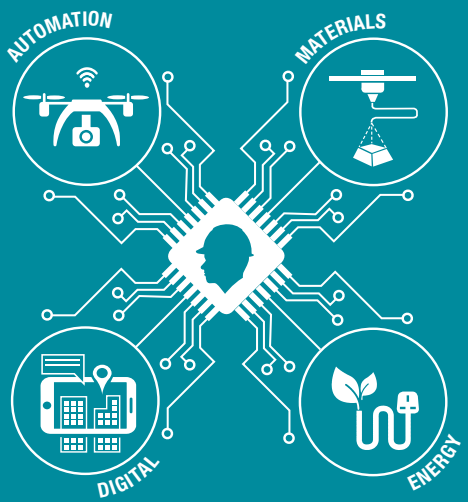
mace

INSIGHTS 2017

MOVING TO INDUSTRY 4.0

A skills revolution



Mark Reynolds
Chief Executive

Appointed Mace's Chief Executive in January 2013, Mark has been a member of the Group Board since the management buyout of the company in 2001.

His vision is for Mace to lead the industry through innovation, be a major British exporter of construction services, deliver a consistent high quality service to clients and ensure that Mace continues to develop, attract and retain the very best people in our industry. Mark gained his early experience in the commercial sector on the Broadgate and Ludgate developments in London, later moving on to projects with BAA.

He was the Deputy Programme Director for the London 2012 Olympic and Paralympic Games, reported as the best ever delivered venue in the history of the modern Olympics.

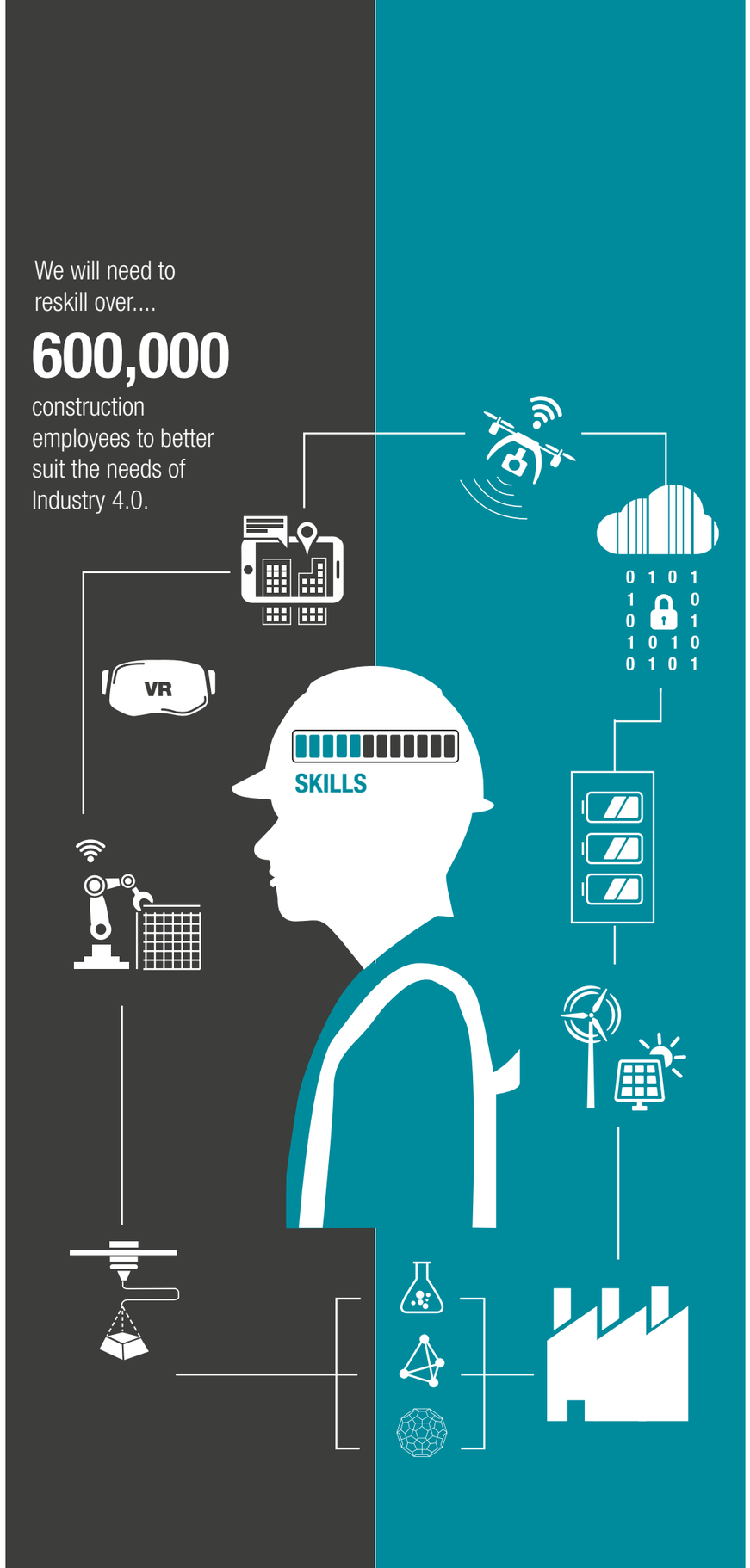
Since 2016 Mark has sat on the board of the widely respected business body London First. In 2017 he was appointed to the UK Government's Construction Leadership Council heading up the skills workstream.

Matt Gough
Director of Innovation and Work Winning

Having joined Mace in 2011 to lead the company's work winning activity, Matt was recently promoted to the Director of Innovation in February 2017.

His role, owning the company innovation strategy, and helping to embed a culture of innovation throughout the company, is supporting Mace to realise its ambition to be the catalyst for the next evolution of the construction industry.

Matt has supported the top line growth of our construction business from £600m to £2bn in 2017, and he played an important role in some of the business' biggest wins during that time. His career started in digital, having studied computing as part of his BA degree, and he is now aligning Mace's interests with the innovation and technology being driven by the digital sector, as part of the transition to Industry 4.0.



The construction industry's lacklustre productivity levels and need for radical productivity improvements are well known across the sector. Over the last decade output per worker has remained flat in construction, whereas the service sector has improved by just over 30% and output in manufacturing has rocketed by more than 50%.

However, this is set to change. According to experts we are now on the verge of a fourth industrial revolution or 'Industry 4.0'. A move to a world in which technology from artificial intelligence to advanced robotics to autonomous vehicles will transform how businesses operate and how buildings are created.

This revolution should radically improve the productivity levels of our industry, improve quality, safety and our impact on the environment. But to seize the opportunities presented by these emerging technologies we will have to embark on a training programme unlike any other our industry has seen before.

Our new analysis estimates that we will need to reskill over 600,000 construction employees over the next two decades, from trades vulnerable to technological change to new roles created by technology.

This report looks at the roles and areas of projects most likely to be affected in the near future, and how we can overcome the challenges in moving to Industry 4.0. More specifically, it examines the challenge we face in making sure that our workforce has the skills and talents required for the century ahead of us, rather than the previous one.

If we are to rise to this challenge, we need to start now. This isn't a problem we can address on our own. Industry must work with training and education providers, there must be a shift away from the traditional trades to skills for the future, training programmes need to be developed and approved quickly by the Institute for Apprenticeships, so that the apprenticeship levy can be used as it is intended – to increase skilled employment.

We must develop innovative ways to not only attract and train the workforce of the future, but also retrain the existing workforce. The industry and policy makers need to create the right environment for a more productive and efficient construction industry that provides world beating value and solutions to help power our economy in the future.

We make a series of recommendations that include lifelong learning, changes to training programmes and the accelerated use of new technology in training. These suggestions are only a start. The construction sector is going to look very different in a decade or two – and so is its workforce. The challenges and opportunities ahead are vast, and to succeed we will need to work together or face a skills cliff-edge.

Mark Reynolds
Chief Executive

THE PROBLEM AND THE OPPORTUNITY TO SOLVE IT

For many years, the poor practices prevalent in the construction industry have hindered our productivity performance. Inadequate design processes, poor project management, insufficiently skilled labour and underinvestment in digitisation, innovation and capital are all parts of the problem.[i]

This means that the construction industry needs to undergo wholesale change if its productivity performance is going to improve.

The good news is that the beginning of a fourth industrial revolution provides a huge opportunity for this much needed improvement to happen. And it is expected that it will be no less transformative than the three that have come before it. The first saw a shift from agriculture to urban industrialisation through the use of water and steam power. The second saw the transformative power of electricity used to develop mass production techniques. The third adopted digital technology to automate production.[ii]

The move to Industry 4.0 will be built on a range of new technologies that can connect the physical, digital and biological worlds. Artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing and nanotechnology are going to completely transform the business and consumer landscape.[iii] These innovations and new technologies have enormous potential for construction, from redefining how cities are planned and buildings are built, to reimagining how people interact with property and infrastructure.

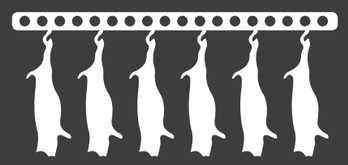
Although the potential is vast, the benefits are by no means guaranteed. The challenge is how we can overcome the construction industry's poor track record on innovating and adopting new technology.

INDUSTRY 4.0
The fourth industrial revolution [ii]

1st INDUSTRIAL REVOLUTION

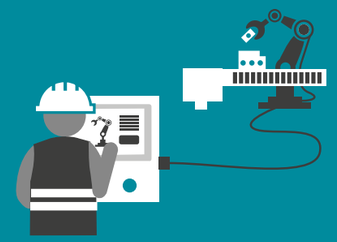
Mechanisation driven by water and steam power
1780s: first mechanical loom.

2nd INDUSTRIAL REVOLUTION



Electricity/mass production
1870: first assembly line (Cincinnati slaughter house).

3rd INDUSTRIAL REVOLUTION



Computer automation
1969: first programmable logic controller.

4th INDUSTRIAL REVOLUTION

Cyber physical systems
Tomorrow: Internet of Things, connecting everything.

Critical to meeting this challenge is making sure that the industry has the skills to take advantage of Industry 4.0. This extends across the entire construction workforce, from the CEO making decisions about investing in new technology to the operative onsite piloting a drone. Ultimately, it is the decisions, actions and capabilities of people that will allow the construction industry to exploit the fourth industrial revolution and its possibilities.

This is the focus of this report – understanding what the construction industry needs to do now so that its workforce has the skills to take advantage of Industry 4.0 in the future.

The report is structured as follows:

- A look at how innovation and new technology in the manufacturing industry and financial services sector are affecting skills requirements.
- Survey analysis of some of the technology that is likely to change how the construction industry works.
- Our projections of how innovation and technology within the construction industry could change the composition of its workforce.
- Policy recommendations that will help prepare construction for Industry 4.0.

The fourth industrial revolution is already changing how other sectors do business. The two very different case studies which follow provide insights into how Industry 4.0 is affecting the workforce skills needs of both manufacturing and financial services and what construction could learn.

Manufacturing – a long history of innovation

The story of modern manufacturing begins in the 19th century, when mechanised factory production displaced the work that had previously been undertaken by highly skilled craftsmen. Production became a series of small and simple tasks, completed in sequential order by workers on an assembly line. This allowed more to be produced at a lower cost.[iv]

This trend continued into the early part of the 20th century, until the people who performed the repetitive tasks began to be replaced by robots. One consequence of this productivity gain was that employment levels in manufacturing went into steady decline, and continued on a downward trajectory into the 21st century.

The decline in manufacturing jobs has not just been driven by automation but has run alongside a wider evolution of the industry. Many companies now combine the manufacturing process and the servicing of the products that they make.

Indeed, one analysis has found that 10% of the decline in manufacturing employment in the period 1998–2006 was explained by manufacturing jobs being reclassified as service jobs.[v]

The move to Industry 4.0 is likely to create another step-change in how the manufacturing industry operates, including the use of:

- **Sensors**
  35% of US manufacturers are currently collecting and using data from sensors to improve performance.[vi] The data helps to monitor factory operations, manage workforce and supply risks and enhance the design process.[vii]
- **3D printing**
  In automotive production 3D printers have been used to both speed-up the prototyping and production of vehicle parts.[viii] As an indication of where the future of 3D printing might lie, Amazon has filed several patents that are part of a plan to print 3D goods on demand (in some cases even from inside delivery trucks).[ix]
- **Augmented reality**
  Complex assembly can be supported by instructions being in a worker's field of vision at all times.[x]

A recent survey found that only...

35%

of manufacturers are currently using data from sensors to improve performance.[vi]

With...

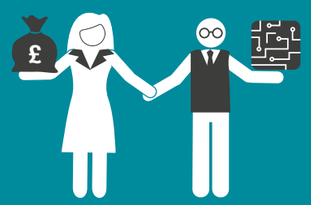
78%

of Fintechs saying that coding was one of the most difficult skills to find.[xvii]

Incumbent financial institutions are developing talent by proxy...

82%

expect to increase their Fintech partnerships in the next 3–5 years.[xx]



The adoption of these technologies is becoming widespread, and the manufacturing workforce needs to adapt. When manufacturers were asked about how their future skills needs would change as a result of innovation, this is what they said:[xi]

- The lines between traditional job roles are becoming blurred. For example, IT skills will no longer sit in a single department, and engineers will become specialists in digital technology.
- The number of generalist roles could increase. Tools such as augmented reality wearables can act as a substitute for, or complement, existing skill sets, allowing workers to become more adaptable to different tasks.
- Attracting younger generations to the industry has become more important. The journey towards greater digitisation can be supported by employing those who have grown up using technology.
- A changing industry has a diverse set of skills needs. In the future, advanced manufacturers expect that they will need: employees who can make judgements on the benefits of new technologies; a stock of highly skilled workers that can contribute to the R&D process; more access to software developers; and, a workforce that has generic IT literacy. [xii]

Despite the manufacturing sector having already benefited from innovation and new technology in the past, it is clear that it also has a long way to go to be regarded as effectively transitioning to Industry 4.0.[xiii] One survey of manufacturing companies found that nearly three-fifths of respondents did not have a director or senior manager with responsibility for developing and implementing new technology.[xiv] Another found that only 4% of Swiss manufacturers had the skills they needed to implement Industry 4.0.[xv]

Financial services – a skills challenge for the established players

Technology is changing every part of the financial services industry. Retail banks are retreating from the high street as people increasingly conduct their banking online. For example investment banks undertake 'high-frequency trading', which uses computer algorithms to analyse markets and to execute orders. Insurers are using smartphone apps to monitor driving performance, which then allows safer drivers to be rewarded with lower premiums.

This is not just about the established players in the industry. All over the world financial technology start-ups (so-called 'Fintechs') are disrupting traditional methods of processing payments, lending, borrowing and managing money. In doing this, they are producing some undeniably positive outcomes. People in less developed countries can now securely transfer money with a mobile phone, travellers can avoid expensive fees when buying foreign currency for trips abroad, and businesses can use the pooled resources of thousands of individual investors to get a loan.

This use of Fintech – or at least some applications of it – is growing at an incredibly rapid rate and is moving into the realms of mass market adoption.[xvi] It has without question led to wholesale change in the skills needs of the industry:

- Fintech firms need coders and software developers. The biggest challenge that Fintech firms face is attracting qualified or suitable talent. In a recent survey, 78% of Fintechs ranked coding and software development in the top three of the most difficult skills to find when recruiting.[xvii]
- The incumbents have had to adapt. The established financial institutions have had to learn how to encourage innovation, and how to manage talent that can encourage and embrace new technology.[xviii]
- Digital skills are seen as a priority in a post-Brexit world. The City of London is currently lobbying for a 'digital skills visa' to shore up the UK's position as a Fintech hub.[XIX]

The final thing to note is that, rather than develop their own talent, incumbent financial institutions are developing it by proxy – 82% expect to increase their Fintech partnerships in the next three to five years.[XX]

The move to Industry 4.0 is beginning to transform the construction industry, just as it has begun to transform the manufacturing and financial services industries.

Innovation in material sciences, nanotechnology and robotics should fundamentally change how property and infrastructure is designed and built. Technologies such as autonomous vehicles, artificial intelligence and the Internet of Things promise to change how humans interact with the built environment and how the built environment interacts with humans.

To better understand the change anticipated from the innovation of the fourth industrial revolution, we conducted a survey of those working within the construction industry. The survey sought to better understand three core aspects of change:

1. Which areas of the property/asset life cycle we might expect to be most impacted by new technological innovation.
2. When we might expect that change to occur.
3. The current skills capability within the industry to adopt the change.

Looking across the 12 specific areas of innovation anticipated as part of Industry 4.0, three key themes arose.

A challenge for every part of the property/asset life cycle

The survey results make clear that every stage of the property/asset life cycle will be affected by Industry 4.0, but that some would naturally be affected more than others. Taking all 12 possible innovations into account, 38% of responses indicated that the 'assemble/build' life cycle stage would be most impacted, followed by 'operate' (22%), 'design' (21%), 'procure' (7%) and 'brief' (3%).

In addition, the results indicate how much each technology is likely to affect different professions within the construction industry. Respondents suggested that augmented or virtual reality will have the most significant impact for designers and architects. Advanced offsite manufacturing and robotics will have the most significant impact for builders. Advanced energy creation and storage and the Internet of Things will have the most significant impact for facilities managers.

A skills shortage in the areas that matter

The three innovations that respondents expected to have the most impact across our industry were:

- Augmented or virtual reality
- Advanced data and analytics
- Advanced energy creation and storage

83% of respondents felt that advanced data and analytics would reach widespread adoption over the next five years, 77% felt that augmented or virtual reality would and 75% felt that energy creation and storage would.

But when asked about the extent of the skills gaps that could hinder the adoption of them, a clear majority felt that the gaps were either severe or moderate. This suggests that there is only a short amount of time for the industry to understand, plan and deliver the training that it needs to accommodate these new technologies.

More generally, two thirds of respondents felt that skills gaps were either severe or moderate when all 12 innovations were considered.

The known unknowns of innovation

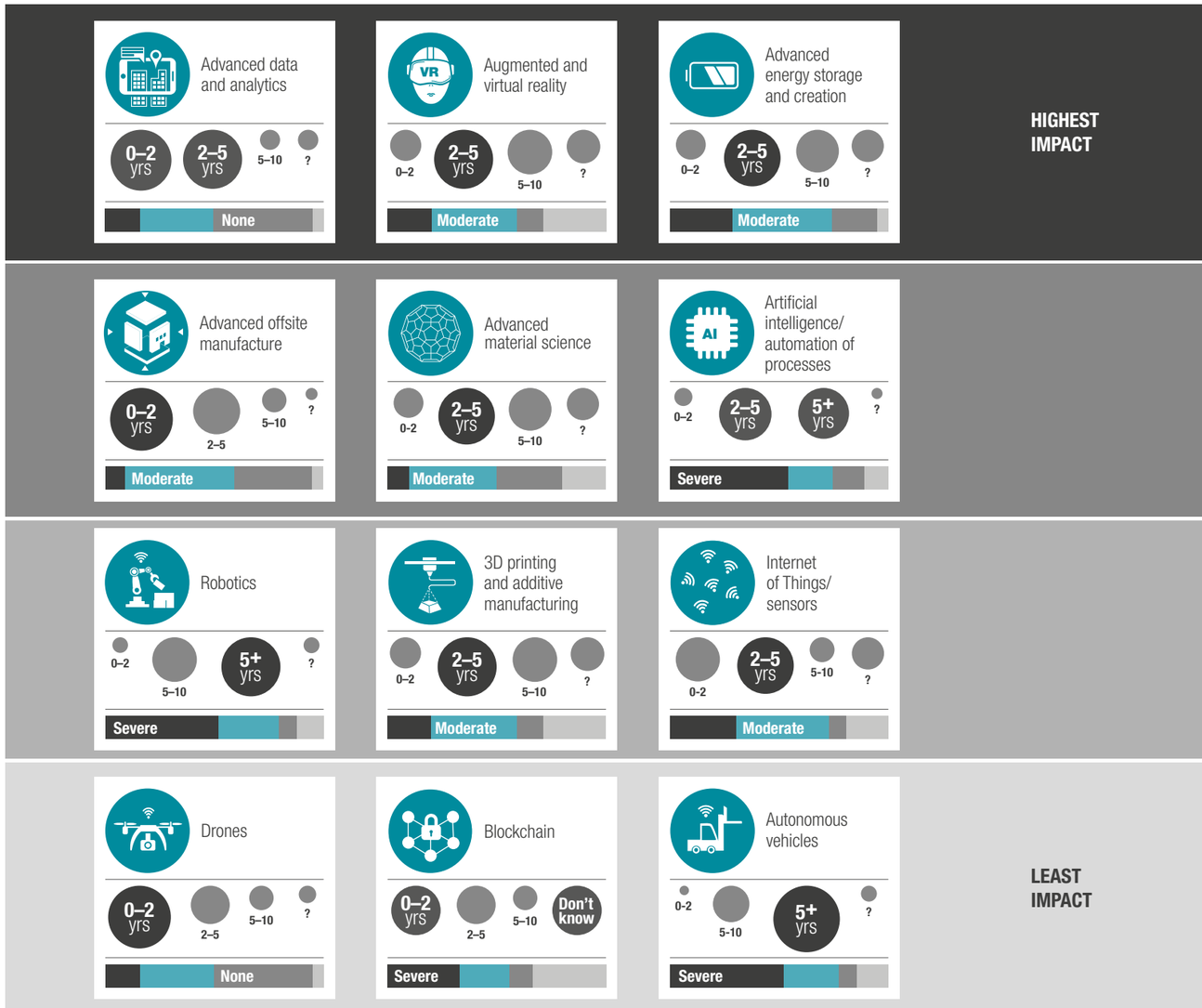
The three innovations that had the largest amount of uncertainty surrounding them were clear in the results. These were:

- Blockchain technology
- The Internet of Things
- Advanced material science

Respectively, 29%, 21% and 20% of respondents 'didn't know' when these innovations may impact the construction industry. And 34%, 20% and 20% 'didn't know' the extent of the skills gaps that existed for them. These proportions were far higher than for any of the other innovations that respondents were asked about.

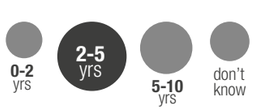
The impact of technology and innovation from Industry 4.0

We surveyed a number of clients, partners and suppliers to get an understanding of which technologies we expect to positively impact and when, and whether the industry has the skills to maximise the opportunity.



KEY

Estimated timescale of wide spread adoption



Area chart shows % of respondents and highlights the most popular response.

Estimated skills gap

Bar chart shows % of respondents and highlights the most popular response.

As the survey results of the previous chapter demonstrate, understanding how the skills needs of the construction industry will change in response to innovation and technology is not straightforward. Nevertheless, it is possible to set out illustrative examples of how skills needs might change.

New analysis done by a former Bank of England economist for this report provides one such example, and presents how innovation and technological advancement could change the composition of the construction industry's workforce under different scenarios.

The construction skills most vulnerable to innovation and technology

A changing industrial landscape will change the skills needs of a workforce.

For example, in Britain between 1979 and 1999 the number of rail signal operatives and crossing keepers fell from 13,800 to 3,600.[xxi] This decline happened in tandem with advancements in railway signalling technology, which was driven by the growth in affordable computing power at the beginning of the 1980s.[xxii] Over the same period – and also as a result of the growth in affordable computing power – the number of software engineers in Britain grew from 34,000 to 171,800.[xxiii]

The question is: which skills are likely to be less in demand as a result of innovation in the construction industry?

Recent research has tried to answer a similar question by measuring the likelihood of different occupations being automated. It found, for example, that in the coming decades managers in the construction industry have a very low probability of being automated, but that roofers have a very high probability of being automated.[xxiv]

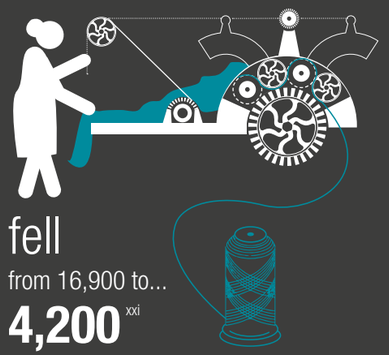
In Britain between 1979 and 1999 the number of coal mine labourers...

fell

from 29,800 to...

1,800[xxi]

In the textile industry, the number of spinners, doublers and twisters...

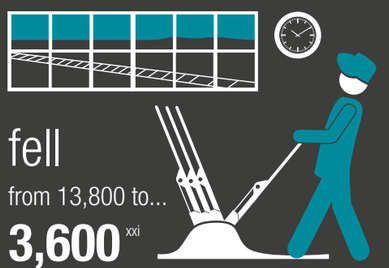


fell

from 16,900 to...

4,200[xxi]

Rail signal operatives and crossing keepers...

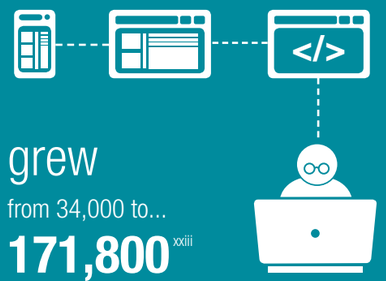


fell

from 13,800 to...

3,600[xxi]

In contrast, between 1979 to 1999, the number of software engineers...

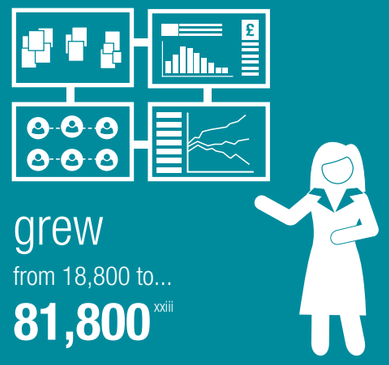


grew

from 34,000 to...

171,800[xxiii]

Management consultants and business analysts...



grew

from 18,800 to...

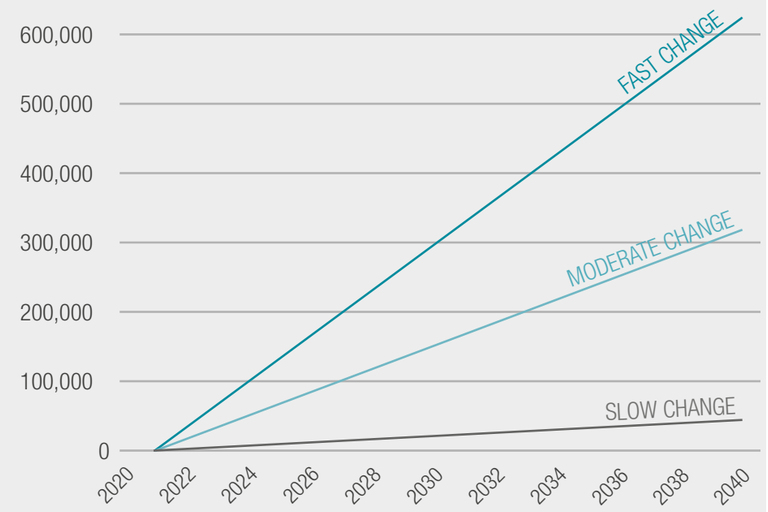
81,800[xxiii]

Building upon these conclusions, the analysis for this report applies downward trends to the construction jobs that are susceptible to automation. The downward trends are based on rates of occupational decline that have occurred under previous instances of industrial change. The trends are used to present scenarios of the impact of slow, medium and fast-paced technological advancement.

The proportion of construction jobs that could be replaced by automation under each scenario over a 20 year period is shown in the chart below.

The analysis for this report looks at the top ten construction occupations most vulnerable to the innovation of Industry 4.0, and how the different scenarios of technological advancement set out above would affect them. The full results, including the specific occupations affected, are presented in Appendix I. The main takeaway, however, is that the number of people working in occupations such as plastering, bricklaying and labouring is likely to fall by tens of thousands of people in the next 20 years.

Number of construction jobs affected at different rates of technological change over a 20 year period



FAST CHANGE Based on the loss in railway signalling jobs (1979–1999)

MODERATE CHANGE Based on the loss in manufacturing jobs (1979–1999)

SLOW CHANGE Based on a 5% loss in jobs over 20 years

This should not be interpreted as the threat of mass redundancies, but rather as an opportunity for reskilling workers and address the need to find a million more workers by 2024. For example, while the overall number of jobs fell over the last 20 years in manufacturing, there was substantial growth in other roles and different sectors.

The reskilling and productivity opportunity

As the vulnerable occupations and their associated skills become less in demand, the opportunity to reskill employees whose jobs have been affected by innovation and technology is created. Evidence from the manufacturing industry suggests that employers believe that retraining and reskilling is integral to realising the benefits of Industry 4.0.[xxv] Not only this, but employees are also aware that a changing economy will require them to retrain at some point in the future.[xxvi]

By taking into account natural workforce attrition and the construction industry occupational change that would happen naturally, we have calculated how many construction employees may be available to reskill in the period up until the year 2040:

- Under a scenario of relatively slow technological change, there will be the opportunity to reskill 40,690 construction employees.
- Under a scenario of moderate change, there will be the opportunity to reskill 309,270 construction employees.
- Under a scenario of fast-paced change, there will be the opportunity to reskill 602,260 construction employees.

A full methodology for how these numbers were derived can be found in Appendix II.

It is important to reiterate that the above are illustrative examples. While innovation will inevitably change the way that the construction industry works, the types of technology that will develop and disrupt established ways of doing things in the coming decades is difficult to predict.

Despite this, the fundamental point remains. The steady decline in demand for some skills presents the opportunity for workers to make their skill sets more relevant to the innovation and technology of Industry 4.0.

In turn, this means there is an opportunity for the construction industry to realise productivity gains. There is a gap between the productivity growth of the construction industry and that of the whole economy (the whole economy outperforms the construction industry). If this gap could be halved by addressing skills needs over the next 20 years, the end result would be construction industry output being £25bn per annum higher than if it was not addressed.

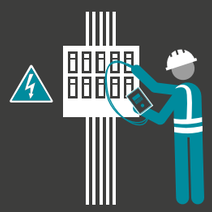
The jobs the construction industry may wish to retrain in

The recent CITB report on which our analysis is based highlights how the construction workforce is likely to change. It suggests that to meet the expected output to 2021, the industry needs to recruit 5,240 employees every year in the occupation category defined as 'non-construction professional, technical, IT and other office-based staff'. This annual recruitment rate is almost twice as many as any other job specification. It far outstrips the needs for plasterers (790 per year), construction trades supervisors (1,440 per year) and even architects (470 per year).[xxxiii]

Fast paced change would have a significant impact on skills and occupations over the next 20 years...

Specialist building operatives would fall from 55,480 to...

3,280

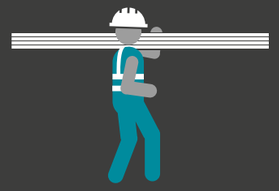


Roofers would fall from 43,830 to...

2,590

Labourers would fall from 127,220 to...

7,520



Wood trades and internal fit out would fall from 262,920 to...

15,550

Floorers would fall from 25,580 to...

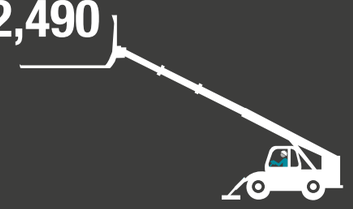
1,510

Bricklayers would fall from 72,760 to...

4,300

Plant operatives would fall from 42,040 to...

2,490

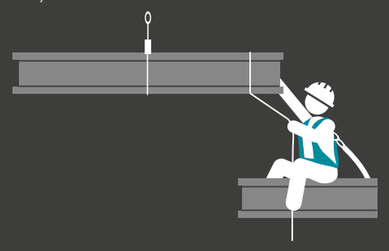


Plasterers would fall from 47,500 to...

2,810

Steel erectors/structural fabricators would fall from 25,450 to...

1,500



Painters and decorators would fall from 111,080 to...

6,570

ACTIONS TO MEET THE CONSTRUCTION SKILLS NEEDS OF INDUSTRY 4.0

There are a number of examples of how other industries are making a concerted effort to address the skills needs created by future technology. The recent efforts in the UK to increase the number of those with digital skills is a case in point:[xxvii] England, for example, was the first country in the world to mandate the teaching of coding in primary and secondary schools and the BBC's Make it Digital programme provided a pocket sized codeable computer to every child in Year 7 or equivalent across the UK to help spur interest in digital creativity.

Some other sectors are also making moves to address the skills needs of Industry 4.0. For instance, the Government's interim report on the subject of industrial digitalisation has touted the idea that industry, government and higher education should work together to create a "…virtual institute of Digital Engineering".[xxviii]

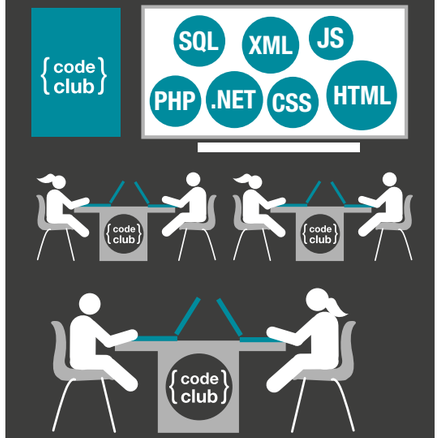
The construction industry has also made some progress. In recent history, policymakers and the industry have worked together to address productivity issues. This has included:

- The mandating of Building Information Modelling, which policymakers see as critical to the implementation of an offsite manufacturing strategy.[xxix]
- The Construction Leadership Council's investigation into the industry's vulnerability to skills shortages, which the Farmer Review reported and made recommendations on.[xxx]
- Increased transparency on planned infrastructure investment, providing greater certainty to the construction supply chain's capacity planning.[xxxi]
- The industry has developed the beginnings of an ecosystem that will support innovation, including involvement with catapult centres and industry collaboration networks.

There are now over...

5,000

code clubs for young people.



There is more that can be done, and while the following recommendations are only a start, they will contribute to the delivery of the skills that the construction industry needs to successfully move to Industry 4.0:

1. Accelerate the use of new technology in training

The digital revolution has changed the way that teaching has evolved, and the potential benefits of using augmented reality to provide new learning environments and to upskill existing staff have already been recognised. Use of this type of innovation in learning should be accelerated immediately, both to improve the training of new skills in apprenticeships and further education courses and to upskill operatives by making training more accessible. In addition, doing something similar by promoting the industry's use of technology in primary and secondary schools would help ingrain the idea of construction as being innovative. The creation of construction clubs could teach children the basics of how buildings are designed and built, and could even include mini construction projects that utilise technology such as 3D printing.

2. Inform lifelong learning decisions

There are very clear benefits to engaging with education and learning across a lifetime. It allows people to upskill for a particular career path, reskill for a career change, catch up on learning, respond to changing circumstances, remain in the labour market for longer and become more productive.[xxxii]

Some of those working in the construction industry will need to adapt their skills to make them more relevant to Industry 4.0. This ultimately means that construction training has to be made suitable across a lifetime, and not just for young people who are entering the industry. But to successfully ensure that the right training is available for people to fill the skills gaps that arise from technological advancement in construction, we have to know what the skills gaps are.

We need to explore how to best gather labour market intelligence on the types of skills gaps that are arising as a result of technological change. This could include experimenting with the data that central Government collects. For example, HMRC payroll data could provide insights into how construction firms are managing their workforce, and aid the design of policy. It could also mean the commissioning of a large-scale annual survey that measures trends in construction innovation and technological advancement.

3. Revolutionise our traditional education programmes

The non-academic routes through the post-16 education system are very important to the construction industry. These routes are currently undergoing significant reform, from implementing a series of recommendations to technical education made by a panel led by Lord Sainsbury, to the current overhaul that is changing the apprenticeship system.

On paper, these reforms are well thought through and make sense. However, given the rate of innovation and technological advancement that is now happening, there is a question about how the content of any route through post-16 education can remain relevant.

Both traditional apprenticeships and the design of the new trailblazer programmes need to incorporate the future need for a multi-skilled, adaptive workforce. New technological advancements, and the inevitable move to more modern methods of construction and off-site assembly must inform the design of course syllabuses now.

These three recommendations are only a starting point, but nonetheless are proposals that we think could start to make a positive impact on the construction sector. We need to work together across our industry to develop the right solutions to address the needs of the future, if we fail to do this we risk the future of our industry.

APPENDIX I – RESULTS OF THE OCCUPATIONAL ANALYSIS

The table below presents the results of an analysis that applies different rates of technological advancement to the occupations within construction that are most susceptible to automation.

To reiterate, these are not predictions and are examples. The table shows the occupations in construction that are currently thought to be most vulnerable to computerisation and applies a downward trend to the levels of employment within those occupations over a period of 20 years.

It may be that the technological advancement stalls and the workers in these occupations are less vulnerable to computerisation that previously thought. Equally, it may be that different occupations in construction become increasingly replaced by technology, rather than the ones listed.

Whatever the outcome, the point is that technology is already changing the skills needs of the construction industry. It will continue to do so, and has the potential to dramatically change the composition of the construction workforce.

		Employment 2040		
Occupation [xxxiii]	**Employment 2021** [xxxiv]	Slow-paced technological change	Medium-paced technological change	Fast-paced technological change
Specialist building operatives	55,480	14,400	8,840	3,281
Roofers	43,830	11,376	6,984	2,592
Labourers	127,220	33,020	20,272	7,524
Wood trades and interior fit out	262,920	68,241	41,895	15,549
Plant operatives	42,040	10,911	6,699	2,486
Plasterers	47,500	12,329	7,569	2,809
Floorers	25,580	6,639	4,076	1,513
Steel erectors/structural fabrication	25,450	6,606	4,055	1,505
Bricklayers	72,760	18,885	11,594	4,303
Painters and decorators	111,080	28,831	17,700	6,569
Total employment	**813,860**	**211,237**	**129,685**	**48,132**

APPENDIX II – METHODOLOGY

The following bullet points describe how the numbers for reskilling and productivity gains in the chapter 'Moving to Industry 4.0 – the skills challenge' were calculated:

The calculation of the number of employees available to reskill is illustrative. It is not a prediction of which occupations will decline and which will grow as a result of innovation and technology (these predictions have been made elsewhere). Instead, the number serves to show that workforce composition can change dramatically (and can change dramatically within a relatively short period of time).

The first step to calculate the number of employees within the construction workforce that will be available to reskill is understanding which occupations are most susceptible to computerisation. To do this, previous research (Frey and Osborne, 2013) was used. Their methodology is described as: "…[aiming] to determine which problems engineers need to solve for specific occupations to be automated. By highlighting these problems, their difficulty and to which occupations they relate, we categorise jobs according to their susceptibility to computerisation".

The ten construction occupations most likely to be computerised according to this research were identified (which are listed in the main body of this report). A downward trend was applied to the number of employees in each of these occupations under three scenarios.

Rate of technological change	Basis for the rate used in the calculation
Fast	The rate of change under this scenario matches that of rail signal operatives and crossing keepers between 1979 and 1999.
Medium	The rate of change under this scenario matches that of manufacturing jobs between 1979 and 1999.
Slow	The rate of change under this scenario is 5% over a 5 year period.

The fast and medium paced scenarios are based upon a previous example of the rate of decline of employees within an occupation over a period of 20 years (where the decline has occurred as a result of industrial change). The slow-paced scenario is illustrative.

Assuming there is a balance between the flows in and out of the industry from factors such as retirement and intra-industry occupational moves, the number of employees that will experience a reduced demand for their occupation has been estimated. This is the number that is presented as the available workers to be reskilled.

The productivity number was calculated by comparing the productivity growth of the construction industry and the whole economy in the period 1997–2016. Assuming that these two numbers will have the same relative difference over the next 20 years, the uplift in construction output is calculated by halving the difference and maintaining output per worker at a constant rate.

REFERENCES

i. McKinsey, February 2017, “Reinventing Construction: A route to higher productivity”, http://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-Executive-summary.ashx

ii. World Economic Forum, January 2016, “The Fourth Industrial Revolution: what it means and how to respond”, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

iii. Ibid

iv. Frey and Osborne, September 2013, “The future of employment: how susceptible are jobs to computerisation?”, http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

v. The Economist, Nov 2016, “Britain’s manufacturing sector is changing beyond all recognition”, https://www.economist.com/news/britain/21709597-manufacturing-less-and-less-industry-britains-man-street-britains-manufacturing

vi. PwC, February 2015, “The internet of things: what it means for US manufacturing”, https://www.pwc.com/us/en/industrial-products/next-manufacturing/big-data-driven-manufacturing.html

vii. Accenture, Smart Production, https://www.accenture.com/t20160119T041002Z__w__/us-en/_acnmedia/PDF-5/Accenture-804893-Smart-Production-POV-Final.pdf

viii. Forbes, February 2013, “What can 3-D printing do?”, https://www.forbes.com/sites/amitchowdhry/2013/10/08/what-can-3d-printing-do-here-are-6-creative-examples/#5f1b97d65491

ix. WSJ, February 2015, “When drones aren’t enough, Amazon envisions trucks with 3D printers”, https://www.economist.com/news/briefing/21724368-recent-advances-make-3d-printing-powerful-competitor-conventional-mass-production-3d

x. Engineering.com, May 2017, “What can augmented reality do for manufacturing?”, http://www.engineering.com/AdvancedManufacturing/ArticleID/14904/What-Can-Augmented-Reality-Do-for-Manufacturing.aspx

xi. EEF, November 2016, 4IR: A primer for manufacturers, https://www.eef.org.uk/resources-and-knowledge/research-and-intelligence/industry-reports/the-4th-industrial-revolution-a-primer-for-manufacturers

xii. UKCES, June 2015, Sector insights: skills and performance challenges in the advanced manufacturing sector”, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/439271/150626_AM_SLMI_exec_summary.pdf

xiii. House of Commons Library, August 2015, “Manufacturing: statistics and policy”, http://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN01942

xiv. EEF, November 2016, 4IR: A primer for manufacturers, https://www.eef.org.uk/resources-and-knowledge/research-and-intelligence/industry-reports/the-4th-industrial-revolution-a-primer-for-manufacturers

xv. Deloitte, 2015,”Industry 4.0: Challenges and Solutions for the digital transformation and use of exponential technologies”, https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf

xvi. EY, June 2017, FinTech Adoption Index 2017, http://new.innovatefinance.com/reports/ey-fintech-adoption-index-2017/

xvii. Ernst and Young, 2017, “UK FinTech Census”, http://www.ey.com/Publication/vwLUAssets/EY-UK-FinTech-Census-2017/$FILE/EY-UK-FinTech-Census-2017.pdf

xviii. PwC, March 2016, “How FinTech is shaping financial services”, https://www.pwc.com/il/en/home/assets/pwc_fintech_global_report.pdf

xix. FT, July 2017, City of London calls for ‘digital skills visa’, https://www.ft.com/content/a1b17cb8-619b-11e7-8814-0ac7eb84e5f1?mhq5j=e7

xx. PwC, 2017, FinTech’s growing influence on Financial Services, https://www.pwc.com/gx/en/industries/financial-services/assets/pwc-fintech-exec-summary-2017.pdf

xxi. Goos and Manning, 2003, “Lousy and Lovely Jobs: the Rising Polarization of Work in Britain”, http://eprints.lse.ac.uk/20002/1/Lousy_and_Lovely_Jobs_the_Rising_Polarization_of_Work_in_Britain.pdf

xxii. Written Evidence to the Transport Select Committee’s report on rail technology, http://data.parliament.uk/WrittenEvidence/CommitteeEvidence.svc/EvidenceDocument/Transport/Rail%20technology%20signalling%20and%20traffic%20management/written/31281.html

xxiii. Ibid.

xxiv. Frey and Osborne, 2013, “The Future of Employment: How susceptible are jobs to computerisation?”, http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

xxv. EEF, November 2016, 4IR: A primer for manufacturers, https://www.eef.org.uk/resources-and-knowledge/research-and-intelligence/industry-reports/the-4th-industrial-revolution-a-primer-for-manufacturers

xxvi. Futurism.com, https://futurism.com/reports-ai-robots-threaten-jobs-5-years/

xxvii. UK Digital Strategy, March 2017, https://www.gov.uk/government/publications/uk-digital-strategy/2-digital-skills-and-inclusion-giving-everyone-access-to-the-digital-skills-they-need

xxviii. Industrial Digitalisation, July 2017, http://industrialdigitalisation.org.uk/wp-content/uploads/2017/07/Interim_Report_Final3_1.pdf

xxix. HM Government, July 2013, “Construction 2025”, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf

xxx. Famer Review, October 2016, “The Farmer Review of the UK construction Labour Model”, http://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf

xxxi. National Infrastructure Pipeline 2016, https://www.gov.uk/government/publications/national-infrastructure-pipeline-201

xxxii. Government Office for Science, September 2016, “Education as the underpinning system: Understanding the propensity for learning across a lifetime", https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/590419/skills-lifelong-learning-learning-across-the-lifetime.pdf

xxxiii. CITB, ,”Industry Insights”, http://www.citb.co.uk/documents/research/csn%202017-2021/csn-national-2017.pdf

xxxiv. Ibid

About the author – Steve Hughes

Steve was previously the Head of Economic and Social Policy at the think tank Policy Exchange, and published reports on increasing savings rates and reducing youth unemployment. Before Policy Exchange he worked at the Bank of England, where he helped manage the regulatory system that governs cash distribution in the UK. He has previously worked as an economist at the British Chambers of Commerce where he advised on tax, international trade and SME finance policy, and in Parliament, where he researched HM Treasury and Department for Work and Pensions legislation as it passed through the House of Commons.

Mace
155 Moorgate
London EC2M 6XB
+44 (0)20 3522 3000

North America
1350 Broadway, Suite 408
New York, NY 10018
+1 917 436 4600

MENA
Aspect Tower: Business Bay
Executive Towers Zone A
Level 21: Office No. 2104
Sheikh Zayed Road, Dubai
+971 4 447 0207

Sub-Saharan Africa
The Pavilion
12 Wessel Road, Rivonia
Johannesburg, 2128
South Africa
+27 (0) 10 591 0222

www.macegroup.com
info@macegroup.com