoption of UK ID technology by the UK food chain - the development of high value UK supply chain technology suppliers servicing the UK market for ID in the food chain;
- Increased exports of UK ID technology by the global food chain - the development of high value UK technology jobs to service the growth in demand for ID in the food chain internationally;
- Significant reductions in supply chain food waste, improved traceability and food safety through the application of ID technology.

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

With a limited land mass and virtually no unused land (DEFRA 2017), the potential to deliver GVA growth in UK agriculture is modest. Similarly, GVA growth at the 'consumer end' of the UK food chain, i.e. food retail and catering, is modest due to a relatively stable market driven by population size (steady but slow growth) and consumer spending per capita (increasing but only slowly). However, the UK has a substantial trade deficit in food, despite a big increase in exports in the last decade, with imports currently (DEFRA 2017 data for 2016) worth more than double (£42.6billion) UK food exports (£20.1billion). Digitisation to improve UK food chain competitiveness could both help to replace imports and increase exports.

The larger opportunity for growth in the food chain lies in focusing on food processing, marketing and distribution, ' the core food chain', connecting primary production on farms (in UK and globally) with consumer facing companies (retail and food service) in the UK and export markets. This sub sector of the food chain has a GVA of £38.7billion per annum (£28.2billion in food processing, £10.5billion in food and drink wholesaling, DEFRA 2017) and employs 614,000 staff.

[170] US Department of Agriculture (USDA) Economic Research Service (2013), Global Food Industry

In addition, the food supply chain accounts for 28% of all global GHG emissions, but nevertheless up to 30% (8.4MT, WRAP 2017) of food is wasted each year. Food poisoning, including over 200,000 incidents from Campylobacter alone, creates misery for many, high costs to the NHS and significant losses in working time. Digitisation to connect the supply chain, match supply and demand, optimise resources and provide immutable traceability has the potential to transform the sector.

The UK needs to develop, manufacture and distribute more food and drink to meet growing demand in UK and export markets. The UK is only about 2.5% of the global food market by value and therefore the potential export market for food chain products and technology is approximately 40 times the size of the UK market. Clearly UK producers would be expected to have a much higher market share of the UK than the global market, but the potential for exports is large and growing for both food products and the technology used to produce them.

The UK has globally leading UK food and digital capability. There is potential to grow the UK food technology sector (in part by replacing imports of food processing equipment and systems) to exploit the growing global market for food technology. Digital technology allows improved production efficiency (e.g. robotics and automation, Industry 4.0 connectivity), connection of the whole supply chain to improve traceability (e.g. internet of things, block chain, cloud data architectures, data analytics), more efficient and rapid supply chains (e.g. artificial intelligence enabling just in time delivery, IoT monitoring, real time system optimisation, highly connected planning software), improved feedback from retailers, consumers and food service (e.g. automatic supply and demand forecasting systems), improved consumer trend monitoring to assist NPD (e.g. POS data analytics, social media analytics).

All these industrial digitalisation (ID) technology areas offer the potential for substantial gains in UK food chain productivity and the development of ID technologies which are exportable. In some technology areas the UK is already a global leader e.g. food and refrigeration monitoring systems via IoT, food safety and traceability systems, with the potential to unite UK food sector expertise with UK IoT and block chain expertise to create globally leading disruptive technologies. In other technologies, e.g. food processing and robotics, the UK currently lags behind some competitors e.g. ABB and Siemens are in the German market, but both companies are strong in the UK and support the IDR focus on the food chain, offering the potential to rapidly improve UK food chain productivity through knowledge transfer at the same time as using the UK's sophisticated food sector to drive future technology development.

Specifically the food processing sector is facing a perfect storm in which its reliance, for at least the last 20 years, on cheap and available labour supplies, is being challenged by a restriction on labour supply (due to Brexit), rapid above inflation rises in labour cost (driven by the National Living Wage) at the same time as robotic system functionality increases and costs fall. In certain sectors (e.g. fresh produce packing, sandwich manufacturing), up to 90% of the line workforce can be migrant "low skilled" workers.

Businesses which rise to this challenge will grow and improve their labour productivity quickly, be able to exploit new market opportunities and grow exports. Digital technologies are at the heart of being able to exploit this opportunity which is multi-faceted and growing rapidly.

BARRIERS TO DIGITALISATION

A food sector event held in Lincoln in June 2017 to feed into the IDR, identified 9 key themes across the food industry where investment from government and industry could unlock productivity growth

- Skills/Talent: Upskilling and retraining the existing workforce
- Regulatory/Policy: Development of a supportive policy framework to enable digitalisation which protecting cyber security and data protection.
- Legacy Integration / Interoperability: Flexible system develop that enables integration of digital technologies (including robotics) into legacy production lines. Generic and wide scale issues with interoperability of systems.
- Technology (Disruptive): Significant opportunities for transformational and disruptive digital technologies within the food supply chain digital ecosystem, such as IoT, blockchain, digital twins and data storage, analytics. Develop a series of demonstrators to showcase and support the development of the technology.
- Confidence/Awareness: The need for demonstration projects to help end users and developers gain confidence in new technologies. This includes demonstration of industrial robotics applied to the food chain, industry 4.0 connectivity illustrations and novel digital technologies.
- Connected Digital Supply Chains: The need to develop the infra structure and a digital ecosystem that can be used across the full extent of the food chain (from farm to consumer). This includes new technologies such as IoT and blockchain that can be applied to connect entire supply chains.
- Funding & Procurement: The need for government support to de-risk innovation projects by SME's, flexible funding mechanisms, tax regime to support investment and financial support.
- Culture and Leadership: The food industry does not have a great perception for career development, and the industry lacks coherent leadership. The development and promotion of modern digital technologies may help change perceptions. The industry requires a unified and coherent leadership council to promote digital technology development.
- Data Security: There are wide range concerns with regard to data ownership, privacy and cyber security. Cyber security concerns are seen as a barrier for SME development and the government needs to develop a clear policy for data ownership and access.

ACTIONS TO ENABLE DIGITALISATION

The recommendations from the food industry consultation event were;

- Establish Industrial Digital Training Institutes
  - Industry / Public / HEI
  - At all levels, especially professional re training
- Demonstrators and Innovation Funding
  - Industrial Robotics, Industry 4.0 etc. Rolling programs at centre of excellence and to support early adopters in industry (manage risk).
  - IoT, Blockchain, Analytics, Traceability systems, Artificial intelligence
- Interoperability, Digital Architecture and Security
  - Standards for interoperability, legacy integration
  - Establish a digital architecture to support the food chain (aka Smart Cities; Data storage, IoT systems, Sensors, Analytics)
  - Support of data security / ownership policy and approach for SME's
- Leadership
  - Industry is large, complex and leadership diffuse, need to change perceptions

OFFSHORE

Creating a sustainable future

Offshore Wind

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

The UK economic opportunity in offshore renewable energy is robust and growing. Over £15bn has been invested in commercial offshore wind projects in the UK to date and a further £15-20bn is in the pipeline. Further cost reductions will lead to deployment of thousands more offshore wind turbines by 2030, allowing UK companies to help deliver value to the UK economy of £4.4bn per year . The cost of electricity from offshore wind has fallen 32% in only four years, surpassing 2020 cost reduction targets and putting the goal of being the cheapest, large-scale clean energy source within reach and now sits alongside nuclear as the UK's clearest route to decarbonisation. A truly global market is emerging through strong growth in Europe, North America and Asia. Offshore renewables align strongly with the aims of the government's technology-driven industrial strategy and are especially important for coastal, economically-challenged areas, creating new business opportunities from Cornwall to Caithness, and Hull to Milford Haven.

Developing the right balance of specialist skills will be essential to continue the area's strong presence at the forefront of innovation. The sector has a strong record in both formal education and private training capabilities and there are strong relationships between Universities and Colleges and businesses. However, there is a shortage of skilled engineers. The skills required within the sector are similar to those existing within other sectors such as general manufacturing and the offshore oil and gas sector. The sector has a strong tradition of delivering engineering skills at all levels from apprenticeships to post graduates and this forms part of the industrial base of the UK. The jobs potential created by offshore wind is significant, with the industry set to support up to 60,000 direct and indirect jobs in the UK by 2032, making a compelling case for ensuring the right skills are developed today for the needs of tomorrow.

Although great progress has been made, the offshore wind sector is at a relatively immature state of development (compared to automotive and aerospace, for example). Consequently, integration and standardisation remains relatively under-developed in a number of aspects from low commoditisation of equipment, through health and safety criteria to training and skills. Supporting collaborative activity within the sector and bridging between business, academia and NGOs/GOs will help sector wide innovations to emerge, facilitate maturation, reduce risk, help bring down costs further and augment the reputation of the UK as a world leader in offshore wind.

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

The progress of the offshore wind market from early demonstrators, through cost reduction and performance improvement, to the current phase of maturing supply chains and consolidation of project developers and OEMs, is significant and it is now set to move into a new phase of global market expansion.

The market prospects in Europe for offshore wind in particular are currently robust, and prospects in North America and Asia are emerging rapidly. In the UK, BEIS is moving ahead with its ambition to provide contracts for up to 10GW of additional offshore wind in the 2020s. Recent scenarios from the Committee on Climate Change[171] forecast a UK installed base of 20-29 GW of offshore wind in 2030. Projects announced in the Netherlands, Denmark and Germany during 2016 indicate a continued rapid fall in the Levelised Cost of Energy (LCOE) and the recent UK auctions have extended this even further.

[171] 1 https://www.theccc.org.uk/wp-content/uploads/2015/10/Power-sector-scenarios-for-the-fifth-carbon-budget.pdf

The UK sector faces the challenge of continuing this trajectory in terms of field deployment in the face of skills shortages, the need to industrialize new technology (such as floating foundations) and the tensions over UK content in UK fields in the context of government subsidies. The maturity of the offshore wind industry is evidenced by the EU wide supply chains for major capital components that are now well established which in some key high value components (such as Nacelles) lie entirely outside the UK. In some balance of plant components (such as Cables), the UK has strong manufacturers that are now winning orders in the emerging markets of the US and Asia. The growth of UK manufacturing would be helped by more stability in market demand through evolving a more stable government intervention method than the current auction methodology. The UK has a strong position in engineering and installation services for offshore wind and excellent capability in operations and maintenance – both aspects offer significant opportunity for export led growth.

There are significant opportunities for the Offshore Wind sector in industrial digitalization that include:

- Big data techniques allied to more extensive use of sensor technologies (both embedded and via drones) that can reduce the cost of electricity by reducing operations and maintenance costs. These techniques have strong export potential.
- Advanced digital simulation at the engineering stage could enhance UK content in offshore wind projects and create valuable export opportunities for UK consultancy companies. This opportunity is particularly strong in foundation design. Although great progress has been made, soil-foundation interaction is still not completely understood and more research is needed to improve simulations and their validation against test data gathered at real-world scale. Floating foundation design is a key export opportunity and also requires significant innovation.
- The creation of a digital database of environmental data would reduce risk for wind farm operators and reduce the cost of electricity. At the moment, there is no comprehensive store of data relating to geological surveys, marine and bird data, wind reserves and other important factors.
- The integration of wind energy into the wider electrical grid is becoming an area of concern – particularly the potential for grid instability and guarantee of supply obligations. Active management of the grid using digital forecasting is already very sophisticated but there is widespread belief that there are opportunities for innovations around available power estimation, localised wind prediction and market trend modelling (at high time granularity) amongst others.
- There is long term potential in the use of specialized robotics to undertake maintenance on hard to reach assets such as turbine blades. This might first develop as robots that can crawl along assets and undertake imaging or other sensing operations (to look for initial stages of cracks for instance) but in time could extend to undertaking actual maintenance (such as injecting repair resins). This is clearly someway in the future at present but given the rapid development of robotics in recent years is worth of consideration. Even further ahead, the development of so-called cobots (collaborating robots that can work alongside humans) might first emerge as dive assistants (for underwater work – such robots do in fact exist at a research stage) and then for more general duties. Such technology would reduce the number of humans required for hazardous field deployments.

BARRIERS TO DIGITALISATION

A number of barriers to digitalisation where identified as part of this review:

- Greater stability of project approval (auction mechanism) would enable UK companies to invest more in innovative digital approaches
- The skills development of the work-force is an issue across the whole sector. A greater familiarity and awareness of the benefits of digitalisation is needed – particularly through examples of good practice within the sector so that the applicability can be clearly demonstrated.
- There is a need for more cross-sector cooperation where relevant digital technologies from sectors such as aerospace and nuclear can be re-engineered for the offshore wind sector.
- There is a lack of specific innovation programs via bodies such as InnovateUK that are focussed on the offshore wind sector and its needs (in contrast to some other sectors that have had targeted support).

ACTIONS TO ENABLE DIGITALISATION

The UK offshore wind sector has significant opportunities for export growth that could be enabled by the adoption of digital technologies. A number of actions would accelerate the realization of those opportunities:

- A more coordinated approach to the development of industrial digitalization in the offshore wind sector should be developed – fostering links between industry, relevant catapults (ORE and Digital) and academic groups. This should be supported through the Industry Strategy
- There are a number of UK SMEs who are developing industrial digitalisation approaches for new products in this sector – such SMEs need more support via mechanisms such as InnovateUK.
- The development of a digital skills in the offshore wind sector could be accelerated through enhanced support via education and training providers at the main industry hubs (for example at Hull) where there are significant concentrations of activity.
- Initiatives such as the Offshore Wind Innovation Hub, Academic Research Hubs and the Supergen programme should be given an even stronger mandate to set the industry-academia agenda in order to ensure best value for money for public and private research and innovation funding and to connect new technologies to the sector.
- The testing at scale of offshore renewable energy technology is a crucial under-pinning factor in innovation and commercialisation of new technologies and services and this must continue to be supported. This will be equally true for industrial digitalisation and testing in the field under real world conditions is crucial. This could be facilitated through appropriately sited centres that can help diffuse innovations.

PHARMACEUTICAL

Digitalisation for patient centric outcome based healthcare

Pharmaceutical

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

The UK's medicines industry is one of our leading manufacturing sectors, with exports worth £25.8bn in 2016. UK data shows the Gross Value Add (GVA) per head for pharmaceutical manufacture was double the GVA of any other manufacturing sector.[172] Industrial competitive pressures worldwide coupled with changes in patient expectations provide real business challenges in terms of the competitiveness of this sector in the UK.

The UK is in a global race to attract investment and compete with other economies across the world in order to sustain its vibrant innovative research community and advanced manufacturing expertise. The pharmaceutical sector is one of the UK's most valuable assets and has a projected total global value of $1.2 trillion in 2016. The pharmaceutical sector delivers a significant contribution to the UK economy and to the population as a whole.[173]

- £11.5 million invested in the UK per day on research and development
- 25% of all expenditure on R&D in UK businesses is by the pharmaceutical industry
- 107,000 people employed directly by bio-pharmaceutical companies in the UK
- Each employee contributing £149,000 to GDP per year
- An eighth of the world's most popular prescription medicines were developed in the UK

In addition to the economic contributions the industry plays a critical role in improving the wellbeing of the UK population and reducing the cost of healthcare.

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

The pharmaceutical sector will require up-skilling and retraining of its workforce in new manufacturing techniques and digital disciplines. We must reposition the UK's capability in pharmaceutical, harnessing the opportunities offered by digital transformations for new product development, manufacturing and integrated supply chains. Using existing expertise, the UK can exploit newer paradigms, translating emerging technologies into new products and manufacturing processes. Alongside a progressive tax regime such as the Patent Box, this could attract pharmaceutical manufacturing to the UK.

Historically, the translation of early innovation development into actual scaled-up medicine production physically in the UK has not been so successful. Examples of lost opportunities include:

- The UK is a leader in scientific research for biological drugs, however the translation of the research and Active Pharmaceutical Ingredient (API) manufacturing capability has been off-shored to the Far East over the last 10-15 years – manufacturers being drawn to lower cost locations, but at the expense of consistent quality/compliance and supply chain security. Two persistent problems for API manufacturing in these locations have been high staff turnover and satisfying the requirements of global regulators for supply back to major markets (i.e. USA, Europe). Disruptive manufacturing technologies are providing a means of reshoring from low cost countries.
- In the UK, we manufacture very few packaging components that are needed for all medicine packs. This results in medicines manufactured in the UK being exported to other markets for final packaging into "patient ready" formats.

[172] http://www.abpi.org.uk/media-centre/newsreleases/2017/Pages/PwC-analysis-highlights-economic-footprint-of-UK-Life-Sciences.aspx

[173] Delivering Value to the UK. The contribution of the pharmaceutical industry to patients, the NHS and the economy". API 2014.

- Outcomes for drug development and their manufacture has largely moved to the USA, Japan, Singapore, Switzerland and Ireland.

This makes UK less self-sufficient, more vulnerable to supply shortages and the UK ultimately is losing high value jobs and manufacturing know-how and skills. Additional opportunities include:

- Regulatory Environment: The medicines manufacturing area is heavily regulated. Whilst major regulatory agencies are encouraging the uptake of advanced manufacturing processes in many parts of the world, registration and approval of advanced processing methods is not an option. Given the global nature of the Pharmaceutical market the lack of a harmonised process for registration and approval is a barrier to adoption but regulatory engagement with the proposed capability build could be a great opportunity for the UK.
- Ground-breaking new ways of developing manufacturing processes based on digital design techniques and mathematical process models require new skills to be acquired by process and product development scientists. This workforce is highly skilled in the areas of Synthetic Chemistry, Analytical Chemistry and Formulation Sciences but lacks the quantitative modelling skills required to exploit these new technologies.
- A major challenge is the lack of sufficient expertise and skills within the Pharmaceutical Industry in emerging digital technologies. This is a key driver in the need for intervention to catalyse the proposed changes.
- Although medicines manufacturing processes could be improved through adoption of digital techniques, the cost of conversion of current commercial processes both in terms of capital costs and the costs of change (development and regulatory) present an obstacle } to implementing these improvements. Opportunities to collaborate and co-fund R&D in this area would help to alleviate this.

There is a sea change happening however. The UK Pharmaceutical Industry is now at a pivotal point. These global challenges offer opportunities to regain the UK's position as the leading country for medicines development and manufacturing, with a focus on not only new molecules but also the novel associated manufacturing technologies to better meet the needs of patients. There is also the opportunity to improve and re-engineer existing manufacturing processes using innovative emerging technologies, tools and techniques to reconfigure the whole end-to-end supply chain. This will integrate various parallel 'game changers' such as digital manufacturing, agile manufacturing, artificial intelligence, smart packaging, big data, analytics, process automation and advanced diagnostics and treatments.

Going forward, digital technology will continue to be a powerful tool in creating medicines. It will continue to shape and influence not just how medicine is discovered, developed and made but also how patients are diagnosed and treated. The digital landscape will feature more and more 'closed-loop' approaches, where systems will learn and predict with increased accuracy.

PHARMACEUTICAL INDUSTRY: DIGITALLY ENABLED SUPPLY CHAIN

RAW MATERIALS	FEEDSTOCK	PRODUCT MANUFACTURE	FORMULATION & TABLETING	SMART PACKAGING	SUPPLY CHAIN LOGISTICS	HEALTHCARE PROVIDERS & PATIENTS	RECYCLE & RECOVERY
1. Bio 2. Non-bio 3. Batch 4. Continuous 5. Sustainable	1. API 2. Excipients 3. Batch 4. Continuous	1. Control Productivity 2. Digital 3. Batch 4. Continuous	1. Process design 2. Personalised 3. Batch 4. Continuous	1. Personalised 2. Location 3. Condition 4. Control	1. Condition 2. Location 3. Control 4. Quality 5. Warehouse	1. Compliance 2. Diagnostics & monitoring apps 3. Novel devices 4. Combined device & drug	1. Circular Economy 2. Resource Efficiency 3. Reuse

ENABLING TECHNOLOGIES

Artificial Intelligence

Smart Plant Equipment

Sensor Networks

RFID/NFC Tags

Robotics & Drones

Advanced Mobile Diagnostics

Advanced Instream Process Control

Emerging Electronics

New Drug Delivery Tech

High Throughput Testing

Flexible Manufacturing

Autonomous Operations

VR. Simulation and Modelling Tools

Wireless Connectivity

BIG DATA

CLOUD SYSTEMS, CYBER SECURITY AND DATA ANALYTICS

Integrated New Medicine and Process Development using Predictive Modelling and Simulation Tools

Integrated (Digital) Design, Trials and Approval e.g. Addopt

Integrated Supply Chain e.g. Remedies

Learning and Improving from the Combination of Manufacturing, Supply Chain and Effectiveness of Treatment

Industry 4.0

Internet of Things

BARRIERS TO DIGITALISATION

Key challenges and opportunities to address digital adoption include:

- The need to accelerate new medicine development using predictive simulation and modelling tools: The use of advanced digital design techniques such as high throughput testing, robotics, artificial intelligence and big data techniques (integrating structured and unstructured data and subsequent advanced analytics) can help to eliminate non-viable drug candidate formulations early on by better predicting properties and performance of the target molecule and its formulation for drug delivery (e.g. compaction, coatings, morphology, stability). This will streamline the overall product development process reducing time-to-market and associated risks and costs.
- The need to accelerate scale up, design and modelling of new manufacturing processes: The age of the blockbuster medicine is coming to an end. This is giving rise to the adoption of more agile manufacturing processes within the pharmaceutical industry, such as small-scale production facilities located close to the point of use, autonomous batch and continuous processes with instream quality control, scalable processes, distributed manufacturing and additive manufacturing. Furthermore, adoption of advanced digital technologies for process and plant design will enable rapid translation of new lab based processes to commercial production facilities.
- The need to boost productivity of manufacturing plants using automation, removal of paper through digitalisation, big data, virtual reality and predictive process control: The use of digitally enabled processing techniques and plant equipment (Industrial IoT connected to cloud-based software systems) that can monitor, predict and control in real-time will ultimately facilitate increased knowledge generation, robustness and lead to deployment of autonomous production systems for pharmaceutical manufacturing processes. Data captured can be used for simulating future plant performance, preventing plant failures and aiding operational decision making. Digital tools like virtual augmented reality can be used in upskilling and training the existing and future workforces; this will help to create a high-skills economy for the future.
- Smart packaging, logistics and optimised supply chains: Effective tracking of pharmaceutical products throughout the supply chain is critical. Close collaboration is needed with the pharmaceutical community (along with logistics providers and customers) to standardise where feasible, and also to continue to drive innovative supply chain solutions to ensure medicine supply is optimised through minimising inventory. This is often a hidden cost and management of this is critical, as shelf life can be short for some components and finished goods. It is also important to establish clear and accurate demand signals. Further, the use of low cost sensors, smart packaging, smart labels, near-field communication tags, RFID tags, printable electronics components and cloud-based software systems can be used to digitally track an individual pack from the manufacturer through to use by the healthcare professionals and patients. This integrated approach can both help to ensure pack quality during transportation and patient compliance. In addition, drone technology can complement existing distribution methods particularly with regard to supplying pharmaceuticals to remote locations.
- Novel diagnostics devices and treatments incorporating digital connectivity with healthcare providers and patients: The internet-of-things (IoT) is giving rise to a smart healthcare ecosystem. The potential for digital technology to help measure, maintain and improve health and wellbeing through preventative approaches and supported health management is considerable and represents a massive opportunity for pharmaceutical industry. The devices developed are evolving rapidly into more complex tools; connected clinical devices are now starting to being used in trials to collect more and more data. A core functionality is gaining acceptance and opening up new possibilities:

- Devices are increasing in capability and the data they generate is more extensive.
- E-mobile and portable point-of-care medical diagnostic devices are driving the requirement for innovation in diagnostics technology.
- Data analysis is getting smarter and more informative with appropriate enabled interventions.
- Data is ultimately being personalised and can enhance patient centricity.
- Longer term studies, where various end points are monitored over time, are generating data that can help the Pharma industry to gain a real-life understanding of how patient's lives are improved.
- Enhancing 'real life' post launch evidence based analysis.

ACTIONS TO ENABLE DIGITALISATION

Digital Factory: Digitally enabled medicine manufacturing for improved productivity and efficiency

New medicines manufacturing is at an inflection point in terms of investment required to respond to the changing environment. Key challenges to produce small molecule medicines and biopharmaceuticals more effectively include:

- Adoption of state-of-the-art digital simulation and modelling tools to accurately characterise and predict the physical properties and manufacturability of target molecules.
- Replacing existing technologies and processes with new approaches, to shift the current process and product design paradigm away from the "make and test" to a more predictive digital framework to enable a more radical 'right first time' approach.
- Improving performance of large scale production plants by enhancing the knowledge of current processes and transforming them into more efficient processes, which could be batch or continuous, with the use of state-of-the-art digital control, algorithms and data analytics.

New infrastructure and skills are also required if the pharmaceutical industry is to embrace this new paradigm for the digital design of drug product and manufacturing processes. To overcome this barrier, the pharmaceutical industry must undergo a step-change in the adoption of state-of-the-art digital simulation-based tools and workflows.

The proposed capability build is closely aligned to the UK Government's industrial strategy, specifically supporting the Strategy for Life Sciences backed by the Office of Life Sciences. It will:

- Support the UK as an international hub for developing and manufacturing medicines to meet the global demand for novel products.
- Ensure the UK continues to be an attractive place for medicines manufacturing investment, increasing the UK's share of a growing global market.
- Through the adoption of novel new technologies this will facilitate on-shoring and reshoring of production of medicine, reversing current trends due to cost effective production enabled by improved and integrated processing and packaging equipment
- The adoption of digital technology in existing and new production facilities will result in significant manufacturing productivity improvements, anticipated to be of the order of 30% - 35% by 2030.
- The development of an automated and autonomous UK based clinical packing capability will radically reduce lead-times by 45% -55% and enable the application of an adaptive supply chain model for better fulfilment and responsiveness to orders. This can be achieved by using advanced sensors and devices which will capture real time data to enable informed decisions.

- The importance of having integrated manufacturing capability for both clinical and commercial supply in future pharma manufacturing is key. Digital tools will drive manufacturing efficiencies and enable more effective scale up capability and technology transfer. Batches will be smaller (especially as we move to more personalised medicines) so the need for flexible production will be the opportunity for the UK to lead in this area.
- Enhance the UK's Knowledge Economy by unlocking real value, supporting balanced growth and developing a highly skilled and competitive workforce through:
  - Harnessing long-standing academic investment in UK science and recent enhancements in E-infrastructure to develop a globally-unique knowledge domain.
  - Providing outputs that enable the UK pharmaceutical sector to make a step-change in the way medicinal products are designed, developed and manufactured.
  - Increasing the significant contribution that the UK pharmaceutical community has already made to Britain's collective scientific knowledge.

Smart Supply Chain: For clinical and commercial supply of medicines

Pharmaceutical manufacturers must have a supply chain (SC) that provides complete control and scalability to ensure end-end quality and production efficiencies. Key challenges include:

- Effective tracking and condition monitoring of packaged medicines through the supply chain in collaboration with logistic and healthcare providers for end-to-end quality assurance. A particular focus is needed for cold chain supply as this will become more commonplace as complex medicines increasingly enter the supply chain.
- Standardisation and innovative supply chain solutions are needed to ensure medicine supply is optimised through minimising inventory (often a hidden cost and management of this is more critical as shelf life can be short for certain medications) as is having clear and accurate demand signals.
- Adoption of printed electronics coupled with advances in data management for the imminent implementation of serialisation in alignment with the new pharmaceutical regulation and for the provision of electronic product information and e-leaflets for healthcare providers and patients.

The creation of excellent capability in UK Pharma packaging and devices would lead to a number of benefits:

- Improved adherence will reduce medicines waste (potentially saving £10-15B) and improve outcomes.[174]
- Better inventory management (avoiding stock outs and write-offs).
- Pack material optimisation will reduce cost of goods (this could be extended to other industries).
- Projects such as electronic leaflets will add value whilst reducing waste and improving patient safety.
- The development of appropriate apps should lead to an improvement in knowledge about medicines, aid adherence and enhance safety reporting - providing benefits to patients, brands and regulators.

[174] https://www.england.nhs.uk/wp-content/uploads/2015/06/pharmaceutical-waste-reduction.pdf

Connected Medicine: From clinical trial to post launch 'real world' use

The challenge – Pharmaceutical companies currently do not have access to anonymised patient data. Current access is limited to patient groups and surveys. For Pharmaceutical companies to develop medicines of value at continuing competitive cost obtaining patient insight feedback could lead to great innovation. Access to patient data will help to manufacturer to shorten medicine development time and save development costs. Smart diagnostic devices will help manage chronic diseases (e.g. respiratory, diabetics in first instance) through better diagnosis and more targeted dispensing, this connected devices concept will inform + empower healthcare professionals (e.g. NHS) and patients. Transformational data access would include:

- Medicinal point of sale data (Pharmacy Serialisation data)
- Patient (pack) use feedback signal open/ depleted (Demand Signal)
- Digital Phenotype data - (Fitbit/ personal digital data behavioural modelling)
- Diagnostic data from the device, packaging or patient monitoring system

Whilst the NHS remains a viable organisation it represents a great opportunity for collaboration with the UK Pharma industry. If digital technology is embraced within the NHS such data, shared under appropriate conditions, could differentiate the country as a place for Pharmaceutical companies to understand further, develop and invest in new methodologies for the most innovative medicines.

This initiative will build capability to capture data to support new Pharmaceutical interaction insights, leading to increased understanding of the medicine through the lens of real life continuous 'clinical trials' thereby leading to safer, more cost-effective medicines. This real-life data will add to the clinical trial results.

- Development of new business models for outcome based service offerings from the Pharma industry. Ability to incorporate effective diagnostics coupled with smarter dispensing (driven by better diagnostics) will ensure that medicine dosing is optimised. The further use of digitalisation and AI to transform pathology is a key area for R&D and commercialisation and impacts Pharma and MedTech.
- Integration of anonymised patient electronic records to support data analytics. This will be coupled with the use of smart sensors and devices. This capability will be used in day to day disease management and in the various clinical phases of drug development including post launch to show 'real world' effectiveness. These platforms will enable data analysis for better health management – which includes use of Big Data and Artificial Intelligence to improve healthcare outcomes. These technologies could initially be focused on asymptomatic chronic diseases.
- Airedale NHS foundation Trust – care anywhere: remote collaboration between GP's and patients in their home. The introduction of telemedicine showed a difference of £1.2million, with a ROI of £6.74 per £1 spent. (Hex, 2015). This precedent highlights how collaboration tools could bring the Pt into direct contact with a number of competencies to support healthcare outcomes[175].

[175] https//www.nutfieldtrust.org/uk/files/2017-01/delivering-benefits-of-digital-technology-web-final-pdf

TEXTILES

Reinvigorating leadership in British fashion and advanced textiles

Textiles

SECTOR DESCRIPTION AND NATIONAL OPPORTUNITY

Textiles production is one of the UK's heritage industries. In the 18th century Britain was the world leader in textiles although the textiles landscape has altered vastly with the passing of time, and the UK is currently the 15th largest textile manufacturer. Two World Wars forced other countries to become independent of Britain's textile expertise and they developed their own skills and manufacturing establishments. Combine this with the introduction of synthetic materials (such as nylon and rayon), and the result was that the demand for the luxury fabrics that Britain was renowned for was in decline, while textile production outside of Britain was on the increase. The 1960's/70's in Britain saw a further decline of the equivalent of 1 textile mill closure per week. During this time, companies have survived, and remain to this day in business; a few are prosperous, whilst others struggle year on year for survival.

Today, the breadth of industrial activities covered in the textiles sector is massively diverse, and can be split broadly into two main categories; traditional textiles (for example, upholstery, clothing, linens, and floor coverings), and technical textiles (for example, load bearing webbings and belts, harness assemblies, and medical textiles such as bandages or implants are all examples). Due to the range of industries included within this sector, the business models relevant are numerous, and consequently this report is selective in those it provides as examples. A useful document that contributes to this review is the Alliance Project Report, a 2015 document produced to provide recommendations to Government regarding the repatriation of UK textiles manufacture. This report was extensive and substantial, based upon interviews and input from over 200 manufacturers and retailers, and (some of) the ultimate findings were these;

- the UK still has significant capabilities within the traditional textiles sector and the supply chain infrastructure is readily here, though the sector has lacked funding and innovation,
- the technical textiles sector has undergone substantial innovation due to significant funding, and is growing,
- increasing costs in competing countries (associated with labour, energy, transport) means that reasons to source outside of the UK are weakening,
- the reasons for sourcing within the UK are strengthening, due to increased customer demands for shorter lead times and genuine British products,
- barriers to growth include an aging workforce with endemic skills shortages, micro-size nature of the supply chain (hampering information exchanges, supply chain integration, large sustained orders and major investments), and a negative image for potential new workforce entrants.
- textile firms are diversifying into higher value opportunities such as technical textiles, seeking alternative manufacturing options for the expertise they possess, such as medical textiles, engineered textiles, industrial materials.

The above suggests that the potential for UK textiles manufacture is unquestionable, though there are sources that suggest other countries are pushing for dominance in this market too. For example, China is expected to account for 44% of the global luxury goods market by 2020. Whilst the UK will need to act pre-emptively to ensure its best success in this area, the evidence provided so far would suggest that it should not be so difficult to achieve great results.

SECTOR CHALLENGE AND OPPORTUNITY FOR DIGITALISATION

The UK textiles sector is predominantly comprised of SMEs without OEMs at the head of supply chain driving investment. The majority of the UK textiles manufacturing asset base includes legacy manufacturing equipment that would need a legacy connectivity initiative to fully realise productivity, quality and lead time reduction benefits of digitalisation. Additionally, the fashion brands work on a traditional two season cycle with long lead times and remote inflexible supply chains. This creates a need for the sector to move to more responsive, agile and local supply chains. Adoption of digital technology would increase the competitive position of UK supply chains.

The specific characteristics and opportunities in the UK textiles sector create an excellent prospect for the application of digital technologies for value creation in the sector. Technical textiles open up new market opportunities for an innovation rich UK textiles sector. Materials and process modelling and digitised process control and verification will enable rapid growth of this sector. At the same time, provenance of textiles is of increasing importance to consumers with respect to ethics of supply and also marketing built on UK source and branding. Digital traceability of raw material through to finished and supplied product will enhance product value for UK made fabric and products and open up opportunities for the UK textiles supply chain. Furthermore, Cut Make Trim (CMT) is a largely manual process relying on skilled but low cost often part time labour. Targeted automation of the sewing process and other aspect of CMT could transform productivity and open up increased capacity addressing current skills shortages.

From responses received within this review, digitalisation can only be positive. It could generate faster product turnaround which in turn

- creating opportunities to work in sectors currently proven to be inaccessible,
- increasing consumer requirements to have items sooner – swaying further the amount of manufacturing occurring within the UK, and
- bringing some of the generations old textile mills into a more secure future, strengthening some of the UK's heritage industry.

However, it is foreseen that some of the older textile mills may (perhaps unknowingly) resist such changes, and would be unlikely to succeed in implementing digitalisation unless it has the necessary skills to see the integration through, perhaps from younger members of the workforce. It is recognised that the integration of digitalisation would require resources and upgraded infrastructure, which would require sound justification to the companies' stakeholders.

BARRIERS TO DIGITALISATION

The phrase "digital technologies" in this case is assumed to mean a configuration of hardware and software that can be used throughout a supply chain to increase connectivity and transparency between links within the supply chain.

Whilst conducting this study, the input from a variety of people within the textiles industry was sought. At times opinions were divided, but one thing was clear – digitalisation can only be a good thing. In the supply chains where the logistics are managed manually, the gains are palpable – a delay at one position in the supply chain may be mitigated effectively, and work activities reprioritised to maximise productivity. In order for this to be effective however, each link of the supply chain needs to be willing and able to integrate this technology, which may be impractical across the globe. For the cluster supply chain system, you could be forgiven for thinking that they already have an optimised system and are producing goods – from concept to product – very rapidly, and already have a well refined business system. But to reduce this manufacturing time still further, could step the purchasing habits of consumers to another level. For example, the fashion industry at present can produce a new garment based on an item a celebrity has been seen wearing and have it available to purchase within 4 days. However, with an increasingly connected supply chain, a customer may be able to design their own product, choose their own colourways, and have a unique item bespoke to them, even faster than that.

Members of the technical textiles industry have stated that the growth they've achieved may also have resulted in the business being more cumbersome, and finding a way to produce materials with a reduced turnaround would be greatly beneficial. However, a concern from the weavers was that the textile machinery downtime during a material changeover is currently a very lengthy (sometimes weeks long) process, and the changes that digitalisation may bring may simply exacerbate this issue. It may be sensible to make efforts to reduce the turnaround time of such an activity, prior to attempting to optimise the rest of the entire supply chain. Some participants of this study felt that they do not necessarily face a strong threat of offshoring and have a manageable and reliable influx of work with a good forecast, but they can struggle to capture work from within a rapid-turnaround environment - in fact, one particular participant within this study claimed that an automotive OEM opted not to place work with them.

ACTIONS TO ENABLE DIGITALISATION

From responses received within this review, digitalisation can only be positive. It could generate faster product turnaround which in turn could:

- create opportunities to work in sectors currently proven to be inaccessible,
- increase consumer requirements to have items sooner – swaying further the amount of manufacturing occurring within the UK, and
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However, it is foreseen that some of the older textile mills may (perhaps unknowingly) resist such changes, and would be unlikely to succeed in implementing digitalisation unless it has the necessary skills to see the integration through, perhaps from younger members of the workforce. It is recognised that the integration of digitalisation would require resources and upgraded infrastructure, which would require sound justification to the companies' stakeholders.

It is also recognised that for digitalisation to be successful it should be integrated across multiple independent companies, and for this the right responses would be required right throughout the supply chain, not only within the individual enterprise. Hence an industry wide integrated effort would be required with the right people in place to maintain impetus. Perhaps a pilot scheme across a micro-supply chain – perhaps even the cluster supply chains mentioned earlier – could be a good first step as a demonstrator to the remainder of the sector.

And finally, widely recognised across the textiles sector is the need to address the availability of skills. Significant portions of the sector demonstrates an aging workforce, with a lack of apprentices at the entry level and fewer being retained within a company, the skills are being lost as the long-serving staff take on retirement. This is believed to be the first hurdle that the textiles sector needs to address to ensure the longevity of textile manufacturing within the UK. Perhaps the digitalisation of the UK textiles sector, combined with an initiative on skills development together could provide security for the future for the UK's textiles sector.

In summary, the textiles sector proposes three key actions to digitalisation:

- Development and integration of future skills
- Resources and upgraded infrastructure
- Connected clusters and supply chains

APPENDIX TWO
INTERNATIONAL GOVERNMENT INDUSTRIAL INTERVENTIONS

9

Appendix 2

International Government Industrial Interventions

Within this section we provide an overview of how other governments are seizing the opportunity to be leaders in the Fourth Industrial Revolution through large National Initiatives, and also highlight a number of IDT interventions particularly supporting SME's.[165] [166]

This includes Germany's National Digital Strategy **DE-DIGITAL**[167] -a large ambitious National programme with the objective to **make Germany the leading supplier and user of Industry 4.0 – and as a result, it will be the most modern industrial location in the world.** Of particular interest is the creation of a national Digital Agency to provide strategic support to the Government, financial support for SME's and start-ups, and encouragement for links with established businesses, tax incentives to encourage investment in IDT, and a focus on cyber and standards.

Another example is the US initiative **America Makes** – this is a group of 14 Technology focused Institutions which due to their relative immaturity has focused on R&D. However, they have established large networks with industry and academia. Going forward they have recognised the need:

- To be more market driven than agency driven in terms of projects
- Shift the focus from R&D to supporting Commercialisation, engagement of SME's and training
- Integrate across the networks to solve broader manufacturing problems (i.e. not single technology problems)
- Improve Governance to support sharing of best practice.

China's Made in China 2025 and Internet Plus[168] **–** these are ambitious initiatives undertaken by the Chinese Government to establish China as a truly global leader in high quality advanced manufacturing products. Core to these initiatives is the development and promotion of IDT. Jack Ma, founder and executive chairman of the Alibaba Group, which owns many highly successful Internet-based brands in China, asserted that "The most important source of energy for future manufacturing is not oil, but data" (Li Q., 2015).

In addition, there are a range of policy intervention across Europe, Singapore, the United States and Japan. These interventions illustrate the global focus from national governments in promoting digital technologies within industry with a focus on collaboration between academia, research organisations and Industry especially involving SMEs as well as direct financial support to start-ups and SMEs.

[165] Roundtable on Digitising European Industry: Working Group 1 – Digital Innovation Hubs

[166] Smart Service Welt – recommendations for Strategic Initiative – Web based services for business

[167] Digital Strategy 2025

[168] The Next Production Revolution – Implications for Government & Business – OECD

Germany: Digital Strategy 2025

Germany's Digital Strategy 2016- 2025 – this is an initiative in which businesses, unions, the scientific community, the government and a motivated public are already developing approaches and projects for digital transformation in Germany – **DE.DIGITAL.**

The strategy places a strong emphasis on Data:

"In the long run, the key competencies of successful companies will revolve around collecting, processing, linking and protecting data – and the specific measures and methods these companies develop to carry out these tasks."

Significant benefit was identified - if digital technologies and German companies' ability to use them are aggressively pursued. Projections put productivity gains of up to 30%, annual efficiency gains at 3.3% and cost reductions at 2.6% annually. The sectors that will benefit most in the next five years are the automotive industry with an increase in revenue of €52.5bn (13.6%), mechanical engineering (€32bn or 13.2%), process industries (€30bn or 8.1%), the electronics industry (€23.5bn or 13%) and ICT (€15bn or 13.4%).

And there is potential for the information and communication sector to have more of an impact: While this sector only contributed 30% to GDP in the EU from 2001 to 2011, it reached figures of up to 55% in the USA over the same period.

Additive manufacturing (3D printing) is becoming particularly important. Global sales in products and services for additive manufacturing has climbed from $529m in 2003 to $3.07bn in 2013, and is projected to be at $21bn by 2020 (share of German companies: 15–20%). In Germany, approximately 1,000 companies are active in this area, and about 90% of those are SMEs. Up until now, additive manufacturing has been used in particular for Rapid Prototyping (24.6%) and for basic technology experiments (28.9%). However, rapid manufacturing and rapid tooling have increasingly gained in importance (9.6%).

There is a forecast increase in the use of service robotics, especially in material logistics, production and handling assistance for handwork jobs. The industry association IFR World Robotics expects global revenues in 2017 of $300m for service robotics in logistics (mainly in manufacturing).

There is bold ambition:

'In digitisation, more than in any previous transformation, the fastest will win. Those who open up new markets early and quickly set new standards will be successful.'

'It is our goal to make Germany the leading supplier and user of Industry 4.0 – and as a result, it will be the most modern industrial location in the world.'

'All government research and development expenditures must be at least at the level of the most innovative regions on the globe.'

Areas of weakness identified:

'German companies invest only 14% of their annual research budget in commercial applications for digital technologies. US companies spend twice as much. We must therefore broaden digital research efforts, especially in traditional industries.'

Big Data solutions in the US made up 49% of total patent applications in 2012, whereas in Germany, they constituted only less than 5%. German companies presently still use old technology for their data analyses. Already in 2014, no less than 509,000 data experts were being sought in Europe. Analysts estimate that, 3.5 million data experts will be needed by 2020.

The strategy was based on 10 Policy Interventions

1. **Creating a gigabit optical fibre network for Germany by 2025**

   Support new distribution channels and logistics processes, the Internet of Things, autonomous driving and Industry 4.0 which all require broadband real-time communication in the gigabit range.

2. **Launching the New Start-up Era: Assisting start-ups and encouraging cooperation between young companies and established companies.**

   Set up a €500m growth facility as well as subsidies and tax refunds, grant funding for compensation of losses, internationalisation promotion, connecting with established businesses, actions for making the process of starting a company easier and more efficient.

3. **Creating a regulatory framework for more investment and innovations: -**

   Create a technical and regulatory Digital Single Markets, legal barriers and other hurdles for cross-border e-commerce to be identified and removed, develop a European data region policy based on common principles (e.g. data security and informational autonomy).

4. **Encouraging "smart networks" in key commercial infrastructure areas of our economy**

   Promote digitisation in major infrastructure areas, such as energy, transportation, health, education and public administration through improved certainty of demand, creation of standards etc.

5. **Strengthening data security and developing informational autonomy**

   Ensure that even those companies not subject to statutory requirements improve their data security; Work together with partners from business and the scientific community to expand the assistance provided under the IT Security in Business initiative; focus on which key technologies and competencies are necessary for maintaining and creating digital independence and provide support for them; Establish a data protection certification. Establish electronic trust services - setting the standards for EU-wide secure and reliable electronic transactions; Eliminate fragmented national data protection rules, legal ambiguities and possibilities for circumvention through creation of European General Data Protection regulation by 2018

6. **Enabling new business models for SMEs, the skilled craft sector and services**

   Develop numerous centres of excellence for digital communication, cloud computing, process management and commerce, and provide support services;
   SMEs provided skills financing for external advisory services in IT security, Internet marketing and digitised business processes; financing for 50% of consultancy services fees for enhancing innovation management in companies with less than 100 employees; specific incentives for SME's investing in the digital transformation;

   €1bn Digital Investment programme for SMEs, investment grants for spurring investments and IT implementation projects at SMEs, including assistance in the implementation process;

   establish showroom for the possibilities and feasibility of such digital projects;

   matching established companies with start-ups and research organisations and with best-practice examples;

   set up an SME Digitisation Task Force and a one-stop agency.

7. **Utilising Industry 4.0 to modernise Germany as a production location**

   Funding programme for microelectronics. The sensor and actuator technology found in machines and robots that is essential for Industry 4.0, including a European research and innovation project for microelectronic with government subsidies of a total of €1bn (2017-2019). Development of an Action Plan for Standardisation of Industry 4.0. Strengthen cooperation on an international level. Bilateral cooperation with China in the context of Industry 4.0 to strengthen the position of German companies on the Chinese market.

8. **Creating excellence in digital technology research, development and innovation**

   Tax incentives to make Investments in digital technology made more attractive.

   Depreciation schedules for hardware and software and for all digital technology devices to be reduced to a maximum of three years. Establish support programmes specifically on innovative technology and applications. Introduce R&D tax breaks for SMEs with up to 1,000 employees. Providing this assistance in the form of a tax allowance would also enable start-ups that have not yet made a profit to benefit from tax advantages.

9. **Introducing digital education to all phases of life**

   An additional €8m investment funding will be made available from 2016 to 2018 to enable industry-wide education centres to be setup to offer further training in digitisation at a high level. Modernising vocational training for IT systems electronics technician, Information technology specialist, IT system support specialist and information technology officer. Work with trade unions and employers to create means of more flexible and individualised digital continuing education, in order to provide employees with industry-wide, practical IT-related basic knowledge and supplemental knowledge on communications and project work. BMWi has already developed an approach to digital continuing education in a half-day format, particularly for SME.

10. **Creating a Digital Agency as a modern centre of excellence**

    Creation of a Digital Agency that will function as a highly efficient and internationally connected centre of excellence at the federal level. The centre will provide competent, neutral and long-term assistance to the federal government both as a think tank in preparing policies, and as a service point for implementation, and would also assist in the digitisation process while representing the interest of business and consumers.

USA: America Makes

- The USA only took action to intervene in Manufacturing technology when it was in crisis
- It created a Manufacturing Network based on 14 Institutions which all have a large network including academia/ and industry
- Their establishment and remit was passed in legislation December 2014
- Objective
  - "create" new production technologies, processes and "capabilities"
  - serve as "proving grounds" to test new technologies and related processes
  - support efforts to "deploy" for new production innovations
  - "build workforce skills" to enhance production and processes for the emerging technologies
- The institutions cover a broad range of Manufacturing technologies:-
  - **The National Additive Manufacturing***
  - The Institute of Advanced Composites Manufacturing Innovation
  - **The Digital Manufacturing and Design Innovation Institute (DMDII)***
  - The Lightweight Innovations for Tomorrow (LIFT) institute

- Power America, for next-generation power electronics
- The Institute for Advanced Composites Manufacturing Innovation (IACMI)
- The American Institute for Manufacturing Integrated Photonics (AIM Photonics)
- NextFlex, for flexible hybrid electronics, Advanced Functional Fabrics of America (AFFOA)
- **The Smart Manufacturing Innovation Institute***
- The Rapid Advancement in Process Intensification Deployment Institute (RAPID)
- The Advanced Regenerative Manufacturing Institute (ARMI)
- The Institute for Reducing EMbodied Energy And Decreasing Emissions in Materials Manufacturing (REMADE)
- The Advanced Robotics Manufacturing (ARM) Institute

*** IDT focused Institutions**

- Due to the relative immaturity, the focus to date has been on R&D, although their remit is TRL3 to TRL7
- They are only publicly funded for five years based on a matched funding public/private.
- Level public funding targeted at between $70m - $140m for each Institute over the initial five years
- Private funding has significantly exceeded match requirement
- Significant eco systems have been developed

Challenges and future focus

- To be more market driven than agency driven in terms of projects
- Shift the focus from R&D to supporting commercialisation, engagement of SMEs and training
- Integration across the networks to solve broader manufacturing problems (i.e. not single technology problems)
- Improved Governance to support sharing of best practice

The Digital Manufacturing and Design Innovation Institute (DMDII) involves the use of integrated computer-based systems, including simulation, three-dimensional visualisation, analytics and collaboration tools, to create simultaneous product and manufacturing process definitions. Design innovation is the ability to apply these technologies, tools, and products to reimagine the entire manufacturing process from end-to-end.

DMDII has 201 members, including major firms from a wide range of sectors, numerous smaller firms and 11 universities. Its $70m in US DoD Army Mantech funding was matched with industry and state funding of $248m. DMDII's mission is digital manufacturing to lower product design costs by fostering deep connections between suppliers. It also aims to lower production costs and reduce capital requirements, through better linkages from end-to-end of the product life cycle. Cutting time to market through faster iterations, developing and implementing innovations in digital design, digital factories and digital supply chains are also goals. Overall, it seeks to develop both new products and improve legacy products.

The Smart Manufacturing Innovation Institute can be characterised as the convergence of information and communications technologies with manufacturing processes, to allow a new level of real-time control of energy, productivity, and costs across factories and companies. Smart manufacturing was identified as a high-priority manufacturing technology area in need of federal investment. Being able to combine advanced sensors, controls,

information technology processes and platforms, and advanced energy and production management systems, smart manufacturing has the potential to increase energy efficiency and manufacturing capability in a wide range of industrial sectors. Of the $140m Smart Manufacturing Innovation Institute budget, $70m over five years is already appropriated federal funding from the Energy Department's Advanced Manufacturing Office. The remainder is in matching funds. The Smart Manufacturing Innovation Institute will focus on integrating information technology in the manufacturing process through devices like smart sensors that reduce energy use. For example, the institute plans to partner with the US DoE's Institute for Advanced Composites Manufacturing Innovation to test advanced sensors in the production of carbon fibre. The Smart Manufacturing Innovation Institute expects to partner with more than 200 companies, universities, national laboratories and non-profits. Microsoft Corp., Alcoa Inc., Corning Inc., ExxonMobil, Google, the National Renewable Energy Laboratory and numerous smaller firms are among the Smart Manufacturing Innovation Institute partners. The institute plans to launch five centres, focusing on technology development and transfer and workforce training, in regions around the country, headed by universities and laboratories in California (UCLA), Texas (Texas A&M), North Carolina (NC State University), New York (Rensselaer Polytechnic Institute), and Washington (Pacific Northwest National Laboratory).

China: Market and Development regarding IDT

The Market for IDT in China is significant and is growing at a rapid rate. For example in 2014, the IoT market in China reached over CNY 600bn ($94bn), growing at a compound annual rate of over 30% since 2011. It has been estimated that applying the IoT in Chinese manufacturing could add $196bn to GDP over the next 15 years (Accenture, 2015).

In 2014, the market for public cloud services reached CNY 7.02bn (around $1.1bn), growing by 47.5% with respect to 2013. The market for big data was approximately CNY 8.4bn ($1.3bn) in 2014. China's big-data market is expected to grow by around 40% a year over 2016-18.

The government is actively intervening in IDT technologies such as robotics and 3D printing. In its national development plan for robotics it aims to achieve a 45% market share for domestic companies in high-end robotics by 2020. The application of robotics, especially industrial robots (IRs), is a direct response to labour shortages and the demand for higher quality output in China. Over 2008-2013, the supply of IRs increased by about 36% per year on average in China. China is the world's largest market for IRs, with 28% supplied domestically.

A national plan for promoting additive manufacturing (2015-2016) was released in 2015. In 2016, a national research project, with a budget of CNY 400m, was started for additive manufacturing and laser manufacturing. Among the seven priorities of the former, five aim at commercialisation and must be led by enterprises. A standards technology committee and an industrial alliance for additive manufacturing were also established in 2016. From 1988-2014, 79 602 industrial 3D printers were installed worldwide. During this period, in the world market for 3D printers costing $5 000 or more, China ranked third, accounting for 9.2% of the total units in use, behind the United States (38.1%) and Japan (9.3%). From 2013-2014 the market for 3D printers in China increased from $315m to $582m and was expected to reach $1.6bn by 2016, according to the China 3D Printing Technology Industry Alliance. By April 2015, China ranked third in the global number of 3D printing patents, behind the United States and Japan.

MADE IN CHINA 2025

This is a national ten-year strategic initiative covering the long-term comprehensive development of China's manufacturing industry for which the Chinese government has established a $2.9bn Modern Manufacturing Investment fund. Core to this strategy is the promotion of IDT.

- The percentage of R&D spending relative to manufacturing sales is targeted to reach 1.68%
- Labour productivity is expected to increase by 7.5% annually to 2020, and thereafter by 6.5% to 2025
- Broadband coverage should rise from 50% in 2015 to 82% in 2025;
- Energy consumption per unit of added value should fall by 34% by 2025 .

Made in China 2025 identifies nine paths to achieving its ambitions. The following are of note with respect to IDT

1. **Enhancing innovation capability**
   The aim is to create a national innovation system in which enterprises lead, government provides services and support for key technology R&D, and research outcomes from academia can be efficiently commercialised.
2. **Promoting digitalisation**
   Aimed at Digitalised manufacturing and covers not only equipment, such as computer numerical control machine tools and robotics, but also intelligent manufacturing processes and related infrastructures.
3. **Making manufacturing greener**
   This consists of applying green technologies to traditional manufacturing sectors while developing low-carbon industries such as new materials and biotechnology, promoting resource recycling, creating green supply chains and logistics, and reinforcing greener standards and environmental inspections.
4. **Targeting priority technologies and products**
   These priorities include ICTs, numerical control tools and robotics, aerospace equipment, ocean engineering equipment and high-tech ships, railway equipment, energy-saving vehicles, power equipment, agricultural machinery, new materials, biological medicine and medical devices.
5. **Developing manufacturing as a service and services for manufacturing**
   This path aims to help manufacturing extend the value chain and develop and sell both products and services. Services for manufacturing range from logistics and human resources to IP services and after-sales services. Services for adopting ICTs and mobile Internet business are emphasised.

INTERNET PLUS

This initiative seeks to better integrate the Internet with industry. Internet Plus promotes digitalisation in 11 sectors,4 and aims by 2025 to see China with an interconnected service-oriented industrial ecosystem. In manufacturing, integrating the Internet means first developing so-called "intelligent factories" by promoting cloud computing, the IoT, industrial robotics and additive manufacturing. Large-scale customised manufacturing is another priority, in Internet Plus is implementation-oriented. Each priority has a designated government department responsible for follow-up. But Internet Plus does not rely heavily on government investments. Emphasis is laid on better public infrastructures, capacity building for innovation, and a more flexible regulatory environment. Openness is also emphasised, with goals established to advance open-source communities, open data, and open infrastructures and facilities.

European Initiatives

Digital Innovation Hubs in Horizon 2020

The European Commission is programming €500m in H2020 (through the work programmes covering the 2016-20 period) towards Digital Innovation Hubs. Concretely, H2020 is funding projects in which competence centres are providing the desired services and facilities to industry.

I4MS

Consists of 11 large Innovation Actions funded by FP7 and H2020. It supports SMEs active in the manufacturing sector to improve their products and processes by letting them experiment with digital technologies, such as HPC cloud-based simulation/analytics services, industrial robotics systems, laser-based manufacturing, smart cyber-physical systems, and Internet of Things. A network of competence centres provides access to competences and technology transfer to SMEs through competitive calls for experiments. Successful candidates receive funding for the experiment, from which both technology suppliers and user SMEs may benefit. So far €110m of European funding has been invested in I4MS since 2013. A further €28m has been invested through a similar network of competence centres supported under SAE, which supports SMEs to improve their products through the inclusion of advanced ICT components and systems.

Data Experimentation Incubators

A series of incubators being set up under H2020 ICT 14 WP. The objective is to foster exchange, linking and re-use of data, as well as to integrate data assets from multiple sectors and across languages and formats. This should lead to the creation of secure environments where researchers and SMEs can test innovative services and product ideas based on open data and business data, and should lead to new innovative companies and services for the data economy.

ECHORD++

An initiative to bring robots from the lab to the market. Activities include: the Robotics Innovation Facilities (RIFs), which allow SMEs to try out new business ideas and make field tests at zero risk. It also helps manufacturing SMEs with small lot sizes and the need for highly flexible solutions to try out innovative robotics technologies.

Pilot Lines in Nanotechnology and Advanced Materials

The PILOTS call activities under the NMBP39 work programmes in Horizon 2020 and FP7 have resulted in 30 projects with a combined funding of €150m. These PILOT projects aim to help transfer new technology developed under Horizon 2020 into industry by providing open access for upscaling and pilot testing to SME users. Additional investments by Member States, public or private organisations have contributed to establishing a variety of pilot upscaling facilities across Europe, mainly in the EU-15 countries.

Mapping of Key Enabling Technology KETs competence centres

A Catalogue of KETs competence centres has been developed as a first step to facilitate cooperation between technology centres and companies, and SMEs in particular.
The Catalogue is a mapping tool that provides an overview of the services available through around 200 KETs-related technology competence centres. The centres are selected according to a set of qualitative and quantitative criteria. They provide services to enterprises, such as help with prototyping, testing, upscaling, first production and product validation.

The aim is to foster synergies between digital and other advanced technologies (e.g. sustainable manufacturing, advanced materials, industrial biotech, nanotech).

The Enterprise Europe Network

This network brings together 3,000 experts from more than 600 member organisations – all renowned for their excellence in business support. Member organizations include: technology poles; innovation support organisations; universities and research institutes; regional development organisations; and chambers of commerce and industry.

European Institute of Innovation and Technology (EIT)

The EIT is a EU initiative that brings together leading universities, research labs and companies to form dynamic pan-European partnerships. Together, these unique partnerships, called Knowledge and Innovation Communities (KICs), carry out a whole range of activities that cover the entire innovation chain, from research to the market, training and education programmes, innovation projects as well as business incubators and accelerators. The EIT is an integral part of Horizon 2020, the EU'sFramework Programme for Research and Innovation.

European National, Regional and Industry Initiatives

GERMANY

Mittelstand-Digital Competence Centres

An initiative of the German Ministry of Economy and Technology under "Plattform Industrie 4.0". Six centres are already operational, with five more launched in 2016, and a further five planned for 2017, providing information, training and support in the implementation of digital technologies in mid-caps and SMEs covering a wide range of manufacturing technologies. Funding is €56m over three years.

German Federation of Industrial Research Associations (AiF)

AiF is Germany's leading national organization promoting applied R&D in SMEs. It is an industry-driven organization managing public programmes of the German federal government. The 'AiF innovation network' consists of 100 industrial research associations representing 50,000 businesses, mostly SMEs. Each research association of the AiF represents a certain business sector from specific branches of the economy or fields of technology. By joining a research association and taking an active part in its committees, companies directly influence the association's research agenda and priorities. In 2014, the AiF disbursed around €500m of public funding, in particular on behalf of the Federal Ministry for Economic Affairs and Energy. Since its foundation in 1954, the AiF has disbursed more than €10bn in funding for more than 200,000 research projects for SMEs.

Cooperation Projects and Networks, Central Innovation Program for SMEs (ZIM Cooperation Projects and Networks)

ZIM is a nation-wide funding programme for SMEs and research organisations closely aligned with businesses. It is the most popular programme coordinated by AiF and it is open to all technologies and sectors (i.e. all German SMEs are eligible for ZIM funding). It is geared to SMEs with business operations in Germany, which want to develop new or significantly improve existing products, processes or technical services. ZIM comprises different support measures: Single Projects (funding of R&D projects undertaken by a single SME);

Cooperation Projects (funding of cooperative R&D projects between SMEs or SMEs and RTOs); and Cooperation Networks (funding of management of innovative company networks and R&D projects generated by them – with a minimum requirement of six German SME partners). The maximum project costs that are eligible for funding are €380,000 per company, and €190,000 per research institute.

IraSME

Is a network of ministries and funding agencies, which are owners, or managers of national and regional funding programmes for cooperative research projects between SMEs and in participation of research and technology organisations (RTOs). IraSME supports SMEs in their transnational innovation activities, helps them to acquire technological know-how, extend their networks and bridge the gap between research and innovation. Twice a year IraSME issues calls for proposals for transnational cooperative research projects between SMEs and RTOs, with the objective to develop innovative products, processes or technical services. Funding is made available through national and regional programmes. IraSME enables consortia of SMEs and RTOs from at least two participating countries to work together in transnational projects. Generally, IraSME Projects have to be research and development activities with significant technical risks to realise new or notably improve existing products, processes or technical services. The clearly describable project outcome has to show real market opportunities. Participation in an IraSME project allows SMEs and RTOs to develop a new state of the art, build new partnerships, benefit from know-how and resources that might not be available in their country or region, and get an insight into the market in other countries.

IT's OWL (Intelligent Technical Systems OstWestfalenLippe)

IT's OWL is a consortium-led initiative focused on key digitalisation topics at the heart of Industry 4.0. Research projects focus on product innovation, as well as on development, deployment, maintenance, and life cycle management of new products and systems.
IT's OWL has seven industry support initiatives to support SME capabilities, including strategic foresight, education/training, internationalisation, start-ups, market orientation, acceptance and prevention of piracy. Key research area include self-optimisation, human-machine interaction, intelligent networking and energy efficiency. It's OWL technology and knowledge transfer concept aims to remove transfer barriers in SMEs. The foundation of the transfer concept is made up of a four-step model for technology transfer. In the first step, companies are introduced to the it's OWL technology platform and provided with basic information.
As part of the second step, understanding of the available content and solutions is broadened even further. Here, the transfer of information is focused on a technological area. The third step includes identification of concrete offers from the technology platform for solving issues from operational practice within companies. Concrete execution of the focused technology transfer projects forms the fourth step of the it's OWL transfer concept. Targeted use and integration of the new technologies in companies is encouraged by project-related collaboration between transfer recipients and transfer providers.

Cluster of Excellence Integrative Production Technology for High-Wage Countries

The Aachen Cluster of Excellence Integrative Production Technology for High-Wage Countries is a major manufacturing research centre initiative funded by the German Research Foundation. The cluster is part of a €180m investment awarded to the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen University to fund education, research and innovation. The goal of this initiative is develop new sustainable production strategies and theories.
The cluster brings together 25 research departments from the RWTH Aachen University and other research institutions and seeks active collaborations with industrial partners. Focusing on SMEs support, the project cyberKMU develops an online platform, which supports SMEs to identify Cyber Physical Systems in order to improve production processes and make them more efficient. The online platform is for producer companies to look for solutions and to offer their solutions, to make it easy to find suitable technology suppliers. To ensure the quality of the evaluation method, the recommended solutions are implemented and validated using demonstrators in the production companies.

OTHER COUNTRIES

Alliance d' Industrie du Futur (France):

Organises and coordinates digital transformation activities of its members (research institutions, public authorities and associations) on national level. Around 1200 SMEs are involved. Four showcases have been developed with Air Liquide, Bosch, SNCF and DAHER on advanced technologies.

Intelligent Factories Technology Cluster (Italy)

Groups large enterprises and SMEs, universities and research centres, entrepreneurial associations, technological districts, and other stakeholders operating in the sector of Manufacturing and Smart Factory. Activities include: research, technology transfer, sharing of research infrastructures and mobility, support to a smart and sustainable entrepreneurship, and support to the growth of human capital. Total funding of €43m is foreseen.

Vinnova (Sweden)

Vinnova is a Swedish government agency under the Ministry of Industry that administers state funding for research and development. Their core function is to allocate funds to innovation projects through call for proposals to both the private and public sector. In 2013 they invested SEK 2.7bn SEK ($309m) in roughly 2,400 different research and innovation projects. These funds were allocated mostly among universities, private companies and research institutes. Vinnova is also Sweden's representative agency in Europe's Eurostar programme. The Eurostar programme is a European funding support programme for R&D activities in SMEs. The programme is backed by €861m of national funding from its countries. It is further supported by €287m of EU funds, for a total of €1.14bn. Under four of its eleven strategic priorities relevant to IDT : Smart Electronics, Internet of Things, Process and IT Automation and Production 2030. Each of these areas benefits from an annual investment of approx. €40m through public and private funding.

Future Industrial Services programme (Finland)

received €36m of funding up to 2015; the companies and higher education institutions in the Finnish Metals and Engineering Competence Cluster fimecc are investigating the key success enablers for future industrial services. Meanwhile, the recently launched Industrial Internet Program will study the potential and impacts of smart services on a broad scale. €100m of funding has been made available to this programme. Finnish examples of the growing importance of services within traditional industrial enterprises include the lift and escalator manufacturers KONE, Ponsse, who have developed a high degree of expertise in digital diagnostics and remote maintenance for their forest machines, and enevo, who install sensors in waste containers and use them to provide a range of smart services.

Tyndall National Institute (Ireland)

s partnering with a number of regional and national clusters to: launch needs-driven regional and national initiatives; coordinate with public authorities and local government; build European partnerships; and provide B2B match-making and brokerage. For example, Tyndall is part of Ascent, a European project providing SMEs with access to state-of-the-art facilities in nanoelectronics.43 It is also a partner in PIXAPP, a H2020 project offering the world's first open access photonics packaging pilot manufacturing line. Other activities apply advanced ICT in sectors as diverse as medicine and agriculture, including support for IoT SMEs in accessing funding. It is helping to create innovation networks with multidisciplinary translational competences.

Fieldlabs (Netherlands)

An initiative under the national Smart Industry strategy, translated to the regional level. Supports a wide spread of technologies (mainly manufacturing) and activities (e.g. business coaching), access to regional funds, with five more hubs planned. Total funding of €100m over five years.

FURTHER TOPICS

Private initiatives

Private initiatives are also in evidence In Barcelona, for example, the I4AM44 initiative aims to create an ecosystem for 3D printing (3DP) and digital manufacturing with a mixture of private and public funding. Led by leading players such as HP, Renishaw, Leitat Technological Center and others, I4AM aims to accelerate the development and adoption of additive manufacturing and 3DP technologies as an alternative way to design, develop and manufacture new competitive products and services.

Relevant national, regional and industry initiatives are being documented in the Catalogue of Digital Innovation Hubs that has recently been launched

Key Enabling Technologies

Key Enabling Technologies (KETs) are a group of six technologies – micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies – that have applications in multiple industries and help tackle societal challenges. Three of the six KETs have a strong digital dimension (micro- and nanoelectronics, photonics, and advanced manufacturing).

Actions undertaken within the KETs initiative include activities on skills and on the facilitation of cross-border industrial projects, fostering successful translation of KETs-related smart specialisation priorities as well as assistance to small businesses in accessing KETs technology centres and expertise. As part of the latter, a catalogue of KETs competence centres52 has been developed (see above) and a pilot network of technology centres providing services to SMEs in the area of advanced manufacturing for clean production is being set up. The European Commission will also support (under COSME and Horizon2020) a pan-European Advanced Manufacturing Support Centre to help SMEs assess the possibility of adopting advanced manufacturing solutions and transforming their business towards a factory of the future. The centre will also help to launch new innovation advisory services for manufacturing SMEs at national and/or regional level on the basis of a coherent EU methodology.

Singapore

Germany-Singapore SME Funding Programme

This programme provides funding for joint R&D projects between German and Singaporean SMEs. Projects should focus on the development of new and innovative products, technology-based services, or processes with strong market potential. The funding schemes are the ZIM programme in Germany and the CDG in Singapore.

Partnerships for Capability Transformation (PACT) initiative

This programme works with large organisations (LO, $100m in sales revenue and above) to identify and implement collaborative projects between the LO and local SMEs in areas of: Knowledge transfer; Capability upgrading; Development and test-bedding of innovative solutions. Under the enhanced Gov-PACT, the government serves as the large organisation with which the SMEs/start-ups work with to develop and test-bed innovation solutions that do not yet exist in the market. Participating companies go through different stages of product development from the ideation stage to pilot runs with the support of the lead demand agency. Approved projects are eligible for up to 70% funding support for qualifying development costs.

National Trade Platform

The NTP can help businesses improve productivity through digital exchange and re-use of data with their business partners and the government. Businesses can streamline their work processes, reduce inefficiencies of manual trade document exchange, and tap on the potential of data analytics to draw insights from their trade data. Potentially bring about up to $600m worth of man-hour savings annually for businesses. Businesses will enjoy these features of the NTP: (a) tools to support digitisation and business needs; (b) capability to support global electronic information exchange; and (c) open innovation platform to facilitate development of value-added services and applications.

Startup SG Tech grant

This grant supports Proof-of-Concept (POC) and Proof-of-Value (POV) for c ommercialisation of innovative technologies. For POC projects, up to 100% of qualifying costs are funded, subject to a maximum of S$250,000 (~ £140,000). For POV projects up to 85% of qualifying costs are funded, subject to a maximum of S$500,000 (~ £280,000). Criteria for eligibility of start-up companies include: registered for less than 5 years at time of award; at least 30% local shareholding; company's group annual sales turnover is not more than $100m or group employment size is not more than 200 workers and; Core activities to be carried out in Singapore. The project should fall under one of the following areas: advanced manufacturing; robotics; biomedical sciences and healthcare; clean technology; information & communications technologies; precision engineering; transport engineering or engineering services.

Innovation & Capability Voucher (ICV)

The aim of this programme is to upgrade and strengthen the core business operations of SMEs through consultancy in the areas of innovation, productivity, human resources and financial management. Apart from consultancy, ICV also supports SMEs in the adoption and implementation of pre-scoped integrated solutions to improve business efficiency and productivity. The duration for each project should not exceed six months. Eligibility criteria include: registered and operating in Singapore; have a minimum of 30% local shareholding; have group annual turnover of not more than $100m or group employment size of not more than 200 employees.

Technology Adoption Programme (TAP)

This programme supports collaboration amongst public sector research institutes, private sector technology providers, Institutes of Higher Learning, Trade Associations and Chambers (TACs) and private sector system integrators, to identify and translate new technologies into Ready-to-Go (RTG) solutions. These RTG solutions aim to address productivity challenges and give SMEs a competitive advantage. The TAP supports sectors identified for the Industry Transformation Maps (ITMs) to formulate and execute technology adoption roadmaps. Approved projects are eligible for up to 70% funding support for qualifying deployment and/or adoption costs under the Capability Development Grant (CDG).

Local Enterprise and Association Development (LEAD) programme

This is an industry development initiative aimed to improve the overall capabilities of local enterprises in their industries and capture opportunities overseas. LEAD promotes partnerships with trade associations and chambers (TACs) which are willing to take the lead in industry development. The programme supports industry development projects in areas such as: technologies adoption, which includes info-communication technology, development of technical standards and establishment of industry-wide infrastructure; expertise and managerial competence, including industry-wide certification; business collaboration; intelligence and research; advisory and consultancy (promotion of best practices and competence).

SIMTech's Knowledge Transfer Office (KTO)

KTO provides technology and case study-based training for manufacturing specialists, engineers, managers, among other industry professionals and executives. The training courses are conducted in close collaboration with the SkillsFuture Singapore (SSG) Agency. The courses offer hands-on practical training in cutting-edge precision engineering technology, allowing participants to upgrade their skills and equipping them to take on advanced roles in the industry.

SIMTech Membership Programme

This programme is a platform for local manufacturing companies to collaborate in R&D initiatives that help reduce their market risks while creating new opportunities. The services provided by this membership programme range from technology intelligence and business management tools, to technology transfer and technical advisory. Members can participate in a wide range of seminars, workshops, and professional networking sessions organised by SIMTech. As a part of the SIMTech Membership Programme, there are a number of Special Interest Groups (SIGs) that cater to specific industrial sectors such as marine, oil & gas, aerospace, and med-tech.

Manufacturing Productivity Technology Centre (MPTC)

MPTC promotes the use of technology to enhance manufacturing productivity by improving efficiency and effectiveness. It supports engaging of local companies to harness A*STAR's technologies, tools, and capabilities in automation, processes, and systems aiming to gain "step-change" improvements in manufacturing productivity. MPTC services include technologies and tools for productivity improvement, such as: Inventory network optimisation; Virtual factory; Virtual machining technology; Integrated production planning & shop floor tracking solution.

Sustainable Manufacturing Centre (SMC)

This innovation centre aims to showcase and promote sustainability in manufacturing and bring together relevant government agencies, industry, and research communities to develop and implement sustainable manufacturing technologies. E2MAPS - Energy Efficiency Monitoring, Analysis, Planning & Solutions is a programme managed by this innovation centre. E2MAPS enables companies to improve their energy efficiency by providing rigorous training to their staff via actual implementation of monitoring, analysis and test-bedding of energy efficiency solutions.

Technology for Enterprise Capability Upgrading (T-UP)

The purpose of this scheme is to identify and implement R&D projects for a period of up to 2 years, with the help of research scientists and engineers from the Agency for Science, Technology and Research's (A*STAR). Project areas include: Data storage; High performance computing; Info communications; Materials research & engineering; Microelectronics; Manufacturing automation & technology; Chemical and engineering sciences; Bioimaging; Bioprocessing; Genomics & Proteomics; Molecular & Cell Biology; Drugs/Biologics Discovery and Development; Bioengineering & Nanotechnology; Computational Biology; Immunology; Medical Technology. T-UP subsidises cover up to 70% of the secondment costs.

Tech Depot

This is a centralised platform under SPRING's SME Portal aimed at improving local enterprises' access to technology and digital solutions. More than 25 technology solutions across a wide range of industries and business functions are currently featured at Tech Depot. These include solutions developed and/or pre-qualified by A*STAR, Info-communications Media Development Authority of Singapore (IMDA) and SPRING Singapore for funding support.

A*STAR collaborative commerce marketplace (ACCM)

ACCM is a free online portal for new businesses and partnership. The portal provides a listing of companies in which the companies' process and skill competencies are profiled and validated. The ACCM helps to facilitate the matching of technological requirements, create opportunities for research collaboration, and to establish collaboration and partnership among local companies and large multinational companies.

United States

Hollings Manufacturing Extension Partnership (MEP)

Part of the Commerce Department's National Institute of Standards and Technology (NIST), MEP is a network of 60 centres and 1,200 manufacturing experts across the US. MEP provides technical expertise to small manufacturers, strengthening the capabilities of individual suppliers and entire supply chains. The budget of MEP was $130m for FY16, with Cost Share Requirements for Centres MEP was created in 1988 with the aim of providing small businesses access to management and technological expertise. Around 30,000 manufacturers were served by MEP in FY15. MEP services focusing on supply chain development and technology acceleration for small manufacturers include: Supplier Improvement and Supply Chain Optimization, Supplier Scouting and Business-to-Business Networks, and Supply Chain Technology Acceleration.

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New Mexico Small Business Assistance (NMSBA) programme

NMSBA helps small businesses in the area by providing access to experts at the local Los Alamos National Laboratory and Sandia National Laboratories. Technical assistance is funded by the state and provided to businesses free of-charge. To help small businesses compete for funding, the NMSBA created a national lab voucher program that since 2000 has helped over 1,000 small businesses gain access to the Los Alamos and Sandia labs. The state government provides the funding for the vouchers through a partnership with the NMSBA. Small businesses can participate in the NMSBA Program through three different types of projects: 1) Individual Projects: projects address challenges specific to the business that can be solved with national laboratory expertise and resources; 2) Leveraged Projects: this category of projects allow multiple small businesses that share technical challenges to request assistance collectively for a larger project.; 3) Contract Projects: through this type of projects NMSBA Program contracts entities that have the capability to provide small business assistance services not available in the private sector at a reasonable cost.

Small Business Innovation Research (SBIR) program

SBIR encourages small businesses to engage in Federal Research/Research and Development (R/R&D) that has the potential for commercialization. The programme is structured in three phases. Phase I: The objective of this phase is to establish the technical merit, feasibility, and commercial potential of the proposed R/R&D efforts and to determine the quality of performance of the small business awardee organization. SBIR Phase I awards normally do not exceed $150,000 total costs for 6 months. Phase II: funding is based on the results achieved in Phase I and the scientific and technical merit and commercial potential of the project proposed in Phase II. SBIR Phase II awards normally do not exceed $1,000,000 total costs for 2 years. Phase III: The objective of this phase is for the small business to pursue commercialization objectives resulting from the Phase I/II R/R&D activities. The SBIR program does not fund Phase III. Some Federal agencies may involve follow-on non-SBIR funded R&D or production contracts for products, processes or services intended for use by the U.S. Government.

Small Business Technology Transfer (STTR)

STTR funds opportunities in the federal innovation research and development (R&D) arena. Central to the program is expansion of the public/private sector partnership to include the joint venture opportunities for small businesses and non-profit research institutions. STTR follows the same three phases than the SBIR programme and involves equal amounts of funding. The unique feature of the STTR program is the requirement for the small business to formally collaborate with a research institution in Phase I and Phase II. STTR's most important role is to bridge the gap between performance of basic science and commercialization of resulting innovations.

National Robotics Initiative (NRI)

This initiative aims to support fundamental research that will accelerate the development and use of robots in the United States that work beside or cooperatively with people. It supports innovative approaches to establish and infuse robotics into educational curricula, advance the robotics workforce through education pathways, and explore the social, behavioural, and economic implications of ubiquitous collaborative robots.

Japan

Industrial Value Chain initiative (IVI)

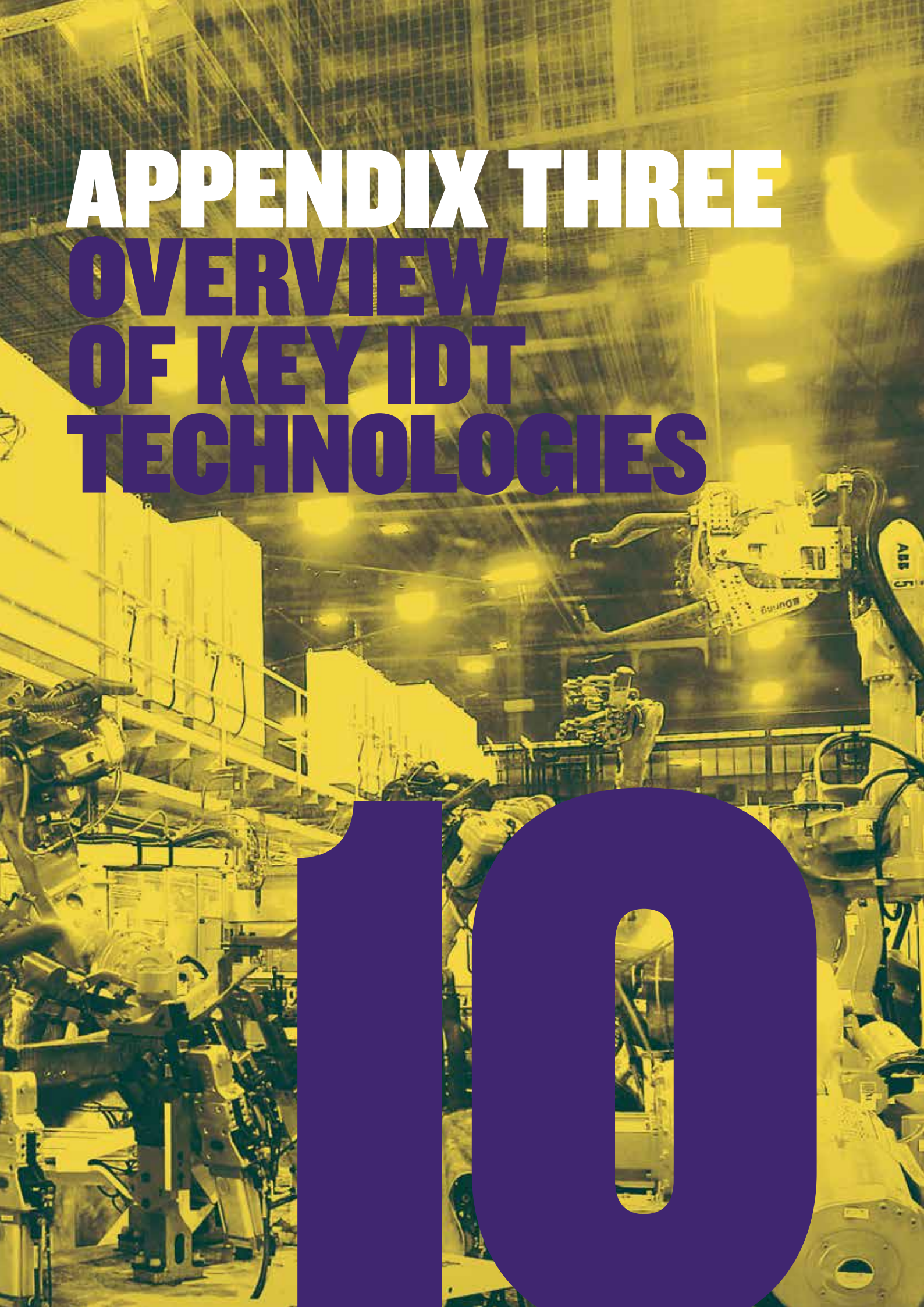
IVI is a collaborative forum that promotes the adoption of Internet of Things-based solutions to address common technical problems found in manufacturing operations. Working groups involving large and small firms are formed to develop solutions across a wide range of 'smart manufacturing scenarios' where improvements can be made by developing and deploying IoT solutions. Based on Japanese concepts of continuous improvement, these scenarios are developed bottom-up to tackle problems and 'create value from data' in manufacturing operation areas including: production process engineering; production planning and control; quality system management; and maintenance planning. One of the most recent efforts to increase adoption of IoT solutions by cash-constrained SMEs is the development of "100,000 yen (~£700) IoT kits". These kits are developed by the working groups with the aim of achieving attractive prices by integrating low-cost components, such as the Raspberry Pi single-board computer. To disseminate the benefits of the initiative among SMEs, IVI works with municipalities and supporting organisations to hold seminars across Japanese regions.

Cross-Ministerial Strategic Innovation Promotion Program (SIP)

SIP is a national project for science, technology and innovation, spearheaded by the Council for Science, Technology and Innovation. The Cabinet Office set aside a budget of ¥50bn (~ £350m), shifting funds to various ministries on the path to creating this program. The programme emphasises the use of digital manufacturing technologies to minimise time and costs for R&D and production, as well as opportunities to utilise digitalisation (internet-of things and smart factories) to respond to customer needs quicker. Such efforts are expected to increase the ability of firms to understand customer requirements and therefore manufacture products that provide superior levels of customer satisfaction. Examples of research projects funded by the SIP Programme, specifically within the theme Innovative Design/Manufacturing Technologies, include production technologies for non-conventional geometries and the application of digital tools to the development of new prototyping systems that could accelerate the scaling-up of products from R&D and design to production.

Programme to promote bridge research and development to second-tier companies and SMEs

This programme aims to promote commercialization of research centres technologies among second-tier companies and SMEs. New Energy and Industrial Technology Development Organization (NEDO) certified 144 publicly funded laboratories and other institutions nationwide as organs with "bridge" functions that help with technology commercialization and provide subsidies (assistance rate of up to two-thirds, maximum assistance of ¥100m, ~ £700,000) to second-tier companies and SMEs implementing joint research.



APPENDIX THREE
OVERVIEW OF KEY IDT TECHNOLOGIES

10

Appendix 3

Overview of Key IDT Technologies

In this appendix, the impact of the following key IDT technologies is discussed in more detail

- Additive Manufacturing,
- Artificial Intelligence/Machine Learning & Data Analytics,
- Robotics and Automation,
- The Industrial Internet of Things (IIOT) and Connectivity (5G, LPWAN etc.)
- Virtual Reality & Augmented Reality,

to

- Understand the UK's relative position within these industries
- And key issues preventing the UK becoming a world leader in these technologies

As part of the MSR a benefits analysis was undertaken for 3 of the key technologies (Additive manufacturing, Artificial Intelligence, Robotics and Automation). To try and determine the approximate geographic distribution of the industry a heat map was developed based on applicants for UK innovation grants as a proxy.

HEAT MAP	NUMBER OF UK INNOVATION GRANT FUNDING APPLICANTS
AI	260
AR/VR	127
ADDITIVE MANUFACTURING	833
ROBOTICS AND AUTONOMOUS SYSTEMS	780
DATA SCIENCE AND ANALYTICS	523

Additive Manufacturing – a compelling case for UK Industrialisation

INTRODUCTION TO ADDITIVE MANUFACTURE

Additive Manufacturing (the successive adding layers of material using generic "3D printing" machines) presents an opportunity to radically transform certain manufacturing lifecycles, changing the very limits of what can be physically and economically produced. It disrupts existing concepts of business models and supply chains, bridging the worlds of digital and physical, and in principle allows even the most complex designs to be digitally transmitted for production at the point of demand. Additive Manufacturing (AM) offers the potential for rapid prototyping, radical design innovation, lower tooling costs, reduced time to market and lower production costs - particularly for custom / low volume / high complexity components.

Although AM can currently only be applied to certain specific manufacturing use cases, it is nevertheless considered to be a key enabler of what has been termed the 4th Industrial Revolution and it lies at the heart of the High Value Manufacturing (HVM) industry, which in the UK contributes more than £100bn GVA and employs an estimated 1 million skilled people. Whilst the directly attributable value of AM products and services is currently a more modest £300m (£6bn worldwide), employing ~35k people in the UK, it is experiencing a steady CAGR of around 30% and this growth is expected to accelerate as issues of standards, raw material consistency, IP protection and parts verification are addressed.

THE UK POSITION

The UK is amongst the world's leaders in research, innovation and adoption of AM technology for high performance applications in medical, aerospace and other industry sectors. It is a global force in advanced materials, technology, life sciences and high value manufacturing. It is equipped with a strong capability in universities, Catapults and R&D organisations.

The UK has world class AM machine manufacturing capability; well established national centres for AM (MTC); university excellence in AM research; and a relatively small but solid foundation of companies applying AM within product development activities for prototyping and tooling.

The potential of AM is recognised by a number of UK companies and academic institutes with an expected industry investment in AM of £600m over the next 5 years, and more than £30m spent on AM related research.

Despite this exciting potential and progress to date, many UK companies, especially within the SME community, lack the awareness, resources or confidence to apply AM as a core and integral part of their manufacturing toolkit. A recent global survey conducted by Ernst & Young showed that only 17% of UK companies have any experience with AM, compared to 37% in Germany and 24% in China (over 50% of Chinese and South Korean companies expect to use AM technologies for production parts within 5 years).

For those UK companies that do make use of AM technologies, the revenue it generates only accounts for approximately 1% of their overall company revenue. This compares with 8.8% in US and a 2% average across all countries. It is clear that in the application of AM, the UK is beginning to lag behind other nations. As a consequence, production is tending to move away from UK, primarily because of capability, but also lower cost. This is highly significant not only because direct part production accounts for around 50% of direct AM related revenues, but also because an understanding of AM production processes is critically important for creating value at other stages of the AM production lifecycle.

Globally, other nations, particularly USA, China, Germany and Italy are seeing AM adoption and growth rates much higher than in the UK, largely because of strategic government investment programmes that back formally announced AM based industrial strategies. Whether directly or indirectly, this puts the UK in a declining position in comparison with the global market. It is estimated that the UK has a window of less than 2 years to reverse this trend of decline if it is to avoid a serious threat to its status as a top 10 global industrial manufacturing player.

The number of UK organisations involved in AM is growing and was estimated to be around 250 in 2014, however this activity appears to have a strong bias towards the research end of the lifecycle and is somewhat fragmented.

"The manufacturing community in the UK is highly fragmented with organisations only networking through projects rather than through a structured network, community of interest or association."

UK Research Mapping Report 2012

For the most part, UK manufacturing companies (particularly within the SME community), view AM as a somewhat immature technology that may offer benefits in terms of prototyping, but for which the barriers to entry for full production applications are too high.

"What is required is a more co-ordinated approach to pull through the UK's world-leading research and innovation to improve process efficiency and material choice, to consolidate critical know-how in design, production and testing, and to de-risk private investment in the supply chain (materials, machinery, software, skills). Only with active and visible government support and funding in these key areas can the requisite manufacturing capability be scaled up and anchored in the UK."

TRANSFORMATION IMPACT OF ADDITIVE MANUFACTURE

Analysis undertaken as part of the MSR identified that the application of Additive Technology within UK industry offered a Value at Stake of £72.1bn to the UK economy with additional benefits identified to both the individual and society (see http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/).

Much of the value that will be realised from AM is not in the efficiency of the production process itself, but in the wider benefits that are introduced through design innovation and the downstream application of new capabilities.

As an example, Airbus has used AM thinking to reinvent its A320 partitions, using designs that mimic bone and cell structures. The result is a 45% reduction in component weight which, if introduced throughout the A320 aircraft fleet, would save up to 465,000 tons of CO2 emissions annually.

AM does not just impact the production of new parts, but can also be used for repair and refurbishment. Siemens uses AM to produce replacement gas turbine burner tips. The worn-out burner tips are removed and AM produced replacement parts are then welded onto the burner. This reduces the lead time to a repair by as much as 90% – from 44 weeks down to 4 weeks. The AM approach also makes it possible to change the geometry of the burner tip at each repair, optimizing the performance of the turbine. This can mean up to 60% less fuel consumption and 50% lower gas emissions.

VALUE AT STAKE FROM ADDITIVE MANUFACTURING IS ESTIMATED TO BE £72.1BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£27.6	• 10% of cost savings, worth £4.4bn, are expected to be passed on to consumers as the manufacturing process becomes more efficient through the use of Additive Manufacturing • 50% increase in customer satisfaction due to personalisation of manufactured products • Increased comfort for prosthetic recipients related to greater access to personalisation of products enabled by Additive Manufacturing	• 12.6 mn tCO_2e reduction in transport emissions in 2027[1] due to reduced transport and structural weight of products • 7% reduction in non-fatal injuries during manufacturing
Cost reduction through digitally enabled R&D	£4.4		
Cost reduction through digitally enabled resource efficiency	£16.7		
Cost reduction through digitally enabled supply chain management	£23.4		
Total value to industry	£27.6 £72.1		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Actions required to specifically accelerate innovation and adoption of Additive Manufacture

UK industry has an excellent track record in R&D and design innovation and should aspire to be a world leader in "Design for AM" and a catalyst for the downstream transformation of product manufacture for selected market segments.

Research would indicate that the top three reasons why AM is not being more widely adopted by industry are: Lack of knowledge; lack of skills; and lack of clear business case for capital investment. There is also a growing concern over the management and protection of design IP. The critical success factors for achieving a truly collaborative AM eco-system for UK industry must seek to address these barriers. The areas for focus should therefore be:

- Stimulate local UK demand for AM by supporting industry and trade associations in raising awareness of the capabilities (and limitations) of AM.
- Address the skills gap by supporting the creation of specialist AM education programmes, including schools, apprenticeships, on-line training courses, further education and in-work reskilling programmes.
- Secure the production of physical AM assets in the UK by providing (e.g.) capital grants for investment in AM machines, especially for those to be made available for use by local communities of SME users. Such investment could be directed at establishing AM co-operatives that have resources able to be accessed on-demand, "as a service" (40% of companies see capital investment in AM machines as the main barrier to adoption).
- Establish a platform for best practice sharing with assured IP protection.

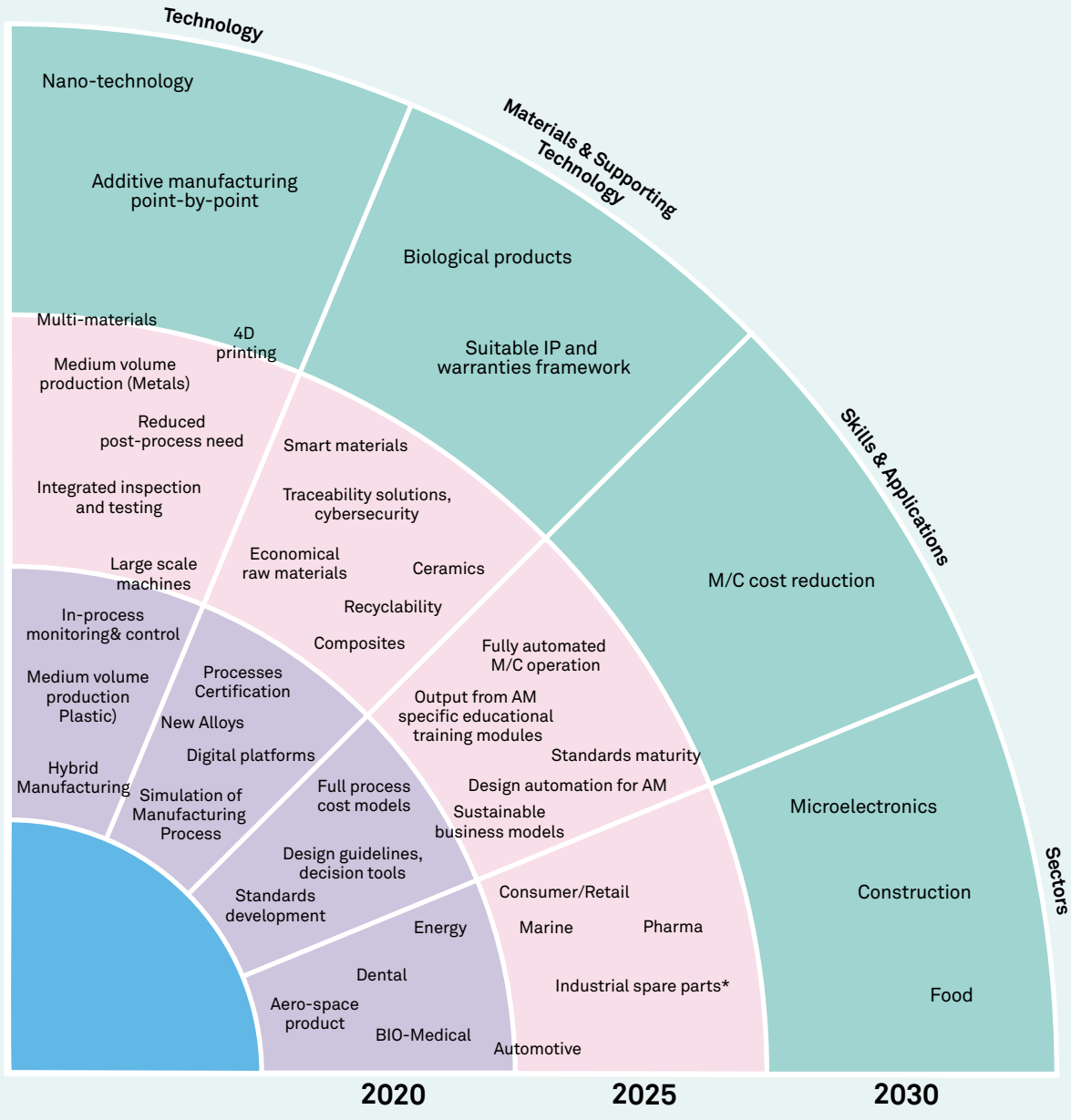
An element of this "Design for AM" leadership would involve clear actions relating to standards and legislation to help address some of the concerns especially with regards to the use of AM produced parts. These include:

- Raw material standards to help resolve the risk of vendor lock-in when AM machine manufacturers restrict approved material sources.
- Finished product testing standards to address concerns over component integrity.
- Business collaboration standards to facilitate co-operation within multi-enterprise eco-systems. These should enable best practice sharing and data exchange without violating IP.

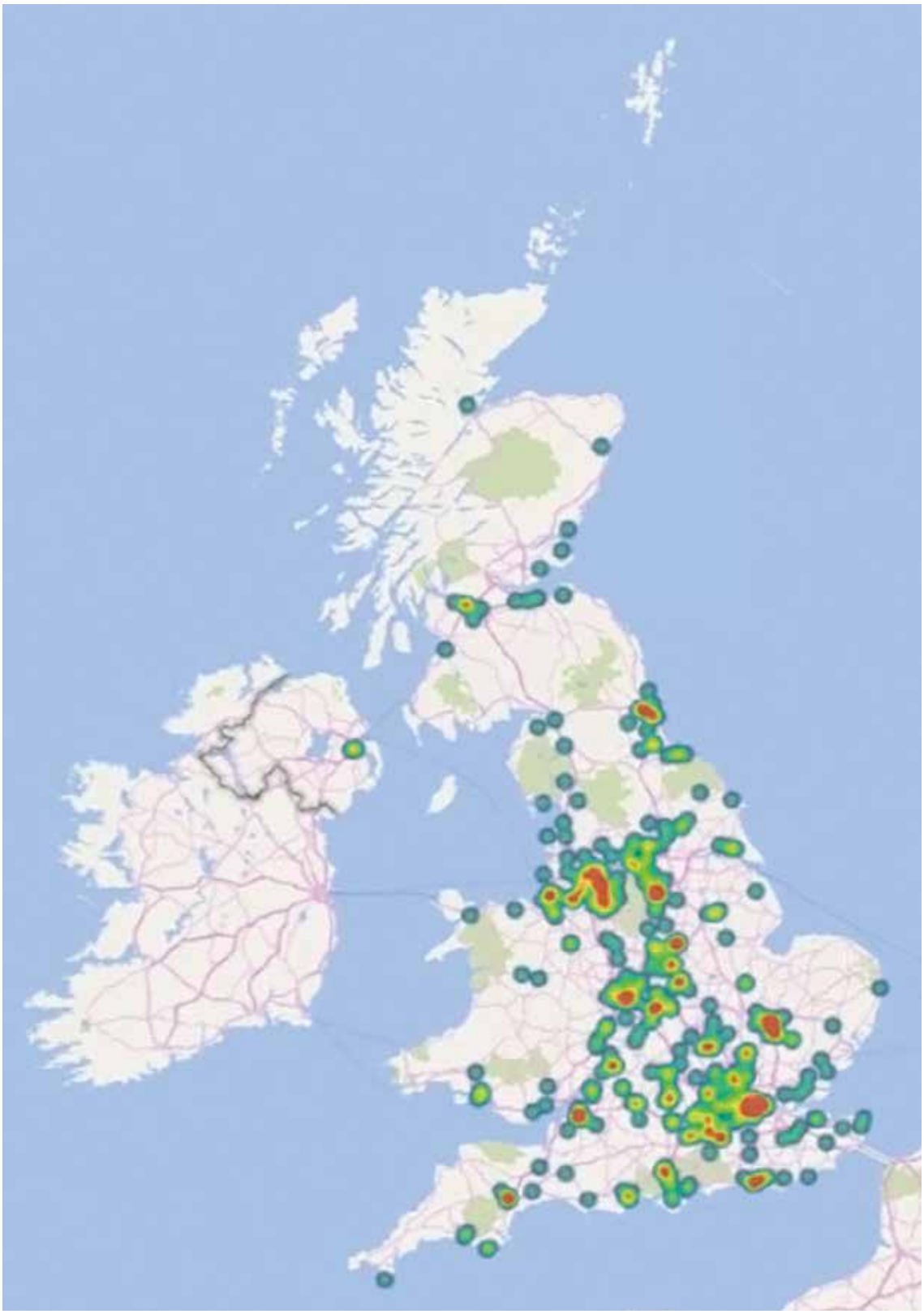
A long-term future perspective

Additive Manufacturing is a rapidly evolving technology. Maintaining a position of market leadership will require continuous innovation and evolution of approaches. Research and Development will need to rapidly move up the technology readiness levels. Technology refinements will inevitably see more automation in areas such as component design (and simulation), machine operation, testing and even post production processes. New materials and methods will open up opportunities in an increasing set of use cases and sectors. The UK must pursue a sustained and sustainable strategy with regard to Additive Manufacturing and its position within the HVM industry.

ADDITIVE MANUFACTURING
AN ANTICIPATED TECHNOLOGY ROADMAP (SUBJECT TO REFINEMENT)



Additive manufacturing heat map



Artificial Intelligence in Industrial Digitalisation

INTRODUCTION TO ARTIFICIAL INTELLIGENCE

We are in the early days of a promising new technology which is as radically different from the programmable systems that have been produced by the IT industry for fifty years as those systems were from the tabulators which preceded them. The technology is commonly referred to as artificial or augmented intelligence, cognitive computing or machine learning and will touch every facet of work and life with the power to radically transform them for the better.

Although the underpinnings of artificial intelligence have been around for seventy years, its ability to live up to expectations has only become possible with the advent of high performance computing over the cloud and widespread connectivity. The vast amounts of data necessary to deliver value from AI are now becoming available in many forms, not least through the availability of cost-effective data capture devices and sensors.

Today we see data being produced at an estimated rate of 2.5bn gigabytes, with 80% of this data being unstructured and more or less invisible to traditional computing systems. AI systems are designed to deal with this massive amount of data and to understand unstructured data, but they are not intended to map the human mind. A significant part of the economic benefit of AI will come from the combination of AI systems and people, allowing the current workforce to focus on the parts of their job that add the most value, complimented by new tools which help them in their decision making. Adding AI capability also allows better use of existing capital investments, improving efficiency as well as quality and reducing costs.

AI technologies are a subject of intense public debate with concerns around their impact on privacy and employment, accompanied by hype concerning the capabilities. In part these perceptions are a result of the maturity of the market and a shortage of real proof points in its adoption.

AI is expected to change the nature of work by augmenting human skills, but as with each successive technological revolution there are fears concerning reduced employment. However, history and experience with AI are so far supporting the view that more and higher value jobs will be created than will be displaced. Previous technology shifts have resulted in the re-shaping of the workforce over time towards higher value professions. Studies suggest that the impact is, at worst, equivocal and, at best, positive. In their 'From Brawns to Brains' report, Deloitte suggests that technology has potentially contributed to the loss of 800,000 jobs in the last 15 years, but helped to create nearly 3.5 million new highly skilled roles paying, on average, £10,000 a year more.[165] A BT survey of IT Directors shows one third expecting AI automation to result in more jobs versus one third expecting fewer.[166]

PwC's UK Economic Outlook in March 2017 is often quoted as concluding that up to 30% of UK jobs could be at risk of automation in general by the early 2030s but it also acknowledges that new AI technologies will increase productivity and generate new jobs elsewhere.[167]

[165] https://www2.deloitte.com/uk/en/pages/growth/articles/from-brawn-to brains--the-impact-of-technology-on-jobs-in-the-u.html#

[166] http://home.bt.com/tech-gadgets/tech-news/impact-of-artificial-intelligence-on-uk-jobs-market-divides-opinion-says-bt-survey-11364187371166

[167] http://www.pwc.co.uk/services/economics-policy/insights/uk-economic-outlook.html

ARTIFICIAL INTELLIGENCE IN UK INDUSTRIAL SECTORS

The UK does have a comparative advantage in developing AI technologies with a thriving ecosystem of researchers, developers and investors. UK AI companies Deep Mind, VocalIQ and Swiftkey have all been acquired by global technology companies on the basis of the technologies they offer.

MMC Ventures estimates there are at least 226 early stage AI software companies in the UK (see AI Heat Map below), more than 60% founded in the last three years, although it is at an earlier stage of development than the US, with 75% at a 'seed' or 'angel' funding stage, compared with 50% in the US. More than 80% deliver specific functional or industry sector focused offerings but the number delivering manufacturing specific solutions appears small compared with the identified opportunity.[168]

The majority of UK businesses will have to work within the constraints of their existing investment in plant and systems. Any approach to adopting AI needs to be able to deal with a combination of instrumented and non-instrumented equipment and a variety of planning systems, but the poor adoption of productivity enhancing technologies in the UK shows there is a great deal to play for. European Commission data for 2015 shows a very low proportion of UK companies using ERP systems to share data internally and enhance productivity. At 17% of all enterprises, this is around half the EU average with the problem concentrated in companies with fewer than 250 employees, although large companies are still 20% lower.[169]

A CBI survey in May 2017 shows that AI tops the list of technologies that UK organisations plan to invest in over the next five years but it also highlights that, while leaders in a number of UK businesses are taking steps to realise the benefits of AI, the slow uptake of others risks creating a divide and leaving many behind.[170]

Engagement with UK businesses during this review has revealed that many are confused by a combination of hype and a lack of specific information on how AI can help solve specific business problems. Those who overcome these challenges then find it difficult to build a business case to invest. The limited number of case studies contribute to the difficulty in quantifying ROI and de-risking projects. There is a gap between those who have started and those who have not, but even the leaders appear to be implementing point solutions rather than making AI investment part of an overall strategy. In addition, businesses raised concerns about the predictability of outcome from machine learning.

Also highlighted has been the need to navigate a complex ecosystem of suppliers, customers, academia, government, regulators and other stakeholders. The complexity of this ecosystem acts as a disincentive to adoption of AI technologies.

A further area mentioned by businesses as a potential block to AI adoption is an inadequate skill level, with limitations falling into two distinct groups. The first concerns the skills necessary to understand, develop and deploy AI solutions, but the second, and potentially larger concern, is the ability of the existing workforce to work alongside AI technologies.

Finally, businesses expressed a variety of concerns about sharing and processing data, ranging from an understanding of the data an organisation processes and its value, through issues of protection, security and liability when sharing and processing that data, to the interoperability standards that will facilitate sharing.

[168] https://medium.com/mmc-writes artificial-intelligence-in-the-uk-landscape-and-learnings-from-226-startups-70b9551f3e4c

[169] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_bde15dip&lang=en

[170] http://www.cbi.org.uk/news/half-of-firms-expect-ai-to-transform-their-industry/

TRANSFORMATION IMPACT OF ARTIFICIAL INTELLIGENCE

Analysis undertaken as part of the MSR identified that the application of Artificial Intelligence within UK industry offered a Value at Stake of £198.7bn to the UK Economy between 2017 and 2027.

VALUE AT STAKE FROM ARTIFICIAL INTELLIGENCE IS ESTIMATED TO BE £198.7BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£91.4	• £10.7bn of cost savings are expected to be passed on to consumers as the manufacturing process becomes more efficient through the use of AI • 19% increase in job satisfaction due to higher value activities	• 5.4 mn tCO_2e reduction in emissions from manufacturing processes in 2027[1] • 70% reduced machinery breakdown, leading to lower resource waste • Improvement in quality of life from AI in healthcare. Treatment costs for hospital patients are estimated to fall by 50% • 72,600 workplace injuries avoided by moving labourers away from machinery
Cost reduction through digitally enabled R&D	£9.5		
Cost reduction through labour productivity improvements	£39.4		
Cost reduction through digitally enabled supply chain management	£58.4		
Total value to industry	£91.4 £198.7		

1) Reduction of emissions is not presented as a cumulative figure, rather as the reduction saving potential in 2027

Other earlier studies identify significant benefits should be expected from the adoption of artificial intelligence. The 2016 Accenture report 'Why Artificial Intelligence is the Future of Growth' conducted with Frontier Economics, proposes that the productivity enhancing impact of AI has the capability to add £650bn GVA to the UK economy through a combination of intelligent automation, augmentation of labour and capital investments and the resulting innovation diffusion across the economy with a productivity level 25% higher than would otherwise be the case for the UK. [171] A February 2016 report from CEBR and the SAS Institute highlighted a cumulative benefit of 'big data' across the economy of £240bn by 2020 with the greatest benefit from efficiency savings and the manufacturing sector gaining the most (£57billion).[172]

AI case studies, while currently limited, are continuing to emerge from implementation of AI by leading organisations; these generally fall into three key business areas and can be used to counter some of the concerns of reluctant adopters referenced above.

Intelligent Assets and Equipment enable assets and equipment equipped with sensors and combined with AI capability to sense, communicate and self-diagnose issues to optimise performance and reduce downtime. Time based maintenance can be replaced by predictive and ultimately prescriptive maintenance where systems not only predict the need for maintenance based on machine learning algorithms but also act on that need. This leads to improved production line performance and reduced (equipment) downtime, improving process efficiency.

[171] https://www.accenture.com/lv-en/_acnmedia/PDF-33/Accenture-Why-AI-is-the-Future-of-Growth.pdf

[172] https://www.sas.com/content/dam/SAS/en_gb/doc/analystreport/cebr-value-of-big-data.pdf

KONE Corporation is using the cloud to gather data from sensors installed in their elevators and escalators and will use prescriptive maintenance capabilities to deliver more cost-effective maintenance whilst improving the service to their customers.[173]

AI Processes and Operations: Cognitive or AI systems support the analysis of the increasing volume and complexity of data collected by businesses to support better decision making and improve operations and quality. Businesses can thus improve productivity and sustainability through inventory and scrap reduction and improving quality and yield.

Smart resource optimisation: Optimising the use of people, energy and knowledge is critical to improving productivity levels and lowering cost. Using AI to analyse data from IoT devices can improve worker safety, productivity and expertise as well as reduce energy consumption.

Combining wearable devices with artificial intelligence systems has allowed North Star Bluescope Steel to monitor the response of employees to a hazardous working environment and provide personalised protection for each employee and improved safety for the workforce as a whole.[174]

Faced with the problem of how to retain and learn from the knowledge and expertise acquired during the construction of offshore platforms, Woodside Energy has used cognitive technology to consolidate 30 years of experience and 38,000 documents to make information available to subsequent projects.[175]

Actions required to specifically accelerate innovation and adoption of AI

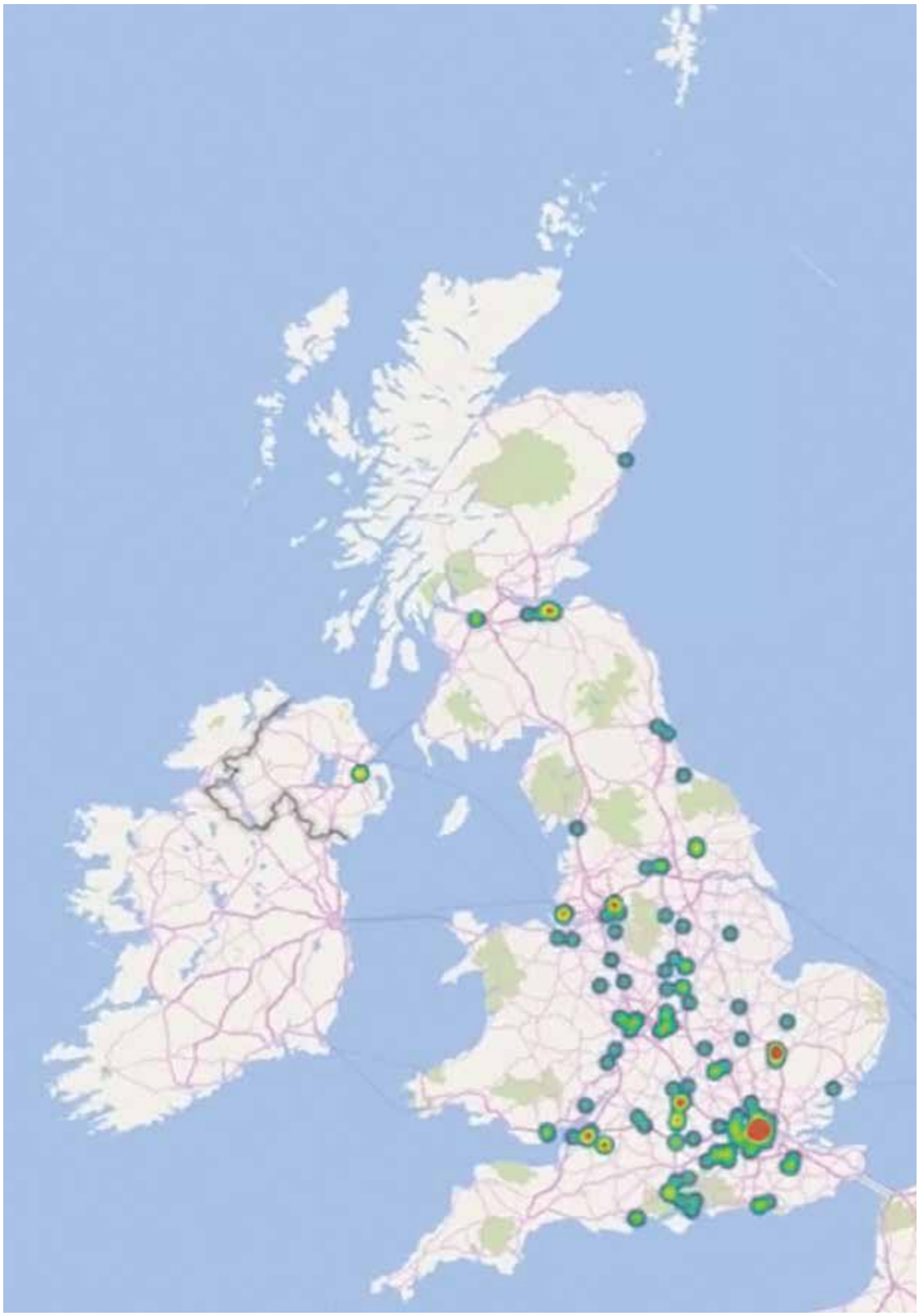
1. **A programme to encourage the business adoption of AI technologies** to solve problems and deliver practical business value. In addition to developing practical propositions which address business problems there is a clear need for expertise to develop and advise, for help in building investment and business cases. Businesses expressed the need to start with a minimum viable product but which permits the ability to mature into an integrated strategy. Reassurance on approaches to security is one key area of intervention.
2. **Transforming the skills of the existing workforce** will be an essential part of any mass adoption programme. Many current policies have focused on training new entrants to the workforce but this will not be sufficient. Government and employers should encourage and provide continual education and training for existing employees through their careers and evaluate how to tailor existing policies and develop new approaches to achieve this.
3. The **skills needed to develop and deploy AI solutions** will still be dependent on an education system which encourages STEM skills, with incentives where necessary, and further education which provides data science and AI skills accompanied by industry and professional certifications.
4. To take forward thinking on **ethics and trust**, a forum for the UK to contribute to this global debate is required, widely drawn from government, academia and industry. It should go beyond the B2C debates around personal data and include frameworks for the safe sharing of B2B data.
5. The Government should focus on **initiatives which encourage the adoption of advanced technologies** to transform productivity. Large publicly funded projects are one way in which the government could encourage technology adoption. More broadly, there are legal and regulatory challenges which can slow down technology adoption and which will require government assistance to overcome. Finally, investment incentives will also have a role to play.

[173] http://www.kone.com/shared/people-flow-magazine/2015-15/

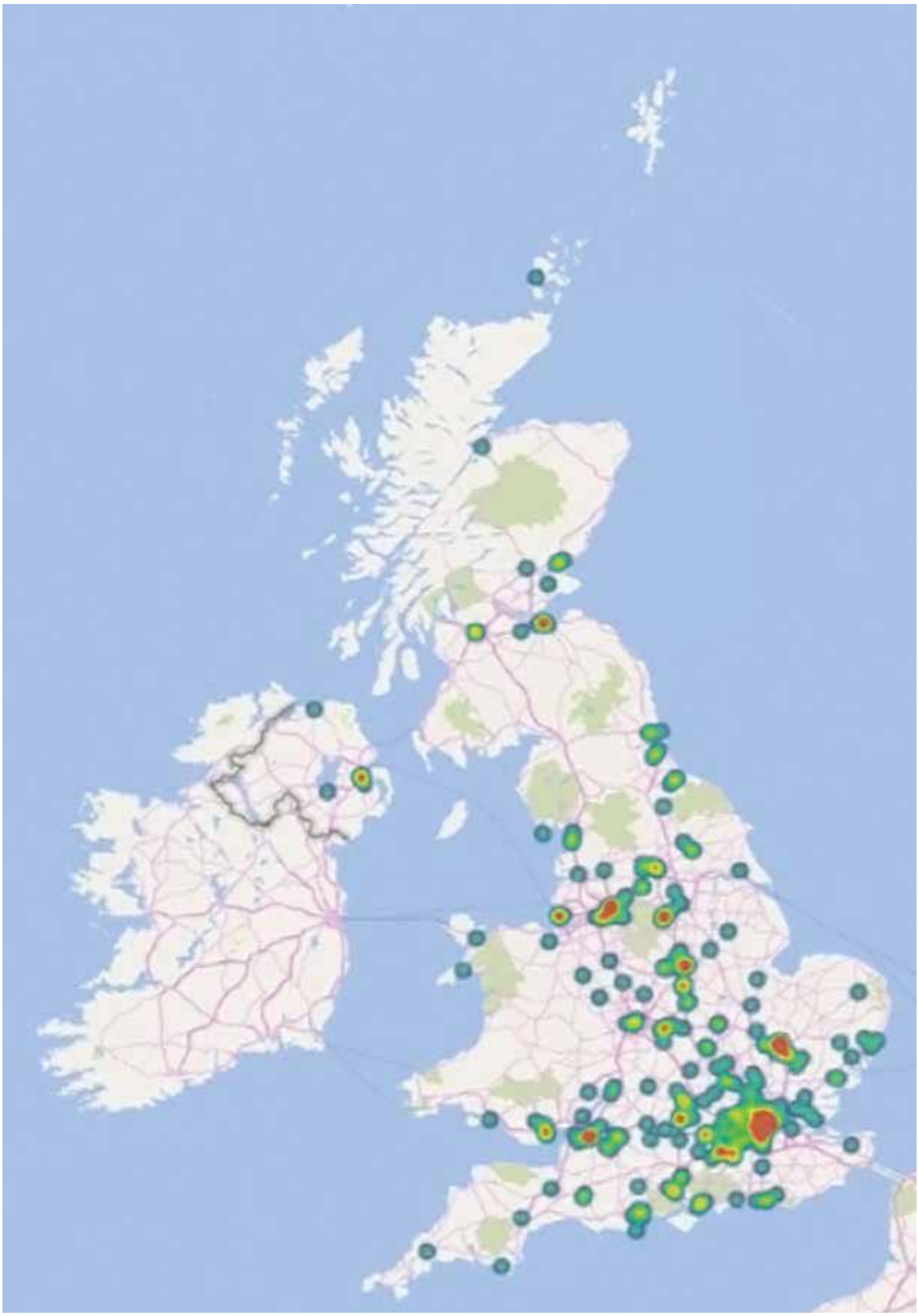
[174] https://brainxchange.io/3-great-use-cases-wearable-tech-ehs/

[175] http://www.woodside.com.au/Working-Sustainably/Technology-and-Innovation/Pages/Data-Science-.aspx

AI Heat Map



Data Science and Analytics Heat Map



ElecTech: Automation and Robotics

INTRODUCTION TO ELECTECH

The digitalisation of manufacturing relies heavily on many different skills, components, and capabilities from the ElecTech sector (electronics, electro-technical + embedded software). The ElecTech sector is widely regarded as one of the sectors driving greatest innovation and creativity in any advanced economy. In Germany, for example, more than 35% of all innovations in manufacturing were initiated by ElecTech industries (source: ZVEI).

The ElecTech industrial sector covers companies who design, deploy and support hardware built using some combination of ultra-low power, highly integrated electronics chips; medium to high power electro-technical systems, and embedded software (the low-level software that controls the hardware). ElecTech is at the heart of every automation system and every robot.

ElecTech is the largest manufacturing category in Europe, employing more than 3m people generating over €675bn revenues. More than 37% of all manufacturing in Europe is of electrical, electronics, ICT and instrumentation (source: OrgaLime 2016). However, it's not just what is made: ElecTech powers every digital factory regardless of what it makes. Investing in ElecTech as the heart of digitalisation impacts manufacturing in every sector.

Almost every aspect of the digitalisation of industry requires many different ElecTech technologies, from communications to power subsystems; from embedded processing for automation and control to intelligent lighting and security systems. Advanced ElecTech computation powers everything from the largest datacentres to the tiniest sensors and servos, doing everything from day to day computing to accelerating AI-based machine learning and making every electric motor smarter and self-maintaining. Without ElecTech, industrial digitalisation simply couldn't be implemented!

ElecTech is a major sector in the UK, employing more than one million people in over 45,000 companies. The UK has one of the strongest Intellectual Property capabilities in ElecTech in the world. The UK already attracts significant inward investment from companies like Apple, Google and Amazon thanks to our strengths in ElecTech technologies and early adopters in the automotive, aerospace and creative industries.

THE UK POSITION

The rise of automation in the 4th Industrial Revolution is as dramatic as the introduction of steam engines in the 1st – only it is happening four times more quickly. Given the UK's pivotal historic role as the leader of the industrial age, it seems disturbing that we appear to be falling ever further down the list of automated, digitalised countries. Yet that is just what is happening.

Automation and digitalisation of manufacturing plays to UK strengths in both core technologies and systems engineering, through leveraging cross-discipline R&D skillsets coming together to integrate and deploy new automated workflows leveraging advanced technologies such as robots.

Many of the ElecTech technologies essential to the future of automation and robotics have industry leaders here in the UK, including silicon chips (ARM), sensors (Renishaw), AR/VR (Imagination), AI (GraphCore), power (Dynex Semiconductor) and communications (5GIC Surrey; CSR, now part of Qualcomm).

The UK already has world-leading research in robotics, in fields as diverse as healthcare, subsea autonomous vehicles and vacuum cleaners. Groups such as the Edinburgh Centre for Robotics, Sheffield Robotics, Bristol Robotics Lab, Imperial College's Hamlyn Centre are all recognised as significant contributors and innovators in global robotics research.

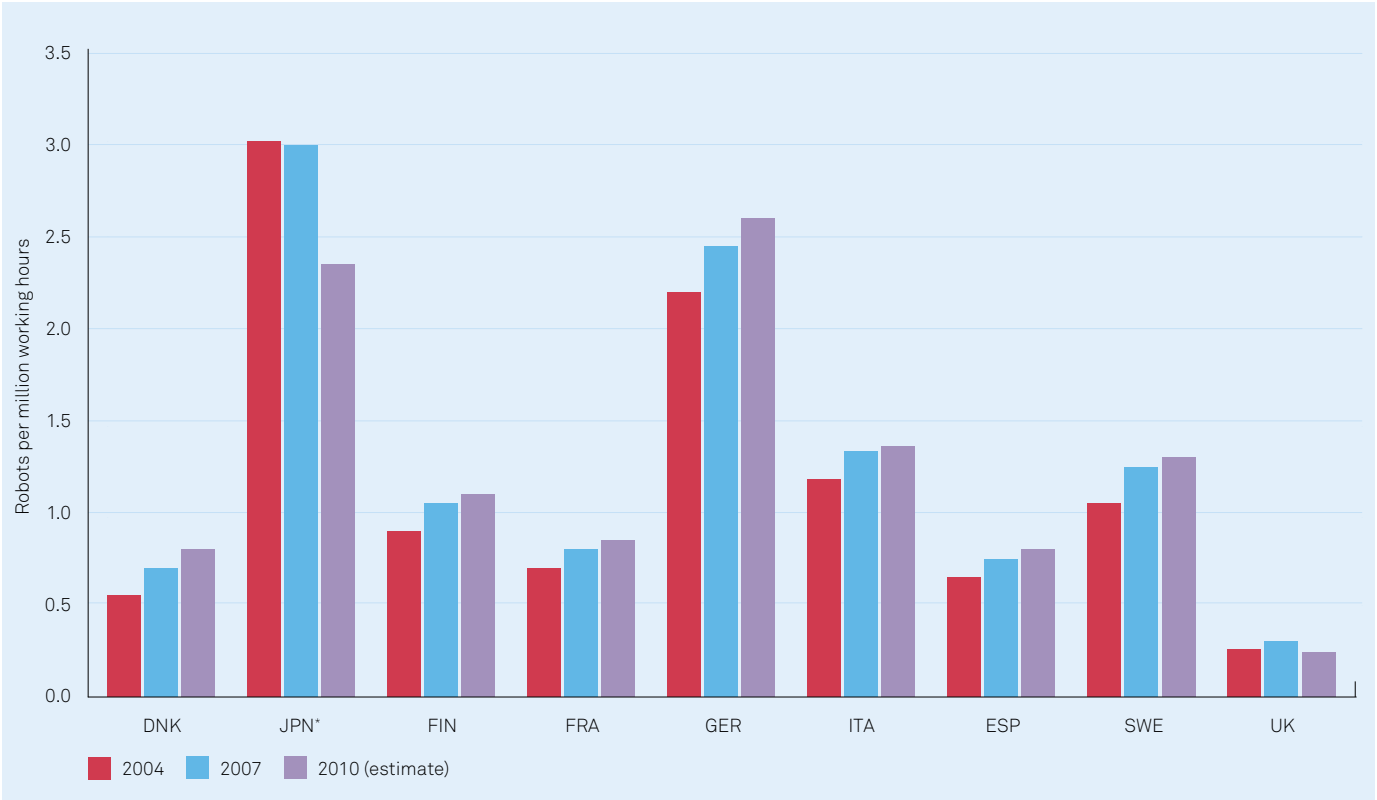
Robots bring together a wide range of ElecTech technologies, such as smart electric motors and servos, power systems, sensors, AI-based control systems, high speed communications, highly integrated silicon chips, embedded software, and AR/VR based modelling of workflows.

The UK has some highly innovative robot companies already, such as the Shadow Robot Company (artificial hand robots), Peak Analysis and Automation (laboratory robots), Engineered Arts (human-emulating interactive robots) and Tharsus (warehouse robots for Ocado and others), while Dyson is an example of a consumer goods company investing tens of millions into robotics for household appliances.

Automotive multi-nationals such as Jaguar Land Rover and Nissan have already seized on the benefits of robots as a key part of their automation strategies in their UK factories – facilities that also happen to be some of the largest employers in their region. Technology innovators such as Ocado leverage networks of thousands of robots to enable them to deliver new levels of productivity and efficiency in warehouse logistics.

However, overall the uptake of manufacturing automation in the UK is disturbingly slow compared to most other developed nations. The UK has only 33 robots per 10,000 employed compared to 93 for the US and 170 for Germany (source: IFR) - and the gap is widening. Germany invests 6.6 times more than the UK in automation, although its manufacturing sector is only 2.7 times the UK's in size (source: ZVEI). And in robots per millions of hours worked, the UK is a factor of 10 lower than Germany or Japan (source: IFR). The UK is falling seriously behind our competitors, based on pretty much every metric.

TOTAL COUNTRY STOCK OF INDUSTRIAL ROBOTS



*Data for JPN 2007 is missing therefore data for 2006 is graphed instead

There appear to be several reasons why in manufacturing the UK is falling behind:

1. **Public perception:** A fear by both business leaders and the public that robots will take too many jobs, fed by the media that human-like robots will replace people completely.
2. **Lack of ambition:** Not enough businesses strive to be more than profitable; the lack of determination to scale-up UK-based business and be seen as a shaker and mover on the world stage.
3. **Risk-averse:** Too many companies have a strong preference to "sweat their assets" by repairing older equipment until it becomes obsolete or fails, rather than upgrading it periodically to remain globally competitive.
4. **Shortage of skills:** The shortage of staff skilled in automation means too many companies don't have internal champions comfortable with adopting new technologies never used before to do more tasks differently.
5. **Finance:** With a lack of incentives from government, and a conservative financial sector unwilling to encourage investment for increasing competitiveness and productivity, it is far too easy for Boards to delay investing in automation – until it's too late.

The reality is that while high growth economies like China are seizing on robots as key to their future growth (see Made in China 2025 at appendix 2) , the UK has so far failed to grasp the significance of embracing the future rather than denying it. Action must be taken soon to change these attitudes, or the UK risks losing yet more of its manufacturing base.

Regional and national variation

The current and future impact of automation varies between regions and between countries and a comparison is beyond the scope of this paper. However, data from IFR and other sources suggests:

- China will emerge as a major robotics manufacturer and user of robots, benefiting from jobs created by robot manufacturing and productivity gains from robot use. China has topped sales of robots to any one single market every year since 2013. The Chinese government has included a focus on robotics in its 10 year strategy. In order to achieve its target of a robot density of 150 units per 10,000 workers by 2020, Chinese companies will have to install around 650,000 new industrial robots between 2016 and 2020 – 2.5 times more than were installed globally in 2015 (International Federation of Robotics, 2016)
- Japan currently has the largest stock of industrial robots in operation, primarily in the automotive industry. Driven by a rapidly ageing population and low productivity rates, the Japanese government has set its sights on a 20-fold increase in the use of robots in the non-manufacturing sector and a three-fold growth rate of labour productivity in the service sector , both by 2020 (Ministry of Economy, Trade and Industry, Japan, 2015).
- Some emerging and developing economies – notably Indonesia and Thailand - are installing robots as a high rate, recognising not only productivity but also quality advantages from automation. (Boston Consulting Group, 2015)

Transformation Impact of Automation & Robotics

One of the most iconic symbols of innovation in automation is robots. Robots are perhaps one of the most powerful and creative technologies being aggressively developed in the race for greater productivity and more cost-effective production.

The design, deployment and support of robot-based manufacturing systems has been embraced by most G7 countries such as Germany, France, Italy and the US, as well as powerhouses such as China and South Korea as key to increasing productivity. These countries recognise that automation changes the underlying economics of manufacturing, enabling them to create high growth and better productivity, enabling their factories to make more competitive products – be it cars, furniture, food or clothing. Indeed a recent study by Barclays estimates that an accelerated level of investment in robots could raise manufacturing Gross Value Added in the UK by 21.0% over 10 years.

TABLE 8. PRODUCTIVITY CHANGE IF AUTOMATION AS IN THE MOST AUTOMATED COUNTRY

	BEST	JAPAN	GERMANY	UK	FRANCE	ITALY	SPAIN	SWEDEN	FINLAND	DENMARK
Food, Tobacco	FIN	13.7%	8.7%	13.7%	11.4%	11.7%	11.2%	7.1%	0.0%	7.4%
Textile, Leather	DNK	9.7%	8.8%	9.7%	9.3%	9.6%	9.5%	9.7%	8.6%	0.0%
Wood, Furniture	DNK	21.5%	1.2%	21.0%	20.4%	19.8%	18.7%	17.4%	19.7%	0.0%
Paper, Publishing	FIN	2.1%	1.8%	2.8%	2.0%	2.3%	2.5%	2.5%	0.0%	1.9%
Chemical products	ITA	13.0%	12.2%	29.4%	22.2%	0.0%	24.3%	19.6%	10.2%	20.7%
Glass, Ceramics, Stone	GER	8.2%	0.0%	9.6%	6.7%	7.2%	7.7%	8.5%	6.8%	4.0%
Metal, Machinery	DNK	5.5%	5.1%	11.7%	8.7%	6.2%	8.7%	1.0%	3.7%	0.0%
Electronic Equipment	JPN	0.0%	16.8%	24.2%	22.5%	22.2%	22.3%	20.3%	13.9%	16.8%
Transport Equipment	GER	15.9%	0.0%	76.3%	28.5%	8.1%	36.0%	65.8%	80.2%	81.4%
All Other	JPN	0.0%	27.9%	41.3%	40.0%	39.3%	38.8%	39.3%	39.0%	39.6%
Total		**8.1%**	**8.0%**	**22.3%**	**15.4%**	**10.5%**	**16.3%**	**15.7%**	**14.9%**	**15.2%**

Automation, labor productivity and employment – a cross country comparison: Lene Kromann, Jan Rose Skaksen, Anders Sørensen, CEBR, Copenhagen Business School

Note: The "Total" is the employment weighted average of the productivity change in all industries.

For each industry we apply the highest ranked country as "best performance". Then, we are able to predict how productivity and employment would have been in each industry within a country the actual measure of robot-intensity was substituted with the intensity of the "best performance".

A study undertaken by the Copenhagen business school identified productivity improvements of 22% if the UK invested in automation in line with the 'Best in Class' for each Industry sector.

Robots enable a growing number of jobs to be done that cannot be safely handled by humans – that's why they enable new businesses and improve productivity. Their ability to operate in hazardous environments, work with dangerous materials and continue operating 24 hours a day are all examples of where robots enhance our workforce.

The ability for aerospace to use robots to enhance specialised skills has already been demonstrated in factories like the GKN Aerospace plant in Bristol, where they use automated carbon fibre placement robots to build 27m wings that would simply be impossible using manual labour.

Analysis undertaken as part of the MSR identified that the application of Automation and Robotics within UK industry offered a Value at Stake of £183.6bn to the UK economy with additional benefits identified to both the individual and society (see URL http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/).

VALUE AT STAKE FROM AUTOMATION AND ROBOTICS IS ESTIMATED TO BE £183.6BN BETWEEN 2017-2027

VALUE LEVER DESCRIPTION	VALUE TO INDUSTRY (£ BN)	VALUE TO INDIVIDUALS	VALUE TO SOCIETY
Revenue growth through new revenue streams	£54.1	• £13bn of cost savings is expected to be passed on to consumers over the next decade, as the manufacturing process becomes more efficient through the use of Automation and Robotics • 13% increase in job satisfaction due to higher value activities	• 4.8 mn tCO_2e reduction in emissions in 2027[1] from more efficient manufacturing processes • 8% reduced waste from more efficient manufacturing processes • Reduction of 633,600 cases of musculoskeletal disorders resulting from manual manufacturing • Improvement in quality of life from robotics in healthcare • 127,050 workplace injuries avoided by moving workforce away from machinery
Cost reduction through digitally enabled R&D	£13.8		
Cost reduction through automation of labour	£44		
Cost reduction through digitally enabled manufacturing and asset maintenance	£71.7		
Total value to industry	£54.1 £183.6		

The value of robots as part of automation strategies is not just for high-tech industries. Enabling cost-effective production is also key to labour-intensive industries such as food and drink or agriculture, where immigration challenges in the coming years mean availability of migrant and transient labour might become harder to attract. If factories in the UK are to remain competitive in an increasingly global marketplace, investment in automation must be seen as integral to raising our competitiveness.

Highly automated manufacturing enables the creation of new factories that generate new jobs, because without automation those factories would not exist. By enabling many more factories to be created across the country, a wider range of highly creative, innovative goods can be produced which would simply not be competitive using conventional manufacturing approaches. Robots can also ensure manual skills are available where otherwise suitable labour is in short supply – a growing problem when trying to revitalise regional economies.

But jobs aren't just created on the production line itself. That's because for every new factory, everything that surrounds that factory creates jobs, too, from the admin to logistics; from supplying canteens to new specialist companies created thanks to the presence of a factory. Automation creates far more jobs than it takes, by enabling new businesses to flourish where they previously could not be competitive or reliably productive.

Actions required to specifically accelerate innovation and adoption of Robotics & Automation

The strategic value of Robotics and Autonomous Systems (RAS) has already been recognised by the government, with the first round of the ISCF allocating £93m for development of world-leading technologies for robots in hazardous environments. However, we believe this is just the start – far more needs to be done to make automation happen much faster in the UK, and overcome the cultural and business resistance to automation and robots. We need to enable the UK to focus on leveraging the advantages of automation in increasing our productivity, competitiveness and global reach.

1. Template factories for SMEs

   We believe the UK should build a series of highly automated showcase factories across the UK, targeting those specific manufacturing sectors which are most successful with SMEs in the UK - as diverse as food & drink, furniture, buildings, pharmaceuticals and consumer goods. These "template" factories producing examples of real goods would enable SME business owners - with little understanding of digital or robotics - to invest confidently in digital factories by simply saying "I want one of those!". Many of these model factories could be part funded by Tier1 companies eager to increase sales of their automation equipment in the UK, enabling far more SME's to easily apply the technologies used in their own factories through various financial incentives.

   By stimulating the creation of highly automated digital factories, accelerated upgrade of existing facilities across the UK, and by showing the new jobs being created with every additional factory built – jobs which would otherwise not exist at all - the government can more quickly challenge the public's concerns about robots taking jobs.

2. Automation Task Force and Mobile Outreach Demonstrators

   An Automation Task Force should be created, specifically briefed to maximise outreach to manufacturers large and small, using the template factories as catalysts for this. The task force should not just be about automation technology, however – it should also actively help any business to raise the finance needed to either increase automation in an existing factory, or build new highly automated plants.

   Too often businesses cannot see automation in action, so they are intimidated by it: seeing is believing. To ensure the message gets to the broadest base of businesses across every part of the UK, the Automation Task Force should operate a mobile demonstration unit, possibly co-funded by automation equipment suppliers, to demonstrate the broad spectrum of automation technologies for every company large or small. The mobile demonstrator should cover everything from robots to simple upgrades to existing low-tech facilities, with a clear emphasis on broadening adoption, not just showcasing high end technologies.

3. Financial incentives encouraging automation adoption
   By strongly incentivising businesses that are willing to invest in automation, especially those leveraging UK ElecTech technologies, an ecosystem across the UK of businesses embracing automation can be created. Not only will this stimulate manufacturing, but it will also create a growing, energetic and innovative network of specialist services and technology companies. By sharing their experiences, participants in this network will encourage more reticent companies to join them, stimulating a virtuous cycle of growth and expansion.

4. Establish an Interoperability Institute
   As already proposed by the ElecTech Council in its response to the BEIS Industrial Strategy Consultation, a new Interoperability Institute should be established, focused on ensuring that automation products all communicate and co-operate with each other regardless of supplier. This would ensure that when companies start investing in automation equipment from a wide range of suppliers, they can be reassured that their investment will not be obsolete if any one component or supplier needs to be upgraded or replaced by another, and that key issues such as security and collaboration are consistently addressed.

The world won't wait for the UK: Industrial digitalisation and the upgrade of our manufacturing infrastructure is key for the future of the UK's global competitiveness. Production costs are rising, and unless action is taken competitiveness will continue to drop. There needs to be greater strategic focus than simply "make more things in the UK". Automation, robotics, and the ElecTech technologies and skills surrounding them, are an ideal focal point to rapidly build the UK's position in the global economy as a leader in the practical application of advanced digital manufacturing for economic growth and global export success.

Robotics and Autonomous Systems Heat Map

Connectivity and the Industrial Internet of Things – the Foundations for Innovative Transformation of Industry.

INTRODUCTION TO INDUSTRIAL INTERNET OF THINGS, CONNECTIVITY AND CYBER SECURITY

The Industrial Internet of Things (IIoT) brings together a number of elements to drive more informed, faster business decisions for industrial organisations. It combines cutting edge machines, advanced analytics and a plethora of devices that connect together by communication technologies which allow for monitoring, collection, exchange and analysis of data of these devices to deliver valuable insights for industrial companies. [176]

In an industrial setting, IIoT allows traditionally non-digital companies to build a data footprint through sensors and monitoring of equipment and machinery. This data footprint allows for new business models to develop and provides greater opportunities for the digital sector to work closer with industry. For example, by taking the data that is generated from IoT devices, there are opportunities to gain insight into the condition of equipment on a factory floor, to monitor environmental factors that may impact quality and to even optimise production lines through an accurate "digital twin" (or direct digital replica) of an industrial process to streamline and increase productivity.

In addition to IIoT, it is also crucial to build the connectivity infrastructure that will underpin the factories of the future. From Low Powered Wide Area Networks (LPWAN) to the next generation of the internet in 5G, there is huge potential to accelerate the transformation of industry. Improved connectivity is essential to utilising the technologies that underpin the 4th Industrial Revolution, and without it you will not achieve the same levels of productivity and efficiency through the adoption of sensor equipment wearables, collaborative robots and digital twin / 3D modelling and VR/AR. Allowing for flexible and reliable connectivity across all of these technologies will help with real time data processing, and to monitor assets distributed across larger areas, and optimise logistic flow across the supply chain.

Further to the importance of connectivity infrastructure, manufacturers also need to step up their cyber security strategies and investment. With the increasing adoption of the Internet of Things in industry, manufacturers have been much slower in their adoption and investment into IT security strategies. The risk of this on a global scale is almost unquantifiable as it can impact reputation, relationships with a broad range of customers and partners across the supply chain - not to mention production, logistics and (as manufacturing begins to develop a closer relationship with consumers) personal data. During the WannaCry ransomware attack earlier this year, manufacturing businesses such as France's Renault were affected which led to them temporarily stopping production at several sites to prevent the spread of the attack. It has been quantified through an independent survey that the reported financial cost to business is also significant, with the average annual cumulative cost being $347,603, in fact larger companies with 500+ employees reported annual accumulative losses of almost $500,000.[177]

Based on the above it is crucial that – to enable the future of connectivity underpinning IIoT and to mitigate against the threat of cyber-crime in manufacturing – the UK needs to increase awareness and adoption of innovation strategies in these technologies across industrial SMEs. This will drive the UK's 4th Industrial Revolution forward and avoid potential stumbling blocks to growth in the future.

[176] "Everything you need to know about the Industrial Internet of Things" by GE Digital http://invent.ge/2eqfX43

[177] The State of Industrial Cyber Security 2017, Global Report - Kaspersky Business Advantage - http://bit.ly/2f1D6WM

THE UK POSITION

The UK is home to a rapidly growing community of companies developing and commercialising IoT component technologies, products and services which are already having an impact on businesses, in homes and in individuals' lives. It is predicted that the Internet of Things will bring 67,000 jobs to the UK by 2020.[178] The UK government has invested significantly in the connected technologies sector through the £32m of funding awarded to the IoTUK Programme in the 2015 Budget. IoTUK is a national initiative designed to support IoT development and uptake in the UK, through applied research, demonstrating the technology at scale, attracting international investment and supporting small companies. IoTUK has also built a database of companies so it can track the activity in the supply side of the UK's IoT industry to demonstrate both breadth and scale, highlight some of the significant commercial products being developed, and to analyse how IoT-focused suppliers are distributed by type, size, application area and location.

The research field in IoT is also vibrant in the UK with much IoT research being driven by universities. As part of the IoTUK Programme [179], the start of 2016 saw the launch of a new Internet of Things Research Hub for the UK, PETRAS[180] , underpinned by £9.8m support from the Engineering and Physical Sciences Research Council (EPSRC) [181], and boosted by partner contributions to approximately £23m. Designed to lead interdisciplinary research in a number of areas critical for the development of the country's Internet of Things capability, the foundation of the PETRAS IoT hub adds to what is already a vibrant and industrious research community. PETRAS comprises nine UK universities – UCL, Imperial College London, University of Oxford, University of Warwick, Lancaster University, University of Southampton, University of Surrey, University of Edinburgh and Cardiff University. It is expected to bring in expertise from over 50 other partners from the public sector and from industry.

Over the next three years PETRAS will continue to research into solving many of the challenges facing IoT developers – including the ethics, privacy, trust, reliability, acceptability and security issues already being given significant attention. The funding awarded to PETRAS accounts for a significant proportion of all UK IoT research value (around 10%).[182] In addition, the consortium represents many of the organisations that have already been most active in UK IoT research.

According to IBM's Cyber Security Intelligence Index, manufacturing was ranked as the 3rd the most frequently hacked industry in 2017. This is due to it being a tempting market with systems within the sector being seen as "weak by design as a result of a failure to be held to compliance standards."

[178] AS Big Data Internet of Things http://bit.ly/2nr38sm

[179] The IoTUK Programme is the UK government's ambitious fully-integrated IoT acceleration programme, which saw £32m of funding distributed across an end-to-end ecosystem of IoT activities from 2015. The programme includes academic research (PETRAS), hardware accelerators (StartUp Bootcamp and R/GA), large scale demonstrators (CityVerve and two NHS Testbeds) and dissemination models to increase take-up rates (Future Cities Catapult and NHS England). The Digital Catapult provides co-ordination, SME acceleration and amplification services to the programme.

[180] http://www.petrashub.org

[181] http://www.epsrc.ac.uk

[182] The IoTNation database has identified £122m of research funding, of which c£100m is still deployed in live projects in 2016. The PETRAS funding of £9.8m is therefore 10% of the total.

It is also almost 40% higher than the average across all industries for "security incidents".[183] The UK manufacturing sector is particularly at risk, with (according to research from EEF) almost half (46%) of manufacturers failing to increase their cyber security investment in the past two years (with 56% of this number being small manufacturers), 20% of manufacturers not making employees aware of cyber risks in company policies, just over half 56% saying that security is given serious attention by their board, just over one third (36%) of manufacturers having an incident response plan in place, and only 24% monitoring cyber threats through business KPIs.[184]

In terms of 5G, the UK Government has laid out plans for the UK to be a global leader in the next generation of mobile technology - seeing good digital infrastructure as the building block of the Government's modern Industrial Strategy. Further to this, the National Infrastructure Commission (NIC) and the Future Communications Challenge Group (FCCG) established by DCMS, set out in December 2016 and January 2017 respectively a series of recommendations and steps to ensure the UK becomes a world leader in the deployment of 5G telecommunications networks. From this a developing strategy around 5G in the UK is emerging, with three universities (King's College London, Universities of Surrey and Bristol) awarded £16m to develop a cutting-edge test network to make sure people and business can enjoy the benefits sooner.

Finally, on Low Powered Wide Area Networks (which can greatly reduce the overhead costs of IIoT connectivity), the UK is behind the rest of Europe who have begun rolling out the wireless network technology over the past few years. The UK is as such playing catch up on the implementation, with Digital Catapult playing a key role in this with its "Things Connected" network that will initially provide a test bed of 50 base stations across London and expand geographically across the UK.

TRANSFORMATIONAL IMPACT AND MITIGATING RISK IN IIOT, CONNECTIVITY AND SECURITY IN MANUFACTURING

On a global scale, IoT is predicted to generate up to $11tn in value to the global economy by 2025[185], while in a report by Accenture, it is projected that adopting the Internet of Things on an industrial level (IIoT) could boost the UK economy by £352bn by 2030. Conservative estimates put IIoT's potential worldwide spending at $20bn in 2012, expected to reach around $500bn by 2020. More optimistic predictions put the value created by the IIoT as high as $15t of global GDP by 2030. [186]

The huge potential impact of IIoT has also been supported and reflected by a 2016 survey of decision makers and analytics professionals in industrial companies, with 69% believing Industrial Analytics will be crucial for business success in 2020, and 15% considering it as already crucial today. Further to this, in the same report and survey, predictive and prescriptive maintenance of machines (79%), customer/marketing related analytics (77%) and analysis of product usage in the field (76%) are the top three applications of industrial analytics in the next 1 to 3 years. [187]

[183] "Security Trends in the Manufacturing Industry, 2017 IBM Security https://ibm.co/2yaH2PK

[184] EEF Cyber Security Survey Results 2016, http://bit.ly/2kAFr0u

[185] Unlocking the Potential of the Internet of Things by James Manyika et al. http://bit.ly/2eRn6X8

[186] "The Growth Game Changer" by Mark Purdy and Ladan Davarzani, https://accntu.re/2mHhAb

[187] Industrial Analytics 2016/17 by Knud Lasse Lueth et al. http://bit.ly/2li6PM1

The increased adoption of Industrial IoT devices in the market will mean there is a huge opportunity for relevant and accurate data to be processed and analysed to underpin Industrial Analytics. If the UK is able to drive this convergence of information technology and industrial automation, it can bring about increased productivity and develop new data-driven business models. To do this, it must create effective collaborations between machine learning researchers and innovators and developers of Industrial IoT devices via IoT platforms – to bridge the gap between the physical and digital systems.

However, in order to utilise the full potential of IIoT it is also crucial to have the connectivity infrastructure around it to maximise its benefits and increase adoption. According to IHS Economics it is estimated that 5G will enable USD$12.3tn of global economic output in 2035.[188] Mobile technologies are seen as constantly evolving and the huge amounts of data traffic post both challenges and opportunities for the UK. 5G will support new consumer experiences based on constant and seamless connectivity. The new technologies, applications and business models that will come from it are still yet to be seen, but 5G is expected to enhance productivity across the economy by opening the door to revolutionary technologies. Adoption of LPWAN is also crucial in manufacturing, with its capability of connecting sensor devices and their data across the factory at a much lower cost and increased reliability when compared to traditional mobile connectivity (3G, 4G etc.). This will reduce the cost overheads for manufacturing SMEs and ensure reliability for IIoT networks across geographically wide and often hard to reach parts of factories.

Actions required to specifically accelerate innovation and adoption of IoT

Research has indicated that adoption of Industrial IoT in the UK is dependent on a number of key factors: lack of understanding around the benefits, a lack of skills, security of IoT devices, the high cost of implementation, inadequate infrastructure, lack of standards and interoperability (legacy concerns). As such the areas of focus should be:

- Driving the adoption of IIoT by supporting industry and innovation agencies in raising awareness of the opportunities afforded through the use of the technology. A concrete example is to enable subsidised access to digital transformation consultants that help businesses to identify initial pilot projects exploring the benefits of IIoT inside their organisations, enabled by digital readiness level assessments.
- Establishing a "library" of best in class IIoT use cases that can act as reference examples for others who wish to implement similar solutions in their organisations. These use cases could be curated from successful early adopters across the country and brought together virtually or even at physical show rooms.
- Encouraging national availability of adequate IoT connectivity networks to underpin the exploding demand for connected devices of the IIoT. This includes the rapid rollout of Low Power Wide Area Networks to minimise the deployment costs for low bandwidth communication use cases and 5G networks to support low latency mission critical applications. Driving open innovation and collaborative exercises to help industrial companies understand the potential of adopting these technologies. It is important that these collaborations result in tangible pilots that allow rapid validation of underlying business cases.
- Raising awareness of security standards for the IIoT and other trust enabling solutions. Rapid adoption of IIoT technology requires that the concerns of industrial organisations are adequately addressed around business sensitivities in order to grow their confidence in the underlying technology base.

[188] IHS Economics / IHS Technology "The 5G economy: How 5G technology will contribute to the global economy" 2017 http://bit.ly/2rWtnta

- Support the UK Government's rollout of 5G and engage industry in the 5G test beds being developed to maximise the visibility and adoption of the technology by IDT innovators across the board (VR/AR, AI/ML, Robotics/Cobotics, Additive Manufacturing etc.)
- Delivery of training and awareness building to encourage appropriate change and influence industry to adopt and develop publicly available standards (PAS) in cyber security.

Virtual Reality and Augmented Reality

Virtual Reality (VR), which immerses users in a computer generated world and Augmented Reality (AR), which overlays digital information onto the physical world, are already reshaping existing ways of doing things and have further potential to increase productivity in engineering and manufacturing.

A recent report by Goldman Sachs Global Investment Research estimates a potential user base of 6 million engineers in the US, Europe and Japan of AR and VR, further democratising the technology. This is further backed by a global addressable ecosystem opportunity of $80bn by 2025. [189] Additionally, a recent PWC report forecasts that VR in the UK entertainment and media industry alone will reach a value of £801m by 2021, making it the fastest growing and largest VR industry in EMEA.

While AR is still in its infancy, UK manufacturing is demonstrating its desire to use this technology. The retail and marketing sectors have already widely adopted this technology, but now the manufacturing sector is realising (and driving) the enterprise adoption.

A recent PWC report identifies nearly 500 companies or institutions in the UK who have adopted or invested in VR or AR in the UK, in the past year. However, this is only the start. In 2016 UK digital tech investment reached £6.8bn, that's 50% higher than any other European country. The UK hosts a number of notable companies in the industrial VR/AR field including Autodesk, Virtalis, and Eon Reality, and it is this applied sector in which much of the future industrial value lies. The construction industry is exploiting this technology to leapfrog and modernise the whole sector through rapid training and increased quality, efficiency and safety of workers. The Construction Leadership Council believes that through digital technologies – mainly AR and VR - there is immense potential to transform the industry.[190]

The UK national body ImmerseUK (supported by InnovateUK), which was launched in 2016, is bringing together the community of industry developers, researchers, government bodies and end users to support UK in becoming the global leader in applications of immersive technologies - including high-end visualisation, VR, AR, haptics and other sensory interfaces with data. This mixed community promotes interaction between industrial sectors and incubates innovative solution development. It also allows manufacturers to have direct access to technology start-ups which may not have engineering and manufacturing as an end-user for their product. The connection between solution providers and end-users will be key to developing the UK as the leader in the development and use of applied visualisation.

VR and AR are already being used by manufacturers to support the development of complex assemblies, planning for the maintenance of equipment and products, the provision of remote expert support, and the enablement of higher quality assurance and increased productivity. For instance, when the UK division of the Hosokawa Micron Group looked to improve its productivity, the route that this innovative powder processing company chose was to couple its market leading equipment and services to the world of virtual and augmented reality, and then to harness this to data analytics. The result has been to transform a business that had appeared to plateau in terms of revenue and growth to one with a target operating income rarely seen in the industry.

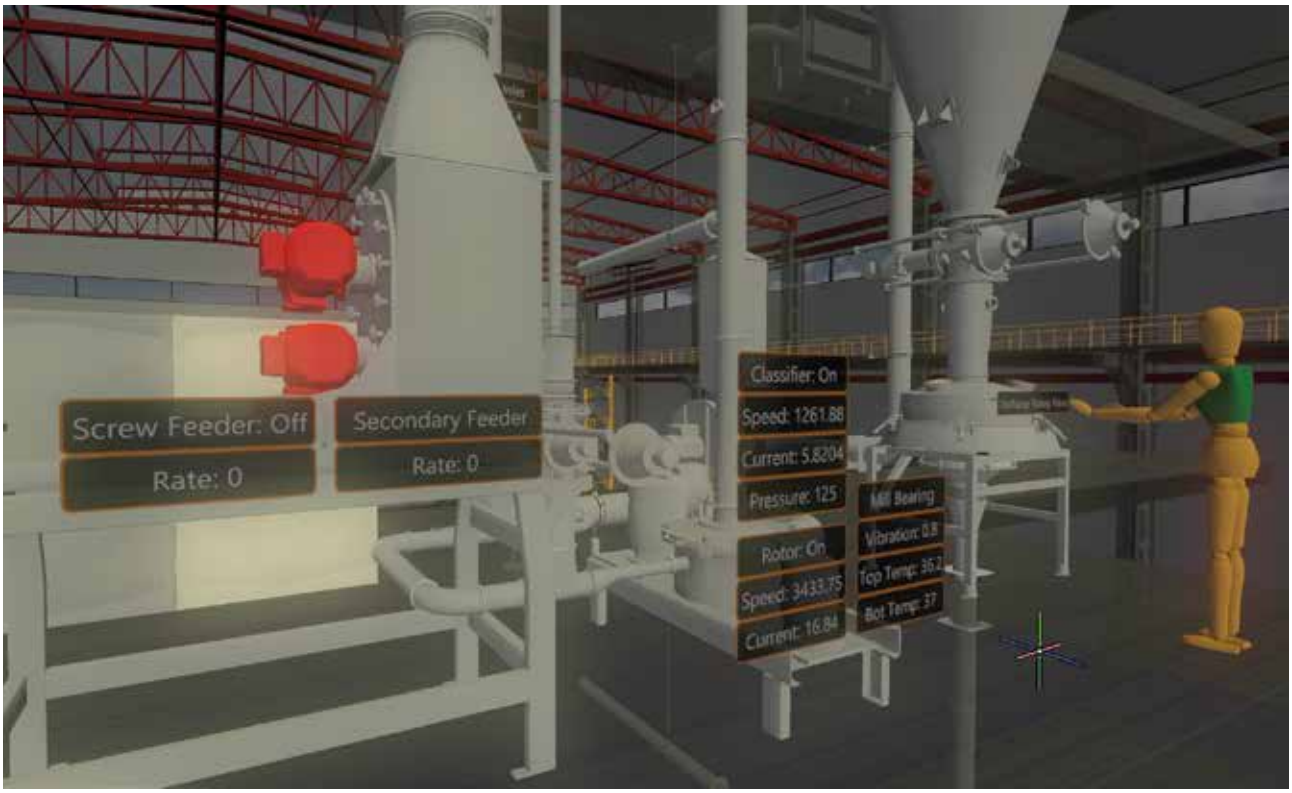
[189] Virtual & Augmented Reality: Understanding the Race for the Next Computing Platform. Goldman Sachs Global Investment Research. 13 January 2016

[190] A New Reality: Immersive Learning in Construction. October 2017

Other users include companies like BAE Systems who are using the technology developed by the video games industry to build warships for the Royal Navy more cheaply and efficiently, which directly supports the aspirations of the National Shipbuilding Strategy. [191] The defence and aerospace company has started to employ 3-D virtual reality, allowing engineers and sailors to "walk" through life-size computer-generated versions of the ships they areworking on.

It is in these potential scenarios, from validating design (VR), to virtually prototyping manufacturing processes (VR), to validating assembly procedures (VR/AR) and delivering operational support (AR) where true value will be obtained. The strategy to 'fail fast, but fail virtually' and provide a 'many to one' support through the adoption of virtual and augmented reality is where true productivity gains can be made.

The UK has both the capability to deliver truly innovative VR and AR solutions and the capacity to lead the way in the adoption of these technologies to help drive UK productivity to new levels.



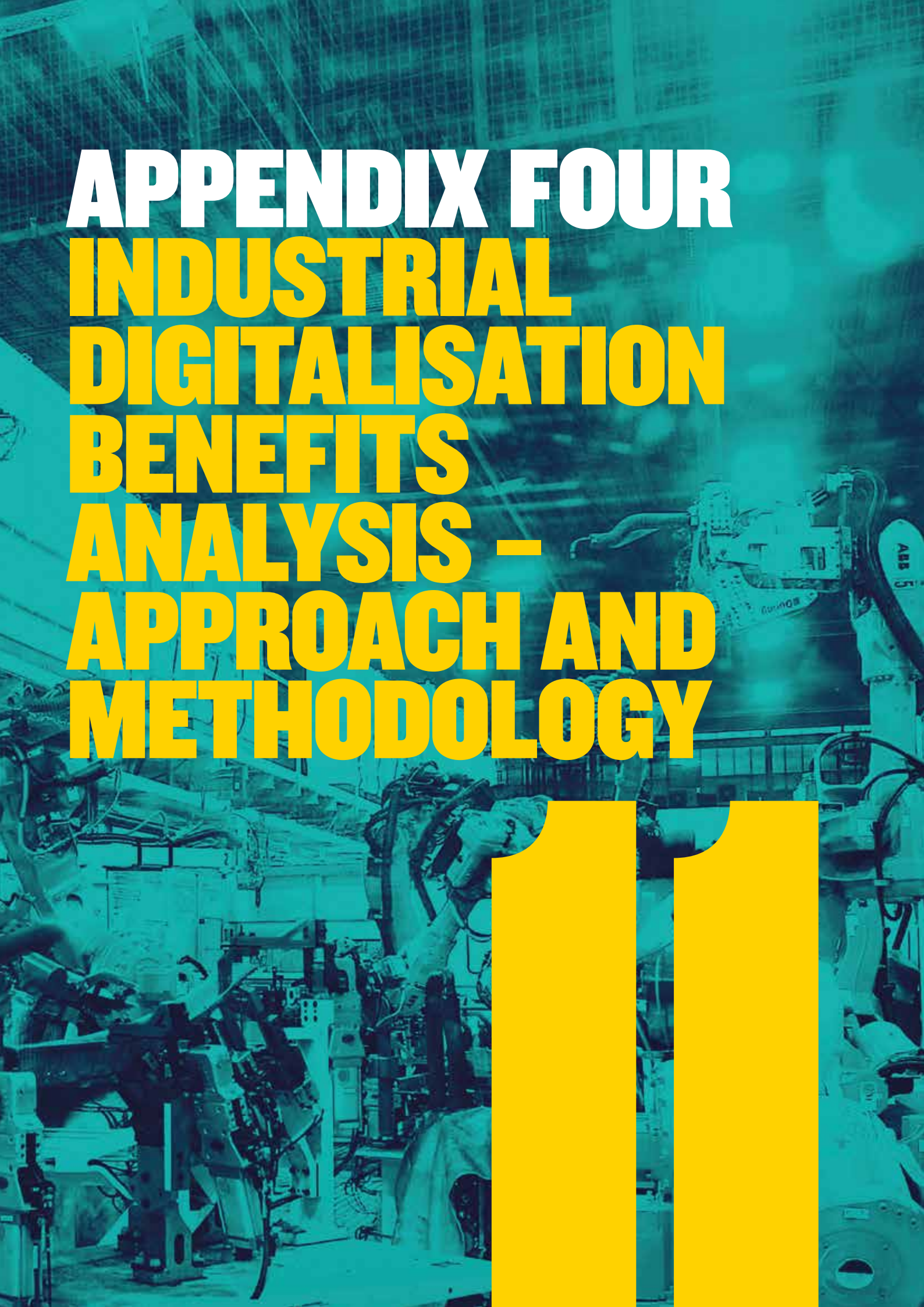
Hosokawa Digital Twin VR model

[191] National Shipbuilding Strategy: The Future of Naval Shipbuilding in the UK. September 2017

VR/ AR Heat Map

APPENDIX FOUR

INDUSTRIAL DIGITALISATION BENEFITS ANALYSIS – APPROACH AND METHODOLOGY



Appendix 4

Industrial Digitalisation Benefits Analysis – Approach and Methodology

INTRODUCTION

In collaboration with industry, government and academia, Accenture analysed the economic and societal impact of digital technologies within UK manufacturing to support the recommendations of the Industrial Digitalisation Review. This 'value at stake' analysis aims to serve as a directional framework for further action and assessment from both government and industry.

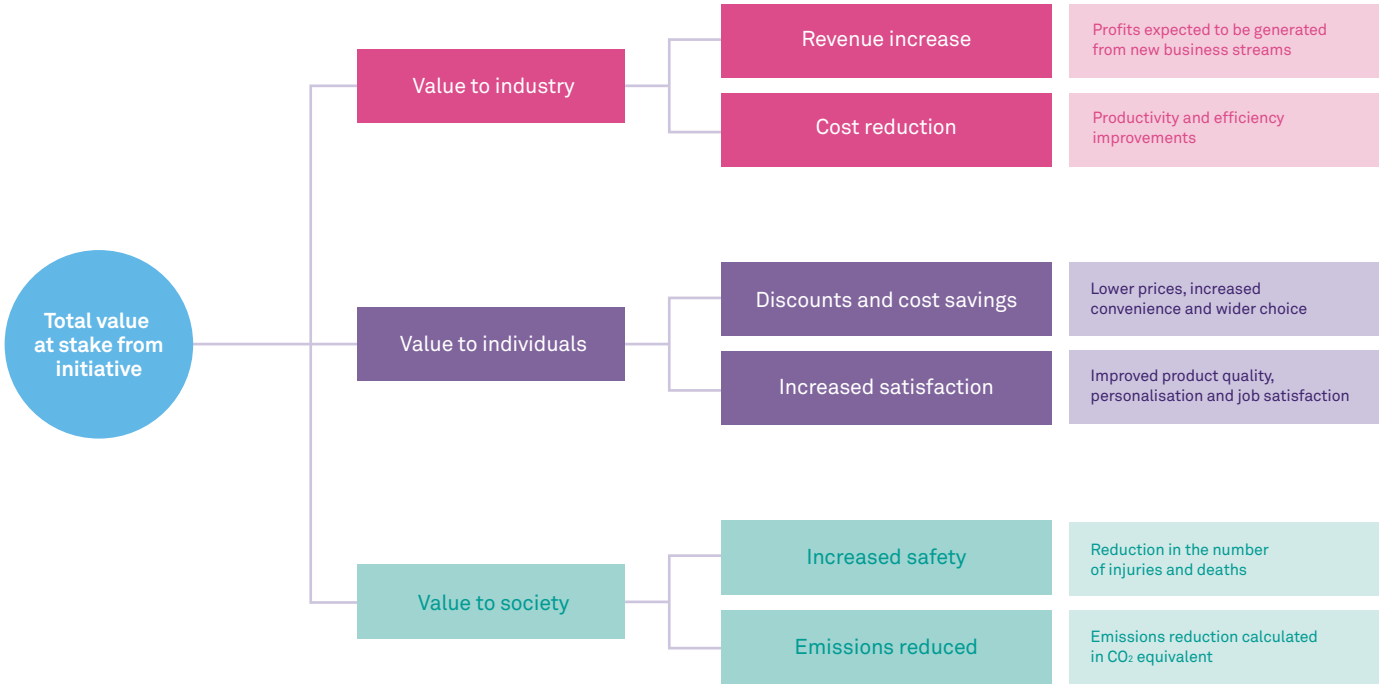
APPROACH

For the benefits analysis, Accenture brought together a unique working group for each industry sector (Aerospace, Construction, Food and Drink, Pharmaceuticals) and Technology, (Additive Manufacturing, Artificial Intelligence, Automation and Robotics) analysed. Working groups combined key stakeholders from UK manufacturing companies, academia and Accenture technology and industry experts.

During a series of workshops, the working groups created a list of use cases that could be applied over the next ten years. These digital use cases form part of the larger digital themes that relate to some of the major trends powering digitalisation.

VALUE AT STAKE FRAMEWORK

To quantify the benefit of these use cases to business and society, we used a value at stake analysis framework developed in partnership with the World Economic Forum. An illustrative example is shown below.



Value at Stake framework

Digital value to industry

Value at stake for an industry comprises of two elements; revenue increase and cost reduction. Within this, value to industry could either be value addition or value migration:

- Value Addition: The potential impact on an industry's (pre-tax) operating profits that will be generated as a result of implementing digital initiatives.

  e.g. a new revenue stream created by selling valuable data collected in the food and drink manufacturing process could potentially create new demand as other companies along the supply chain could optimise their operations using analytics. As such, this new demand would predominantly be value added to the economy.

- Value Migration: Operating profits that will shift between different industry players.

  e.g. additive manufacturing could be used to create building parts that are challenging to construct on-site. As demand for additive manufacturing increases, this may decrease construction companies' demand for specialist builders who are skilled in these types of activities. This loss of demand could potentially net out some of the value created from the introduction of additive manufacturing in construction.

Digital value to individuals

Value impact for individuals is the potential gain to individuals (B2C) in the form of cost and time savings, as well as increased job or customer satisfaction.

Digital value to society

Includes benefits to the wider environment, as well as society. Each element is measured as follows:

- Value impact for society: the impact of digital initiatives, e.g. lives saved (these vary by industry).
- Value impact on the environment: the estimated impact of digital initiatives on increasing or reducing emissions of CO2 and other gases (these vary by industry).

APPLICATION OF VALUE AT STAKE APPROACH

The value at stake approach is further explained as follows:

1. Define the value drivers that impact industry and society: with input from the working groups, 70+ digital use cases for industries and 40+ for technologies that could impact manufacturing over the next decade were identified. The value at stake framework was then used to categorise these initiatives (i.e. value to industry or environment).
2. Uplift factors for value at stake were calculated: The modelling team found uplift factors for each use case. When calculating the uplift factors, several checks were performed to ensure the uplift factors were mutually exclusive, applied an addressable market and had multiple data points that supported the assumptions made.
3. Apply uplift values to the baseline over 10 years: Uplift factors were then applied to the related industry baselines. The baseline forecasts for value to industry were based on ONS manufacturing growth examined over the last 10 years.
4. Apply adoption rate of technology over 10 years: The next step was to assume an adoption rate (or uptake) of the digital technologies for each industry. Each working group had the chance to provide feedback on whether they thought the adoption rate would be linear or exponential and over what timeframe. After application of the adoption rates, aggregate value at stake was calculated for the 10-year period.
5. Testing, revision and validation of assumptions and results with academics, economists and IDR working group members.

Comparison of findings with other studies

Our approach to estimating value at stake was limited to a range of industries and technologies and therefore may not be directly comparable to other studies.

Despite these scope limitations, we identified reports that are held in high regard by industry participants and are cited for their contribution to quantifying the future benefits of digital and its role in industry 4.0. Among others, reports include BCG's analysis of the UK's readiness for the 4th industrial revolution, PwC's industry 4.0.

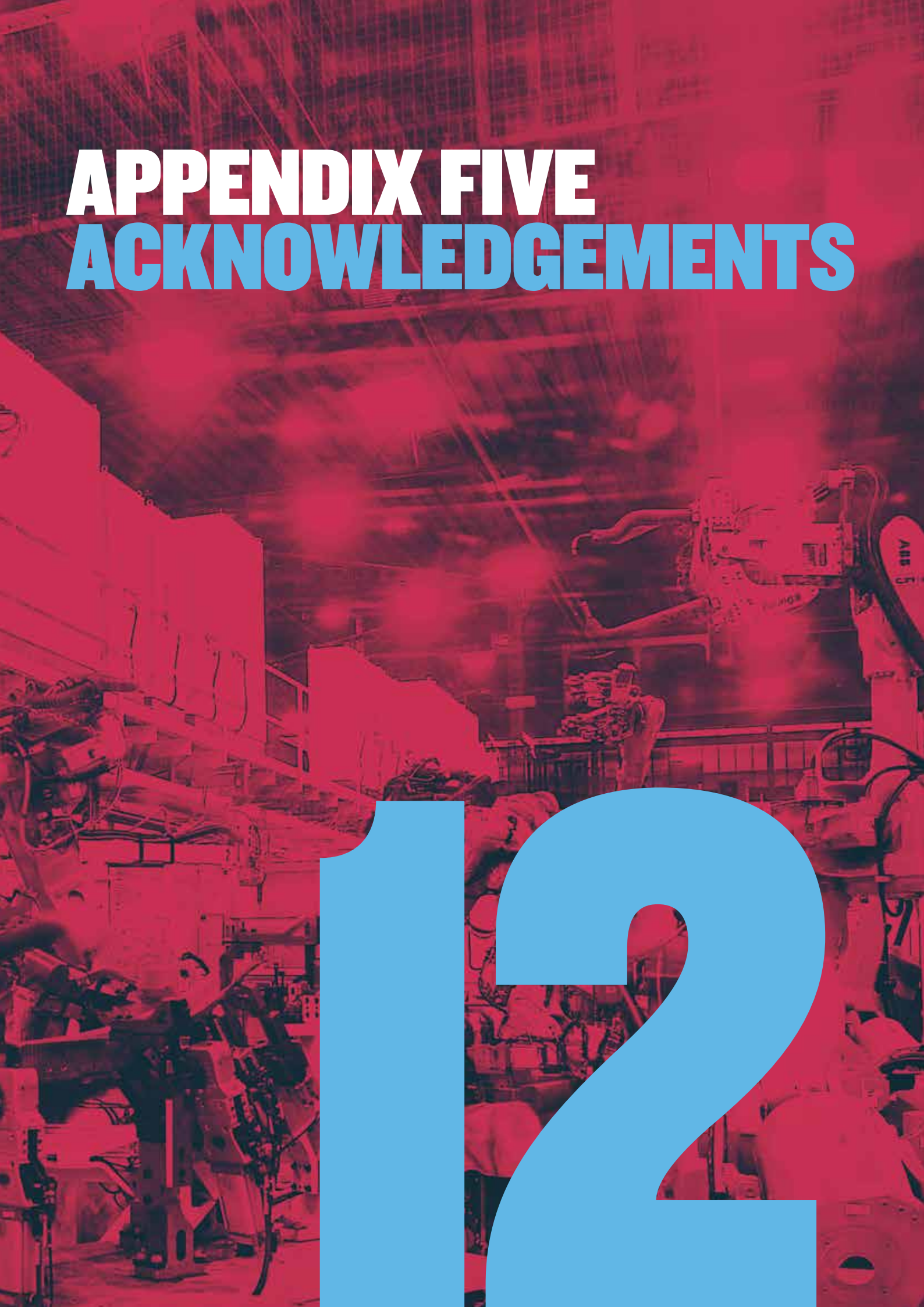
AREAS OF COMPARISON

1. Size of the opportunity for UK manufacturing industry: Triangulation of data points with alternative reports confirm the size of the opportunity identified seems to be in line with other studies. BCG estimates a 0.5% increase in annual GDP by 2025[165], whilst PwC estimate a revenue increase of 2.9% and cost reduction of 3.6% annually[166]. Most reports also agree that benefits could be much higher with a clear national strategy that supports the UK's industrial digital transformation plans.
2. Size of the opportunity for UK society: Few reports analysed consistently compare the benefits of digital to society as well as to industry. As mentioned within this report, the value to society from implementing digital technologies are likely to be significant in terms of reducing carbon emissions, waste and workplace incidents.
3. Proportion of value realised from cost savings compared to new revenue streams: The reports mentioned find that cost reduction opportunities are significant and proportionally higher in value than new revenue streams. BCG analysis suggests that the UK could realise industrial efficiency gains of 25%, with manufacturing sector growth of 1.5-3%. Similarly, PwC estimate cost reduction to be 0.7% higher than revenue increase. This is in line with the IDR findings presented in this analysis.

The detailed analysis can be found at: http://industrialdigitalisation.org.uk/industrial-digitalisation-review-benefits-analysis/

[165] Source: https://media-publications.bcg.com/Is-UK-Industry-Ready-for-the-Fourth-Industrial-Revolution.pdf

[166] Source: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page industry-4.0-building-your-digital-enterprise-april-.pdf



APPENDIX FIVE
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12

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BABCOCK
BAE SYSTEMS
BAKKOVAR PLC
BARCLAYS
BBC
BOSCH
BEIS
BERRY GARDENS
BOC
B&R AUTOMATION
BCS
BENTLEY MOTORS
BP
BRE GROUP
BROMPTON BICYCLE
BSMIMPACT
BSI
BT
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CAMBRIDGE UNIVERSITY
CAPGEMINI UK
CARILLION
CARRS
CENSIS
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CFMS SERVICES
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DFE
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EVRI INSIGHT
FORECAM
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GAMBICA
GE AVIATION
GKN
GLAXO SMITHKLINE
GREATER LINCOLNSHIRE
GREEN-ALLIANCE
GOOGLE
GSK
HACKNEY COMMUNITY COLLEGE
HERIOT-WATT UNIVERSITY
HEWLETT PACKARD
HENNIK GROUP
HOME OFFICE
HOSOKAWA
HOWDEN HPE
HP
HSBC
IBM
IET
IFS
IG GROUP PLC
IMI PRECISION
IMS LTD
IMS EVOLVE
INNOVATE UK
INTEL
INVMA
IQE
IQEP
ISHIDA
JDR CABLES
JJ CHURCHILL
JLR
JOHN LEWIS PARTNERSHIP
JP MORGAN
KEB UK
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LANCASTER UNIVERSITY
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LEONARDO
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LLOYDS BANK
MANUFACTURE AI
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MCCANN ENTERPRISE
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MERCKS
MICROSOFT
MIDDLESEX UNIVERSITY
MOTT MACDONALD
MTA
MTC
MTL INSTRUMENTS
MULLEN LOWE GROUP
NATIONAL GRID
NETWORK RAIL
NEWCASTLE UNIVERSITY
NISSAN
NOTTINGHAM UNIVERSITY
NORTH EAST AUTOMOTIVE ALLIANCE
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OCF
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PSE
PTC
PWC
QUICKSILVA
RA ENG
RAS COUNCIL
RAYNORS
RELIANCE
RENISHAW
RESONATE GROUP
ROBINSON BROTHERS
ROCKWELL AUTOMATION
ROLLS ROYCE
ROBERT BOSCH
ROYAL ACADEMY OF ENGINEERING
SAP
SAFRAN
SEMTA
SFIA FOUNDATION
SHOP DIRECT
SIEMENS
SMMT
SONY
SSE ENERGY
STARTUPBOOTCAMP IOT
SUMMIT ENGINEERING
SYCORA RESEARCH
TATA CONSULTANCY
TECHCITY
TECH UK
TECH PARTNERSHIP
TELEFONICA
THALES
TESCO PLC
THE ITP
THE MANUFACTURER
TOYOTA
TRANSPORT FOR LONDON
TRAVIS PERKINS
TRIDIUM EUROPE
TUI GROUP
TWI TWO SISTERS PLC
TWI
UNIVERSITY COLLEGE LONDON
UCLH
UNILEVER
UNIVERSITY OF LIVERPOOL
UNIVERSITY OF SHEFFIELD
VMWARE
VERSON
WALES QUALITY CENTRE
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WINSAFEL LTD
WIPRO
WORK FOUNDATION
WOOGIE
XEREDIA UK
XPERTRULE
XPERTRUME
VERTIZAN