The Future for Construction Product Manufacturing

Digitalisation, Industry 4.0 and the Circular Economy

October 2016




cpa construction products association

Contents

"The UK's construction products manufacturing sector is well-placed to support Britain's future, but we are at a critical point when industry and government must work even closer together if we are to further the modernisation of the wider construction sector here whilst increasing our global competitive edge. This partnership can ensure that we seize the opportunities that Digital Built Britain presents and deliver its benefits across our entire economy."

John Sinfield
Chairman
Construction Products Association

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Forewords

Foreword by Jesse Norman MP,
Parliamentary Under Secretary of State, Minister for Industry and Energy.

The Government is developing an Industrial Strategy designed to boost productivity, create good jobs and ensure sustainable economic growth. The key to that lies in building on our existing industrial, scientific, creative and commercial strengths - and doing so in a way which does not defend incumbency but encourages innovation and entrepreneurship.

Many industries are already benefiting from the widespread use of digital technologies, and to its credit the construction sector is now accelerating its own adoption of these technologies and embracing the new opportunities which they enable and the benefits they provide.

The Government's Construction Strategy of 2011 led this revolution by mandating the adoption of BIM (Building Information Modelling) on its central capital projects from April 2016, providing a powerful incentive to firms to invest in BIM capability so as to remain eligible to compete for future government contracts. The Government has also supported the construction supply chain in developing the necessary initial common standards and protocols, and in making them available in accessible formats, without cost, to encourage as wide a take-up as possible, especially among SMEs.

For their part supply chain companies have come together to develop a suite of new standards designed specifically for the modern digital construction environment. As a result the UK is among the world leaders in utilising digital technology in construction, and BIM is believed to have contributed significantly to savings of over £3bn made on central government procurements since 2011. The increased adoption of BIM throughout the entire construction supply chain is a central to the Government's ambition to save a further £1.7bn through productivity gains by the end of this Parliament.

This report clearly identifies the critical part that digital technology can play in linking the production line to the construction process. In principle this can enable the creation of seamless supply chains, leading to improved productivity, reduced waste and a faster rate of innovation.

The Government has given significant support to the digitalisation of our construction industry, and I would congratulate the Construction Products Association for the leadership it is giving to these processes. Digital technologies have the potential to transform the construction sector, and in so doing to create new opportunities in both domestic and international markets.

Jesse Norman *October 2016*

Foreword by Dr Diana Montgomery,
Chief Exec of the Construction Products Association.

Many industries have long understood the benefits of a fully engaged digital approach to everyday business. The advantages have been clearly established in immensely greater productivity, efficiency, accuracy and delivered customer satisfaction.

The construction industry in contrast has been stubbornly resistant to structural change despite many efforts to embed approaches which other industries have considered the norm for many years.

This has now started to change. The momentum created by government showing initiative and thought leadership has created a fundamental move to embrace digitalisation.

A vast, complex industry that contributes more than £100 billion to the economy and employs around three million people will always take time to change; however, the acknowledgement of the benefits can now be clearly seen across the whole construction industry.

Particularly over the last three years, the use of digital techniques in design and construction has started to mature and even become the norm for many companies. Clients are clear that the future must be mapped out in the digital arena.

The Construction Products Association represents 87% of the UK's construction products manufacturers – a £50 billion per annum sector in its own right. Many have a well-established practice of digital processing in product manufacturing.

Linking the inherent intelligence through the data to the design and construction, as well as 'in use' phases of built assets, is already underway and accepted as a necessary objective. Embracing this across all areas and all projects will take some time, but the trend is clearly established.

CPA members are universally supportive and keen to see the whole industry communicating and undertaking business using digital methodologies. Our work developing a common approach to product data and digital identification takes our approach from the theoretical to robustly practical. We seek to develop and engage with further programmes which will strengthen and align manufacturing's contribution to the digitalisation of construction.

This report seeks to identify the progress made in the construction manufacturing sector in support of Building Information Modelling and digitalisation. Many see the development and deployment of other technologies supporting the success to date as pushing us towards the 4th Industrial Revolution. We hope this report provides clear evidence that manufacturing is doing more than its bit, generating and championing the use of those digital methodologies and helping to put the UK in the lead on the world stage.

Dr Diana Montgomery *October 2016*

Construction Manufacturing 2025

The Vision:
A Sustainable, World-leading and High-value Digital Construction Product Sector

With current forecast growth in UK construction output, the construction product sector is likely to reach a capacity pinch-point as soon as 2019. At the same time, the trade gap for products and materials is increasing, with £7.9 billion more imports than exports in 2015.

Through a combination of digitalisation, automation and optimised manufacturing-led supply chains, the sector can grow over £30 billion by 2025, assets can be delivered over 30% cheaper and 40% quicker, and the trade gap can be reduced to 50% by 2025 whilst supporting employment growth in the sector and wider economy.

This report illustrates how the vision can be delivered by linking BIM (Building Information Modelling), Industry 4.0 (smart factories) and intelligent assets through optimised supply chains and a circular UK construction economy.

- **World leading BIM (Building Information Modelling) Level 2 and Digital Built Britain programmes** - driving digitalisation of construction and connected, intelligent assets
- **Product data** - LEXiCON, a world first in defining digital product information for data exchange
- **Growth** - potential additional £30+ billion by 2025
- **Skills** - growth in highly skilled and exportable roles, supported by automation and virtual supply chains
- **Building performance** - eliminating the performance gap between as-designed and as-built performance of buildings, providing more energy-efficient assets
- **Manufacturing-led supply chains** - already demonstrating potential savings of 30% whilst spending 40% less time on site for the same form of construction. Led by individual or consortia of manufacturers that deliver either full or parts of an asset, they involve coordinated production, interfaces, logistics and installation. Optimisation is achieved through understanding the relationships between elements and is enabled through BIM - constructing an asset in the virtual world before repeating in the physical world

Current supply chain confusion and on-costs

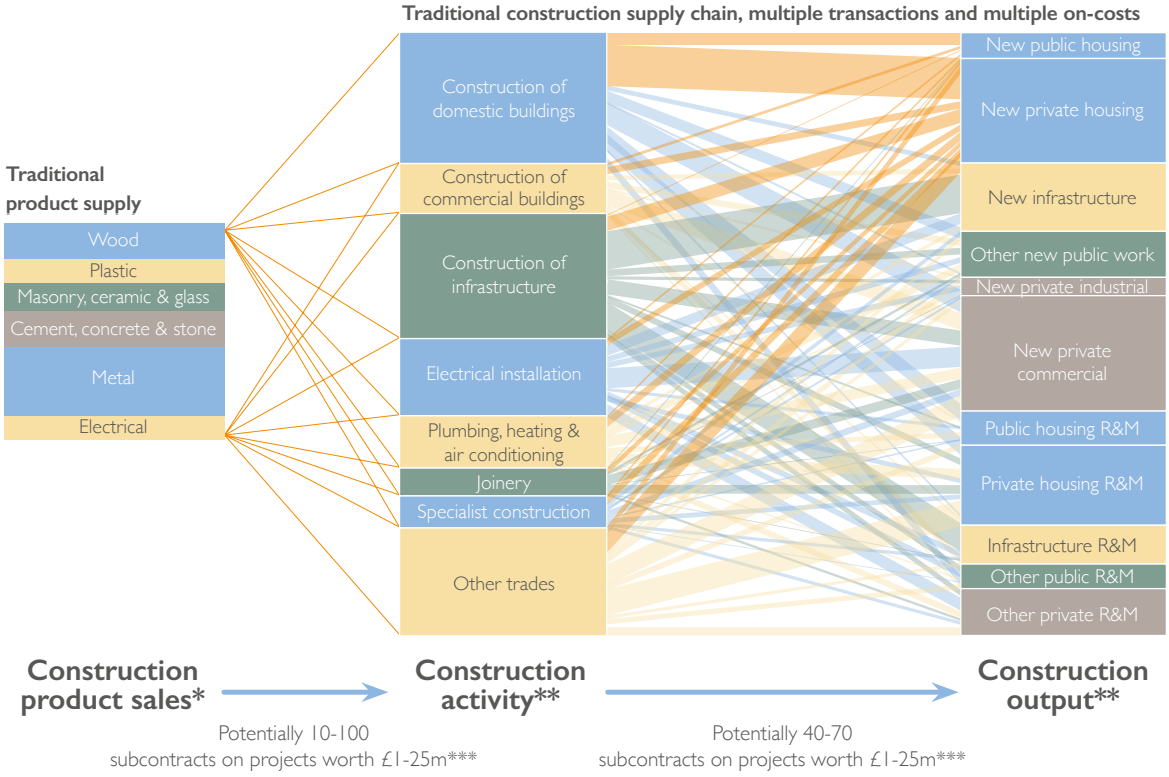


Figure 1(a) Proportional UK construction product sales, construction activity and construction output by value

Manufacturer-led supply chain

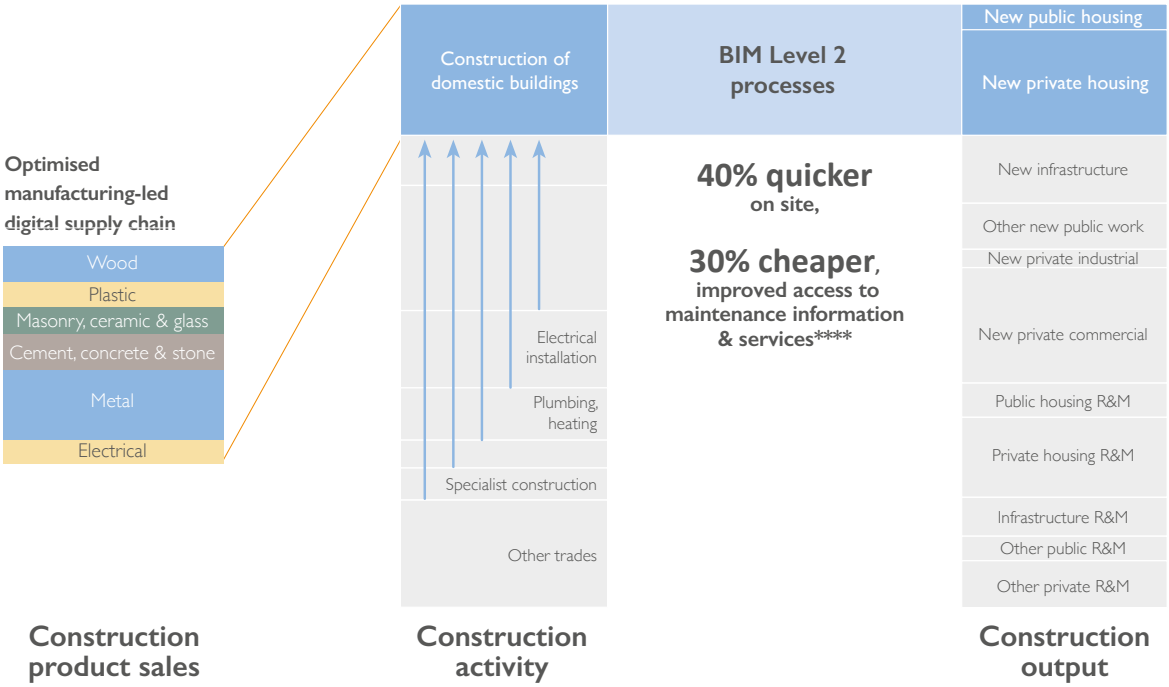
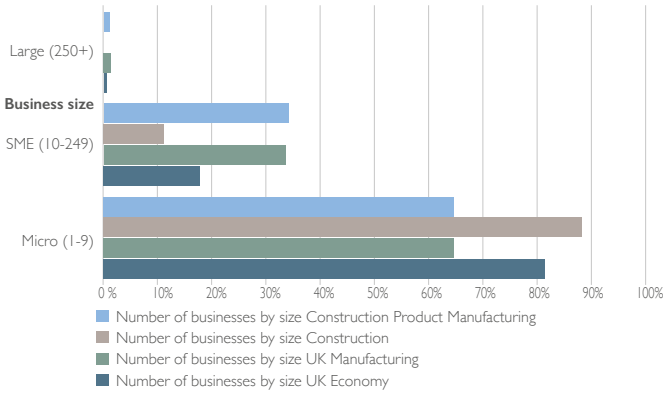


Figure 1(b) Potential for optimised, manufacturing-led supply chain and implementation of BIM processes to deliver significant cost, time and resource efficiencies

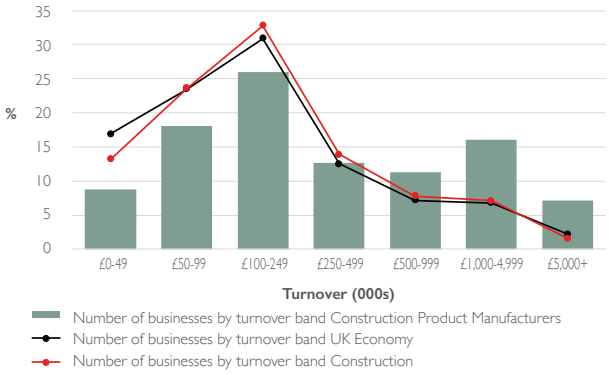
*Source: UK Manufacturers' Sales by Product Survey (PRODCOM) Provisional Estimates 2015.
**Source: Construction Statistics Annual Tables 2015, Table 2.8: Private contractors: Value of work done, by trade of firm and type of work
***Source: BIS(2013), Supply Chain Analysis into the Construction Industry
****Source: Wienerberger, comparison of pre-construction estimates and as-built results using the e4 brick house concept

The construction product sector

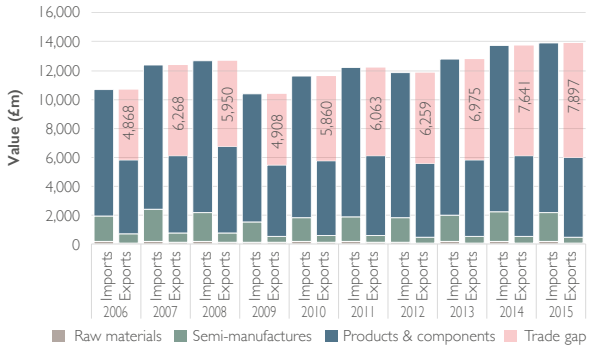
Percentage of businesses by size



Percentage of businesses by turnover band



Construction material and product imports and exports



Why it matters today

The UK construction product sector is worth over £50 billion annually, which is over a third of UK construction output.

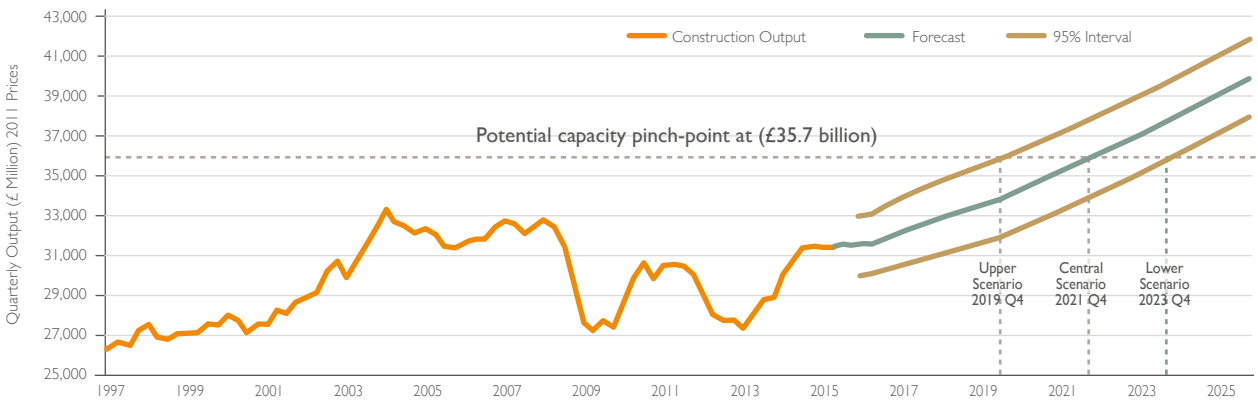
It directly employs over 313,000 across every constituency in the UK, and includes over 21,000 businesses ranging from very small (65% with less than 10 employees) to large multi-nationals.

Whilst the proportion of small to large businesses is in line with the rest of UK manufacturing, there are proportionally more large players in the construction product sector than in construction and the UK economy as a whole, both in terms of number of employees and turnover.

The construction product sector is forecast to grow quicker than UK manufacturing as a whole over the next 10 years, rising along with overall construction output. However, without further investment to keep up with the increasing demand, the sector is expected to reach a capacity pinch-point between 2019 and 2023.

Along with HM Government's policy commitment to reduce the trade gap between construction product and material imports and exports by 50% by 2025, there needs to be a step-change in construction product output. Over recent years the trade gap has increased steadily (from £4.8 billion in 2006 to £7.9 billion in 2015), so to achieve the sector's goals and support the built environment sector as a whole there needs to be a structural shift in the sector; more integrated supply chains through the lifecycle of assets, supported by an efficient, adaptable product sector.

This report identifies the opportunities to achieve sustainable growth by combining the disruptive technologies and processes of Industry 4.0 (the 4th Industrial Revolution), BIM (Building Information Modelling), intelligent assets and a circular construction economy.



The built environment in 2025

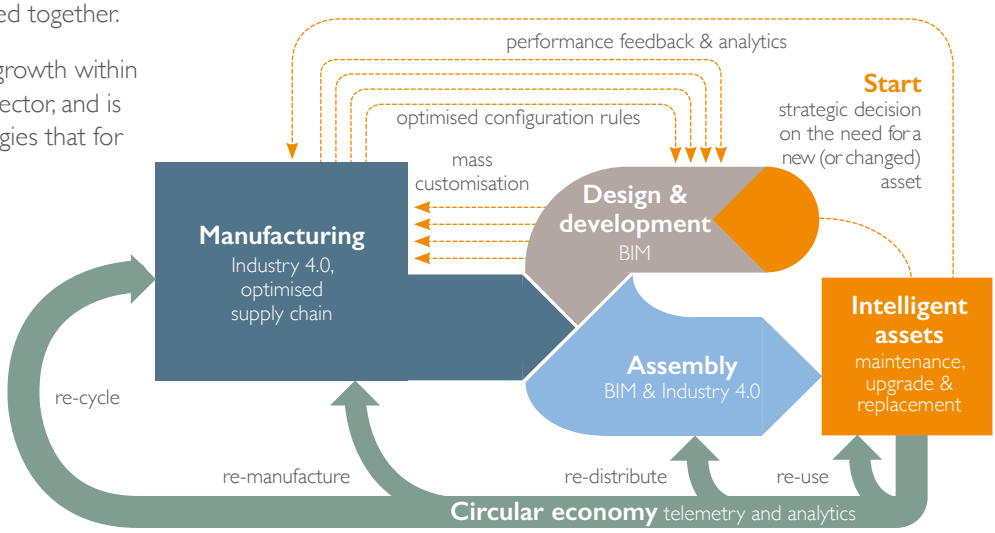
Merging Industry 4.0, intelligent assets and the circular economy

BIM (Building Information Modelling) has led the way in digitalisation of the construction industry over recent years, which will continue with the Digital Built Britain initiative.

The Construction Product 2025 Roadmap illustrated on the next page highlights a number of trends, influences and outcomes expected over the coming years, which will impact the construction sector as a whole. The envisaged combination of virtual and physical worlds has the potential to deliver a step-change in efficiency and cost savings across the built environment, but needs to be considered holistically. In particular, BIM, Industry 4.0, intelligent assets and the circular economy are intrinsically linked; to maximise their potential value and achieve the growth forecast over the next 10 years they need be explored together.

Each requires change and growth within the construction product sector, and is enabled by digital technologies that for the first time have caught up with the vision of a smarter, more efficient and responsive built environment;

- **Industry 4.0** and servitisation is driven by the customer, and **intelligent assets** provide data on the requirements for customisation and performance in-use data that supports new product development
- **Intelligent assets** require the integration of sensors and product data through **Industry 4.0**
- A **circular economy** benefits from the knowledge of products and materials forming **intelligent assets** and their properties, location and condition, and the logistical and optimising production capability of **Industry 4.0**



The following provides a brief overview of how Industry 4.0, intelligent assets and the circular economy relate to the construction product sector, and identifies opportunities that emerge from pulling them together.

Industry 4.0

- The 4th Industrial Revolution – linking real objects with information and processes via networks (e.g. the internet)
- Vertical integration of smart business systems and processes
- Horizontal integration through Global Value Chains
- Supply chain optimisation
- Organisation and control over the entire product lifecycle and value chain, focussed on improving customisation to meet the needs of end users
- Servitisation - a shift from services that support the product, to services that support the customer and their businesses, from reactive services such as warranties to proactive services such as leasing products or systems, or selling outcomes, not products.

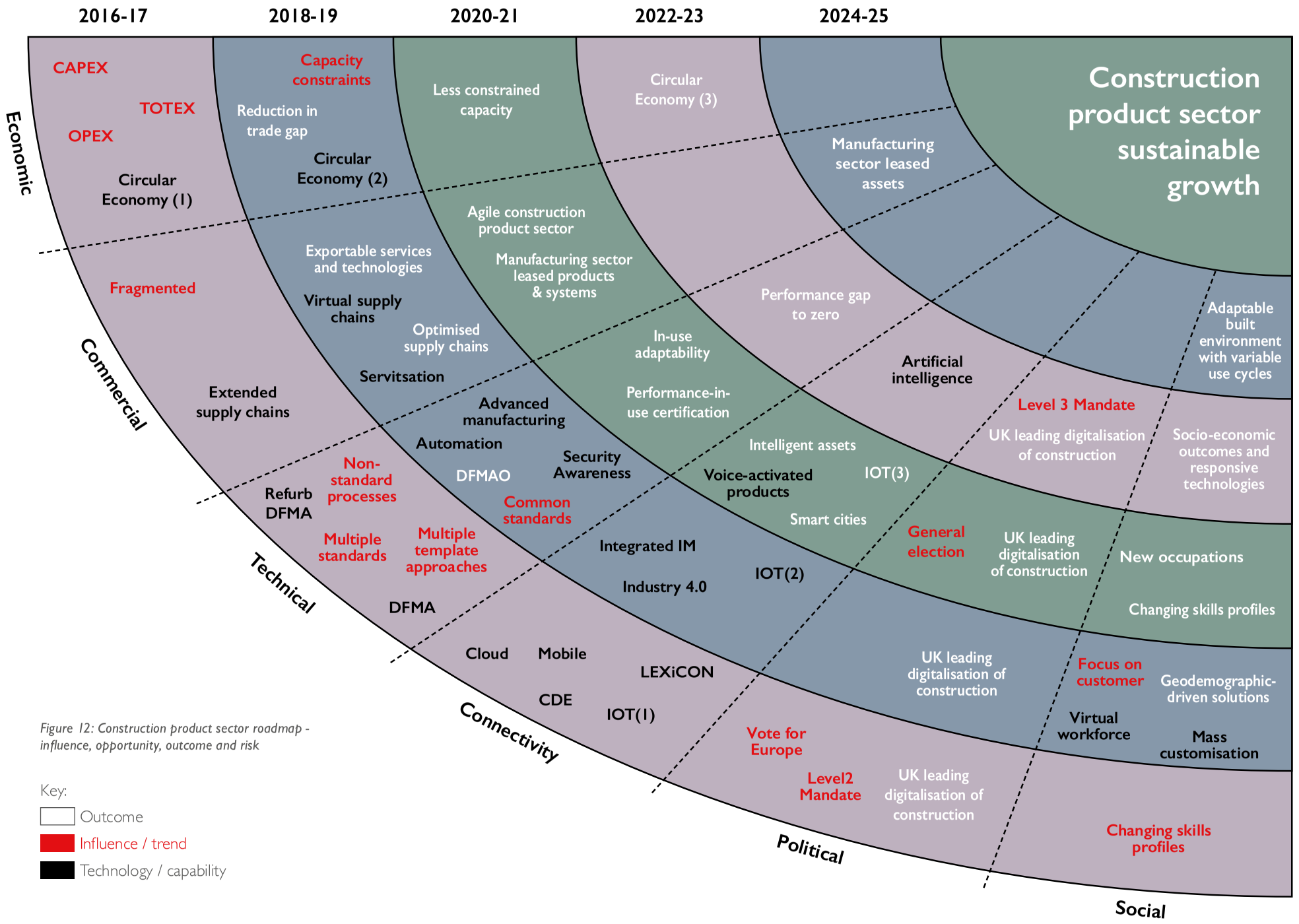


Figure 12: Construction product sector roadmap - influence, opportunity, outcome and risk

Intelligent assets: the Internet of Things

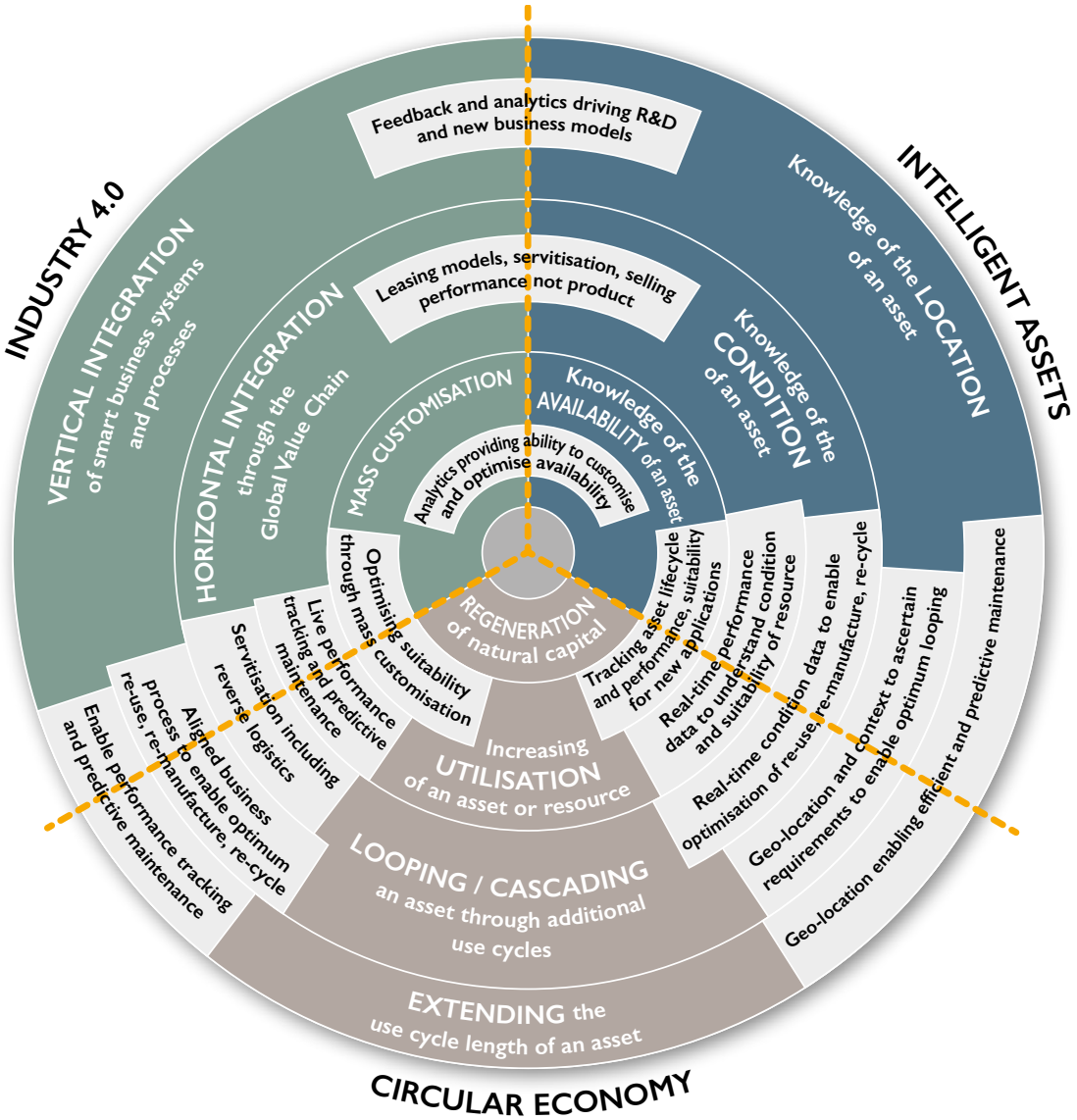
- Buildings, roads, bridges, products and systems knowing where they are and how they are performing
- Enables reduction in the as-designed, as-built performance gap, supporting more energy-efficient assets
- Connected Cyber-Physical Systems (CPS) enabling communication between products and systems, asset owners, operators and occupants and suppliers
- Feedback on actual performance, the need for maintenance and automation of re-ordering, potential for product development and added service

Circular economy

- *"A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles."*

  - Ellen MacArthur Foundation

- Digitally-enabled return supply chains to enable products and systems to be:
  - Re-used
  - Re-distributed
  - Re-manufactured
  - Re-cycled
- Reducing the need for raw material and product imports
- Increasing the flexibility of an asset to extend its use cycle



Growth

A potential growth of £32 billion in the UK construction product sector by 2025 through automation, digital processes and manufacturer-led supply chains

Growth in the UK construction product sector is no longer just a 'nice-to-have'. It is essential if the UK is to remain competitive internationally in terms of smart assets and cities, and to reduce the trade gap between imports and exports of construction products. Through a combination of automation, implementation of BIM Level 2 and Digital Built Britain, and manufacturing-led supply chains the sector is forecast to grow by 63% to **£82.4 billion** by 2025.

Automation

If the UK construction product sector invest a similar percentage of turnover in Industry 4.0 as German manufacturers, and achieve the same returns, manufacturers can expect an annual increase in revenues of **£7.1 billion**. In addition, this level of investment in Industry 4.0 within the construction sector is expected to provide over 10,200 jobs in the sector, and over 3,100 in other parts of the economy.

Growth in construction output

The UK construction sector is expected to grow to £158 billion by 2025. If the construction product sector grows at the same rate to keep up with the increase in demand, an additional **£6.93 billion** is forecast.

Reducing the trade gap

In the Government's Construction 2025 strategy, a key commitment is to reduce the trade gap between imported and exported construction products and materials by 50% by 2025. Achieving this commitment means an additional growth of **£5.04 billion** by 2025.

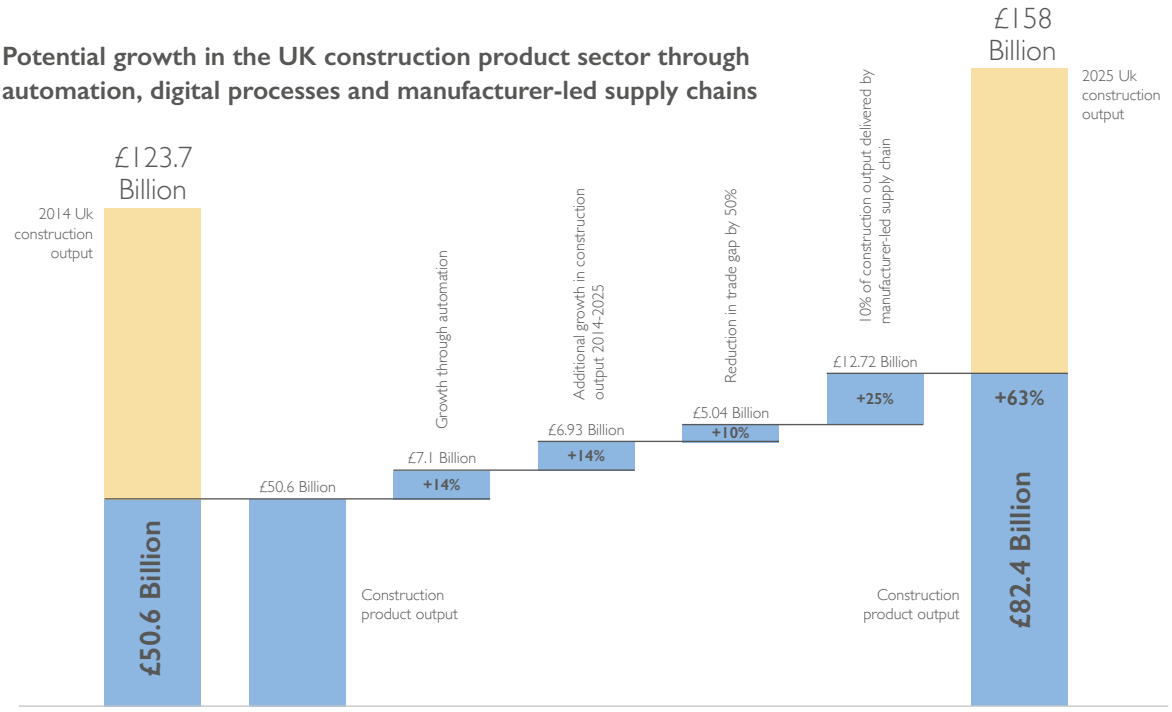
Manufacturer-led supply chains

By delivering only 10% of UK construction output by manufacturing-led, digitally enabled supply chains in 2025 an additional growth of **£12.72 billion** is forecast plus over £800 million savings in construction spend. If 20% of the sector is delivered in this way the product sector can grow to £95.1 billion by 2025.

International growth

The ability for manufacturer consortia to deliver and export combined offers is significantly enhanced through the application of BIM and Industry 4.0. The UK is recognised as a world leader in BIM, and with a global construction sector forecast to grow to **£10.3 trillion** by 2030, there are real opportunities for the UK construction product.

Potential growth in the UK construction product sector through automation, digital processes and manufacturer-led supply chains



Skills

Transitioning to a digital built environment; global skills markets, changing skills requirements, new roles and cross-sector capabilities

The shift from an analogue to digital construction industry, and from a product to a service-based construction manufacturing sector, will no doubt bring significant change in the skills that are required to meet capacity and enable growth. Do digitalisation and automation mean fewer employees? Do they mean there is likely to be more off-shoring of skills? These are risks, but previous evidence of significant technological change such as the steam engine, production line and electricity suggest otherwise. However, the labour market will be disrupted and occupations and tasks will undoubtedly change. By one popular estimate, over 65% of children entering primary school today will ultimately end up working in jobs that do not currently exist.

Based on current numbers employed across 39 different roles analysed in this report across construction and product manufacturing, over 880,000 individual roles are likely to be impacted by automation, either fully automated or significantly affected as the tasks that they perform will change as a result of automation.

Whilst automation is likely to particularly impact routine tasks, highly skilled roles will also be impacted.

Digital Built Britain, and the general trends to improved information management and increased awareness of the operational phases of assets is having a significant impact on more highly skilled roles within the built environment.

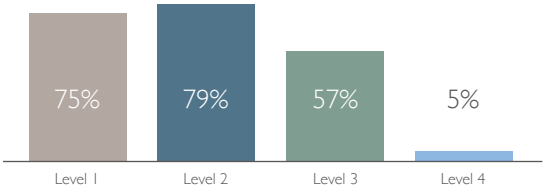
Through effective processes and the availability of structured data, decision making is becoming more evidence-based, and whilst more highly skilled roles are less likely to be fully automated, they are likely to become more focussed on the less repetitive, more cognitive tasks and abilities.

However, the likelihood of automation does not mean that the focus for future skills development should only be for highly skilled roles; the potential for automation through Industry 4.0 within the manufacturing sector provides a significant opportunity for UK industry to optimise production processes, and enable production to remain in the UK, whilst providing the ability to take advantage of supply chain integration and export. Therefore a focus on highly skilled roles alone is likely to have a detrimental impact on both the UK labour market and economy.

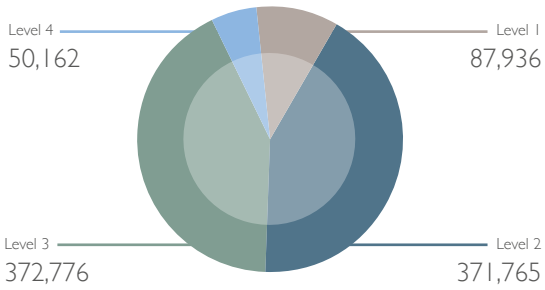
The virtual workforce

From an individual's perspective, imagine making your skills and availability discoverable with a manufacturer, a number of organisations or a service akin to the Uber of construction; providing employers with the ability to automatically prebook or appoint you to carry out pre-defined activities based on your location and their needs. This approach already exists in some sectors, and can provide both parties with access to opportunities and skills that may otherwise not be apparent.

Average % likelihood of automation



Number of jobs likely to be automated by skill level



Impacted skills and abilities

Across manufacturing **Key ABILITIES** • Manual dexterity and precision • Problem sensitivity • Logical reasoning	**Key SKILLS** • Monitoring self and others • Critical thinking • Active listening • Equipment operation and control • Reading compensation
+ assemble **Key ABILITIES** • Physical strength • Visualisation • Cognitive flexibility	**Key SKILLS** • Coordinating with others • Quality control • Oral expression • Judgement and decision making • Time management
+ assemble + design **Key ABILITIES** • Mathematical reasoning	**Key SKILLS** • Complex problem solving • Active learning • People management • Written expression • ICT literacy

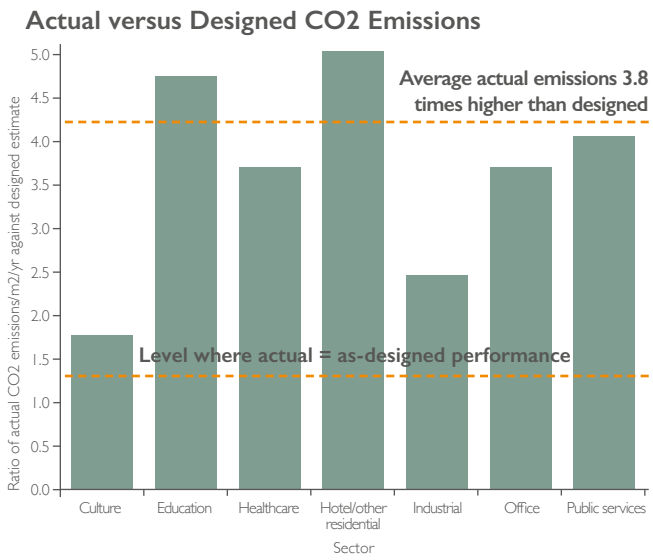
ABILITIES and SKILLS listed in white text are not within the top 5 SKILLS or top 3 ABILITIES for roles at a high risk of automation.
All listed SKILLS and ABILITIES are cumulative, so those identified in + assemble are in addition to those already identified in Across Manufacturing.

Building performance

Reducing the performance gap and increasing performance certainty through digitalisation and analytics

It has been clear for many years that there is a significant difference between how building designs are assessed to demonstrate compliance in the virtual world, and how buildings perform in the physical world, known as the 'performance gap'.

A recent detailed study by Innovate UK of 50 non-residential projects and 76 homes illustrated the gap; for non-residential buildings the carbon emissions were on average 3.8 times higher than designed, and up to 4.6 times as high.



There are a number of reasons for the gap. The key factors and potential solutions through smart, digital manufacturing and construction sectors are:

- **The assumptions made and accuracy of calculation software** through the integration of real-life performance data, and the use of generative tools in the future, the accuracy of design software can be improved.
- **Feedback from completed assets back to the design and delivery teams of future assets,** or a longer term relationship between capital delivery and operation teams - by sharing real-time analytics on performance in use, and by extending the manufacturer's role into the operational phase of an asset, performance and best practice can be linked through the supply chain.
- **Workmanship quality and certainty**
  - The Innovate UK programme indicates that where performance in-use is tested, such as airtightness, then the performance improves significantly as more care is taken. In addition, knowledge of what is important to achieve performance also improves. Integrated sensors can be used to track quality of workmanship
  - Imagine a red LED notifying you that a system has not been installed correctly, or a message on your smartphone informing you that a hidden element has been moved.
- **Certifying performance in-use**
  Products and system performance is typically certified under strict laboratory conditions, which are different to performance in-use. Data collection and analytics could be used in the future to certify performance in-use, providing certainty on how a product will actually perform.
- **Awareness of implications of ad-hoc decisions**
  Using BIM, telemetry and analytics to increase awareness of the impact of other products or elements already installed by previous trades, or the knock-on impact of varying from designed proposals on follow-on trades and building performance.
- **Addressing non-regulated energy use**
  Not all energy use is regulated, so whilst the average in-use emissions for regulated energy was still 2.37 times the designed performance, non-regulated energy has a significant impact.
  By tracking actual energy use and disaggregating it by where it is being used and when, it is much easier to reduce non-regulated energy.
- **Predictive maintenance**
  Using telemetry and analytics to optimise maintenance and performance through a product and asset's lifecycle, and minimising the need for disruptive surveys which may affect the performance of other building elements.

Stronger together

Industry and Government working in partnership

BIM Level 2 - setting the direction and a number of world firsts

HMG's BIM Level 2 programme has enabled manufacturers to share product information in more accessible forms than has previously been achievable. The awareness of data and the possibilities that effective use can bring have been widespread. As a result many manufacturers are using data and information modelling to change the way they operate internally, as well as sharing information with others in the construction supply chain. However, there are a number of formats in which product information can be provided, in many different templates, which can cause confusion for all concerned. To achieve consistency, a new initiative called LEXiCON has been developed by the construction product sector with HMG BIM Task Group, and is now being led by the CPA. HMG's BIM Task Group developed a Product Data Definition specification to enable consistency and interoperability of product information through the BIM process, and LEXiCON is the implementation of this specification by industry.

LEXiCON is a world first, and enables manufacturers and other users to define information requirements easily, for free.

The tool is freely available through the Construction Products Association's website and is governed by recognised industry bodies known as Relevant Authorities, to ensure the language being used is correct and consistent. Whilst data dictionaries and product templates exist elsewhere, never before has there been such broad industry engagement and governance, with over 70 percent of UK trade associations signing up to become Relevant Authorities and manage how their products are defined.

LEXiCON has received international recognition, and is now being considered as part of a cross-nation proposal as the basis for a new European standard.

Product trade associations & merchants

Professional institutes & other industry bodies

LEXiCON Relevant Authorities - cross-industry engagement to define product data requirements

Newly formed authorities to define specific requirements

Catapults

The Government's Catapult Programme provides excellent opportunities to develop and prepare for commercialisation of innovative technologies in areas of potential growth. The existing Catapults only touch the edges of the construction product sector, the most relevant being:

- High Value Manufacturing Catapult
- Digital Catapult
- Future Cities Catapult

With the structural change in the construction industry over the next ten years, and the construction product sector's importance to the UK economy in particular to reduce the trade gap and support smart cities and assets, we believe the construction sector should be recognised as High Value Manufacturing. We aim to encourage investment within the sector and provide the necessary support to provide the solid platform required for future growth.

Key recommendations for Government and industry to deliver sustainable growth in the UK construction product sector

Recommendations	Description
The UK construction product sector should be recognised as High Value Manufacturing	The construction product sector provides over a third of construction turnover in the UK, and is a crucial enabler for the application of disruptive technologies and growth in the wider built environment. Industry 4.0, the circular economy, intelligent assets, smart cities and BIM (Building Information Modelling) rely heavily on the growth and digitalisation of the sector.
Investment in automation and Industry 4.0 initiatives in the construction product sector	Investment from both HM Government and Industry in automation and Industry 4.0 initiatives relating to construction products is essential to enable the necessary growth in the sector and attract global manufacturers to the UK for both production and high value servitisation activities. Without investment in automation there is an increased risk of falling behind internationally.
Manufacturers to sponsor schools through Class Of Your Own initiative	The "Adopt a School" scheme assists organisations to provide genuine support for secondary school teachers and their students, focussing on developing key digital skills a firm understanding of modern technical and professional processes in the built environment.
Investment in cross-sector skills, research and development focussing on the impacts of digitalisation, automation and servitisation and future skills requirements	The skills landscape is significantly changing and will continue to do so with the disruptive technologies that are already beginning to be implemented across the built environment and wider economy. Research and strategies for future skills requirements are urgently needed, and go beyond traditional skills and roles within the built environment.
Government and industry to explore certification of construction products and systems based on performance in use, enabled by integration of telemetry and analytics	Construction products are typically certified based on laboratory testing and performance, which is very different to performance in-use. The use of sensors, real-time feedback and data analytics can increase understanding of actual performance, and reduce the as-designed, as-built performance gap to provide more energy-efficient assets.
World BIM leadership	Ensure that the UK's position as a leader in digitalisation of construction is supported on the world stage; critically, continuing involvement in the development of European and world standards and methodology. The international adoption of methodologies aligned to those developed in the UK is immensely valuable for UK business.
HM Government promotion of the UK construction product sector	Promotion of the UK construction product sector to the wider economy and population at large. Giving support on the national stage to the construction industry and its digitalisation provides momentum and leverage with other parts of the economy and its customers.
Government thought leadership	Continue to provide the thought leadership and consistent national voice for digital support. This has been extremely successful in the organisation and promotion of BIM to date. Continued non-financial support is critical.
Promote leading edge technologies	Development of leading edge initiatives is critical and many projects are being developed through Innovate UK. To ensure the UK keeps its prime position, further technical developments are required. Materials and products can then identify maintenance or replacement requirements.

1.0 Introduction

The global economy, driven by the combination of a number of megatrends including rapid urbanisation, increasing resource scarcity and an exponential growth in the availability of smart technologies and connectivity is entering a transformative phase.

In the built environment this step-change can be seen through the rapid digitalisation of the construction sector and development of the Internet of Things, the move towards a resource-efficient circular economy, and the drive for more efficient, agile and customisable manufacturing through Industry 4.0, the fourth industrial revolution.

The construction product sector (which accounts for 37% of construction output) needs to position itself as a key enabler in realising the full potential of these changes, through the development of smarter, more connected and efficient products, systems, processes and commercial models.

In the future products will know what and where they are, be capable of identifying the need for predictive maintenance and self-repair or replacement. Through the pervasive integration of technology they will enable links between virtual and physical environments, and be more integrated with changing consumer and societial needs than ever before.

This report begins by putting the UK's construction product sector into context, looking at how the sector has changed and adapted over recent years in response to economic, political and technological shifts and the Government's Level 2 and 3 BIM programmes. It then moves on to outline opportunities for growth within the product sector, and explains how these can provide growth within the sector, and support growth within the built environment and wider UK economy over the next 10 years.

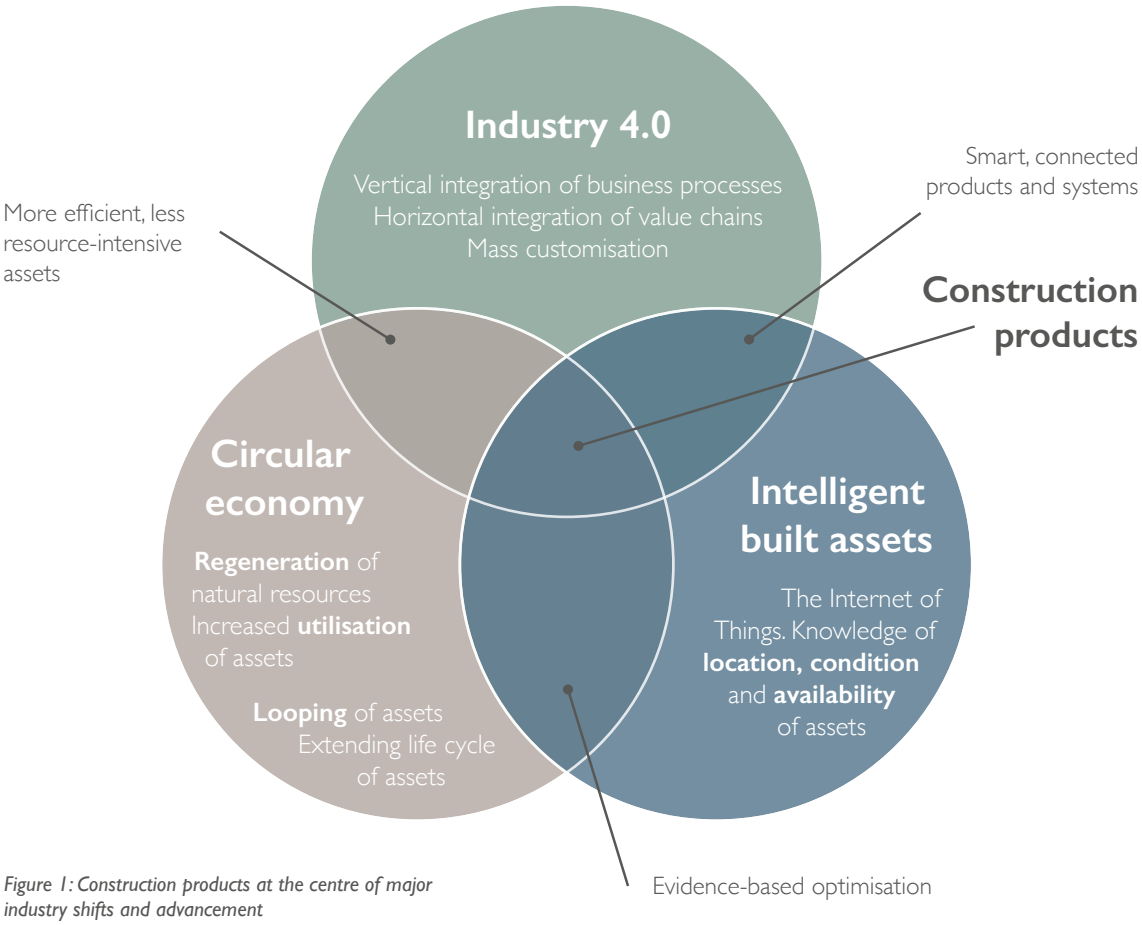


Figure 1: Construction products at the centre of major industry shifts and advancement

2.0 The construction product manufacturing sector context

The UK construction product sector is worth over £50 billion annually, which is over a third of UK construction output.

It directly employs over 313,000 across every constituency in the UK, and includes over 21,000 businesses ranging from very small (65% with less than 10 employees) to large multi-nationals.

Whilst the proportion of small to large businesses is in line with the rest of UK manufacturing, there are proportionally more large players in the construction product sector than in construction and the UK economy as a whole, both in terms of number of employees and turnover.

Percentage of businesses by size

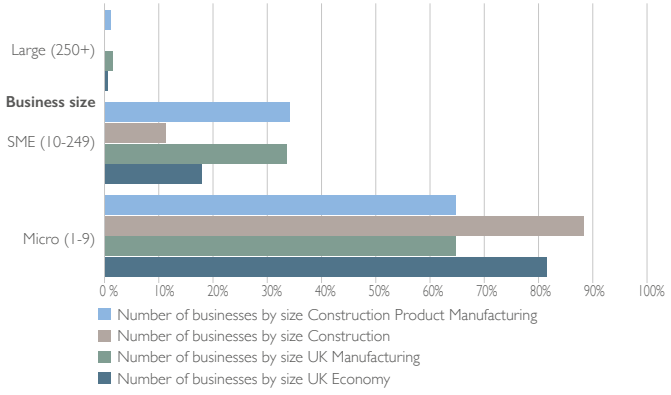


Figure 2: Percentage of UK construction product businesses by size and number of employees. Source: CPA

Percentage of businesses by turnover band

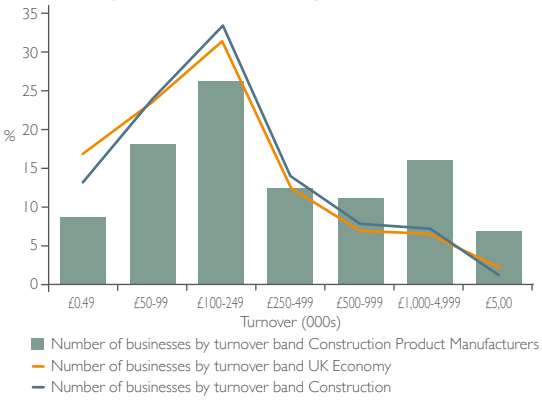


Figure 3: Percentage of UK construction product businesses by turnover. Source: CPA

Slow growth is forecast for the UK manufacturing sector as a whole over the coming years, however the construction product sector is forecast to rise along with construction output. The key industry sectors are expected to be housing, infrastructure and commercial. At current forecast levels, without further investment and assuming that imports remain at a similar level to recent averages (between 7.9 and 10.9% of construction output) the UK construction product sector is expected to reach a capacity pinch-point between 2019 and 2023.

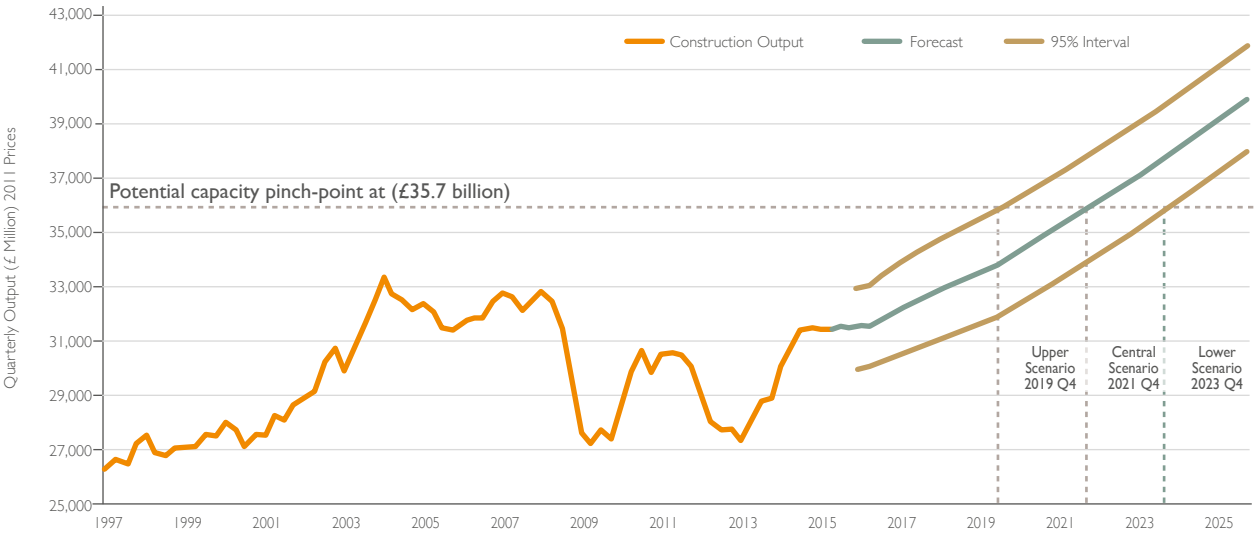


Figure 4: Forecast construction output and construction product sector capacity constraints

Source: ONS, Construction Products Association

2.1 Manufacturing capabilities and the value chain

In 2014 the World Economic Forum (WEF) described three stages of national manufacturing sector development that commonly occur in line with economic growth[1]. These were:

1. Comparative advantages - based on factors such as resource availability and labour costs compared with other nations
2. Competitiveness - efficiency-driven, focused on improving comparative advantages for example through investment, policy and infrastructure
3. Capabilities - focused on value-adding capabilities to increase competitiveness in the face of global competition, including through innovation and value-adding services

By focusing on value-adding capabilities the UK construction product sector can become more competitive on the global stage, but this needs to be in combination with, not instead of competitive, flexible production to maximise value.

In progressing from the competitiveness to capabilities stages the WEF identifies a series of potential upgrades to capability including Product (designing, fabricating and distributing higher value products), Functional (additional services and activities along the value chain), and Process (improving fabrication and distribution).

In addition to these upgrades, there are opportunities within the construction product sector to develop further value-adding capability in the remaining product value chain, including after-sales service, assembly or installation, maintenance and re-manufacture.

These and other opportunities are discussed further later in the report.

At the same time there is a global trend of manufacturers increasing their provision of value-adding services to their products (known as servitisation) and growth is forecast in advanced manufacturing.

To enable future construction product demand to be met by UK businesses, and to reduce the growing trade gap between imports and exports (Government policy commitment to reduce trade gap by 50% by 2025, was £4.8 billion in 2006 to £7.8 billion in 2015), there needs to be a shift in focus towards value-adding capabilities within manufacturing and the construction product value chain. This shift has already begun, and will increase rapidly over the next five years through automation and servitisation.

Construction material and product imports and exports

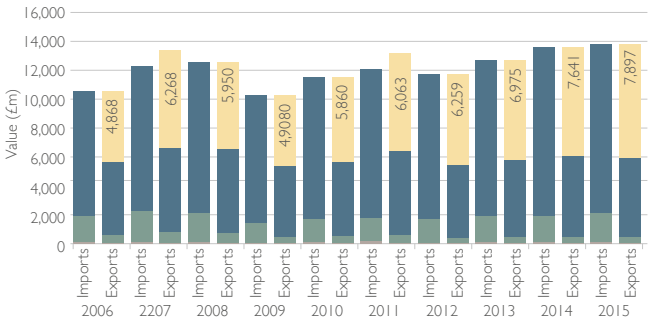
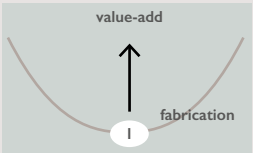


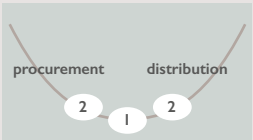
Figure 5: Imports and exports of construction materials and products. Semi-manufactures are products that provide input into the production of other manufactured products. Source: ONS

Box 1: Upgrading a product value chain

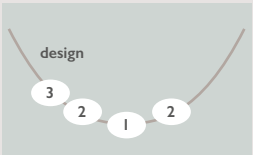
Source: WEF 2014



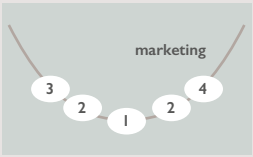
1 - Fabrication
Focus on fabrication; suppliers assemble inputs, following buyers' spec. Product focus may be relatively narrow.



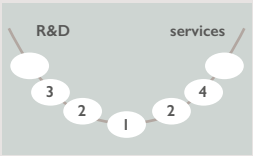
2 - Supply chain
Broader range of manufacturing-related functions, incl. sourcing inputs and inbound logistics as well as fabrication. Potentially outbound distribution activities.



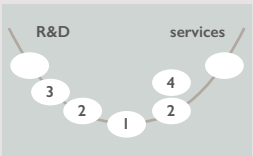
3 - Product design
Supplier carries out part of pre- production processes, e.g. design or product development. Design may be in collaboration with the buyer.



4 - Product brand
Supplier acquires post-production capabilities and is able to fully develop products under its own brand names. Can be in collaboration with the buyer or by new market channel.



Product upgrading
Increase unit value by producing more complex products, enabled by increased capabilities. Businesses move from low-cost to higher value products, labour costs increase.

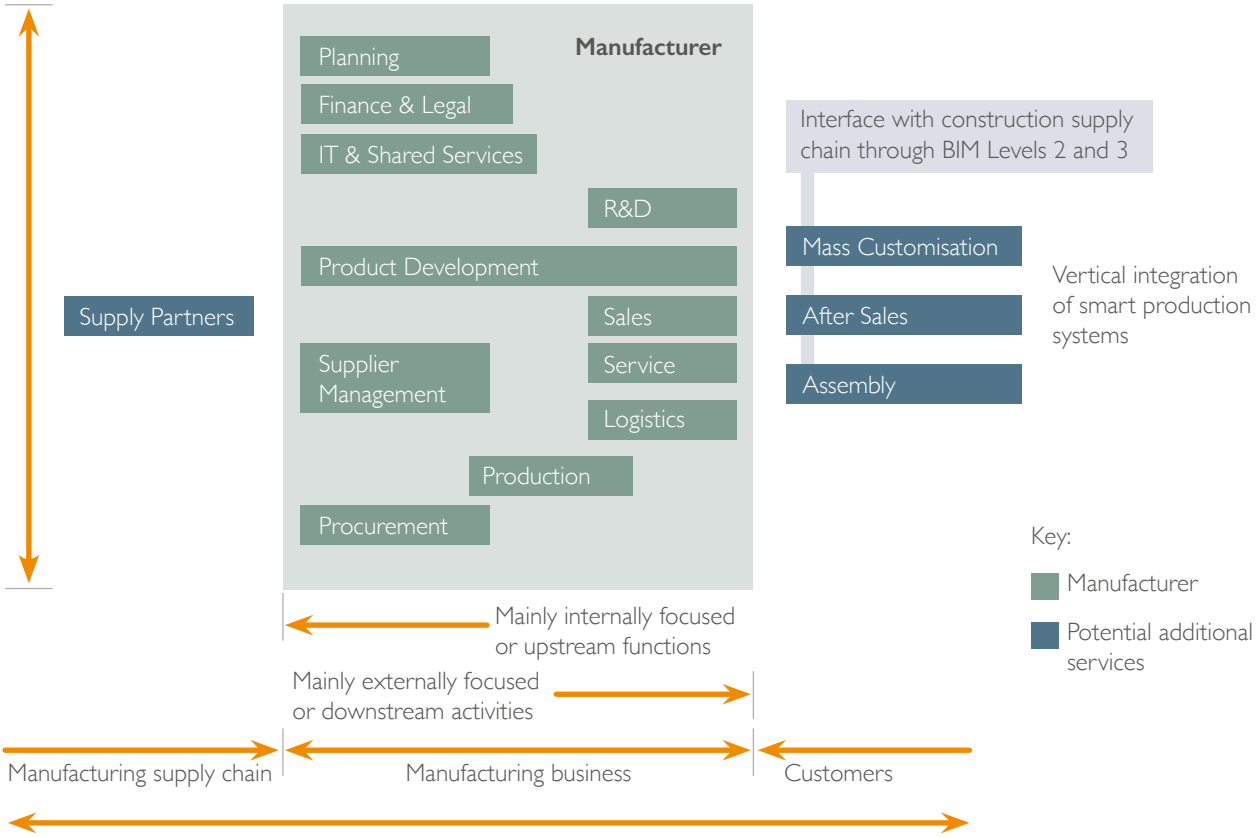


Process upgrading
Improving productivity through new capital investments. Improving IT and logistics. Reducing lead time and increasing flexibility of supply chain process.

1. The Future of Global Manufacturing: Driving Capabilities, Enabling Investments, WEF 2014

2.2 Smart factories - automation, advanced manufacturing and Industry 4.0

Global Value Chains (GVCs) can be viewed on two axes, the first (vertical) by functions such as design, procurement, production & distribution. The second (horizontal) is by added value through integration of the value chain with a focus on the end customer; both axes are significantly impacted by the exponential growth in technologies, not least digital technologies, automation and connectivity. Whilst the next five years represent a significant technological and cultural shift for manufacturing in general, the impact on the construction product sector is likely to be even greater as a result of a move towards a circular economy, implementation of BIM Level 2, and Digital Built Britain driving the digitalisation of construction and Industry 4.0, the 4th industrial revolution.



According to a recent survey by The Manufacturer spanning a number of sectors, manufacturers envisaged Industry 4.0 having an impact across most areas of their business. Over 80% of respondents agreed that it will have a medium to very high impact on their ability to mass customise, to develop new business models including servitisation, to improve customer service, to engineer throughout the entire value chain and to increase the value of automisation and robotics.

The same survey suggests that over 70% plan to invest in production capability, 44% in R&D and 42% in IT. What is most impressive is that over 60% intend to invest over the next 12 months, and over 85% by the end of 2017, so manufacturers are already preparing for the future.

This trend can also be seen in the construction product sector, where manufacturers are planning to invest in R&D over the next year, in addition to product improvement, e-commerce and developing export markets. In terms of building information modelling (BIM), product manufacturers are increasingly sharing data on their products with customers, and the next stage will be to fully integrate the sharing and use of data across the whole value chain, including within manufacturing businesses and supply chains.

We believe that with an increased focus on automation, servitisation, digitalisation and the increasing demand for mass customisation the construction product sector will develop into the realm of advanced manufacturing[2] within the next five years, and it will become commonplace within the next ten years. The integration of sensors into products and materials, the ability to geo-locate and to know how they are performing will become the norm within developed economies, and provides an opportunity for the UK to lead in these areas. The UK is recognised as the second most innovative country in the world[3], the eighth most competitive for manufacturers[4] and as world leaders in BIM.

2.3 Automation

As indicated in Box 1 (page 19) it is difficult for the UK construction product sector to compete with other countries for basic low-skill activities that can be carried out by a low-skilled workforce. To address this, automation is key if those activities are to remain in the UK, to support the drive to reduce the trade gap for construction products and materials, and to enable focus on higher value products, systems and services. It is at the higher value end that the greatest percentage of construction product imports lie.

As a result, the UK manufacturing sector is gradually increasing its level of automation, with 83% of those surveyed in 2015 having implemented some form of automation in the last five years (the construction product sector has one of the highest levels of automation according to a recent survey, with 75% of respondents saying they have already invested in automation to some degree[5]), with 77% expecting to either invest the same or more in 2016. The main drivers for increasing automation were identified as improving business efficiency, reducing production cycle time and improving quality, with a typical return on investment of 2-3 years. It suggests that automation is not just being seen as an opportunity to increase productivity, but also to support wider growth through linking to other business functions and customers.

Box 2: Industry 4.0

Source: Platform Industry 4.0 (translated from German).

"The term Industry 4.0 stands for the fourth industrial revolution. Best understood as a new level of organisation and control over the entire value chain of the life cycle of products, it is geared towards increasingly individualised customer requirements. This cycle begins at the product idea, covers the order placement and extends through to development and manufacturing, all the way to the product delivery for the end customer, and concludes with recycling, encompassing all resultant services.

The basis for the fourth industrial revolution is the availability of all relevant information in real time by connecting all instances involved in the value chain. The ability to derive the optimal value-added flow at any time from the data is also vital. The connection of people, things and systems creates dynamic, self-organising, real time optimised value-added connections within and across companies. These can be optimised according to different criteria such as costs, availability and consumption of resources."

2.4 Servitisation

The majority of manufacturers across all sectors provide services as part of their business, but the difference with servitisation is a shift from services that support the product, to services that support the customer and their businesses, from reactive services such as warranties to proactive services such as leasing products or systems, or selling outcomes, in addition to products.

"Servitization is the concept of manufacturers offering services tightly coupled to their products. It's about moving from a transactional (just sell a product) to a relationship based business model (delivering a capability) featuring long-term, incentivised, 'pay-as-you-go' contracts." - Aston Business School

Servitisation can achieve sustained growth of 5-10% for manufacturers, and savings of up to 30% for their customers[6]. An example from another sector is Michelin tyres, who are shifting from selling tyres to selling performance (supported by a money-back guarantee). The approach, which can save over 2% of the cost of ownership for truck fleet operators, incorporates telemetry, eco-driving training and an optimised tyre management system[7].

2. 'Advanced manufacturing is defined as the technological, organizational, social and environmental strategies that improve manufacturing so that it can meet the goals of enterprises, society and governments, and adapt to change. This definition reflects the growing level of integration across the value chains of the functions of production, distribution and consumption' - The Future of Global Manufacturing: Driving Capabilities, Enabling Investments, WEF 2014 3. Global Innovation Index 2015 4. Deloitte 2016 Global Manufacturing Competitiveness Index 5 Future-proofing UK manufacturing, Barclays 6. Aston Business School, 2014 7 WEF, 2016

3.0 The opportunities: growth, innovation, collaboration and integration

3.1 Global trends and the construction product sector

Disruptive technologies enabled by an analogue to digital shift

There is no doubt that the exponential increase in computing power and digital technologies over recent decades has had a revolutionary impact on society and the global economy. Figure 7 highlights twelve technologies identified by McKinsey[1] as being disruptive and having the potential for significant economic and societal impact over the next decade; the five technologies forecast to have the most significant economic impact are all enabled by digital technologies, and nine of the twelve (indicated in orange) will have an impact on the built environment and construction product sectors. Through digitalisation, global non-residential construction is forecast to have the capability of producing annual cost savings of $0.7-1.2 trillion (13-21%) during design and construction and $0.3-0.5 trillion (10-17%) in an asset's operations phase through digitalisation[2].

Whilst the manufacturing sector is often seen as one of the most innovative areas of industry[3], the construction sector is typically perceived to be at the opposite end of the scale; only over the last five years is the application of digital technologies showing signs of becoming ubiquitous, driven largely through initiatives such as the UK Government's BIM (Building Information Modelling) strategy. The UK's mandate for Government departments to implement BIM Level 2 on projects from 2016 has led to a step-change[4] in the digitalisation of a fragmented construction sector due largely to the increased focus on data, which will continue to adapt and consolidate through Digital Built Britain and the Construction 2025 strategy.

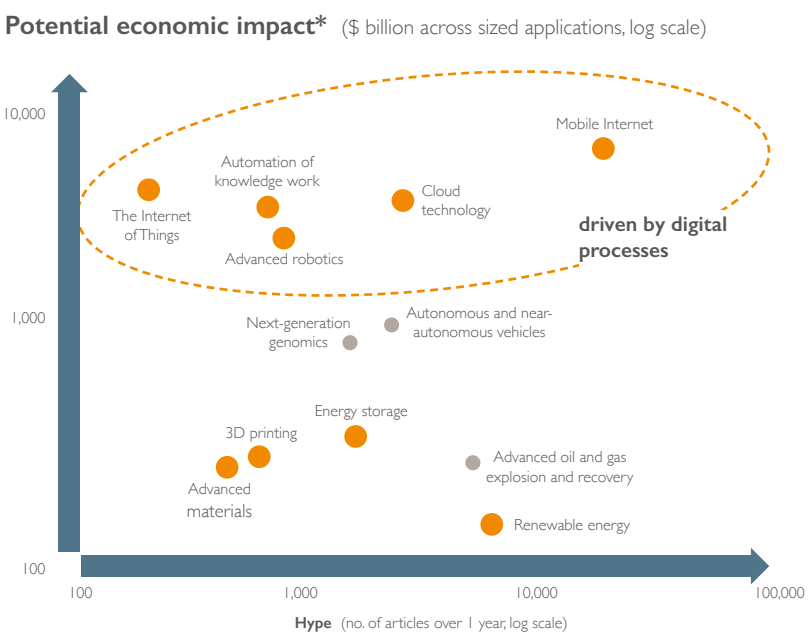


Figure 7: Disruptive technologies and potential economic value. Source: McKinsey 2013

- Mobile internet – Increasingly inexpensive and capable mobile computing and connectivity
- Automation of knowledge work – intelligent software systems that can perform tasks involving unstructured commands and subtle judgments
- The Internet of Things – networks of low-cost sensors and actuators for data collection, monitoring, decision-making and process optimisation
- Cloud technology – use of computer hardware and software resources delivered over a network or the internet, often as a service
- Energy storage – devices or systems that store energy for later use
- 3D printing – additive manufacturing techniques to create objects by printing layers of material based on digital models
- Advanced materials – materials designed to have superior characteristics (e.g. strength, weight, conductivity) or functionality
- Renewable energy – generation of electricity from renewable sources with reduced harmful climate impact
- Advanced robotics – increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans

1. Disruptive technologies: Advances that will transform life, business, and the global economy, McKinsey 2013 2. Digital in Engineering & Construction: The Transformative Power of Building Information Modelling, BCG 2016 3. UK Innovation Survey 2015, BIS 4. Many nations are now developing or implementing digital strategies for construction, and the UK is seen as a global leader. ISO and CEN standards are in development. Global BIM market was worth US$2.76 bn in 2014 and is expected to reach US$11.54 bn by 2022, with a Compound Annual Growth Rate (CAGR) of 19.1%. Source: Building Information Modelling (BIM) Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2015 - 2022

In addition to the shift from analogue to digital, another megatrend that is already having a significant impact on the built environment sector is urbanisation. Between 2015 and 2050 the world's urban population is forecast to increase by over 60%, an increase of 2.5 billion. To put this into context, more than 1,900 apartment buildings, each housing 100 occupants needs to be built every single day between now and 2050, and with the shift from rural to urban areas, the majority of this housing will need to be affordable.

In addition to housing, these occupants also need schools, transportation, infrastructure, employment and shops; as a result the logistical challenge for the construction industry is immense. In addition, there is the growing need to improve resource efficiency and achieve significantly more with significantly less as part of a circular economy. To meet the challenge we need to enable effective two-way communication between the virtual and physical worlds, enabled through smart assets and effective information management through BIM Level 2 and Level 3.

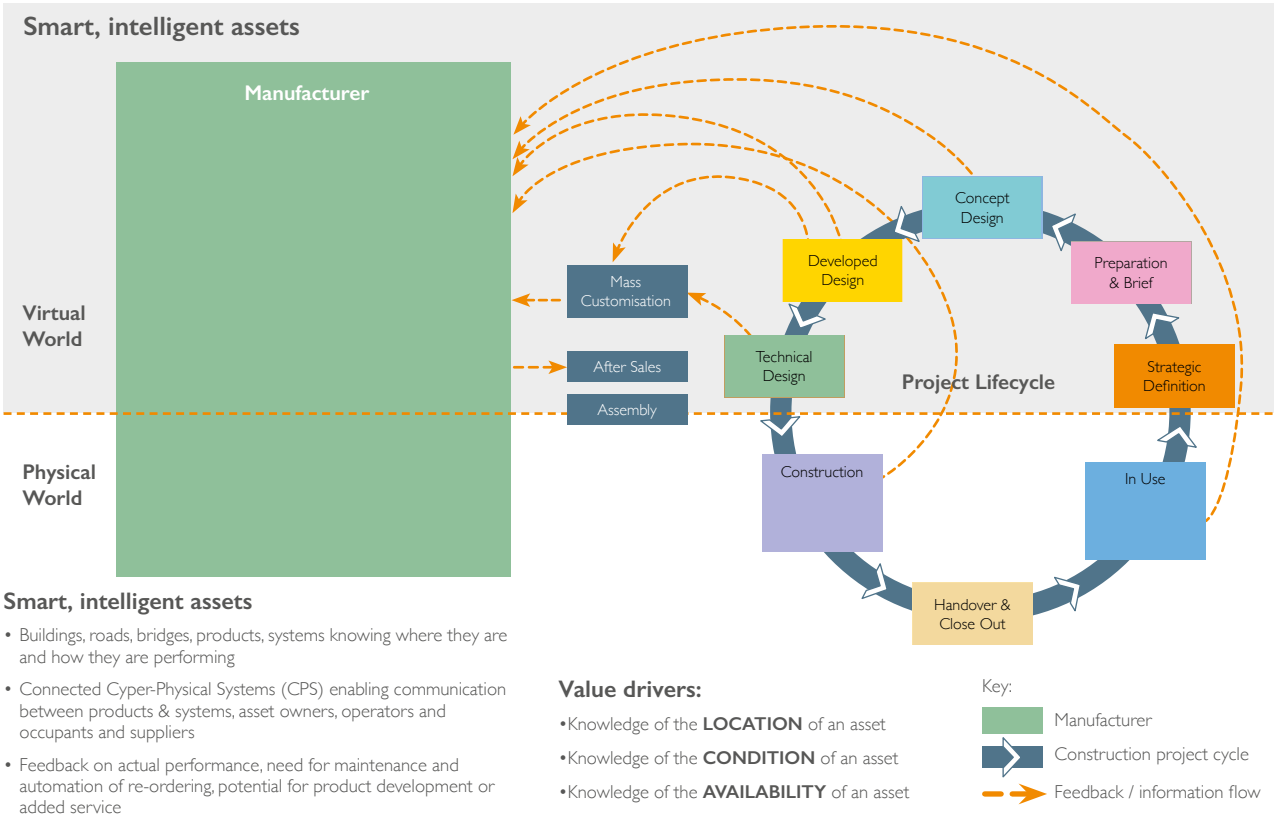


Figure 8: Smart, intelligent assets providing analytics, feedback and geo-location of assets

Smart, Intelligent Assets: the Internet of Things

Value is typically created from information in several stages; data is first created, then it's communicated, aggregated, analysed and then acted upon. In the first instance we need to create data, and in the built environment the ability to create and communicate this data is achieved through smart assets.

Smart assets are where physical objects and systems can communicate with each other, with computer systems and with humans through cyber-physical networks. Enabled by the Internet of Things (connected devices), the key value drivers for smart assets are:

Knowledge of the **LOCATION** of an asset

Knowledge of the **CONDITION** of an asset

knowledge of the **AVAILABILITY** of an asset

There are two key areas of data that can be obtained from smart assets; the first being live data on the location, condition, characteristics and performance of an asset (such as a product). The second is data relating to the context of the asset, for example what is adjacent to the asset, the temperature around a sensor, or movement and changes in light around sensors.

The former has significant value all the way through the product and built asset's life cycle, including the manufacturing, logistics and construction phases to enable geo-location, optimise construction delivery and maintenance. RFID (radio frequency identification) tags that can be used to geo-locate assets can now be produced as small as 0.15mm by 0.15mm, meaning they can already be embedded in materials and products. Sensors can also provide data on the performance of a product or system in use.

Data relating to the context of an asset, such as measuring the environmental performance or use of a space, can provide significant added value particularly in the asset's use phase, enabling tracking of whether the environment within a space is fit for purpose and within the boundaries of acceptability, whether contractually or in terms of user comfort.

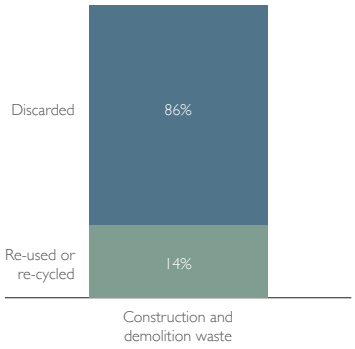
A circular economy

The basic premise of a circular economy is to decouple economic development from the consumption of finite resources. Replacing the linear 'take, make, dispose'[5] model we can significantly reduce waste, and minimise supply and price risk by re-using, re-distributing, re-manufacturing or re-cycling assets. With a global increase in population, the shift to a more consumer-oriented society and the increasing demand for tailored products and assets, we must also consider how to most efficiently provide mass customisation, the ability to customise without significantly reducing the efficiency of a manufacturing process.

The four key value drivers of a circular economy are identified by the World Economic Forum (WEF) as:

- Increasing **UTILISATION** of an asset or resource
- **LOOPING / CASCADING** an asset through additional use cycles (using more than once)
- **EXTENDING** the use cycle length of an asset
- **REGENERATION** of natural capital

UK Construction and demolition waste[6]



5. Source - Ellen MacArthur Foundation 6. UK Statistics on Waste, DEFRA

Each of these provide opportunities for the construction product sector to add value by developing new business models and opportunities, and are discussed later in this section.

The circular economy predominantly relates to the efficient use and distribution of physical resources, and whilst this relates very much to the physical world, without the virtual world to support it with rich information and feedback loops, the circular economy would be unlikely to achieve its true potential. This is where BIM Levels 2 and 3 are predicted to have a significant impact on the delivery of a circular economy.

Circular economy

- *"A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"*
  - Ellen MacArthur Foundation[7]

Value drivers:

- **REGENERATION** of natural capital
- Increasing **UTILISATION** of an asset or resource
- **LOOPING/CASCADING** an asset through additional use cycles
- **EXTENDING** the use cycle length of an asset

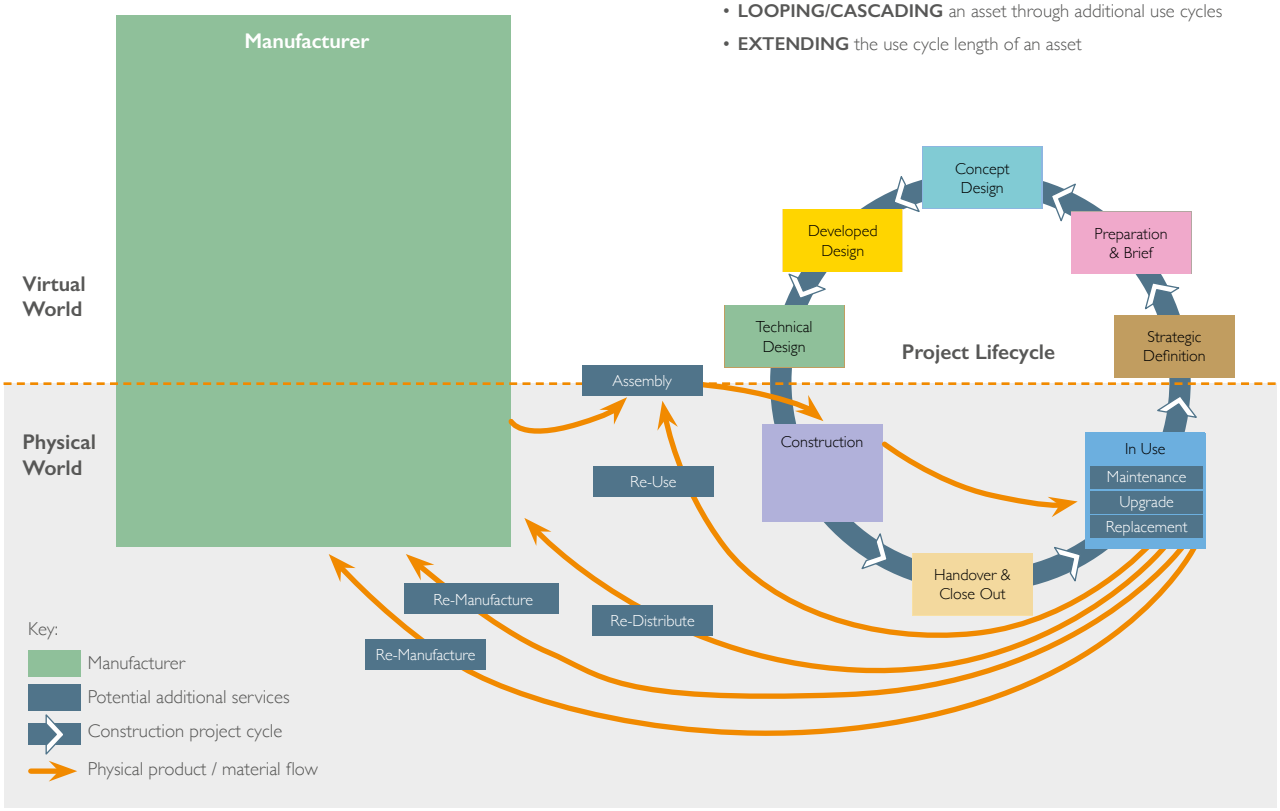


Figure 10: A circular economy optimising resource efficiency by considering the value of materials, product and systems throughout their full life cycle, including how they can be re-used, re-distributed, re-manufactured or re-cycled at maximum value

Box 3: Circular economy

Within the UK, there are a variety of initiatives taking forward the ideas of circular economy in construction. These include the joint industry government Green Construction Board's Circular Economy Working Group which seeks to embed the ideas of circular economy across the sector.

Most UK construction sites now having closed loop recycling where waste from manufacturing is recycled back into production of product, with many companies having waste targets usually as part of company or sector sustainability strategies, and a number of having commercially viable take-back schemes.

7. Intelligent Assets: unlocking the circular economy potential, Ellen MacArthur Foundation 2016

3.2 Merging Industry 4.0, Intelligent Assets and the Circular Economy

Industry 4.0, intelligent assets and the circular economy are intrinsically linked; to maximise their potential value and to efficiently deliver them they need be explored together. Each requires change and growth within the construction product sector, and is enabled by digital technologies that for the first time have caught up with the vision of a smarter, more efficient and responsive built environment;

- **Industry 4.0** and servitisation is driven by the customer, and **intelligent assets** provide **data** on the requirements for customisation and performance in-use data that supports new **product** development
- **Intelligent assets** require the integration of sensors and **product data** through **Industry 4.0**
- A **circular economy** benefits from the **knowledge** of **products and materials** forming **intelligent assets** and their properties, location and condition, and the logistical and optimising production capability of **Industry 4.0**

Figure 11 highlights a number of potential opportunities that are enabled by combining value drivers from the three initiatives, and Figure 12, expands on the potential influences, technologies, opportunities and outcomes that can be achieved between now and 2025.

The roadmap shown in Figure 13 takes account of HMG's Construction 2025 strategy, and the opportunities for growth and advancement in the following sections are organised into the key areas of that strategy;

- **PEOPLE:** an industry that is known for its talented and diverse workforce
- **SMART**: an industry that is efficient and technologically advanced
- **SUSTAINABLE:** an industry that leads the world in low-carbon and green construction exports
- **GROWTH**: an industry that drives growth across the entire economy
- **LEADERSHIP**: an industry with clear leadership

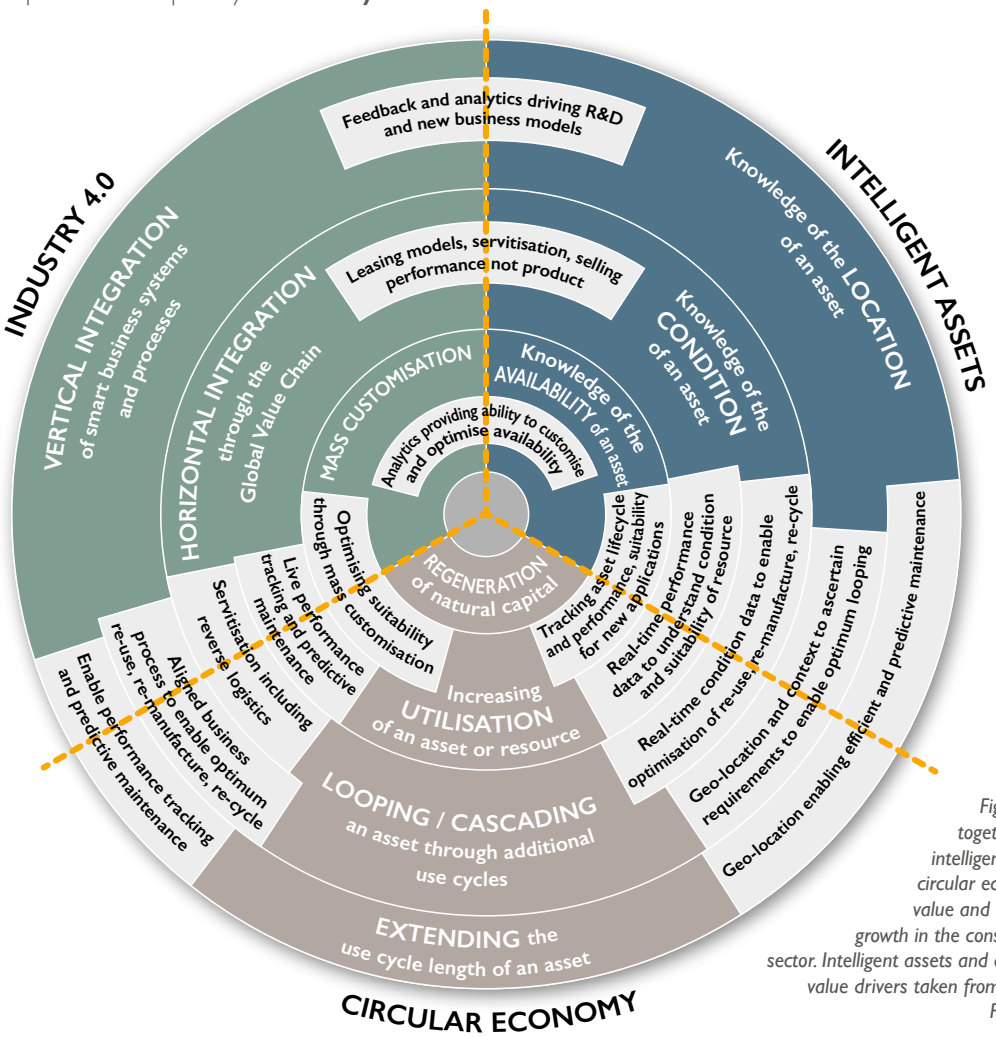


Figure 11: Bringing together Industry 4.0, intelligent assets and the circular economy to create value and opportunities for growth in the construction product sector. Intelligent assets and circular economy value drivers taken from Ellen McArthur Foundation 2015

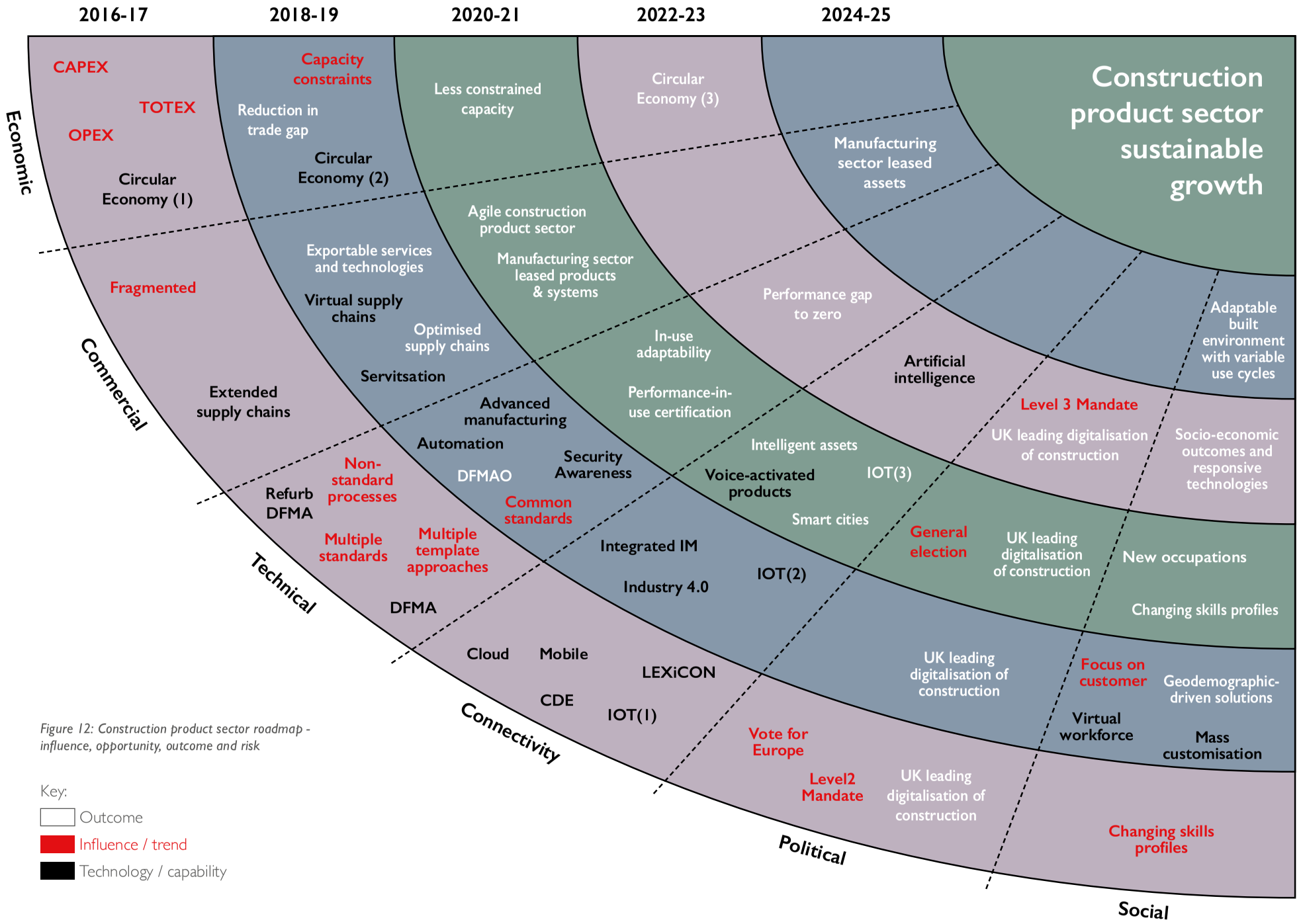
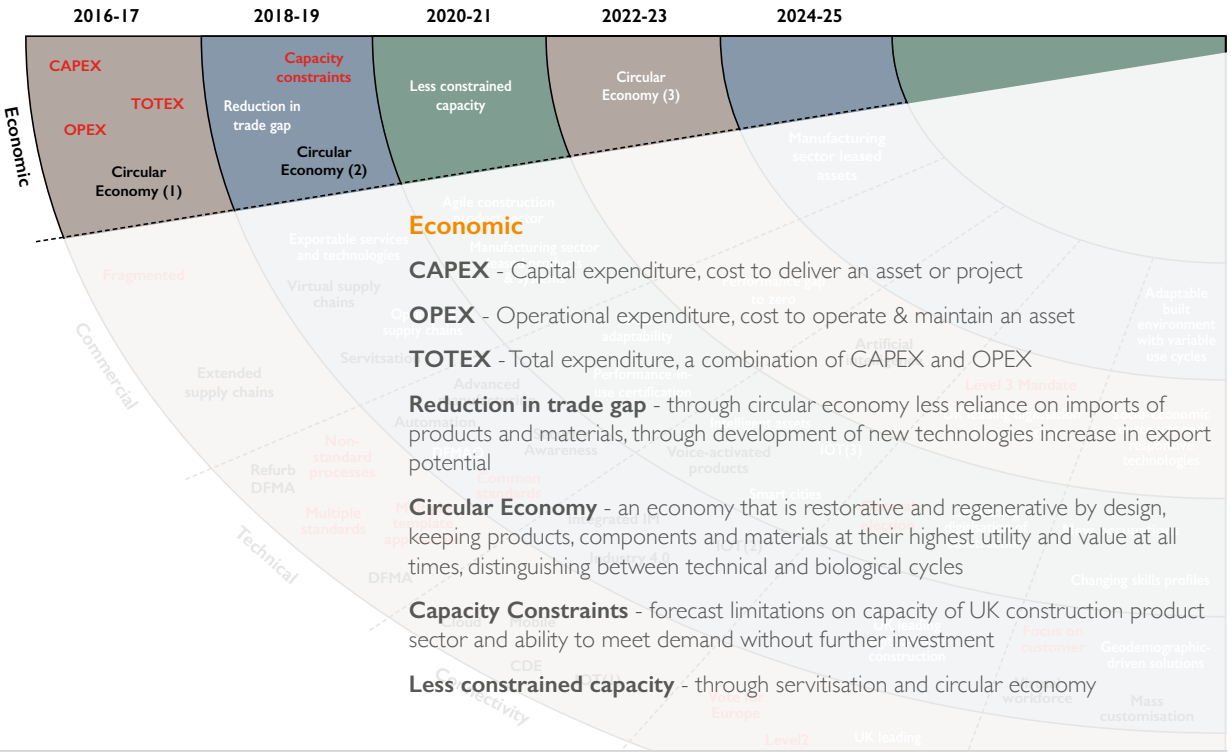


Figure 12: Construction product sector roadmap - influence, opportunity, outcome and risk



Economic

CAPEX - Capital expenditure, cost to deliver an asset or project

OPEX - Operational expenditure, cost to operate & maintain an asset

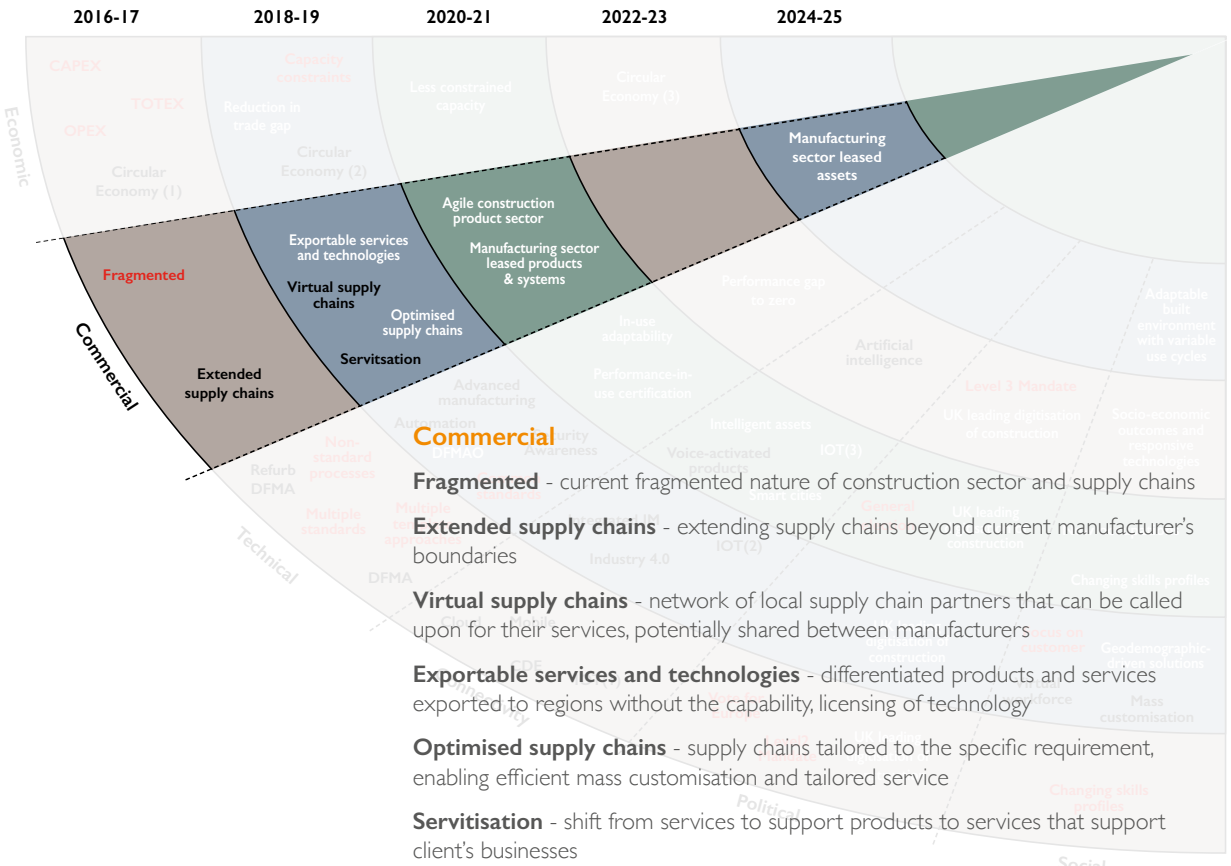
TOTEX - Total expenditure, a combination of CAPEX and OPEX

Reduction in trade gap - through circular economy less reliance on imports of products and materials, through development of new technologies increase in export potential

Circular Economy - an economy that is restorative and regenerative by design, keeping products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles

Capacity Constraints - forecast limitations on capacity of UK construction product sector and ability to meet demand without further investment

Less constrained capacity - through servitisation and circular economy



Commercial

Fragmented - current fragmented nature of construction sector and supply chains

Extended supply chains - extending supply chains beyond current manufacturer's boundaries

Virtual supply chains - network of local supply chain partners that can be called upon for their services, potentially shared between manufacturers

Exportable services and technologies - differentiated products and services exported to regions without the capability, licensing of technology

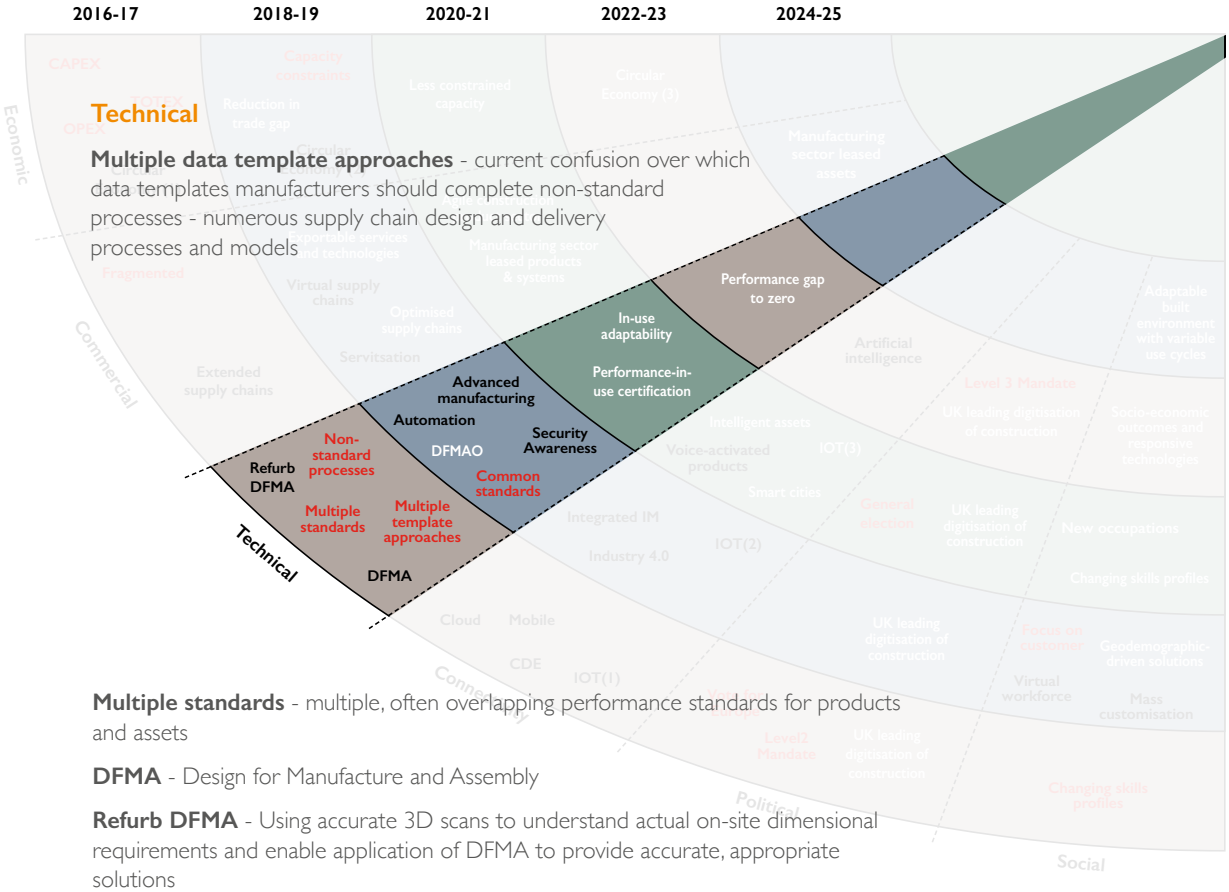
Optimised supply chains - supply chains tailored to the specific requirement, enabling efficient mass customisation and tailored service

Servitisation - shift from services to support products to services that support client's businesses

Agile construction product sector - ability to respond to changing demand without significant investment

Leasing products & systems - part of servitisation, selling performance of an asset as a service instead of selling products

Manufacturers leasing assets - step on from leasing products & systems, potential to deliver and lease entire assets with guaranteed performance



Multiple standards - multiple, often overlapping performance standards for products and assets

DFMA - Design for Manufacture and Assembly

Refurb DFMA - Using accurate 3D scans to understand actual on-site dimensional requirements and enable application of DFMA to provide accurate, appropriate solutions

DFMAO - DFMA with additional focus on designing and constructing to optimise technical solution across the life cycle of an asset

Advanced manufacturing - integration across the value chains of the functions of production, distribution and consumption

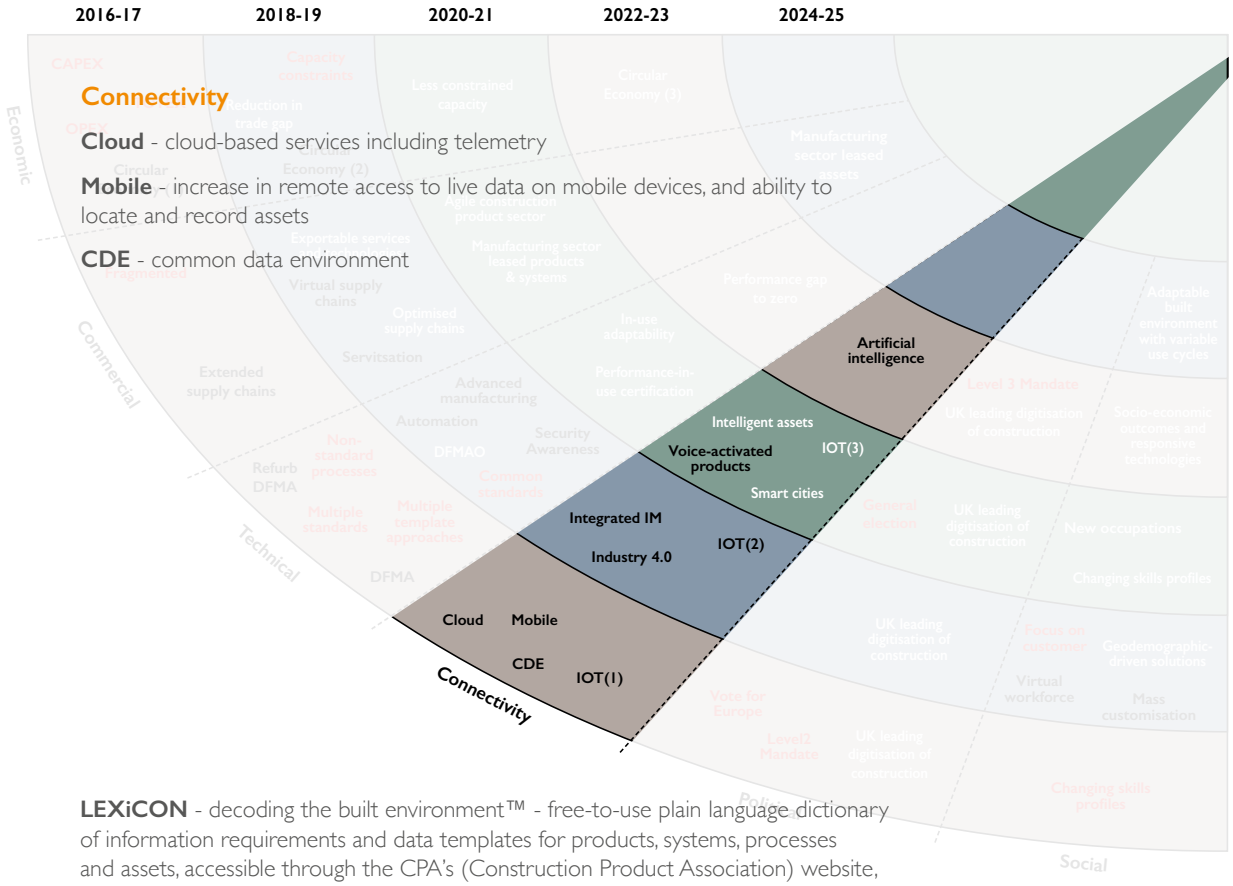
Common standards - multiple linked performance standards for products and assets

Security awareness - management of secure asset information, and ability for products and systems to raise awareness of any breach or theft, and to be geo-located

Automation - use of automatic equipment and processes within manufacturing and assembly

Performance in use certification - products, systems or assets certified in-use through onsite measurement enabled by telemetry instead of certification under laboratory conditions

Performance gap to zero - eliminating the difference between as-design and as-built performance of an asset

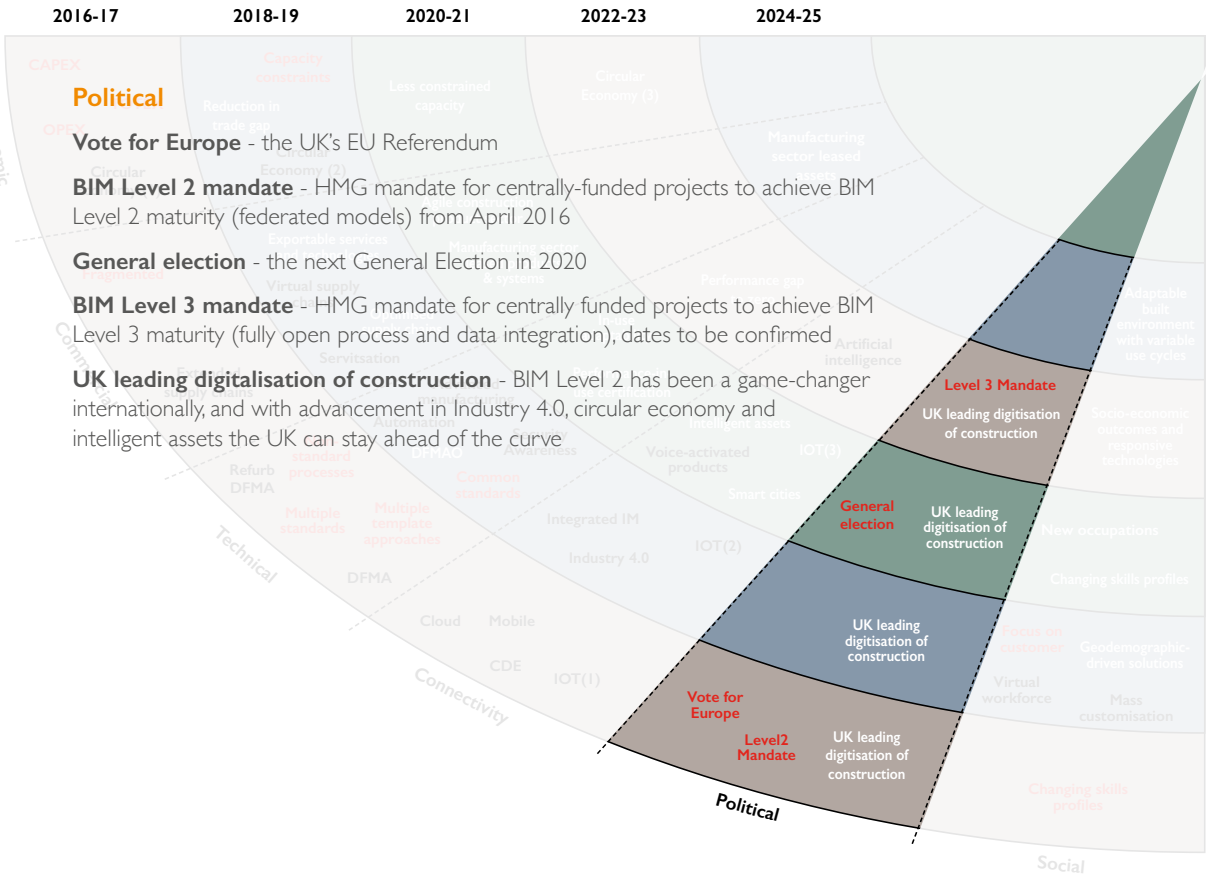


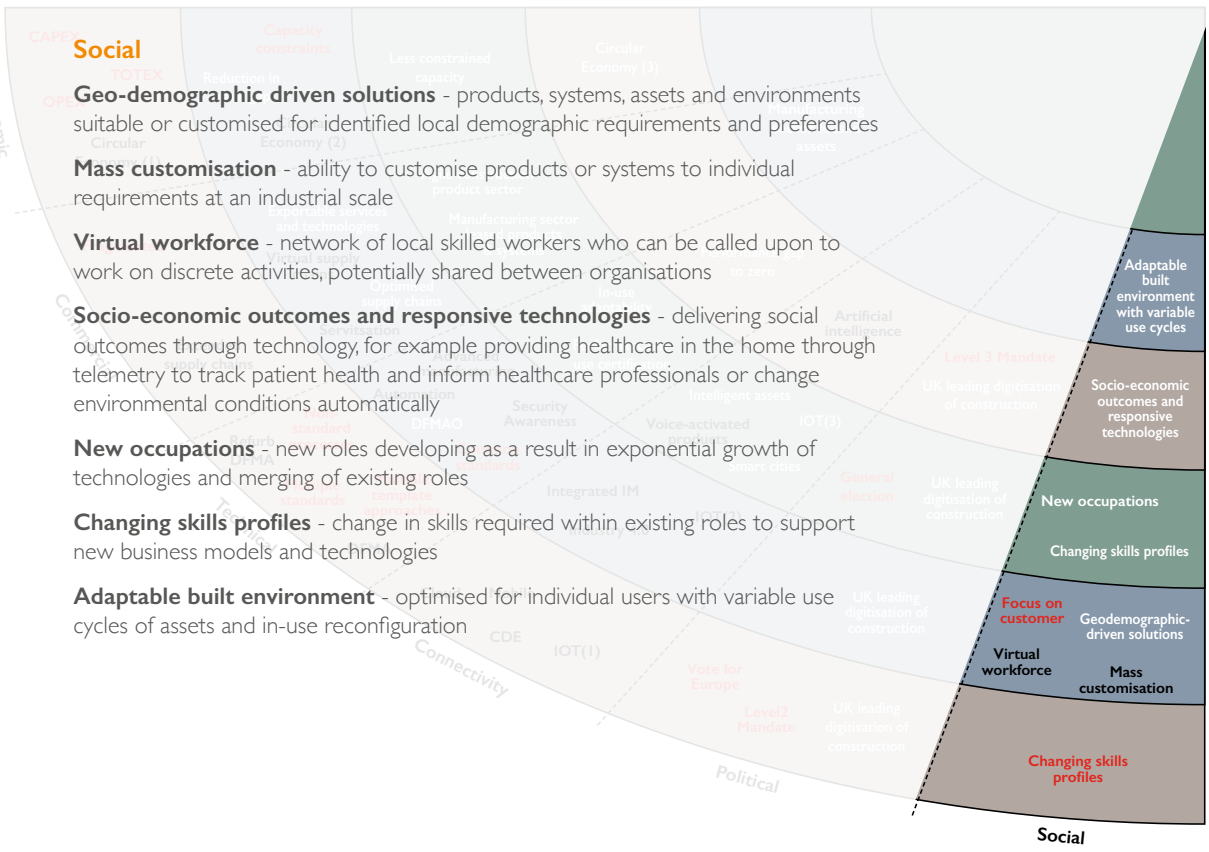
LEXiCON - decoding the built environment™ - free-to-use plain language dictionary of information requirements and data templates for products, systems, processes and assets, accessible through the CPA's (Construction Product Association) website, managed by the CPA and UK BIM Alliance (UKBA) with support from professional institutes and trade associations. Developed through HMG BIM Task Group

Integrated IM - Integrated information management - management of information through a business, life cycle or supply chain to ensure a single source of truth and being able to provide the right information to the right place at the right time

Industry 4.0 - the fourth industrial revolution, combines automation and data exchange in manufacturing technologies. It includes cyber-physical systems (CPS), the Internet of Things and cloud computing to create smart factories that enable mass customisation and maximise production efficiency

LEXiCON | decoding the built environment


2016-17
2018-19
2020-21
2022-23
2024-25
Political
Vote for Europe - the UK's EU Referendum
BIM Level 2 mandate - HMG mandate for centrally-funded projects to achieve BIM Level 2 maturity (federated models) from April 2016
General election - the next General Election in 2020
BIM Level 3 mandate - HMG mandate for centrally funded projects to achieve BIM Level 3 maturity (fully open process and data integration), dates to be confirmed
UK leading digitalisation of construction - BIM Level 2 has been a game-changer internationally, and with advancement in Industry 4.0, circular economy and intelligent assets the UK can stay ahead of the curve
Level 3 Mandate
UK leading digitisation of construction
General election
UK leading digitisation of construction
UK leading digitisation of construction
Vote for Europe
Level2 Mandate
UK leading digitisation of construction
Political
Social
Economic
Technical
Connectivity


2016-17
2018-19
2020-21
2022-23
2024-25
Social
Geo-demographic driven solutions - products, systems, assets and environments suitable or customised for identified local demographic requirements and preferences
Mass customisation - ability to customise products or systems to individual requirements at an industrial scale
Virtual workforce - network of local skilled workers who can be called upon to work on discrete activities, potentially shared between organisations
Socio-economic outcomes and responsive technologies - delivering social outcomes through technology, for example providing healthcare in the home through telemetry to track patient health and inform healthcare professionals or change environmental conditions automatically
New occupations - new roles developing as a result in exponential growth of technologies and merging of existing roles
Changing skills profiles - change in skills required within existing roles to support new business models and technologies
Adaptable built environment - optimised for individual users with variable use cycles of assets and in-use reconfiguration
Adaptable built environment with variable use cycles
Socio-economic outcomes and responsive technologies
New occupations
Changing skills profiles
Focus on customer
Geodemographic-driven solutions
Virtual workforce
Mass customisation
Changing skills profiles
Social
Economic
Technical
Connectivity

3.3 People

"An environment…is an environment only by virtue of the life that it surrounds…we do not talk about surroundings without reference to the people surrounded, nor should we talk about housing as a thing of intrinsic value separate from the people housed."
- John Turner (1974)

It can easily be forgotten, but the built environment has been created to support us in our daily lives, surrounding us through life, work and play. A combination of physical objects (products, systems, buildings, bridges, infrastructure) and spaces, it should be a willing receptacle for the life it supports. However, even if the same occupants remain in an asset for its entire life cycle, their needs are likely to change significantly over time as circumstances or preferences change, and new technologies become available.

In-use adaptability - meeting changing requirements and potential for products and services

Looking at homes as an example, we need to consider housing as a long-term resource that can grow and adapt as part of a circular economy. Through careful consideration during the design and production of homes based on the needs of the occupants at both individual and community levels we can, to a large extent, future-proof our homes; allowing them to adapt to their changing requirements over time and cope with external as well as internal contextual differences.

We can enable efficient future upgrades or replacements whilst also providing flexibility to develop an unlimited range of typologies to suit different requirements using the same or similar components and methodologies. We can do this by combining effective information management and data exchange with flexible product manufacturing and supply chains; the concept of adaptable homes has been around for over a century, but digital and production technologies have now caught up with the vision, and it presents a real opportunity for the construction product sector. It doesn't mean that we need to design in the flexibility to support every possible household type, more that we need to design out the inflexibility that may otherwise lead to compromise by future likely occupants. By using geo-demographic information and consumer marketing it is possible to understand the likely users of a development based on the location and user preferences, and feed these into the design and delivery of more flexible assets. To achieve this, there needs to be a shift from product-driven to customer-driven solutions, from DFMA (Design for Manufacture and Assembly) to DFMAO (Design for Manufacture, Assembly and Operation), from capital delivery to through-life value.

The ManuBuild programme explored the potential for open building DFMAO systems that enabled this level of adaptability and demonstrated the potential social value, energy savings and re-use of components over the life cycle of an apartment. This approach is not to standardise spaces, but to concentrate on creating the place for activities and facilitating these through DFMAO, instead of concentrating on the development of product alone.

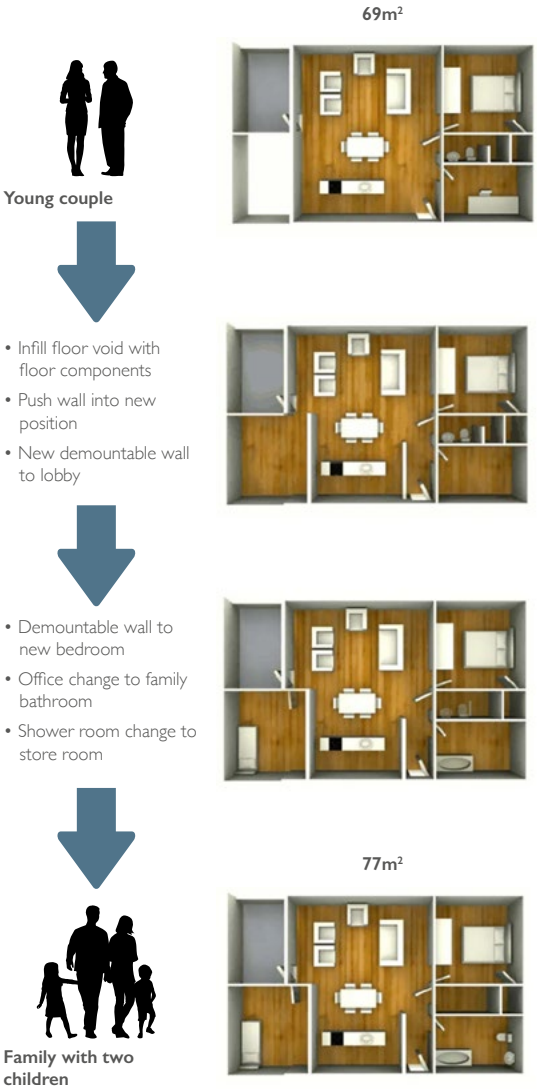


Figure 13: Re-configurable apartment study, ManuBuild WP 2.5

Using this flexible approach provides construction product manufacturers the opportunity for new business models, including the sale of performance and value achieved instead of product alone. Manufacturers are beginning to explore the potential for leasing their products or systems over a longer period of time instead of selling outright; plasterboard and insulation manufacturers amongst others are already exploring the potential to integrate RFID tags and sensors within their products or materials to enable them to be identified and located, and for their performance in-use to be tracked.

In England alone, there are currently over 600,000 empty homes[8], and analysis suggests that the proportion of empty homes increases quite significantly in areas of low house prices. There are a number of reasons why homes may be left empty, and these include:

- A landlord needing to carry out significant improvement works that are unaffordable or will not make a return in areas of low house prices and rental values
- Owners have bought a property to do up, but cannot afford the work to complete
- Owners are holding a property empty anticipating a rise in its value before selling

The statistics suggest that while there is typically demand for affordable housing in areas that have a relatively high proportion of empty homes, it is the affordability and quality of the assets that can cause the mis-match.

Offering finance on products such as external wall insulation that can be paid back gradually as the building is in use and making a return can provide manufacturers with more stable revenue streams. It can also enable buildings to return to use, and potentially lead to further product and service sales as a result.

The virtual workforce

The shift from an analogue to digital construction industry, and from a product to a service-based construction manufacturing sector, will no doubt bring significant change in the skills that are required to meet capacity and enable growth[9]. We are already experiencing this within existing sector roles, but there are also new roles developing that cross traditional boundaries, such as information managers or multi-trade onsite capability to connect disparate manufactured building systems onsite. The construction sector is already competing with others for high value skills such as information technology professionals, and the demand for such skills will only grow over the next decade.

In addition to changing skills there will be a significant cultural change as digital technologies and more collaborative working methods become the norm; the need for flexibility and acceptance of new skills and roles within the sector. These changes do provide a risk in the short term with the rush to employ individuals with digital capabilities for example, also regional trade skills shortages. However, there is also an opportunity to develop a more flexible, highly skilled workforce by disaggregating the skills required and using technologies already in existence in other walks of life.

From an individual's perspective, imagine making your skills and availability discoverable with a manufacturer, a number of organisations or a service akin to the Uber of construction; providing employers with the ability to automatically pre-book or appoint you to carry out pre-defined activities based on your location and their needs. It can provide both parties with access to opportunities and skills that may otherwise not be apparent and provide greater flexibility to cope with ever-changing demand whilst using local skills and resources where possible. Similar virtual workforce services exist in the freelance sector; Upwork is the largest online talent site, with over nine million freelancers predominantly in the information technology, web and design fields. Their research suggests that whilst in the virtual world it takes an average of three days to fill a vacancy, in the physical world the average is as high as forty-three[10].

8. Empty Homes in England, Empty Homes, 2015 9. Technology and skills in the construction industry, UKCES 2013
10. Digital Transformation of Industries, WEF 2016

3.4 Smart

The ability to integrate sensors and create smart assets has been discussed earlier; incorporating sensors into products and systems to enable them to be geo-located, performance in-use to be measured and tracked and for the collection of data to feed back into product development and support the circular economy.

Box 4 highlights key capabilities and principles that can support business growth through digitalisation; certainly not all opportunities rely on the incorporation of sensors, and here we look at key themes through an asset's life cycle in more detail. These themes are:

- Managing complexity
- Generative design
- Production and supply chain optimisation
- Operation and feedback
- Occupant and manufacturer interaction

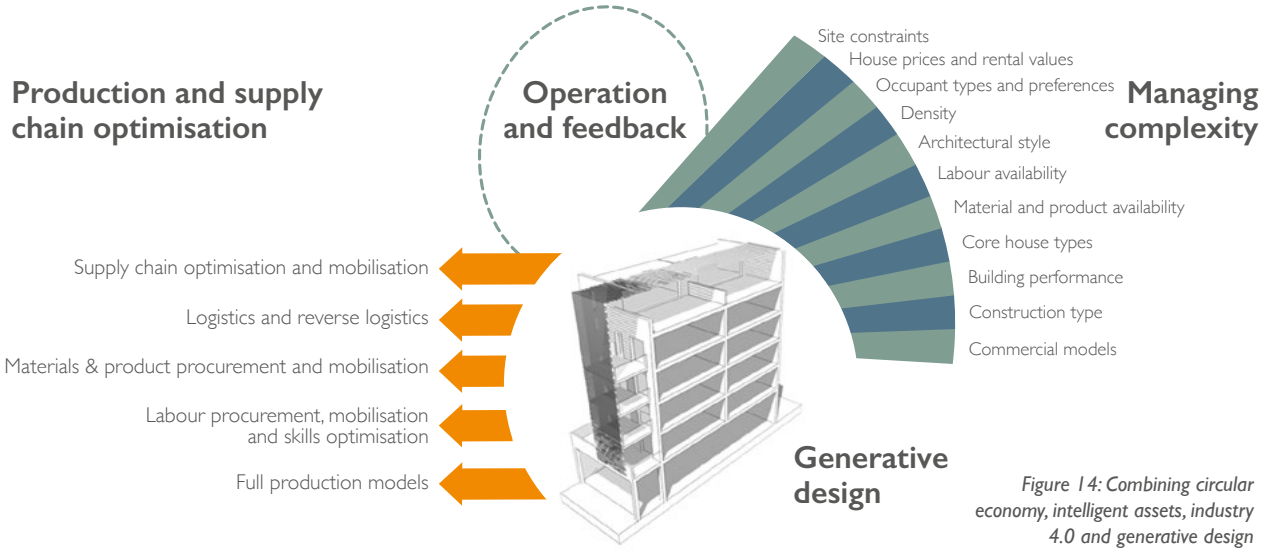


Figure 14: Combining circular economy, intelligent assets, industry 4.0 and generative design

Box 4: 'No regret' digital capabilities

Source: Digital Transformation of Industries, WEF 2016

The following are a set of no regret capabilities that apply across industries, which are fundamental to the creation of digital operating models or operational efficiencies:

1. **Sense and interpret disruption.** Look beyond your own industry. Be prepared to blur the lines between the physical and digital worlds.

2. **Experiment to develop and launch ideas faster.** Stop innovating and look to solve customer problems instead. Develop platforms for fast and cheap experiments. Find or fund one venture that could most disrupt you.

3. **Understand and leverage data.** Organise data hackathons. Think beyond big data to consider different types of data. Find new ways to monetise data. Create an analytics team.

4. **Build and maintain a high-quotient digital team.** Be honest about how digitally savvy you and your workforce are. Create digital boot camps to re-skill employees.

5. **Partner and invest for all non-core activities.** One of the characteristics of effective digital leaders is their intuitive understanding that the journey is not one to be undertaken alone.

6. **Organise for speed.** Ensure CEO support and the presence of a dedicated central team to drive the new digital growth is supported by a team of digitally savvy executers.

7. **Design a delightful user experience.** User experience drives IT architectures, and not vice versa.

Managing complexity

With the complex range of drivers, benefits, value, risks and factors involved when considering a potential development, and the fragmented nature of a project-based construction industry, it can be difficult to understand the full implications of early decisions or to share learning from previous experiences. However, with the plethora of open data sources from the likes of the Land Registry, the ONS (Office of National Statistics) and other organisations, there is the potential to aggregate and analyse data to provide insights before significant expense is expelled.

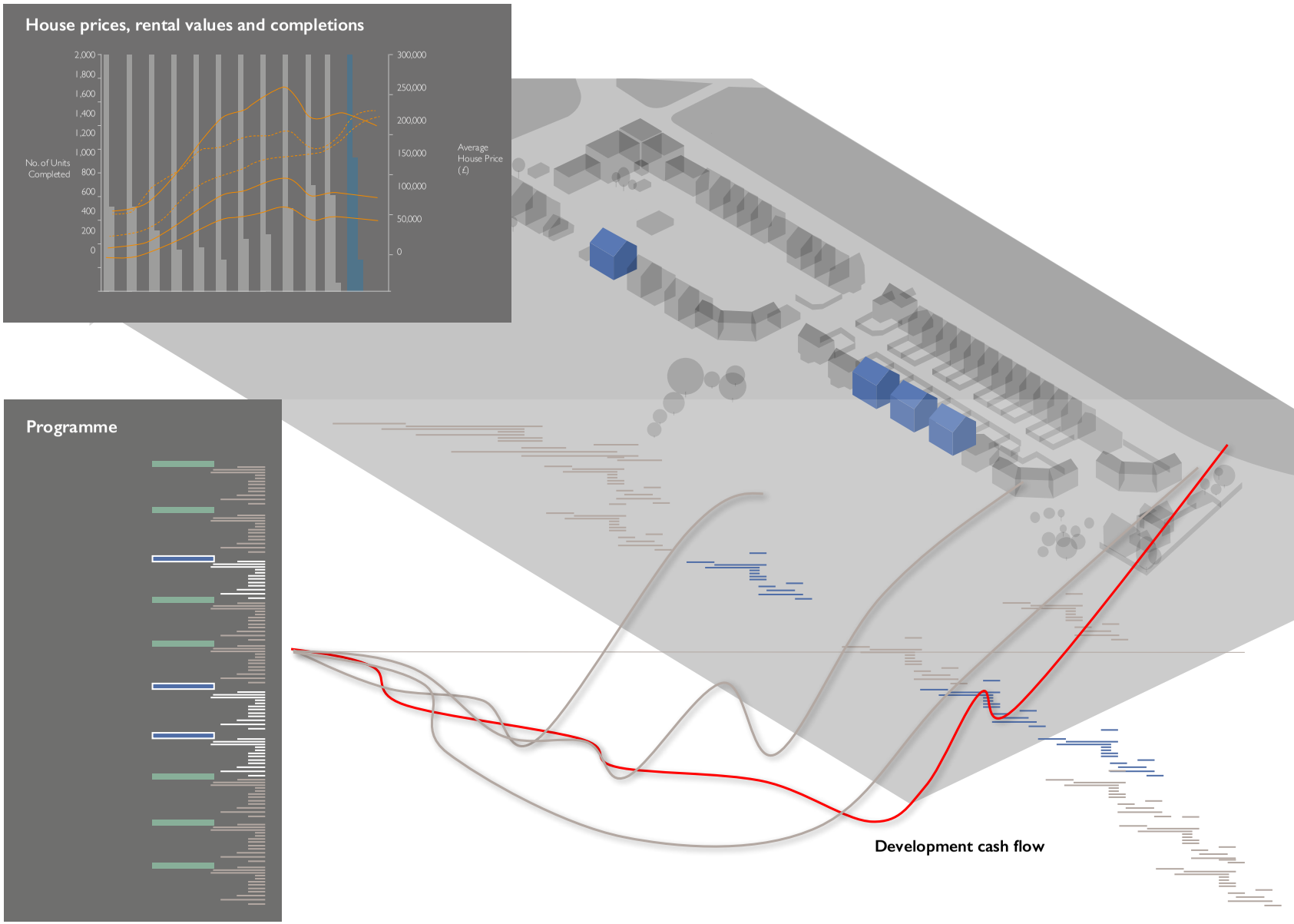
A leading digital construction strategy consultancy is developing a data tool that supports decision making on the viability and optioneering for residential developments, initially in the UK. For any location in the UK, the tool enables users to immediately ascertain local house prices, rental values, occupant types and their housing, tenure and layout preferences, trade skills availability and typical densities and sales rates. In addition information is available on local housing demand, regional developers and their business models and land values to understand the potential viability of a scheme.

Using either existing or bespoke data on the time and resource requirements for different construction technologies at an individual task level, the tool can then produce tailored delivery programmes and (when linked to further data sets) accurate cost estimates that can be optimised by adapting resource availability and display project cashflows based on different commercial models. Such tools enable product manufacturers to understand and demonstrate the potential value of their technologies, but also to test different commercial models with clients and supply chain partners.

Generative design

Generative design methods, where the output is generated by algorithms (a set of rules), can significantly improve the ability to act upon the data that can be aggregated and analysed from a number of sources, and to use it to deliver mass customised products, systems and assets.

Much of the industry's current design software has developed over a number of years, but still constrains the ability for input data to be acted upon to provide output that can be shared throughout the full design, delivery and operation phases of an asset. Even progressing from initial design concept through to detailed design and fabrication usually requires a number of software packages, models and data translations to occur, leading to potential errors.



Housetype 1

- Dimensions
  - GIFA 87.42²
  - Volume
  - Gross internal width
  - Gross internal depth
  - Storeys
  - Bedrooms - 3
  - Bathrooms - 2
  - Person - 5
  - Tenure - private for sale
  - Phase - 2
  - Construction type - panel
  - Plot area

Demographics

- Secure families
- Blue-collar roots
- Struggling families
- Affluent greys
- Settled suburbia

Housetype preferences

- 3 bed 5 person semi, private for sale
- 3 bed 5 person det, private for sale
- 4 bed 6 person det, private for sale
- 3 bed 5 person semi, shared ownership
- 2 bed 4 person semi, private for sale

Skills availability

- Bricklayers
- Civil engineering
- Construction managers
- Electrical trades
- Floorers
- Labourers
- Painters and decorators

Figure 15: Residential viability tool proof of concept incorporating location-specific housing market data, geo-demographics and preferences, resource availability, programme and development cashflow, courtesy of PCSG.

In addition, interfaces between products and systems can be difficult or even impossible to model, meaning only part of a final solution can be accurately assessed prior to transitioning from the virtual to physical worlds.

Generative design systems are being developed that remove current modelling constraints, and can accurately and simultaneously model products, interfaces, processes and supply chain relationships through the design and development process. A leading example is RST (Ravnikar Soper Technology), a generative modelling software technology that uses algorithms, data storage techniques and an underlying logical structure to produce fully resolved models.

Starting with a logical structure based on key functional requirements (such as how many floors a building may have), RST then defines concepts locally, known as the locality principle.

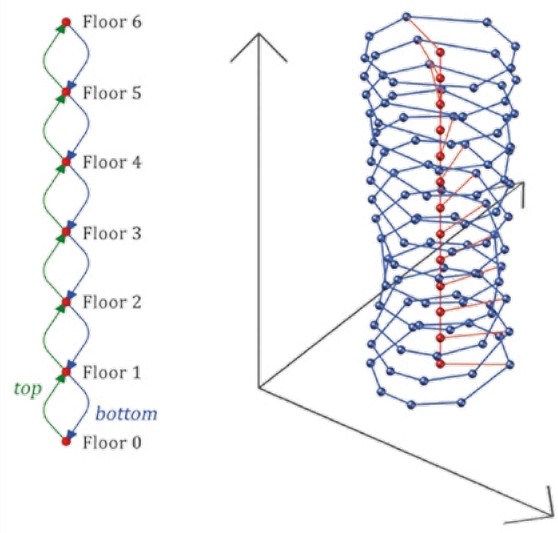


Figure 16: RST logical structure concept

This enables products, processes, spaces and supply chain relationships all to be assigned locally, relative to the logical structure and applied globally, where they automatically adapt to local situations; accurately holding as much product, material and process performance data as needed to support downstream activities. Completely reliable data-driven models can be produced down to the detail level of production, fabrication, assembly and logistics without loss of model performance; in combination with tools such as the viability tool described, RST can potentially provide fully resolved and customised solutions almost instantaneously, based on the interpretation of requirements and rules created at the outset.

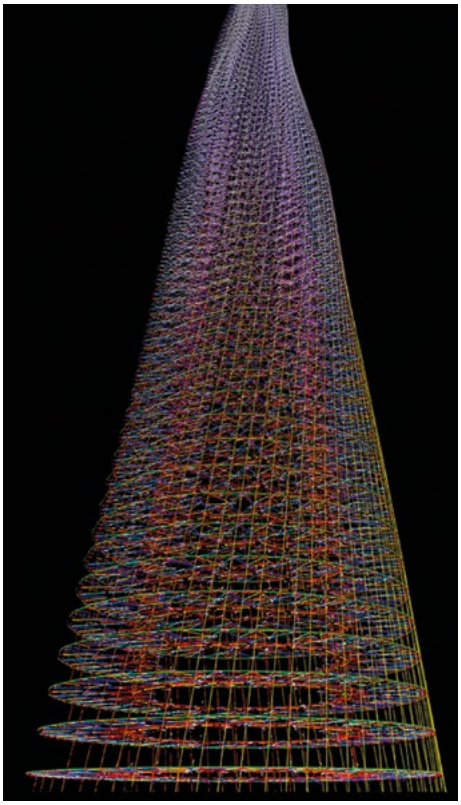


Figure 17: Example RST logical structure

Figure 18: Concepts defined locally

Figure 19: Details applied globally

Production and supply chain optimisation

By linking customers with products and services, focusing on their needs and potential direct interactions through the circular economy, construction product manufacturers can play a key role in optimising the delivery and operation of assets by selecting supply channels based on the value that they add. Whether traditional or manufactured building products and systems are used, supply chains can be optimised by reducing the number of non-value adding processes or transactions. By considering the supply chain from end clients through to key manufacturers, it can be easier to understand the optimal delivery channels for any given project. Clearly this requires either clients with multiple assets, or consortia that focus on delivery of similar solutions for a number of clients. Either way, the benefits come through leadership and engagement through the supply chain.

A good example of the opportunities for a direct link between product and customer need is the Factory in a Box for GSK.

The challenge set by GSK was for a 'zero incident, zero defect, zero waste' approach to the delivery of a factory solution to enable GSK product to reach 80% of the African population by 2020. In addition to the challenging construction programme in difficult, varied and often underdeveloped markets, GSK required best practice, a minimal cost footprint and delivery in an unprecedented time frame. The construction system developed by Bryden Wood is designed around the principles of rapid, safe construction by a low skilled team delivered through composite DfMA components that can be shipped out of Europe or procured locally as required; a virtual, flexible supply chain that is tailored to specific project requirements.

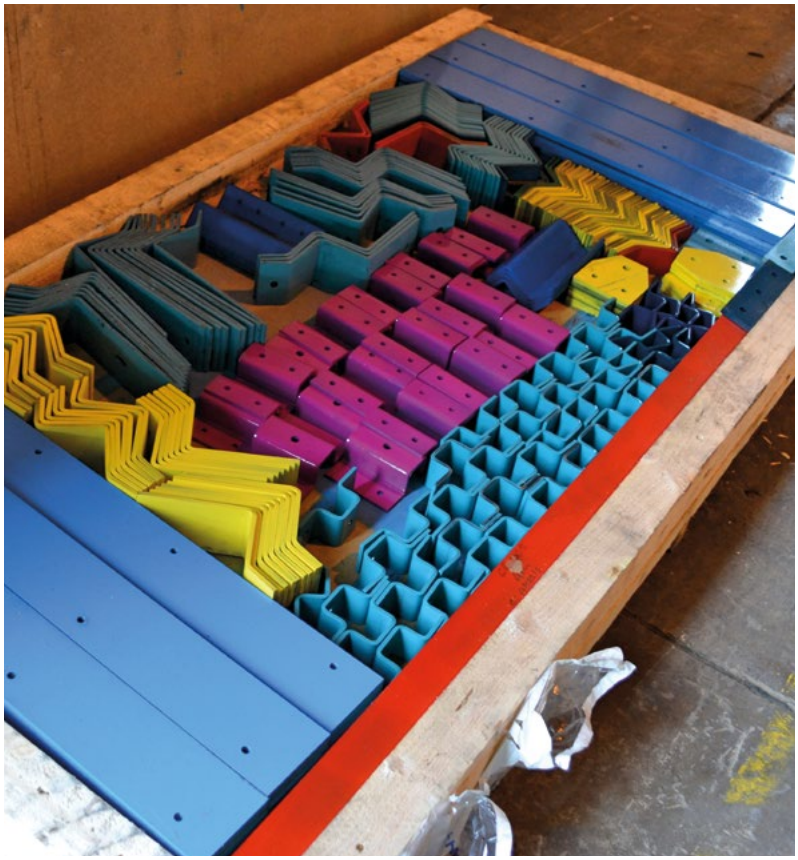


Figure 20: GSK Factory in a Box by Bryden Wood

Mass customisation and in-use adaptability are incorporated and tuned to GSK's specific business requirements. Best practice operation and maintenance is provided via standardised materials, operation and infrastructure. Finally, the design extends into a tailored BIM solution enabling rapid optioneering with early cost control and allows all components to be tracked through design, manufacture, logistics, construction, operation and maintenance via an integrated QR code asset management system.

Returning to the new-build residential sector, a focus on added value by linking manufacturers with the delivery and use of assets can also provide the opportunity for increased margins on the products and services they provide. Consider the typical residual value calculation for developments:

• Residual land value = GDV - construction costs - fees - developer profit

Where GDV (gross development value) is the sum of all property sales on the development (assuming no affordable housing or further contributions), a typical developer profit for a top 25 housebuilder is in the region of 20%.

The value of land and the ability to achieve the desired profit is used to determine the viability of a development for a given developer, and the GDV is clearly affected by what houses are expected to be sold for, which is typically assessed by comparing to local house prices. At a very basic level, it is easy to see that housing development is less attractive to a private developer in areas where house prices are low, or sales rates are low which will impact on a development cash flow.

In this model, the landowner makes a profit when selling the land, the developer makes the profit when they sell the houses, the construction team in building the homes and product manufacturers through selling product. Now consider the following alternative models:

- **Alternative model 1** - product/system manufacturers provide more integrated solutions and/or manage the supply chain reduce the need for contractor/developer integration, risk and hence margin. In such a model the construction cost is reduced, and the product manufacturer achieves higher margins on the products they sell. Overall development cost is reduced as a result of lower construction costs.
- **Alternative model 2** - product/system manufacturers provide more integrated solutions and/or manage the supply chain and take on a proportion of the development risk in exchange for higher product margins. Overall development cost is reduced as a result of lower construction costs and developer profit.
- **Alternative model 3** - product/system solutions and/or manage the supply chain, and reduce upfront costs by retaining a share in the development once completed and taking on a proportion of the development risk. Overall development cash flow is improved, meaning cash is coming into the development before all of the costs are incurred. Overall development cost is reduced as a result of lower construction costs and developer profit.
- **Alternative model 4** - product/system manufacturers provide more integrated solutions and/or manage the supply chain, and lease instead of sell their technologies, significantly reducing construction costs. Overall development cash flow is significantly improved, meaning cash is coming into the development before all of the costs are incurred. Overall development cost is significantly reduced as a result of lower construction costs and developer profit. Manufacturers retain a longer-term investment in the built assets and a more secure longer-term income.
- **Alternative model 5** - product/system manufacturers deliver the full construction of the houses, and retain full ownership of the physical asset. They lease building performance, not product, so guarantee the energy efficiency and performance of the asset in use. Overall development costs are reduced significantly, with only the cost of land and remediation paid upfront, housing occupants have the comfort of knowing that their homes will be maintained and performance guaranteed for as long as the contract. Manufacturers retain a longer-term investment in the built assets and secure a longer-term income, have the ability to monitor performance in use and feed that data back into product development, and are encouraged to innovate and upgrade properties to become more energy efficient and increase their profits accordingly.

These alternative models, in particular models 3, 4 and 5 have the potential to turn otherwise non-viable residential developments into viable developments, by shifting the role of integration and risk towards the manufacturer, integrating the supply chain and moving expenditure from the capital to operational phases. It is important however to ensure that in increasing the use of manufactured buildings, such systems do not dictate the aesthetics or style of housing unnecessarily due to their clumsy integration; through mass customisation and the careful integration of technologies housing can come in almost any style and configuration.

In addition to the benefits of construction flexibility in achieving unrestricted architectural styles, it also enables buildings to be constructed in a range of different ways dependant on project drivers, constraints and preferences; a system can be regionally refined to suit the needs of a specific project, so for example constructed as a 3D volumetric system where speed on site is a concern, in 2D panels where space is more constrained, and as stick components where speed is less of a concern and access is heavily restricted. Figure 21 illustrates this concept from the ManuBuild programme, where the systems developed could be constructed in 1D, 2D or 3D using the same components and opening up new market opportunities for manufactured systems.

Operation and feedback

Continuing the theme of manufacturers extending their involvement into the delivery and operation of assets, there is significant potential for providing additional services, leasing systems and even whole manufactured buildings. Through the development of a circular economy opportunities also exist to directly link built assets back to the manufacturing process; the potential to re-use, re-distribute, re-manufacture or re-cycle.

The ability to re-use products and systems does not necessarily lead to the prolonging of asset use cycles; instead we should be looking to optimise use cycles, so that when a building use or user preferences change, the asset can either be re-configured or even replaced to create a suitable environment. Imagine the scenario of leasing the use of a building from a manufacturer (including a home); as requirements change, you can either order a re-configured building, a performance upgrade, or even a new replacement building on the same site, all taken care of by the manufacturer, and paid for over an agreed period. Imagine taking delivery of a new home on the same site as your previous home, as you would take delivery of a new car, and the ability to remain in the same community instead of needing to re-locate purely because of changing space requirements.

This is achievable today through the combination of digital and manufacturing systems, but there is certainly a cultural change required before this approach becomes widespread. Such an approach can enable the manufacturer to receive live performance feedback on their products in-use, and also potentially enable the need for predictive maintenance to be flagged and even procured automatically. From a legislative perspective such data would also enable products and assets to be certified based on performance in use instead of under laboratory conditions that are unlikely to ever be replicated within a built asset.

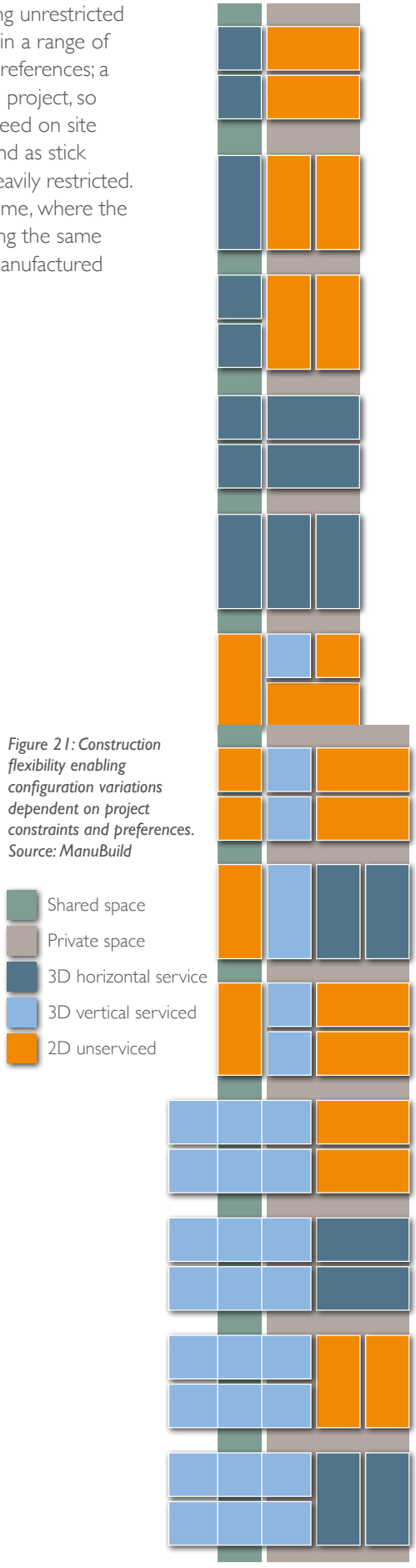


Figure 21: Construction flexibility enabling configuration variations dependent on project constraints and preferences. Source: ManuBuild

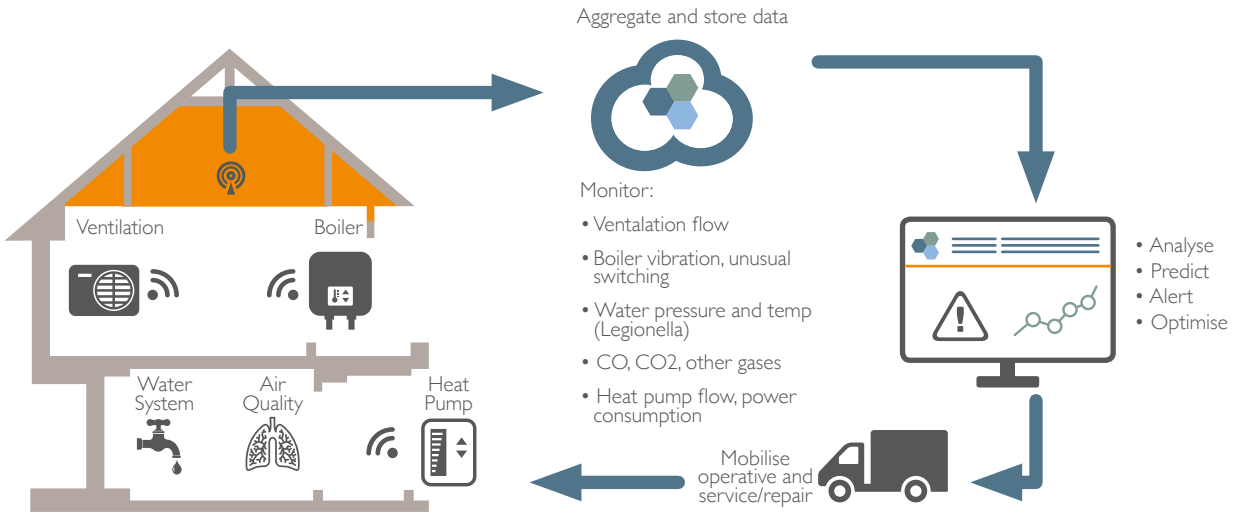


Figure 22: e4 predictive maintenance

In considering the life cycle of an asset, and the potential to develop a circular economy through the re-use of construction products, it is crucial that interfaces and future accessibility for maintenance and replacement has been taken into account.

Stewart Brand[10] identifies the following six simple layers based on their potential life cycle:

1. **Site** - geographical setting, the permanent, but changing context
2. **Structure** - the most durable built elements likely to traditionally last over 100 years
3. **Skin** - exterior envelope, less permanent than structure with a lifespan between 30 and 60 years
4. **Services** - likely to have a shorter lifespan, and certainly need to be separated from the structure to avoid unnecessary disruption
5. **Space-plan** - internal partitions, ceilings and floors with shorter lifespans, anywhere between three years for rapidly changing commercial environments to over 30 years in homes that may not traditionally change
6. **Stuff** - furniture and all things that may change and move many times a day

Figure 23: e4 control app for occupants

10. How buildings learn: What happens after they're built, Stewart Brand, 1994

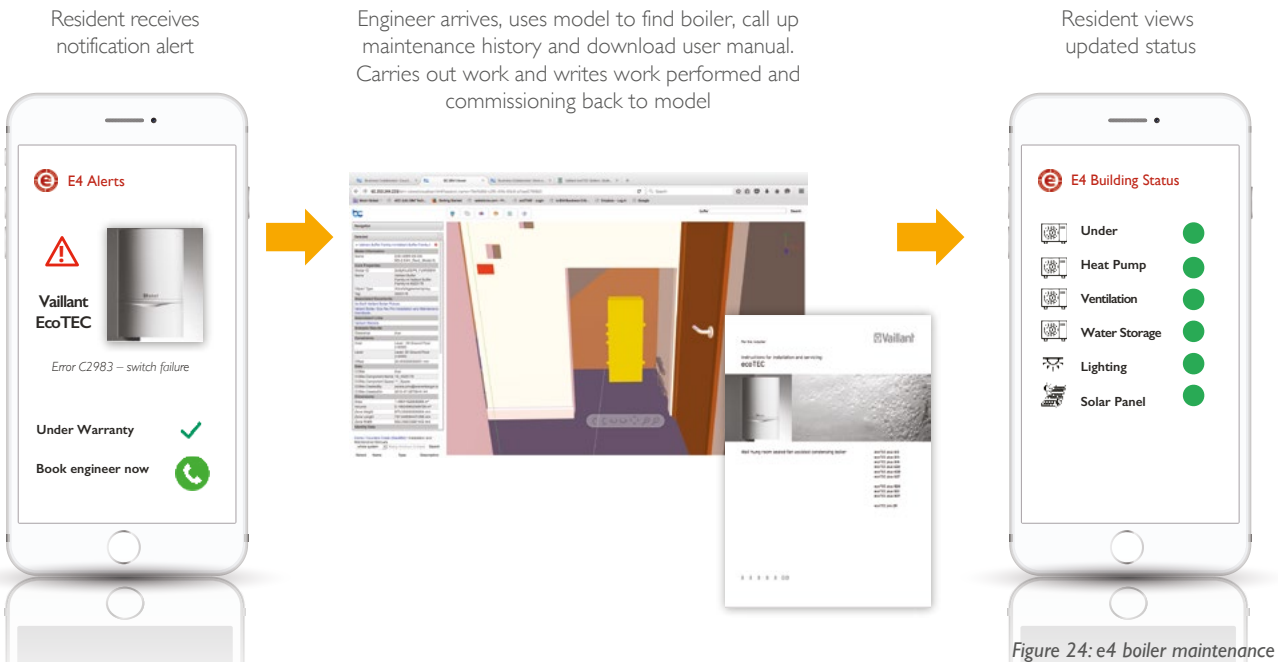


Figure 24: e4 boiler maintenance

Figure 25: e4 concept is applied to a range of home types

End user and manufacturer interaction

Weinerberger, a manufacturer of bricks, blocks and roof tiles amongst other products, has developed a housing concept called the e4 house, focusing on:

- energy
- economy
- environment
- emotion

Weinerberger has set up a consortium to deliver products and systems that they do not produce to deliver a whole house solution, and has supported this with full digital capability to support delivery and operation of the home. Occupants are provided with a full digital model of their home and apps that enable the user to track building performance, and organise predictive maintenance.

3.5 Sustainable

Closing the performance gap

It has been clear for many years that there is a significant difference between how building designs are assessed to demonstrate compliance in the virtual world, and how buildings perform in the physical world, known as the performance gap. A recent detailed study by Innovate UK[11] of 50 non-residential projects and 76 homes illustrates the gap; for non-residential buildings the carbon emissions were on average 3.8 times higher than designed, and up to 4.6 times as high. There are a number of reasons for the gap; the key factors and potential solutions through smart, digital manufacturing and construction sectors are:

- The assumptions made and accuracy of calculation software - through the integration of real-life performance data, and the use of generative tools in the future, the accuracy of design software can be improved.
- Lack of feedback from completed assets back to the design and delivery teams of future assets, or a longer-term relationship between capital delivery and operation teams - by sharing real-time analytics on performance in-use, and by extending the manufacturer's role into the operation phase of an asset, performance and best practice can be linked through the supply chain.
- Poor quality workmanship, not constructing assets as they were designed - the Innovate UK programme indicates that where performance in-use is tested, such as airtightness, then the performance improves significantly as more care is taken. In addition, knowledge of what is important to achieve the necessary performance improves, as is the case in the development of Robust Standard Details for acoustic performance. Integrated sensors can be used to track quality of workmanship - imagine a red LED notifying you that a system has not been installed correctly, or a message on your smartphone informing you that a hidden element has been moved.
- Products and system performance is certified under strict laboratory conditions, which are different to performance in-use - the collection and analytics could be used in the future to certify performance in-use, providing certainty on how a product will actually perform.
- Lack of awareness of the implications of moving or re-arranging products and systems (for example moving insulation to insert building services, and not replacing) - as with Robust Standard Details and airtightness testing, by certifying performance in-use industry will quickly learn how designed performance can be achieved in reality.
- Not all energy use is regulated, so whilst the average in-use emissions for regulated energy was still 2.37 times the designed performance, non-regulated energy has a significant impact. By tracking actual energy use and disaggregating it by where it is being used and when, it is much easier to reduce non-regulated energy.

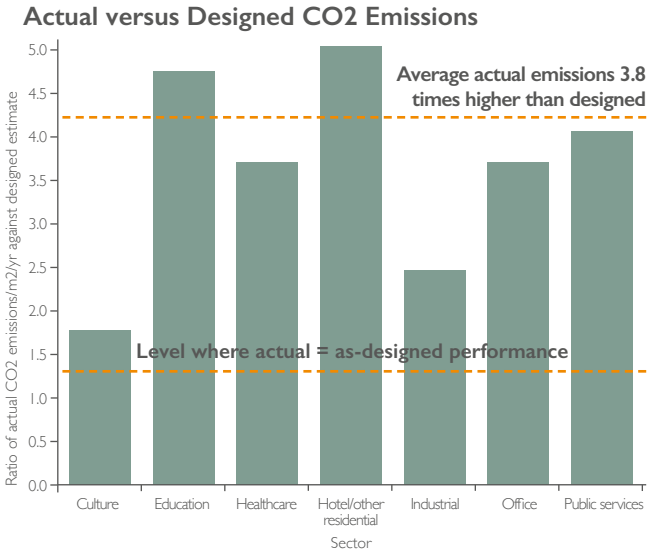


Figure 26: Comparison between as-designed and as-built carbon emissions measured over 50 projects. Source: Building Performance Evaluation Programme, Innovate UK 2016

11. Innovate UK funded an £8million Building Performance Evaluation Programme to provide evidence on the performance gap and understand how it can be reduced.

The first steps towards a circular economy

Many manufacturers already have schemes to take back material at the end of life, to minimise waste taken to landfill. British Gypsum and Siniat both have dedicated plasterboard recycling schemes for example, and Armstrong Ceilings has a similar scheme for acoustic ceiling tiles. To support this trend and provide consistency FIS (the Finishes and Interiors Sector trade association) has worked with others to develop an initiative to signal that materials will be re-used or recycled at the end of their use within a built asset. Pre-cycle agreements will be issued by manufacturers at the point-of-sale and confirms that there is a take-back scheme for the product or material at the end-of-a-use case; the agreement also confirms that none of the material returned will be sent to landfill.

This simple initiative is designed to encourage manufacturers to develop products that are designed for deconstruction, using materials that can be viewed as a resource and not waste.

Buildings as material banks

BAMB (Buildings As Materials Bank) is a four year long project funded by the European Commission (under the H2020 call) which started at the end of 2015. 16 partners from eight European countries are working together to enable a systemic shift in the building sector by creating circular solutions. Whether an industry goes circular or not depends on the value of the materials within it, and so BAMB is looking to create ways to increase this value. The project is developing and integrating tools that will enable the shift; Materials Passports and Reversible Building Design – supported by new business models, policy propositions and management and decision-making models. During the course of the project these new approaches will be demonstrated and refined with input from six pilot projects.

Inter-seasonal energy storage

The Innovate UK project INTRESTS (Inter-seasonal Thermochemical Renewable Energy Storage System) led by Tata Steel, incorporates the largest technical demonstration of the potential to upscale absorption storage for thermal energy suitable for capture and storage of low temperature heat from cost-effective solar collectors. Low grade heat generated by transpired solar collectors in the building's envelope can be stored during summer and subsequently released, on demand, when required during the winter. The heat is stored using chemical salts synthesised onto a host matrix, which under testing has shown energy densities above 500 kWh/m3 and heat release greater than 60°C.

Health & Safety

The implementation of BIM Level 2, and the ability to accurately model construction and operational scenarios before work even begins on site, has significant potential to reduce health & safety risk in construction and asset operation. From a product supplier's perspective, accurate and maintained asset information can be accessed by facilities management teams on any product that requires maintenance, including any potential hazardous materials, maintenance and replacement information.

The BIM4Regs special interest group, set up as part of the BIM Level 2 programme, is exploring methods of using BIM to demonstrate and check compliance with building regulations. The ability to check accurate models at an early stage can further reduce any risk of non-compliance.

3.6 Growth

Digital technologies are already widespread throughout the UK economy, but there is much to benefit from companies across all sectors of the economy making the best use of digitalisation. In 2016, the CBI highlighted that 92% of member firms surveyed stated that there were clear economic benefits to be gained from greater use of digitalisation and 73% of firms stated that there were clear job creation benefits.

In the broader European market, the benefits of increased digitalisation are significant. McKinsey estimates that a digital single market could add between €145 billion and €375 billion to annual GDP by 2022 due to sectors that extensively utilise digitalisation. Furthermore, it estimates that if sectors that do not extensively utilise digitalisation, such as manufacturing and construction, were to double their digital intensity then the digitalisation of companies in Europe could add €2.5 trillion to European GDP by 2025.

Growth in the UK construction product sector is no longer just a nice-to-have. It is essential if the UK is to remain competitive internationally in terms of smart assets and cities, and to reduce the trade gap between imports and exports of construction products.

The UK construction products sector was worth £42.9 billion in 2011, prior to the introduction of BIM into the Government's Construction Strategy, in 2012. The sector has grown 18.0% since then and is currently worth over £50.0 billion from a total UK construction sector that is worth £128 billion.

Since 2012 we have seen the majority of product suppliers invest in BIM (58% according to the 2015 BIM4M2 survey), and the BIM4M2 (BIM for Manufacturers and Manufacturing) special interest group becoming replicated internationally. According to a recent report by Barclays on automation, 75% of respondents from the construction product sector have already invested in automation, the third highest sector behind heavy industry and medical devices. So the construction product sector is investing in the future, but more investment and longer-term certainty is needed from Government and industry alike.

Through a combination of initiatives and targets, the UK construction product sector has the potential to grow by 63% to £82.4 billion by 2025, from 37% to 52% of construction output.

Potential growth in the UK construction product sector through automation, digital processes and manufacturer-led supply chains

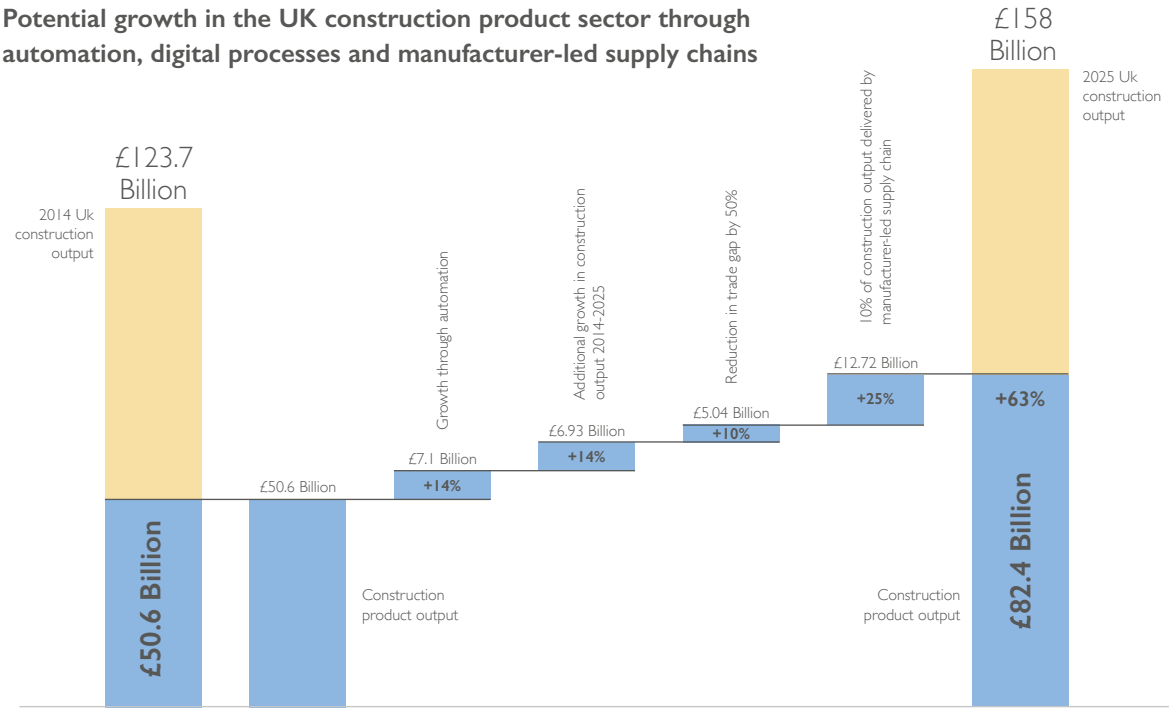


Figure 27

Automation

A recent Price Waterhouse Cooper's report (PWC2014) suggests that German manufacturers invest on average 3.3 percent of their turnover in Industry 4.0, and expect to get a return of 12.5% of turnover as a result over the next decade. If the UK construction product sector were to invest the same percentage and achieve similar returns, this will lead to a **£7.1 billion** growth of the sector.

A survey by Barclays (Barclays 2015), suggests that larger manufacturers are more likely to invest in automation than smaller organisation (only 21% of manufacturers with turnover less than £1m have already invested, whereas 71% with turnovers in excess of £10 million have already invested). However, due to the nature of the construction industry where many suppliers are used on any given project and integrated into systems, investment in automation and digitalisation does not only benefit larger manufacturers who are more likely to invest, but also their wider supply chain partners.

In addition to the potential for economic growth, the investment in automation is predicted to increase manufacturing jobs within construction by 4,627 by 2020, and 10,263 by 2025, with a further 3,163 additional jobs in other parts of the economy.

Additional growth in construction output

The UK construction sector is expected to grow to £158 billion by 2025. If the construction product sector were to grow at the same rate to keep up with demand, this would mean an increase of £14 billion, but as £7.1 billion can already be delivered through the efficiencies of automation, the sector needs to grow by a further **£6.93 billion** just to meet demand. If this isn't achieved, the trade gap (difference between import and exports of construction products and materials) is likely to increase by 88% from £7.8 billion in 2015 to £14.73 billion in 2025.

Reducing the trade gap

In the Government's Construction 2025 strategy, one of the key commitments is to reduce the trade gap for construction products and materials by 50% by 2025. With the forecast growth in construction output this means that to achieve the reduction, the UK construction product sector needs to grow by an additional **£5.04 billion** by 2020. The challenge is not simply the scale of growth required, but also the structural change.

In 2015, 79% of the trade gap by value was for finished products, with only the remaining 21% being for raw materials or semi-finished products. If the UK construction product sector is to grow to meet demand, there needs to be investment in the whole manufacturing chain to enable an increase in exports of the high value finished product. As already discussed, automation is likely to form a key part of the success in this area, but also increasing the re-use of products and materials by implementing a circular construction economy is likely to add significant value.

Manufacturer-led supply chains

The typical investment cycle for a manufacturing business is likely to be between 10 and 30 years for new facilities, so much longer than a typical construction firm or parliamentary cycle. Bearing in mind that a significant proportion of UK product supply is delivered by multi-national companies who can choose where to build their new factories, it is important for UK growth that the environment is encouraging for investment in UK manufacturing.

Due to the fragmented nature of the construction industry, it can often be difficult for manufacturers to ascertain the future size of market for their products. However, driven largely through digitalisation of the construction industry led by the Government's BIM strategies, there is the potential to change and provide much greater certainty. In a traditional construction market, manufacturers are often concerned that their products will be substituted for alternatives that may, or may not be of the same value for an asset, but may be cheaper at face value. Through BIM Levels 2 and 3, and increasing awareness of the value of products in use, it is easier to make informed decisions on the right product for the client. In addition, there is the potential for manufacturers to lead the delivery of large proportions of an asset, or in some cases the full delivery. As with the Wienerberger example in Section 3.4, a large manufacturer has assembled a consortium of manufacturers to deliver a whole house solution, delivered in line with BIM Level 2, and in doing so guarantee their product sales for any asset delivered using that model. This approach not only has the potential to increase volumes of product sales, but also the margins that can be achieved. As the margins and volume are both increased, it is possible to reduce, or in some instances eliminate the need to charge margins for the assembly or integration of an asset. Based on average on-costs for construction of 5% for main contractors, 6% for integrators

(Tier 2s) and 12% for specialist contractors, if 10% of the UK's construction output were delivered this way it can provide a **£12.72 billion** growth to the UK construction product sector. This does not include any additional volume of products, only the increased margins from optimising the supply chain. At the same time, it leads to over **£800 million of savings** on construction spend by reducing waste and unnecessary on-costs through the supply chain. A further benefit of this approach is the reduced risk associated with availability of labour. A recent Build UK State of Trade Survey reports that 18% of contractor respondents say labour shortages have resulted in late completion of work, and 16% say labour shortages have prevented them from bidding for work.

International growth

The ability for manufacturer consortia to deliver combined offers and to export these is significantly enhanced through the application of BIM and Industry 4.0, as the value can be demonstrated before construction begins.

Indirectly, there are further benefits to the UK construction products sector and UK economy through the UK becoming a world leader in BIM within the construction products sector. Exports of construction products only account for 15% of UK construction products manufacturing and the UK currently operates a trade deficit on construction products. However, if the UK can continue its progress to become a world leader in its use of BIM then it creates a first-mover advantage through technological leadership and effectively creates a new market through which construction product manufacturers can export their knowledge and processes throughout the world. As a consequence of this, the UK's construction supply chain will then be in a prime position to take advantage of its knowledge and experience in BIM in an increasingly digitalised global construction sector. The global construction sector was worth an estimated £5.7 trillion in 2015 and is expected to grow to £6.7 trillion in 2020 before rising to £10.3 trillion in 2030.

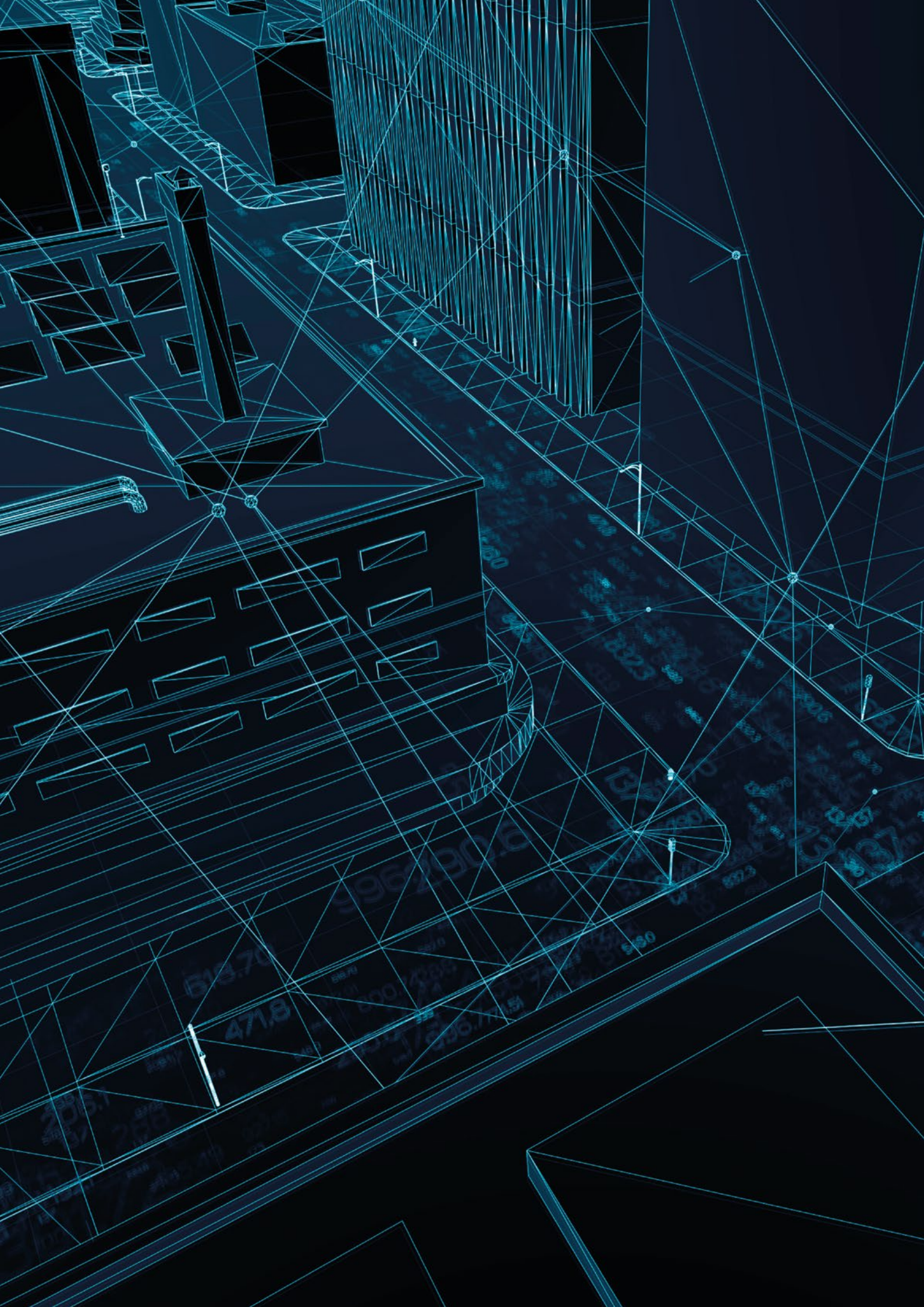
3.7 Leadership

The construction product sector has a significant role to play in the potential for a circular construction economy, through providing smarter assets, more efficient production and servitisation, and through reverse logistics to keep the value of materials at their highest at all times. The sector needs consistency in its approach if it is to fully achieve its potential through digitalisation, however assets are delivered very differently in different parts of the industry dependent on the organisations involved. Here we describe three categories and potential approaches to providing consistent approaches towards digitalisation:

1. **Client-led** - where capital delivery is driven by a repeat client, with a consistent and clear approach that supply chains are familiar with. Such an approach can be linked directly to business requirements, and enable shared best practice and measurement across a portfolio. HMG and the BIM Level 2 mandate is a good example of this in action. For the construction product sector, the information requirements should be clearly defined, however they may be different for a number of individual clients.

2. **Consortium-led** - where an intelligent, integrated supply chain is in place that works together to deliver projects to numerous clients, and employ consistent approaches in doing so. The e4 house consortium is a good example, and in that case it is led by a manufacturer, Weinerberger. As with the client-led option, there should be clearly defined information requirements for product manufacturers to respond to, although in this model the approach is driven by the value information management adds to the supply chain and the client.

3. **Common** - mass adoption of a common approach, likely to be as a result of either legislation or recommendations by industry bodies such as trade associations or professional institutes. This market segment can provide the greatest challenge to product manufacturers and supply chains, as it can be very inconsistent and require a number of different responses to approaches developed in silos.



4.0 The skills challenge

New roles, skills and processes in a more open, collaborative environment. Engaging a new generation and cross-sector expertise

In addition to the technological changes envisaged over the coming decades, there are also significant socio-economic and demographic shifts occuring; the United Nations, for example, predicts an increase in urban population of 2.45 billion by 2050, which alone has a real impact on the availability of labour. Whilst this report focusses on the UK construction product sector, it is important to be aware of the impact of global value chains and global manufacturing businesses who can choose to locate their resources (physical and human) in any number of territories (it's common for these businesses to have centres of excellence for different job functions to take advantage of capability and availability of resources). With the rapid development of digitalisation through BIM Levels 2, 3 and 4, global access to construction products is set to increase significantly. Therefore, in considering the skills shift required over the next decade and beyond, we also need to consider which future roles and skills will best support future growth of UK industry. Do digitalisation and automation mean fewer employees? Do they mean there is likely to be more off-shoring of skills? These are risks, but previous evidence of significant technological change such as the steam engine, production line and electricity suggest otherwise. However, the labour market will be disrupted and occupations and tasks will undoubtedly change. Recent figures produced by the OECD (2016) suggest that across all sectors, 10% of all UK jobs are at a high risk of automation (over 70% risk). That compares to an average across all OECD countries of 8.9%, and a maximum of 12% (Austria). However, in addition a further 25% of UK jobs are forecast to have a 50-70% risk of a significant change in the tasks that they will perform.

The UK construction industry has lost 343,000 jobs since the financial crisis and will lose another 400,000 to retirement in the coming decade. The Construction Industry Training Board (CITB) estimates that we will need approximately 224,000 construction workers over the next five years. However, in looking to attract current and future generations into the built environment, it is important to appreciate that like-for-like replacement of those skills likely to be lost through retirement or any other means is unlikely to be the answer for the future of the industry. By one estimate, 65% of children entering primary school today will ultimately end up working in completely new jobs that don't currently exist.

Getting future generations excited about construction: Class Of Your Own

The 'Adopt a School' scheme was established by Class Of Your Own, the social business led by Alison Watson, creator of the Design Engineer Construct! (DEC!) learning programme. The national scheme assists organisations to provide genuine support for secondary school teachers and their students as they progress through DEC!, complementing structured teacher training and workshops that focus on developing key digital skills and a firm understanding of modern technical and professional processes in the built environment.

Design Engineer Construct!
http://designengineerconstruct. com/who-benefits/dec-industry/

To enable construction product manufacturers to take advantage of the opportunities discussed in Section 3, including supply chain optimisation, automation, product installation and new commercial models, there needs to be an equivalent shift in the mix and availability of skills and roles. With the rapid digitalisation of the construction sector and increase in automation, we need to look beyond the traditional boundaries of construction; with increased focus on the whole life of an asset identified in Construction 2025 and being delivered through Level 2 BIM and Digital Built Britain, a product supplier's significance through the lifecycle is increased, as is the need for new skills to support this shift. However, many of the skills required in a more digitalised world are common across a number of industries, and will become increasingly so.

To assess the potential impact of digitalisation and automation on construction product manufacturers, we have used an approach similar to the World Economic Forum, OECD and

Frey & Osborne. The detailed methodology is described in Appendix A, but is based on analysing the skills and abilities required for a range of occupations described in the O*Net Content Model, and applying the potential risk of automation to these occupations to identify the potential shift in skills to support those roles that are less likely to be automated.

Figure 30 (pages 52-53) presents the detailed analysis of the identified occupations, skills and abilities along with their potential risk of automation, and Figure 29 provides a key to the diagrams.

The analysis suggests that across the 39 different occupations assessed the range in risk of automation is extreme, from 0.3% chance of automation to 98% chance. There are however clear trends, which as we would expect, more routine, lower skilled jobs are significantly more likely to be automated. Roles at skill Level 1 (defined in SOC 2010 as roles requiring general education) are at a 75% risk of automation, whereas those at skill Level 4 (defined as professional or high level managerial roles) are only at a 5% risk of automation. Whilst these figures need to be used with caution, as likelihood of automation is impacted by a number of factors, they do represent a clear trend. In terms of numbers of roles potentially impacted, based on current numbers employed in each role in the UK over 880,000 (41%) of individual roles are at risk of automation. However, recent analysis by OECD (2016) that focusses on the automation of tasks instead of occupations, suggests that the estimates are high. If the cross-sector percentages for automation are applied, it would reduce the number of individual roles impacted across the 39 occupations to 217,000 (10%), with a further 540,000 (25%) having a significant impact on the tasks that they perform.

Figure 28 highlights the key skills and abilities that are required across the 39 occupations studied, and for three different scenarios:

1. Existing product manufacturing model, supply only
2. As above, plus assembly of products or systems
3. As above, plus design services beyond the scope of a manufacturer's product, for example the complete design of an asset

It also indicates those skills and abilities that are required in roles at a low risk of automation.

Skills and abilities impacted by digitalisation

Figure 28

Across manufacturing

Key ABILITIES
- Manual dexterity and precision
- Problem sensitivity
- Logical reasoning

Key SKILLS
- Monitoring self and others
- Critical thinking
- Active listening
- Equipment operation and control
- Reading comprehension

+ assemble

Key ABILITIES
- Physical strength
- Visualisation
- Cognitive flexibility

Key SKILLS
- Coordinating with others
- Quality control
- Oral expression
- Judgement and decision making
- Time management

+ assemble + design

Key ABILITIES
- Mathematical reasoning

Key SKILLS
- Complex problem solving
- Active learning
- People management
- Written expression
- ICT literacy

ABILITIES and SKILLS listed in white text are not within the top 5 SKILLS or top 3 ABILITIES for roles at a high risk of automation. All listed SKILLS and ABILITIES are cumulative, so those identified in + assemble are in addition to those already identified in Across Manufacturing

Key to Figure 30

Figure 29

It is clear that automation is likely to have the most significant impact on the labour market in more routine occupations at skill Levels 1 and 2, and also that the key skills and abilities that will be impacted by automation from those studied apply to current manufacturing roles. In terms of developing future skills therefore, there needs to be a focus on those required for more highly skilled roles, and those that are likely to apply to a number of current and future occupations. By focussing on skills and abilities, comparisons can also be made with current occupations and training in other industries that require similar capabilities, to understand where there may be cross-over. Digital Built Britain, and the general trends to improved information management and increased awareness of the operational phases of assets is having a significant impact on more highly skilled roles within the built environment. Through effective processes and the availability of structured data, decision-making is becoming more evidence-based, and whilst more highly skilled roles are less likely to be fully automated, they are likely to become more focussed on the less repetitive, more cognitive tasks and abilities.

As described in Section 3.3 (page 33), whilst the focus for future skills development is likely to be for highly skilled roles, the potential for automation through Industry 4.0 within the manufacturing sector provides a significant opportunity for UK industry to optimise production processes, and enable production to remain in the UK, whilst providing the ability to take advantage of supply chain integration and export. A focus on highly skilled roles alone is likely to have a detrimental impact on both the UK labour market and economy.

	Percentage likelihood of automation	72%	97%	98%	82%	65%	91%	82%	97%	88%	93%	83%	37%	18%	95%	0%	82%	77%
	Total currently employed	122,134	43,156	43,759	45,829	4,736	12,467	31,974	22.002	32,109	20,714	15,677	6,802	23,863	119,592	11,985	27,428	68,596
	Number likely to be automated	87,936	41,861	42,884	37,580	9,578	11,345	26,219	21,342	28,256	19,264	13,012	2,517	4,295	113,612	36	22,491	52,819
Abilities	Cognitive flexibility																	
	Creativity																	
	Logical reasoning																	
	Problem sensitivity																	
	Mathematical reasoning																	
	Visualisation																	
	Manual dexterity and precision																	
	Physical strength																	
Skills	Active learning																	
	Oral expression																	
	Reading comprehension																	
	Written expression																	
	ICT literacy																	
	Active listening																	
	Critical thinking																	
	Monitoring self and others																	
	Complex problem solving																	
	People management																	
	Time management																	
	Coordinating with others																	
	Emotional intelligence																	
	Persuasion																	
	Judgement and decision making																	
	Equipment maintenance and repair																	
	Equipment operation and control																	
	Programming																	
	Quality control																	
	Troubleshooting																	

	Level 1	Level 2															
Roles	Elementary construction occupations	Assemblers and routine operatives n.e.c	Assemblers (electrical and electronic products)	Assemblers (vehicles and metal goods)	Crane drivers	Metal making and treating process operatives	Mobile machine drivers and operatives n.e.c	Paper and wood machine operatives	Plant and machine operatives n.e.c	Plastic process operatives	Process operatives n.e.c	Rubber process operatives	Scaffolders, stagers and riggers	Stock control clerks and assistants	Air-conditioning and refridgeration engineers	Bricklayers and masons	Buyers and procurement officers

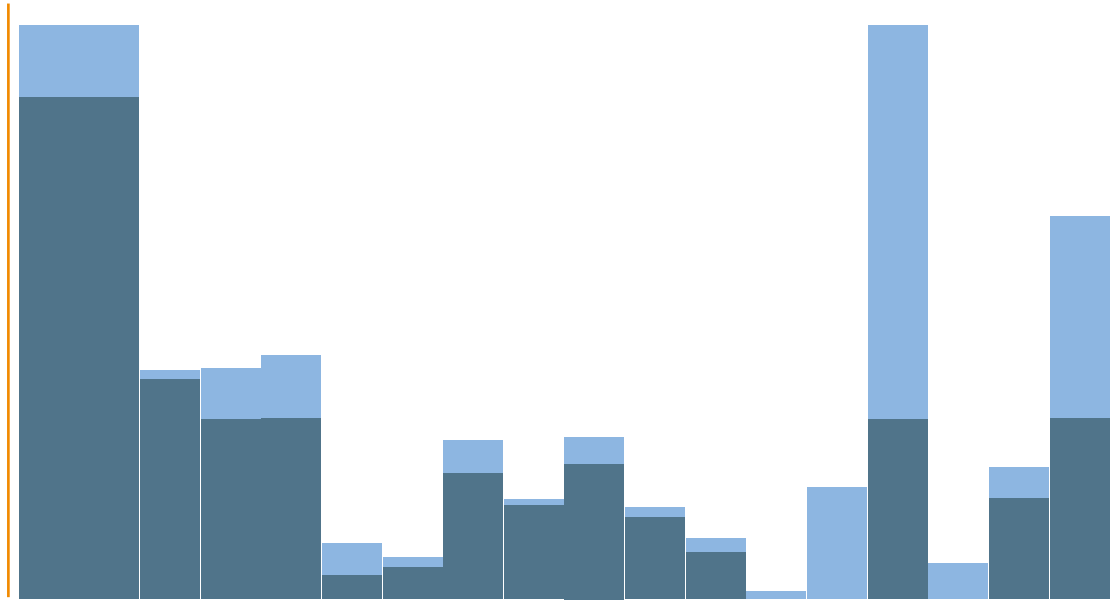
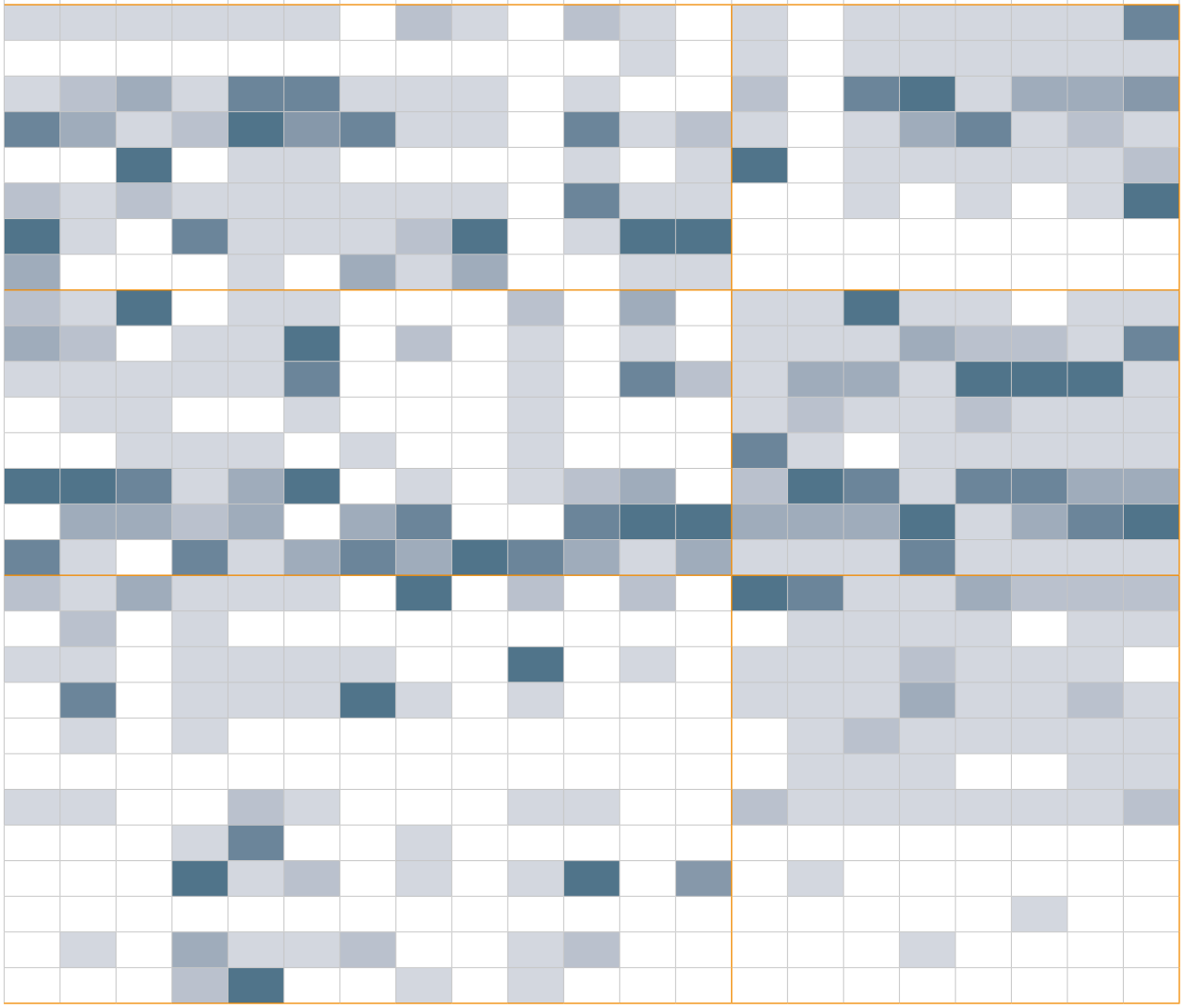


Figure 30

72%	17%	68%	81%	15%	24%	75%	49%	67%	36%	84%	39%	94%	4%	10%	1%	3%	3%	13%	2%	2%
101,497	55,645	26,368	21,683	187,702	67,084	8,745	33,146	4,556	24,069	14,807	8,162	68,183	23,821	35,093	153,683	263,052	62,691	257,224	39,526	27,013
73,078	9,460	17,930	17,568	28,155	16,100	6,559	16,242	3,053	8,665	12,438	3,183	64,092	834	3,509	1,998	7,892	1,818	33,439	672	0



Key

- High relevance
- Low relevance
- Not relevant

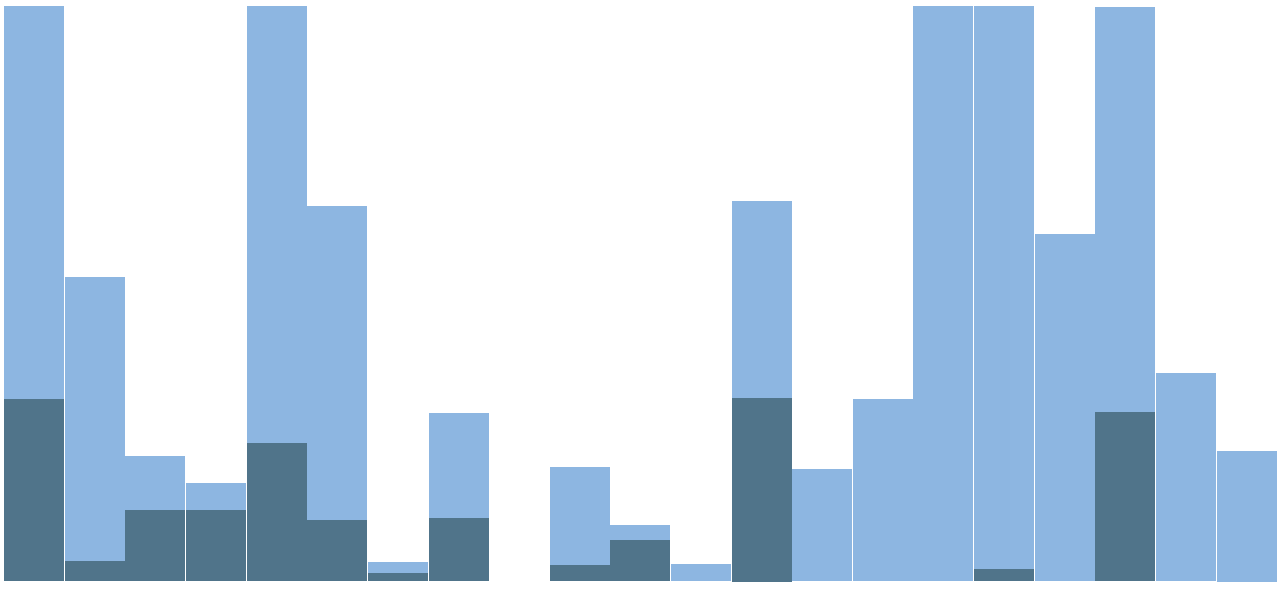
Level 3

- Carpenters and joiners
- Construction and building trades supervisors
- Draughtspersons
- Electrical and electronics technicians
- Electrical and electronics fitters
- Engineering technicians
- Floorers and wall tilers
- IT engineers
- Moulders, core makers and die casters
- Planning, process and production technicians
- Tool makers, tool fitters and markers-out
- Upholsterers
- Welding trades

Level 4

- Actuaries, economists and statisticians
- Electrical engineers
- Marketing and sales directors
- Production managers and directors in manufacturing
- Production and process engineers
- Programmers and software development professionals
- Research and development managers
- Architects

- Core manufacturing role
- Assembly's/ subcontract role with potential for manufacturing
- Specification/ selection role with potential for IoT

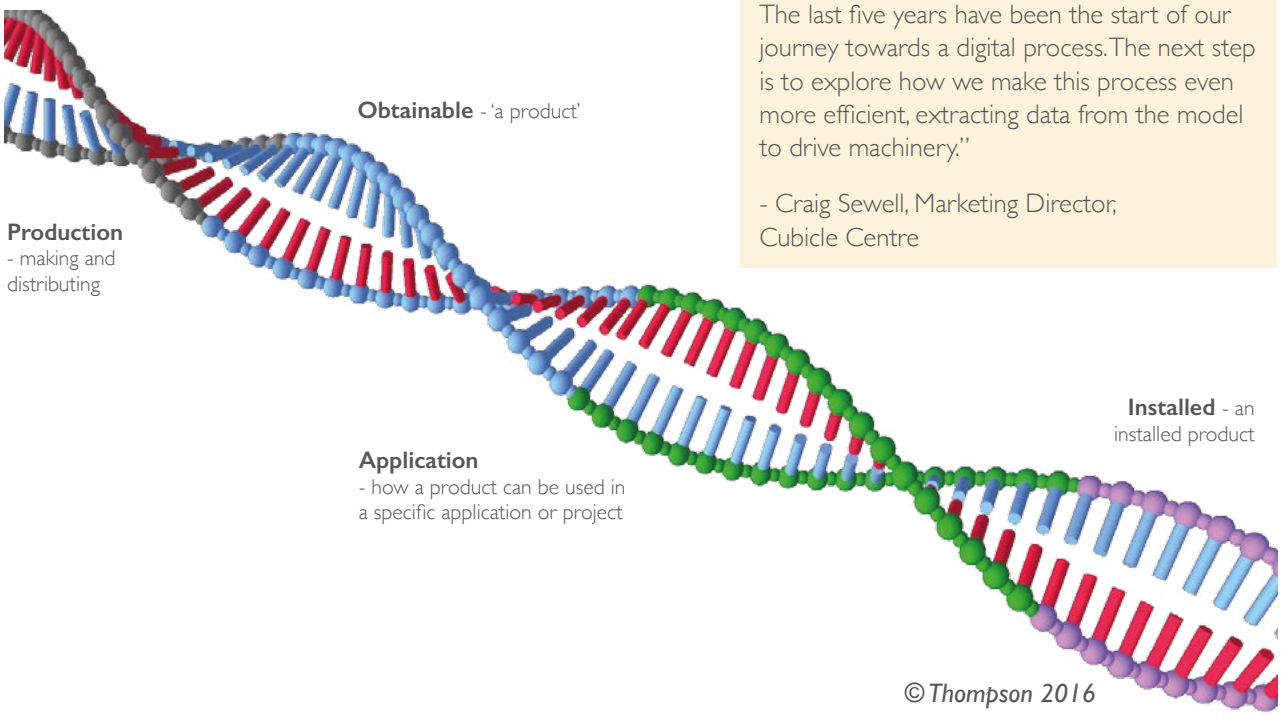


- Volume of individuals currently employed in a role in the UK
- Volume of thise employed that are likely to be automated

5.0 BIM Level 2 and Catapults - Setting the direction

HMG's BIM Level 2 programme has enabled manufacturers to share product information in more accessible forms than has previously been achievable. The awareness of data and the possibilities effective use can bring have been widespread. As a result many manufacturers are using data and information modelling to change the way they operate internally, as well as sharing information with others in the construction supply chain. However, there are a number of formats in which product information can be provided, in many different templates, which can cause confusion for all concerned. To achieve consistency, a new initiative called LEXiCON has been developed by the construction product sector with HMG BIM Task Group, and is now being led by the CPA. HMG's BIM Task Group developed a Product Data Definition specification to enable consistency and interoperability of product information through the BIM process. LEXiCON is the implementation of this specification by industry.

Figure 31: The Product DNA Concept, forming the basis for LEXiCON and enabling translation of information requirements between request for information and information response



Box 4: Steps in the right direction

"The first question we looked to answer was, 'How can BIM improve OUR business process?' After a period of initial research, we saw an opportunity to take aspects of BIM and use these to strengthen Cubicle Centre's position in the market.

Most washroom projects demand a fast turnaround. Cubicle Centre already had some of the shortest lead times in the cubicle industry. By digitalising the design-to-manufacture process we have been able to further reduce lead times.

Moving from hand-drawn manufacturer drawings and typing cutting lists into spreadsheets, Cubicle Centre now models washrooms with manufacturer-level BIM objects. Cutting lists are automatically generated from the data within these intelligent components.

Evolving from hand-drawing to modelling has the potential to **save the business five working weeks per year in office hours.** Customers receive clearer information (2D and 3D), improving communication earlier on in our process. **We are also seeing the benefit of using 100% accurate data - reducing errors and costs.**

The last five years have been the start of our journey towards a digital process. The next step is to explore how we make this process even more efficient, extracting data from the model to drive machinery."

- Craig Sewell, Marketing Director, Cubicle Centre

LEXiCON - decoding the built environment

The concept of LEXiCON is to provide a plain language approach to defining information requirements, based on information that is needed for a purpose. The aim is to enable the efficient flow of quality information on products and systems through the life cycle of an asset. In the current marketplace there are a number of methods for defining information requirements for products, however from a manufacturer's perspective it is difficult to provide information in the number of different formats to meet everyone's needs, and to keep the information up to date, leading to the potential for inaccurate or incomplete information. LEXiCON focusses on the language that should be used, and providing the tools to enable users to select which information they need, and in which format. The language used needs to be accessible to everyone that is requesting or providing information; if you need information, you should be able to ask for it in a language that you are familiar with, for example 'I want this amount and type of space', 'I want to achieve this performance'. If you are providing information you should be able to provide it in a language and form you are familiar with, for example 'my product spans 8m', 'this detail achieves an improvement of 5dB over building regulations', 'here's my Declaration of Performance'.

LEXiCON then enables translation between the request and response by mapping to core properties, but all of this is done under the hood; most of the industry don't need to know or see how this is done, or learn a new language to enable exchange of information, as this leads to errors and poor quality data.

Both the request and response should use real-world definitions, and where possible come from existing recognised sources, such as British or International standards, specification or costing systems or as defined by a specific industry body. LEXiCON provides a plain language dictionary which enables translation between the two, and the necessary exchange of information, occurs within the virtual world of open information exchange, which the majority of actors within the product and asset life cycles do not need to concern themselves with. The approach is intended to increase the accessibility of product information for both those requesting and those providing information. The concept also enables information to be defined for any point in the life cycle, meaning that information sets can be created between the key information exchanges within a project and used to track changes in specifications and responsibilities. For example, the tools identify which role (for example manufacturer, installer) should provide information in response to a question, and also identify who has actually completed the information, so every response has an identified owner.

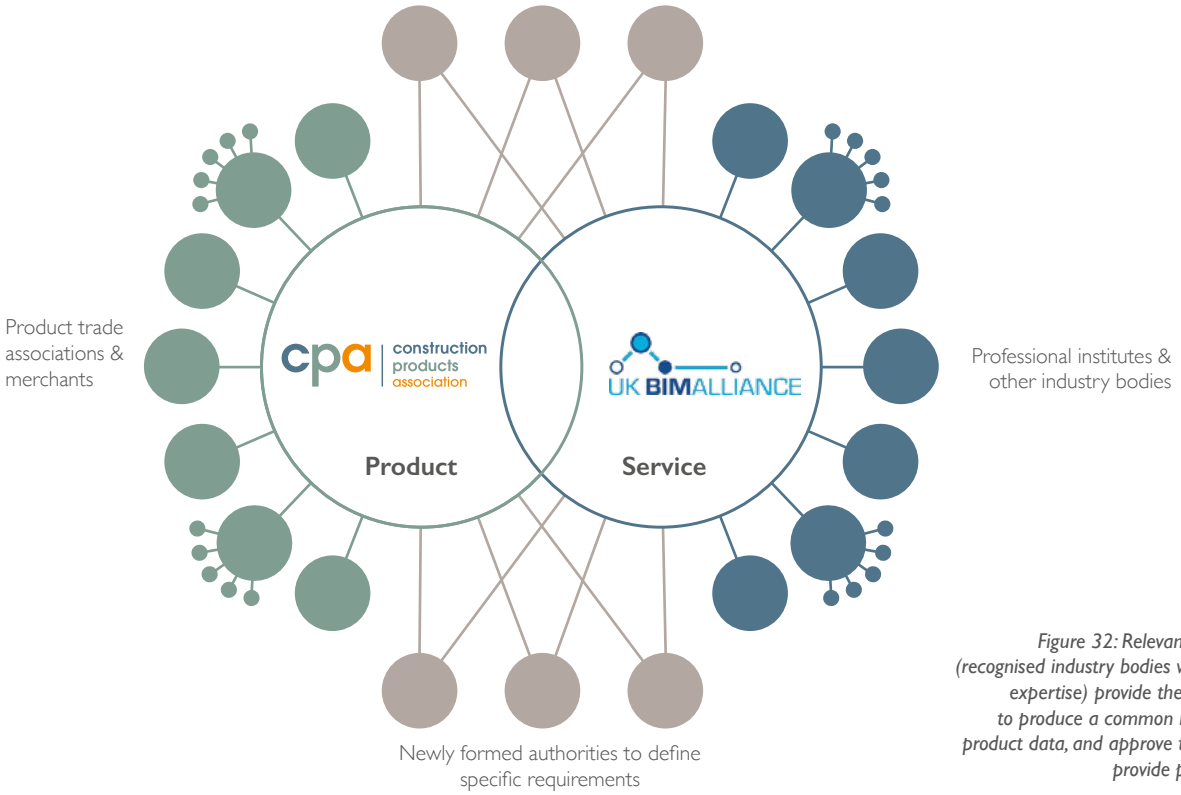


Figure 32: Relevant Authorities (recognised industry bodies with relevant expertise) provide the governance to produce a common language for product data, and approve templates to provide product data

In addition to products, systems and elements, the approach can be applied to interfaces such as the junctions between walls and floors, or walls and roofs. By linking existing common terminology to open exchange standards such as IFC 4 (Industry Foundation Classes), the information from different asset life cycle stages and granularity can be mapped to relevant information requirements at a product level. For example, the need at an early stage for a large clear span space can be mapped to structural systems that are capable of achieving the requirements later in the specification / delivery phase.

LEXiCON is a world first, and provides manufacturers and other users with the ability to define information requirements easily, and for free. The tool is freely available through the Construction Products Association's website and is governed by recognised industry bodies known as Relevant Authorities, to ensure the language being used is correct and consistent. Whilst data dictionaries and product templates exist elsewhere, never before has there been such broad industry engagement and governance, with over 70 percent of UK trade associations signing up to become Relevant Authorities and managing how their products are defined. From a process side, the Lead Relevant Authority is the UK BIM Alliance, representing a cross-industry group including professional institutes and bodies, with the role of implementing BIM Level 2 across the UK built environment sector between now and 2020.

To enable information requirements from a range of sources and disciplines to be considered, and to enable the flow of information between different actors and life cycle stages, sources of information requirements are categorised by their type as described in Figure 33. This enables information requirements to be selected quickly, and data templates to be created and tailored to different needs at any stage in the life cycle of an asset.

By focusing on providing a common language, the tools and templates created in LEXiCON can be used across different software platforms and information can be requested to the level of detail or quantity that suits the purpose; if only one line of data is required to answer a question, one line of data can be requested, and the response can be tracked to include who has provided the response.

By using GUIDS (globally unique identifiers) for each property, information can be shared between different parties and software packages, and enable data to be either included in, linked or separated from the geometrical model.

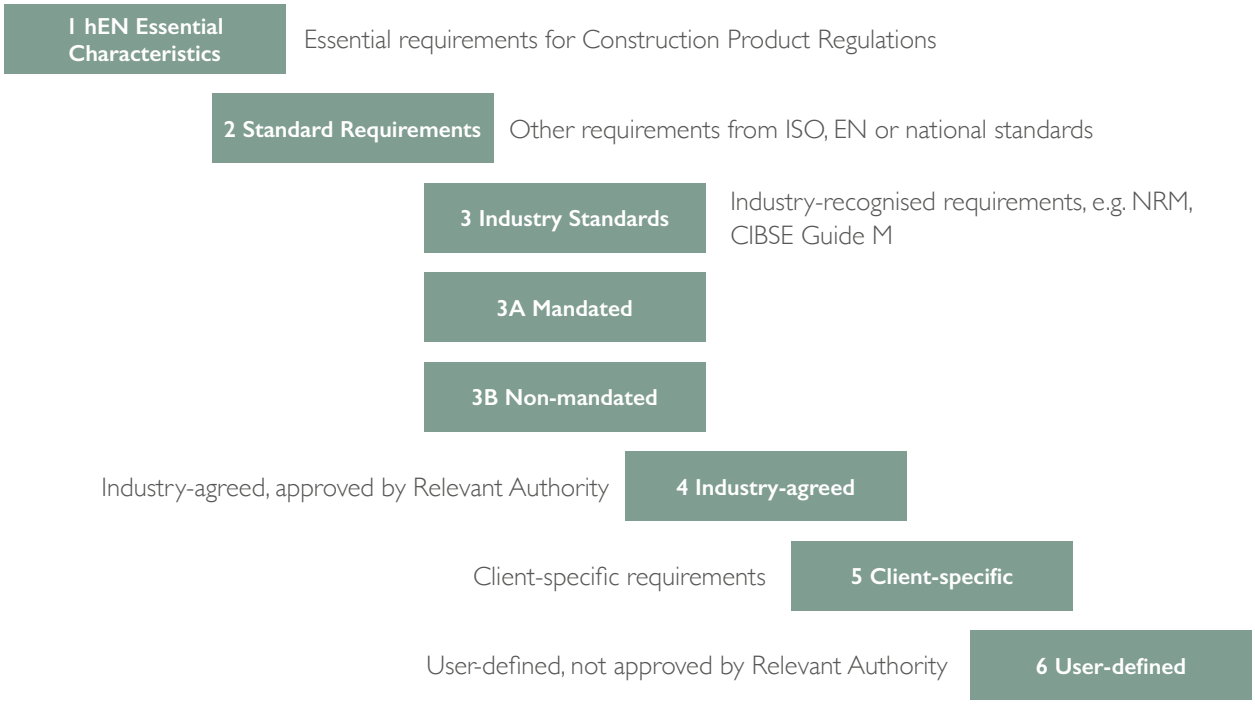


Figure 33: Different information source types, enabling information from a number of sources to be filtered to specify exactly what is required using a common language.

5.1 Catapults

The Government's Catapult Programme provides excellent opportunities to develop and prepare for commercialisation of innovative technologies in areas of potential growth. The existing Catapults only touch the edges of the construction product sector, the most relevant being:

- High Value Manufacturing Catapult
- Digital Catapult
- Future Cities Catapult

With the structural change in the construction industry over the next ten years, and the construction product sector's importance to the UK economy in particular to reduce the trade gap and support smart cities and assets, we believe the construction sector should be recognised as High Value Manufacturing. We aim to encourage investment within the sector and provide the necessary support to provide the solid platform required for future growth.

What is a Catapult?

The Catapult Programme was announced by the UK Government in October 2010, to close the gap between innovation and commercialisation. The Catapult Programme is key to the UK's aim to rebalance the economy by spreading economic success across sectors and supporting our world class industries, as set out in the Government's Plan for Growth, the Science and Innovation Strategy and the Industrial Strategies. The Catapult themes were selected for their competitive strength and their potential for generating significant growth to the UK economy.

"High value manufacturing is the application of leading-edge technical knowledge and expertise to the creation of products, production processes, and associate services which have strong potential to bring sustainable growth and high economic value to the UK."

High Value Manufacturing Strategy 2012-15 – Innovate UK

6.0 Stronger together - industry and government working in partnership

Key recommendations for Government and industry to deliver sustainable growth in the UK construction product sector

Recommendations	Description
The UK construction product sector should be recognised as High Value Manufacturing	The construction product sector provides over a third of construction turnover in the UK, and is a crucial enabler for the application of disruptive technologies and growth in the wider built environment. Industry 4.0, the circular economy, intelligent assets, smart cities and BIM (Building Information Modelling) rely heavily on the growth and digitalisation of the sector.
Investment in automation and Industry 4.0 initiatives in the construction product sector	Investment from both HM Government and Industry in automation and Industry 4.0 initiatives relating to construction products is essential to enable the necessary growth in the sector and attract global manufacturers to the UK for both production and high value servitisation activities. Without investment in automation there is an increased risk of falling behind internationally.
Manufacturers to sponsor schools through Class Of Your Own initiative	The "Adopt a School" scheme assists organisations to provide genuine support for secondary school teachers and their students, focussing on developing key digital skills a firm understanding of modern technical and professional processes in the built environment.
Investment in cross-sector skills, research and development focussing on the impacts of digitalisation, automation and servitisation and future skills requirements	The skills landscape is significantly changing and will continue to do so with the disruptive technologies that are already beginning to be implemented across the built environment and wider economy. Research and strategies for future skills requirements are urgently needed, and go beyond traditional skills and roles within the built environment.
Government and industry to explore certification of construction products and systems based on performance in use, enabled by integration of telemetry and analytics	Construction products are typically certified based on laboratory testing and performance, which is very different to performance in-use. The use of sensors, real-time feedback and data analytics can increase understanding of actual performance, and reduce the as-designed, as-built performance gap to provide more energy-efficient assets.
World BIM leadership	Ensure that the UK's position as a leader in digitalisation of construction is supported on the world stage; critically, continuing involvement in the development of European and world standards and methodology. The international adoption of methodologies aligned to those developed in the UK is immensely valuable for UK business.
HM Government promotion of the UK construction product sector	Promotion of the UK construction product sector to the wider economy and population at large. Giving support on the national stage to the construction industry and its digitalisation provides momentum and leverage with other parts of the economy and its customers.
Government thought leadership	Continue to provide the thought leadership and consistent national voice for digital support. This has been extremely successful in the organisation and promotion of BIM to date. Continued non-financial support is critical.
Promote leading edge technologies	Development of leading edge initiatives is critical and many projects are being developed through Innovate UK. To ensure the UK keeps its prime position, further technical developments are required. Materials and products can then identify maintenance or replacement requirements.

Appendix A - Skills Analysis Methodology

The UK's Standard Occupational Classification (SOC) 2010 classification has been used to identify occupations that are relevant to construction product manufacturing. In addition, roles were identified that may form part of a product manufacturer's scope in the next 10 years as a result of digitalisation and other trends identified in this report.

Each occupation described in SOC 2010 is identified as requiring a skill Level from 1 to 4, with 1 being general education and 4 being more complex, technical or managerial occupations.

Along with each identified relevant occupation, the number of employees currently employed in a role in the UK is recorded from the ONS Table EMP04: Employment by occupation April-June 2015.

For the purposes of analysis of the skills and abilities required for a given occupation, the O*Net Content Model is used, which also identifies relevant tasks and qualifications. The O*Net classification does not map directly to the UK SOC 2010. Instead, the SOC 2010 occupations are mapped to the International Standard Occupational Classification (ISOC 2008), and then from ISOC to O*Net. This process leaves the 39 occupations included in the final analysis.

To summarise the skills and abilities that are most relevant to each occupation, the skills and abilities have been grouped into the categories shown in Figure 34

The top five skills and abilities for each occupation are colour-coded on the chart, with all relevant other identified skills and abilities identified as a single colour.

The likelihood of automation is assessed by using the possibility ratio for each role as identified in the Frey & Osborne study, 'The Future of Employment: How susceptible are jobs to computerisation?' The ratio is then applied to the number currently employed to identify the potential impact of automation on each occupation.

The most common and most important skills and abilities are then identified for each of the three main scenarios to ascertain what additional skills and abilities construction product manufacturers are likely to need in the future. The three scenarios are:

- existing product manufacturing model, supply only
- as above, plus assembly of products or systems
- as above, plus design services beyond the scope of a manufacturer's product, for example the complete design of an asset

Skills and abilities most relevant to occupations

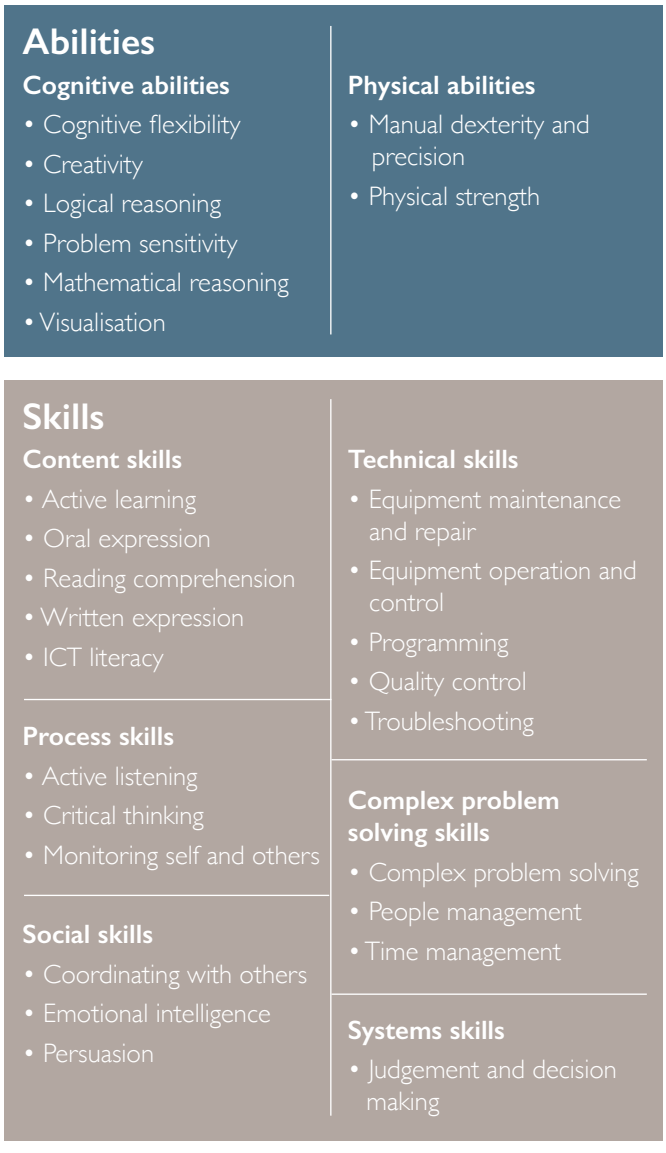


Figure 34

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