



25% by 2025

Streamlined construction:
Seven steps to offsite and modular building

August 2018

Balfour Beatty

Foreword



The construction and infrastructure industry is one of the UK's largest employers and most important economic enablers. Yet we know there is a massive backup of essential projects to be delivered and a growing shortfall of skills and capacity.

At the same time, we know this is an industry that lives on thin margins, is plagued by time and cost overruns and inherently operates in one of the higher risk environments of any sector – risk in terms of cost, time and, above all, human safety.

But do we also think of this as an industry with one of the largest opportunities of any sector to transform its model? Can we think of many industries where the size of the prize is to shift 25% of current output to a solution that radically improves speed, quality and safety – all while creating (not destroying) jobs?

Today a new generation of industrialised construction methods, including offsite and modular building techniques, are increasingly being recognised as the best way for the UK construction industry to boost productivity and plug skills shortages. And moving to these methods drives better outcomes for all stakeholders: for the customer, reducing onsite construction times and waste; for the construction supply chain, by improving quality, repeatability (and therefore output) of infrastructure; for the workforce above all, by raising safety performance and securing long-term employment.

On a national level, industrialised construction would lead to the creation of thousands of jobs across the country over the next few years - if we invest now. Whereas today, many of those using prefabrication and modular approaches are forced to import products due to the lack of capacity in the UK market, new factories established in areas of economic need across Britain could rapidly boost local economies and upskill local workforces.

If we get this right, the “by-product” is thus a new expertise for the UK and a massive export opportunity.

Yet today, only 12% of construction involves offsite methods¹. Despite a groundswell of recognition about its benefits, there is also the understandable inertia of a conservative industry with long project cycles and unaligned interests. From customers' needs through architects' designs to final completion, many projects run for as much as 5-10 years. Competition is so keen and margins often so tight that “breaking the mold” literally does not enter the equation. Many commissioning infrastructure remain cautious. The fear of failing by trying something new pervades – but doing the same things in the same way will not lead to a more efficient or productive construction industry. The mainstreaming of industrialised construction methods must be client-led.

At Balfour Beatty, we believe that if we do not find a way as a country to commit more firmly to this agenda we will miss the opportunity to reap its game-changing benefits and allow overseas competitors – in many cases more advanced in this area than our domestic companies – to steal a march on us.

To address the existing barriers – from the reluctance of procurers to use it and the lack of capacity in the UK market to produce it – the time has come to move beyond traditional construction mind-sets and create a virtuous triangle – among designers/specifiers, customers and the construction supply chain.

More must be done to educate and inform – both to build the evidence base about the benefits of offsite and modular building, and also to improve understanding about elements which are key to success, such as the need to aggregate schemes over a longer timeframe rather than dealing with each scheme individually; the importance

¹ Construction, Building Services Engineering and Planning: Sector Skills Assessment 2012, UKCES, 2012

of building in repeatability and the need for a more collaborative, less adversarial approach in commissioning infrastructure.

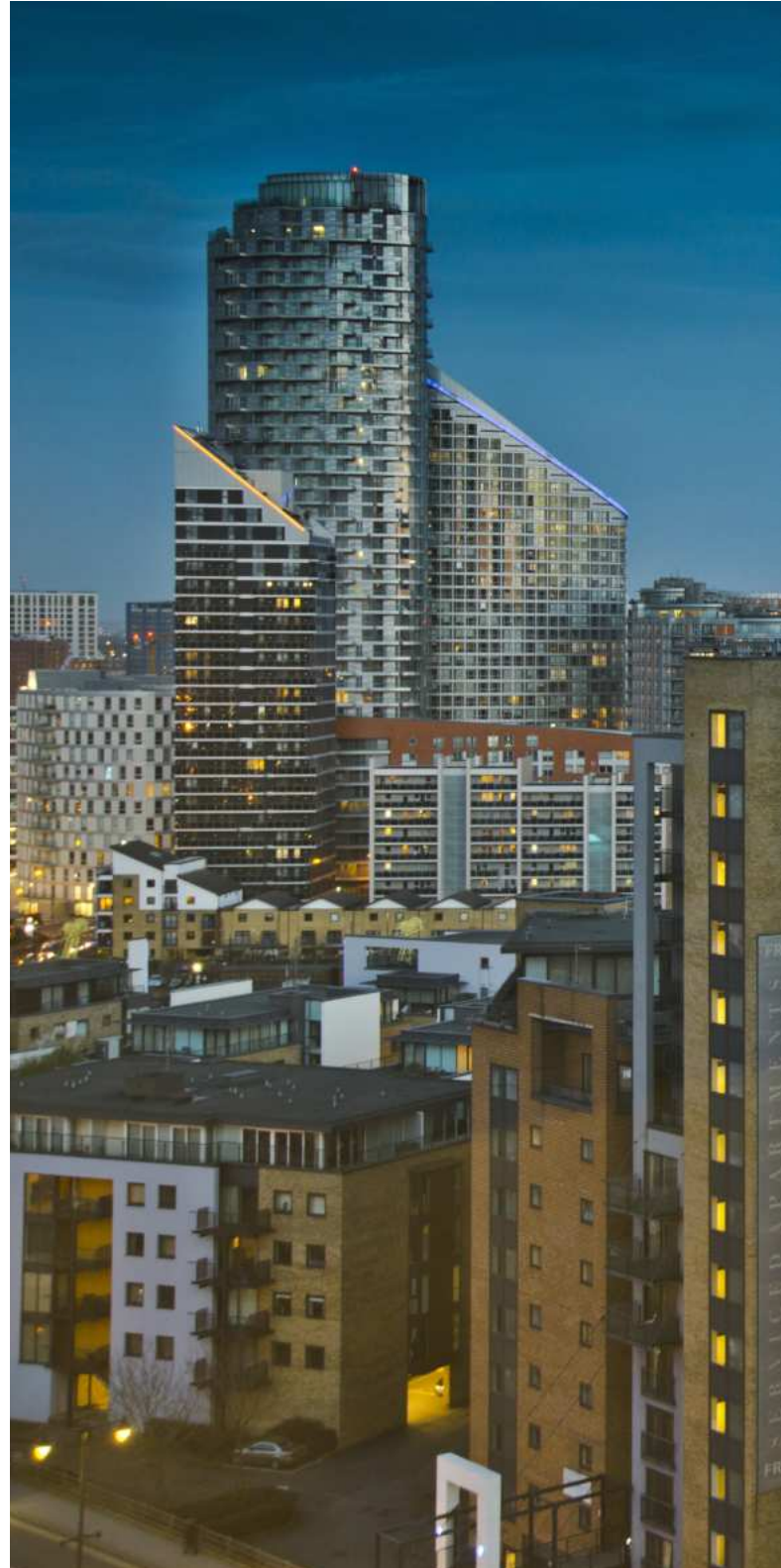
There are pockets of excellence. Heathrow is looking at how to capitalise on the benefits of offsite while simultaneously helping to boost the UK's capacity. They are encouraging those commissioning other large schemes – including Highways England and HS2 – to use the new hubs they are creating.

Providers, too, must change. While Balfour Beatty has committed to reducing the amount of work we undertake onsite by 25% by 2025 and others on the supply side are following suit, there are those in the industry itself who are not yet investing in innovative approaches. They are held back by the significant upfront investment needed (in a low margin sector) and the limited profitability of offsite while the market for it remains narrow. Clearly something needs to be done to incentivize the sector to create capacity now for when it is needed.

And this is why Government can make the difference. As the industry's largest client, it has the means, motivation and responsibility to throw its weight fully behind this agenda to release substantial productivity and job creation in the construction and infrastructure sector.



Leo Quinn
Group Chief Executive



Key points and recommendations

25 by 2025

While many companies are beginning to consider offsite and modularisation on a case-by-case basis for new schemes, Balfour Beatty has made it a core part of our strategy. We have committed to reducing onsite activity by 25% by 2025. Supporting the Government's 2025 strategy for lower cost, lower emissions and faster delivery, we aim to remove those activities we can from sites in order to free up our workforce's time to focus on delivery and reduce waste. This gives us the scope to create complex structures safely and efficiently offsite, assembling them quickly onsite. It not only saves time, but also reduces labour costs, improving overall efficiency compared with traditional methods of construction. The use of a range of different materials teamed with smart engineering and modern construction techniques helps us to deliver better against the construction requirements.

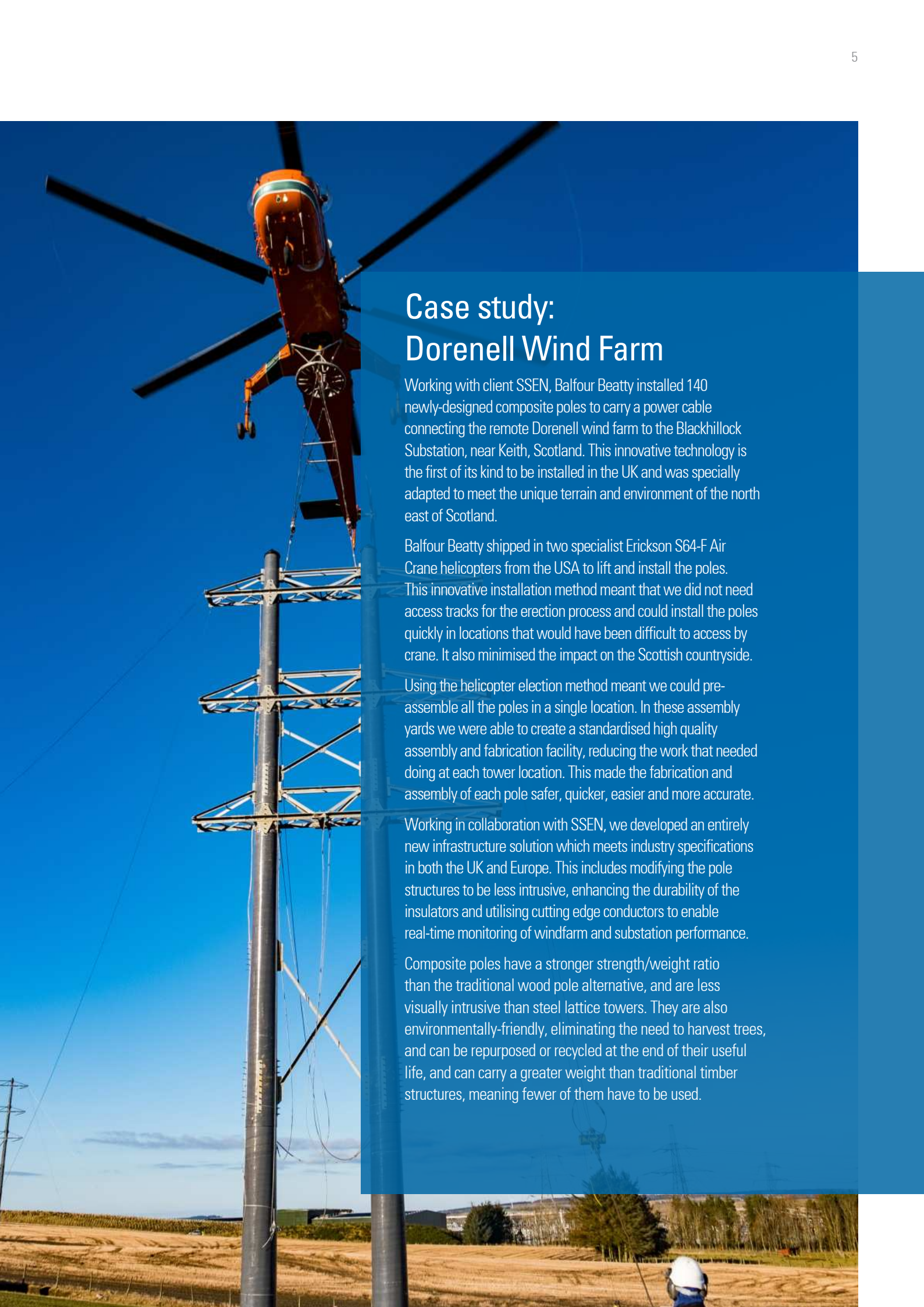
It also means that we are able to construct schemes more sustainably, reducing our impact on the environment by cutting waste, increasing the recycling of materials we do not use and controlling our energy use, all of which are made easier in a factory environment and by using standard designs for key components. Involving contractors at the design stage, as has to happen in order to maximise the potential of industrialised construction methods, also leads to a reduction in the amount of waste schemes generate.

We believe that a new wave of innovation, coupled with a more efficient partnership model, will enable us to increase build efficiency and speed while driving down operational costs.

We expect our 25 by 2025 strategy to deliver:

- Enhanced health, safety and well-being in our workforce
- Productivity gains, by concentrating on improving how we work
- Reduced logistics costs
- Quality assured projects with reduced onsite rework
- Greater certainty of programme delivery
- Shorter overall construction programmes
- A 'design once, use often' mindset which discourages designing bespoke systems and components

1. As around a third of all construction is Government funded, the Government has considerable purchasing power to work with the construction industry to drive change more quickly.
2. The Government should move towards a procurement model which favours risk sharing rather than risk transfer and incentivises investment in new construction techniques such as offsite and modular.
3. The construction industries in some other European countries are already more advanced in the use of industrialised construction methods than the UK market and fulfill much of the requirement the UK currently has for modular components for example. Those companies will be better placed to benefit when the UK does commit more firmly to using offsite and modular techniques – unless we accelerate the pace of change.
4. For industrialised construction to take hold, those procuring infrastructure must look at their needs over a longer period of time than they do at the moment. Economies of scale are not delivered through one scheme, but in the construction of a number of them. Public bodies are uniquely positioned to support and then benefit from industrialisation given the volume of projects they procure.
5. Performance criteria and measurement should be set for the Government's presumption in favour of offsite.
6. Work should begin now on the Government's proposed library of standardised components with the Government and the industry working together to develop it as soon as possible. Prioritising the standardisation of designs and components will incentivise increased use of offsite manufacture and help deliver significant benefits to the public sector.
7. We must invest in the new skills the industry will need in the future – training and education providers must be ready with the training and apprenticeship programmes which will be needed in offsite manufacture and management.
8. More must be invested into research and development to make the UK construction industry a leader in industrialised construction methods.
9. To ensure a strong UK construction industry, we must ensure that the supply chain is developing its capability and capacity also.



Case study: Dorenell Wind Farm

Working with client SSEN, Balfour Beatty installed 140 newly-designed composite poles to carry a power cable connecting the remote Dorenell wind farm to the Blackhillock Substation, near Keith, Scotland. This innovative technology is the first of its kind to be installed in the UK and was specially adapted to meet the unique terrain and environment of the north east of Scotland.

Balfour Beatty shipped in two specialist Erickson S64-F Air Crane helicopters from the USA to lift and install the poles. This innovative installation method meant that we did not need access tracks for the erection process and could install the poles quickly in locations that would have been difficult to access by crane. It also minimised the impact on the Scottish countryside.

Using the helicopter erection method meant we could pre-assemble all the poles in a single location. In these assembly yards we were able to create a standardised high quality assembly and fabrication facility, reducing the work that needed doing at each tower location. This made the fabrication and assembly of each pole safer, quicker, easier and more accurate.

Working in collaboration with SSEN, we developed an entirely new infrastructure solution which meets industry specifications in both the UK and Europe. This includes modifying the pole structures to be less intrusive, enhancing the durability of the insulators and utilising cutting edge conductors to enable real-time monitoring of windfarm and substation performance.

Composite poles have a stronger strength/weight ratio than the traditional wood pole alternative, and are less visually intrusive than steel lattice towers. They are also environmentally-friendly, eliminating the need to harvest trees, and can be repurposed or recycled at the end of their useful life, and can carry a greater weight than traditional timber structures, meaning fewer of them have to be used.

Increasing the use of industrialised construction methods

The UK construction industry could be transformed by technology. However, that change is arguably happening more slowly than it could be in key areas including in offsite and modular construction. With around a third of all construction being Government funded, the Government has considerable purchasing power to work with the construction industry to drive change more quickly and help modernize it. The construction industries in some other European countries and especially in China for example, are already more advanced than the UK market in the use of industrialised construction methods and fulfill much of the requirement the UK currently has for modular components. This means that those companies will be better placed to benefit when the UK does commit more firmly to using offsite and modular techniques – unless we accelerate the pace of change in the following key areas:

1. Ensuring the continuity of pipeline flow

We recognize that much of the responsibility for changing the industry and investing in new technology must lie with the sector itself. However, the industry currently operates largely on the basis of individual projects in which the significant up-front costs of offsite manufacturing and investing in new, large factories and an upskilled workforce, cannot always be justified.

For this new technology to take hold we need multiple projects and longer time horizons. Those procuring infrastructure must look at their needs over a longer period of time than they do at the moment. The economies of scale are not felt in constructing one scheme, but over a longer timeframe, in the construction of a number of them. Because this is not yet understood or has not yet been acted on, those companies which have invested significantly in offsite have not seen it yield a significant financial reward which can be passed on to the customer.

The Government has committed to a presumption in favour of offsite in five Government departments by 2019². That means that these departments will consider offsite, alongside other possible construction methods, when commissioning new schemes. Balfour Beatty welcomes this step. However, we note both that these departments are already using elements of offsite in the schemes they commission; and

that no performance criteria or measurement has been set for the measure. We believe that, if the Government more consistently demonstrates that this approach is endorsed, it could be a really effective driver. However, it remains to be seen how the requirement will work in practice.

Collaborative frameworks such as Scape and the North West Construction Hub could play a key role here in helping to support the move to offsite and aggregate the market. Once a contractor knows that it is a supplier on that framework for five years, for example, it can begin an investment programme which enables it to deliver economies of scale, because it knows that it will have a secure pipeline of work with, hopefully, repeatability.

2. Improve the standardisation of components and design

While methods such as modular and offsite construction are already established in certain markets, for example, student housing and hotel construction, in other areas there has been poor take-up of the technique, meaning that the benefits such as earlier handover of schemes and improved quality are being missed. More must be done to tackle this and to help procurers understand that offsite manufacture requires repeatability. We welcome announcements such as that the NHS will consider using modular design for new infrastructure where it does not need to be bespoke³. Prioritising the standardisation of designs and components will incentivise increased use of offsite manufacture and help deliver significant benefits to the public sector. Cost savings in particular will only be realized once there is a significant enough volume of construction being undertaken offsite - ultimately, cost is related to volume.

The Government has spoken of the need to develop a library of standardised components in the future that will allow a range of different types of infrastructure to be constructed from a base number of different parts. We believe that this work should begin now and urge the Government to work in collaboration with the industry to come up with these standards.

² Autumn Budget, HMG, 2017

³ Health Minister Stephen Barclay speaking to The Times, 9 June 2018

Moving to offsite manufacturing: Highways

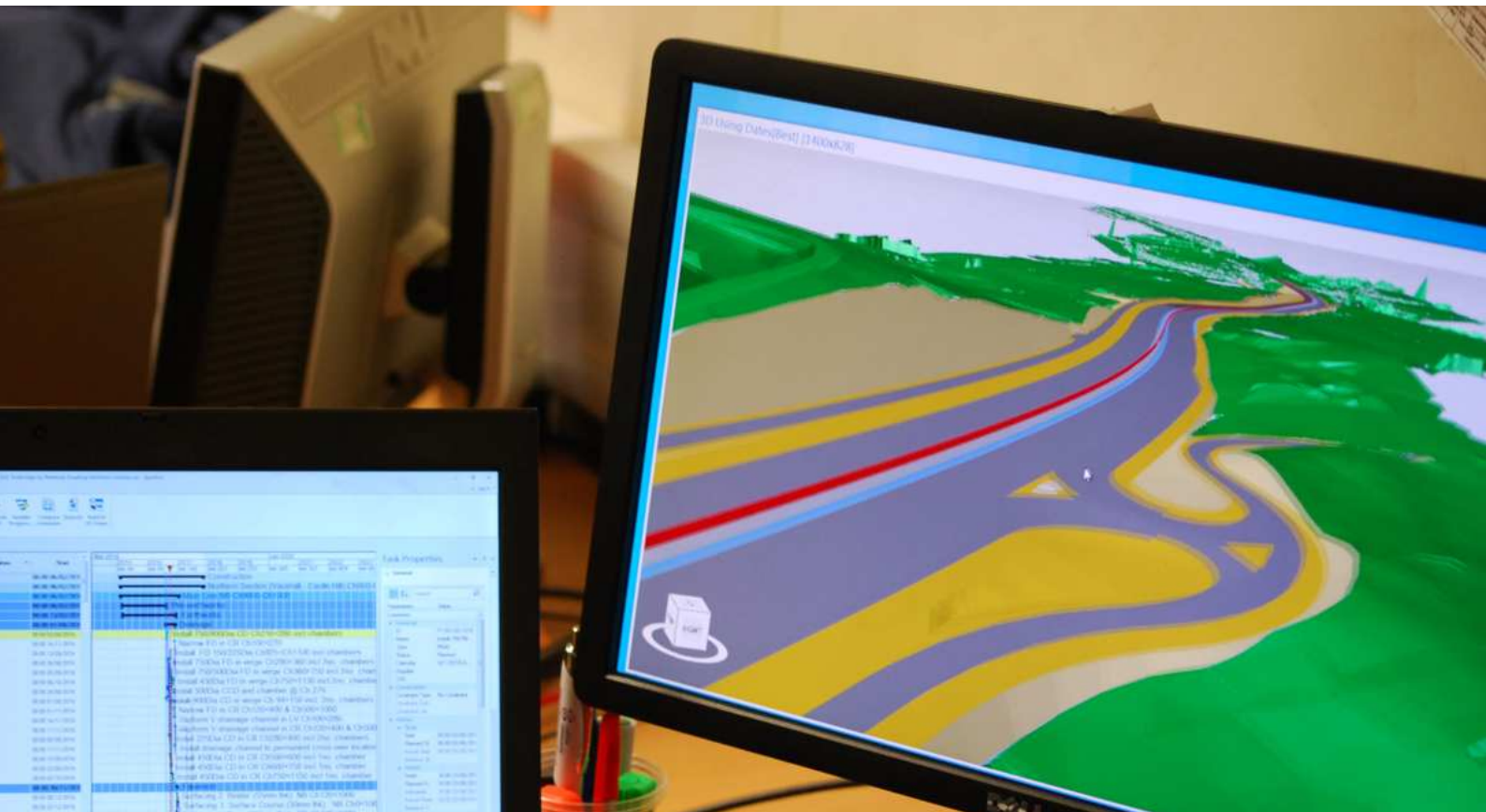
Over the past decades, the way roads are built has seen only incremental changes. Balfour Beatty believes it is time to reimagine road construction in order to better deliver for the customer. Much of this will require the increased use of innovative construction techniques and digital technology including Design for Manufacture and Assembly (DfMA). DfMA can reduce build time by 30-50% by allowing the work on two phases or more to take place simultaneously: while one part of the scheme is being completed onsite, the elements needed for the next phase can be constructed elsewhere.

As well as delivering more quickly for the motorist, less time onsite means less impact on those living and working in the area surrounding the scheme, while a shorter construction time also minimises labour costs, leading to a more efficient scheme. With many motorists and local businesses calling for more accurate

information relating to how long roadworks will take and when they will be completed⁴, the more reliable construction times these techniques allow are a key way of delivering for the customer.

Under our 25 by 2025 strategy, Balfour Beatty's Highways team have developed a philosophy of 'Design in a day, change in a minute and build in a week.' To help us deliver this, we are building a 'digital core', which will enable us to create standard solutions, develop libraries of standard products and to test their principles and buildability in a 'Digital Rehearsal Room'. This space will enable us to test, destruct and refine solutions to deliver the best possible product.

Flowing from this is a move to autonomous design – our aspiration is to get to 70% autonomous design where standard solutions and standard products are plugged into 5D BIM models.



⁴The National Road Users' Satisfaction Survey, Transport Focus, July 2017

3. Invest in research and development (R&D)

We welcome the £170 million Transforming Construction Programme, which aims to leverage a further £250 million of matched funding from the industry through its contribution to funding R&D projects. £70 million will be invested in a centre that will take forward the development and commercialisation of digital and off-site manufacturing technologies, while a further £70 million, will be awarded via competitions to support R&D projects and demonstration projects. While we are supportive of these initiatives, and of the focus in the Construction Sector Deal⁵ on the need for R&D to help mainstream industrialised construction, the amount being invested are very small given that this involves a change to how the construction industry has operated since its inception; that the changes will benefit the taxpayer as much as they will revitalize the construction industry; and that it is the Government itself as the industry's key client that must be persuaded to use these technologies. This is a key area in helping make the UK construction industry a leader in these technologies and more must be invested into making it a reality.

Investing in innovation: Rail

Balfour Beatty's cutting-edge Rail Innovation Centre in Derby brings together our expertise in systems engineering, computer science, robotics, data analytics, electronics and electrical and mechanical engineering. Combined with our York and Matlock offices, we employ more than 150 leading technicians, engineers, data scientists and developers to assist the industry's digital transformation.

The innovation hub is working on the latest developments in measurement systems, 'predict and prevent' technology, advanced digital surveying techniques, signalling and data science. Products and software being used at the facility include TrueTrak, OmniVision, OmniSurveyor3D, OmniCapture3D, DataMap and AssetView.

The hub puts Balfour Beatty at the forefront of rail innovation and is helping create a more reliable, cost efficient and safe railway network for all users across the UK and overseas.

4. Change the construction procurement model

The Government rightly wants to ensure that procurement delivers the maximum value for the taxpayer. However, in our view, the current procurement model, which favours lowest-cost tendering and excessive risk transfer to the private sector, leads to short-term cost savings at the expense of investment in things such as skills and innovative new techniques and materials. The current approach also stifles innovation in another way: contractors are unlikely to use innovative approaches if they are expected to take all the risk but share the benefits of success.

The question, then, is how to deliver major infrastructure schemes to scope and on time, while ensuring the strength of the domestic infrastructure industry and its ability to invest in techniques such as offsite and modular. Balfour Beatty believes the solution is a move by the Government towards a more sustainable procurement model. In particular, the emphasis should be on positive incentives rather than the current adversarial, punitive approach which is eroding the sector's capital base. As a major procurer of the construction industry, the Government has an opportunity to use its weight and influence to move towards a more collaborative approach which favours risk sharing rather than risk transfer, and incentivises investment in techniques such as offsite. Contract types already exist which aim to encourage innovation. What is missing is a common desire from both the Government and the industry to drive this change.

A more sustainable procurement model would also enable the industry to do more to deliver against the long-term strategic objectives of its public sector clients, by investing more in social value in terms of skills, employment, business, community and environmental outcomes. Balfour Beatty believes that the construction and infrastructure industry has means to deliver more inclusive growth, with the jobs, training opportunities and local supply chain spend that flow from investment in infrastructure. It needs to be given the opportunity to do so.

⁵The Construction Sector Deal, HMG, July 2018

5. Collaborate relentlessly

Companies in the construction sector must also become more collaborative and work harder at sharing best practice in order to drive change. The sector is highly competitive and therefore not always good at sharing ideas and best practice – this must change if we are to transform the industry.

Furthermore, Tier 1 contractors must ensure that they are driving change down their supply chains, supporting them

Moving to offsite manufacturing: Rail

Industrialised construction offers many benefits to the rail sector. In particular, Network Rail has introduced a new focus on modular systems. Bringing components and equipment that have been manufactured elsewhere, to be installed onsite, has less impact on the passenger and improves both efficiency and the safety of those working on the railway. This approach has been brought in with the construction of modular stations, with signalling, and on-track with switches and crossing (S&C) installations.

Switches and crossings

Following the creation of standard designs for modular S&C and the trialling of installation methods, components can now be assembled into layouts in factory conditions offsite by expert teams rather than at the side of the track, often in difficult conditions, as had previously been the case. These assembled layouts are then split into modular panels and loaded onto tilting rail wagons for transportation to site, before being installed using a rail crane and fixed together using steel brackets.

The introduction of this approach means that a crossover can now be installed in a series of mid-week night-time possessions, rather than requiring long weekend closures or diversions that are costly and have a significant impact on the travelling public. Balfour Beatty is proud to have played a leading role in supporting the introduction of and ultimately proving this new approach, helping to make the seven day railway a reality.

Modular S&C is now business as usual across the national rail network and is a great example of the successful implementation of off-site manufacturing.

in their own development. We must ensure that suppliers and subcontractors are ready to deliver once the balance tips towards industrialised construction methods. Not only must we ensure there is the capacity in the supply chain, but companies that are not ready will be left behind. To ensure a strong UK construction industry, we must ensure that the supply chain is developing its capability and capacity also.

6. Learn from the manufacturing industry

Balfour Beatty believes that there is much that the construction industry and that those procuring infrastructure can learn from the manufacturing industry. For example, the aerospace and automotive sectors use manufacturing techniques that go all the way from digital models through to components in a factory. This is not yet how modular and offsite manufacturing works in the UK in the construction sector. Offsite in construction is often understood as constructing elements at a different location – sometimes using the same techniques and processes as would be used onsite. This means that some of the key benefits of efficiency are being missed. This must be addressed if we are to harness the “lean” principles that have made such impressive productivity gains in the manufacturing sector. However, changing the way the industry operates requires investment, which in turn relies on a reliable pipeline. Furthermore, with others such as China, Japan and Scandinavian countries being more advanced in using modular techniques, it may be that there is more we can learn from them. Balfour Beatty’s 50:50 Far East joint venture, Hong Kong-based Gammon Construction, for instance, undertakes a considerable amount of work offsite, with the completed predominantly precast Cathay Pacific Cargo Terminal at Hong Kong International Airport a recent example.

7. Invest in skills for the future

The construction industry has a well-documented skills shortage. The existing workforce is also ageing and, given the significant number of non-UK EU workers in the industry, has challenges relating to the uncertainty surrounding Brexit. We believe that offsite offers the answer to those challenges over the medium-to-long-term.

With the move to offsite and other industrialised construction techniques, the skills that the industry needs are changing dramatically. While traditional construction techniques are time-consuming and labour intensive, offsite manufacturing requires a completely different approach.

Furthermore, the amount of training needed to get a workforce constructing prefabricated components, for example - to the required high level of competence - is significantly less than required for traditional construction techniques: offsite manufacture requires highly-skilled and trained people to set it up, but people who are not quite as skilled to operate it. We also believe that the offsite workforce will be increasingly made up of multi-skilled operatives – people who can do many trades on-site rather than just one.

There will also be a need for other, new skills to be invested in and developed. For example, those needed for the digital management of buildings. Prefabrication and modular approaches also require infrastructure to be designed in detail at planning stage, which calls for the technical and design teams to work more closely together supported by greater use of BIM (Building Information Modelling) and other integrated digital platforms.

This calls for both significant investment in the new skills the industry will need in the future, and for training and education providers to ensure they are ready with the training and apprenticeship programmes in offsite manufacture and management which will be needed.

Case study: Innovative repair of local roads

As part of its contracts for Derbyshire County Council and Herefordshire County Council, Balfour Beatty has been repairing and upgrading local roads, tackling issues such as potholes, using innovative road repair techniques which significantly reduce disruption to road users. These techniques are being used to improve efficiency, quality and cost-effectiveness and include:

- **Spray injection patching.** This is a rapid patching technique, suitable for use on rural and urban roads using cold emulsion asphalt which is placed into the void depression in the road surface under high pressure. Spray injection patching cleans, tacks, fills and compacts in one continuous operation. The process requires a one- or two-person crew, and, as it is self-compacting, it does not require other equipment such as rollers. Using this approach, potholes can be repaired in around three minutes, compared to up to an hour using more conventional methods. Costs are significantly lower, as is the environmental impact of repairing defects.
- **Infra-red thermal road repair.** This mends surface defects by recycling the existing Macadam and creating a hot-to-hot bond between it and the new asphalt. It results in a permanent, seamless and safe surface repair.

The national average road defect repair cost for local authorities in 2017 using traditional planned repair techniques was £49⁶. By using this combination of innovative patching techniques, the average road defect repair cost achieved on the project during 2017 was £35. A total of 31,877 defects were repaired resulting in a saving to the customer of over £446k against the national average local authority repair cost for traditional repairs.

Balfour Beatty understands that poor road conditions are a major frustration for motorists, as are delays caused by the essential work to repair and maintain the network. We are committed to exploring and deploying new methods where we think they will help to deliver for our local authority clients and local road users.

⁶ Annual Local Authority Road Maintenance Survey, 2017

Conclusion

Industrialised construction has the potential to deliver significant benefits for all parties, but there are many hurdles to overcome before widespread offsite construction becomes a reality.

While there seems to more or less be a consensus that we should be modernising the way we build, both the industry and the Government as its key customer must increase the pace of change in order to reap the benefits.

About Balfour Beatty

The UK's largest construction contractor, Balfour Beatty, was founded in 1909 and is listed on the London Stock Exchange. With 15,000 employees and over 40 offices in the UK, Balfour Beatty finances, develops, builds and maintains the increasingly complex infrastructure that underpins the UK's daily life.

With a legacy of projects across transportation, power and utility systems, social and commercial buildings: from Crossrail and Heathrow T2b to the M25 and M4/M5; and Sellafield; to the Olympics Aquatic Centre, we are proud to be a British company delivering iconic structures, bold engineering feats, behind-the-scenes innovation and joined-up thinking, financing and partnerships.

Balfour Beatty continually assesses how we can use technology and innovation to mitigate safety risks, increase project efficiencies and overcome challenges. To fuel this drive for continuous improvement, our innovation and technology teams are focused on research, development and the deployment of leading-edge best practices, lean processes and technologies that help us deliver higher quality, more efficient and cost-effective solutions.





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