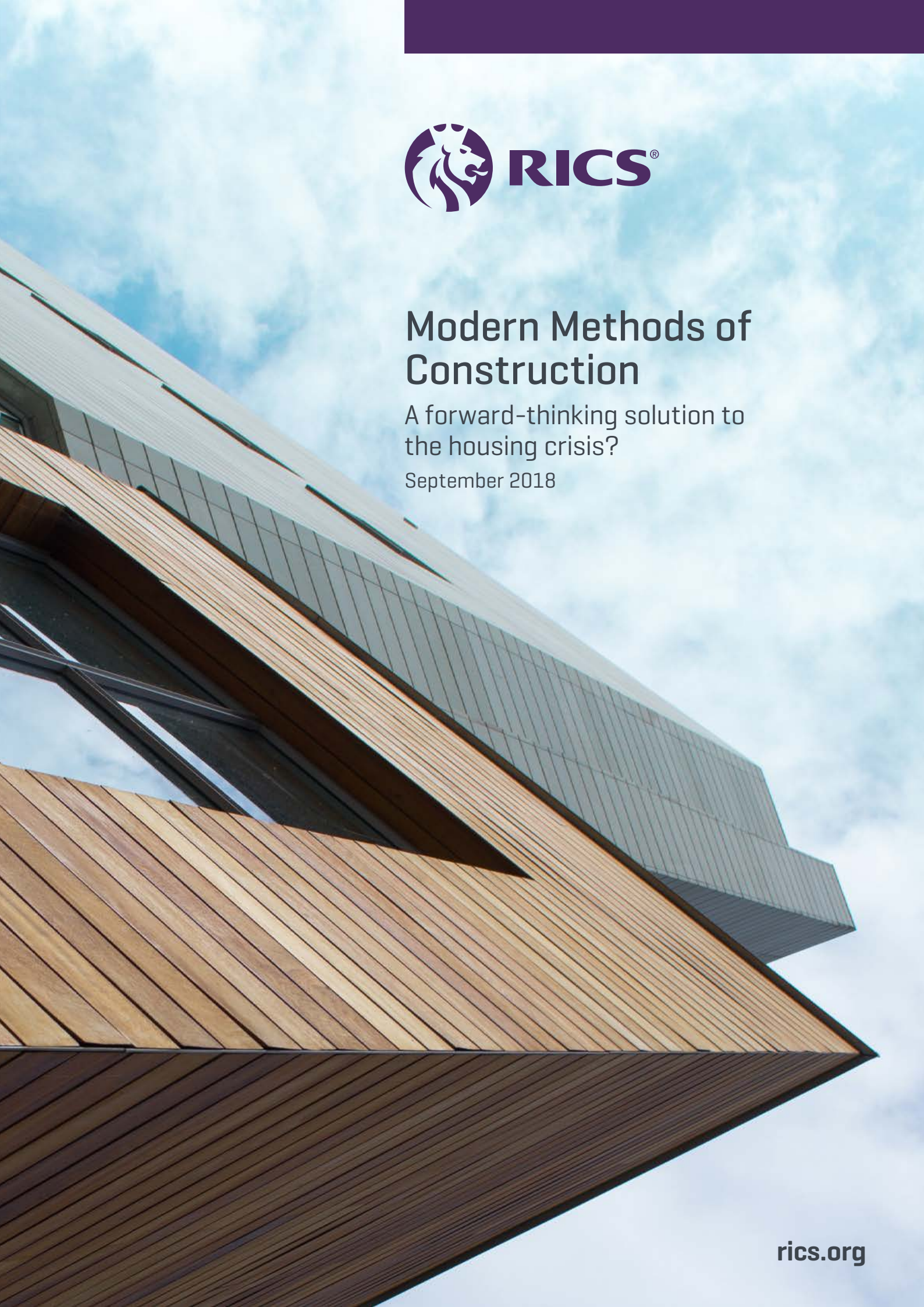

Modern Methods of Construction

A forward-thinking solution to the housing crisis?

September 2018

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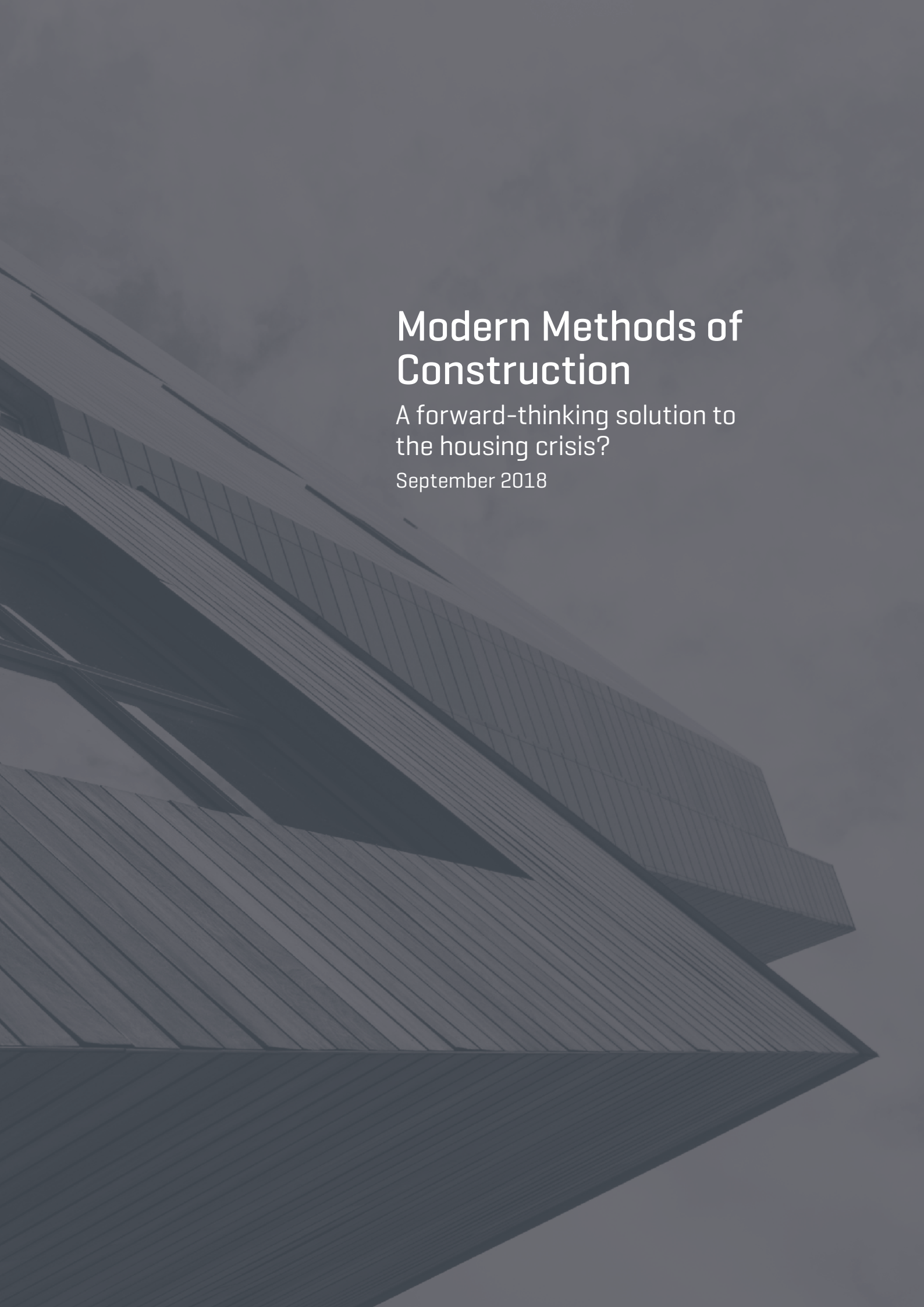

Modern Methods of Construction

A forward-thinking solution to the housing crisis?

September 2018

Report for RICS

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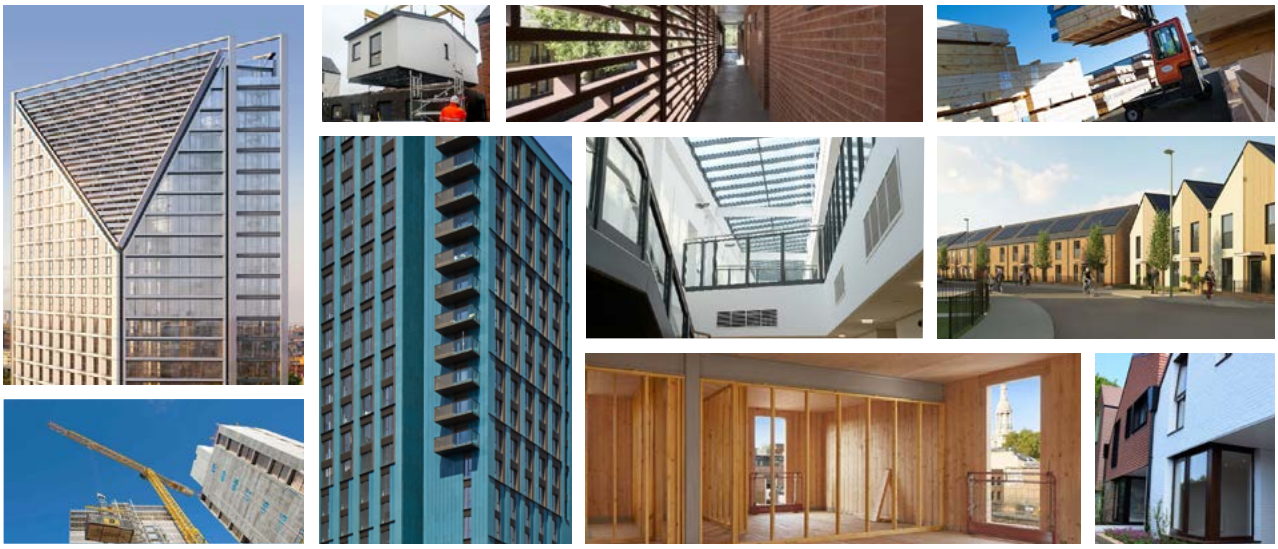


The UK construction sector is a strategically significant part of the UK economy. Representing 8% of GDP and 9% of employment, every year £150 billion is invested through the public and private sectors. It is not only important in terms of its contribution to economy, it is also an enabler of wider economic growth and development, providing the homes, infrastructure and environment that allows the nation to function and prosper.

The sector has been struggling however, to meet growing demand for its services in residential, with issues such as supply and demand imbalances which contribute to unaffordability and in extremis, homelessness.

Market-led solutions alone have not met the needs of large segments of the population, as housing affordability has moved beyond the reach of so many. The construction sector for residential is part of the challenge. It is characterised by low productivity, variable quality, output lagging behind target, and slim margins for builders. This is partly due to the cyclical nature of the residential sales-led trader model, creating unstable foundations for the construction sector to operate and invest in.

Offsite manufacture represents an opportunity to address many of these issues in addition to increasing capacity and investment in the industry. Its properties and characteristics can supplement our existing capacities, supporting alternative models for delivery and allowing for more options to be considered when tackling the complicated process of housebuilding. However, it is not a panacea that will resolve all the problems in the sector, but, once fully embedded, will go some way to improving our capacity to meet need.

The Buildoffsite Property Assurance Scheme (BOPAS) accreditation of non-traditional build, was one of the first systematic attempts to help mainstream MMC. This offered durability and maintenance assessment carried out by Building Life Plans Ltd (BLP), process accreditation carried out by Lloyds Register, and a web enabled database providing valuers, lenders and surveyors with details of housing units by scheme.

Launched in 2013, having been jointly developed by Buildoffsite, RICS, Lloyd's Register and BLP Insurance, in consultation with the Council of Mortgage Lenders (now integrated into UK Finance) and the Building Societies Association (BSA), the scheme seeks to address confidence issues with MMC. We now recognise that we need to increase support for MMC to make it a much more prominent part of the UK's construction capacity.

This RICS report showcases some of the potential benefits and impacts of the technologies on offer. While there is already take-up of the technology and some adoption in the market, more can be done to eradicate obstacles and speed up the growth of the sector. The research provides clear evidence and best practice examples on which to base future MMC strategy for both industry and government.

We thank those who have participated in the interviews for taking the trouble to engage with us.

Mike Basquill MRICS
Global Property Standards Associate Director, RICS

Introduction

The demands on the residential construction sector are substantial. At a time when we are facing a skills shortage, we have increasing workloads and aspirations to deliver ambitious infrastructure projects and targets alongside other modernisation goals such as improving productivity.

A key issue at play, beyond planning and developers' business planning, is industry capacity. In his 2016 report about the construction industry, *Modernise or Die*, Mark Farmer identified a skills crisis in mainstream construction, likely to result in a decrease of 20-25% in the workforce over the next decade. The workforce is ageing, and the rate of new entrants is lagging behind those leaving. This is likely to be exacerbated by Brexit, as one in eight UK construction workers are foreign, rising to around one in four in London.

In addition, the weakening pound has increased the cost of imported materials, with some 20% of bricks and brick-making components imported, mostly from the EU.

Recognising some of these problems, on 5th July 2018 the Government and the Construction Leadership Council published the Construction Sector Deal, allocating £420m in support of industry transformation.

The sector deal is based on three simple principles:

- **Digitising** – Delivering better, more certain outcomes using digital technologies;
- **Manufacturing** – Improving productivity, quality and safety by increasing the use of manufacturing; and
- **Performance** – Optimising whole life performance through the development of energy efficient, smart assets.

These are applied to five key themes:

- **Ideas** – investment in the development of digital and manufacturing-based approaches to construction;
- **People** – reforming industry recruitment and training to attract, retain and develop the skills that the industry needs;
- **Infrastructure** – taking forward the investment set out in the National Infrastructure and Construction Pipeline;
- **Business environment** – developing a sustainable business model for construction and establishing the UK as a global leader in infrastructure delivery; and
- **Places** – working across the sector to strengthen the supply chain and skills base across the UK.

MMC resonates with all these principles and themes. As a consequence of using manufacturing production methods, the workflow is significantly different to traditional building. As much more of the production value comes at the design and assembly phase, digitisation and efficiency gains are achievable.

This paper explores some of the potential issues and opportunities that MMC offers. By examining a series of case studies where BOPAS-accredited MMC variants have been deployed, we explore the pros and cons of the technologies on offer. We round off the studies with a call for action on various fronts, recognising that though MMC is not a panacea, it can play a substantial role in solving the problems we face in property and construction.

The drive towards mainstreaming MMC is building momentum. This paper seeks to highlight this and add further momentum.

Drivers of change

A combination of acute housing demand and market failures in terms of cost, quantity and quality, are forcing the industry and government to look at MMC as a solution. This has culminated in Government including MMC in major housing strategy announcements, recognising that it has the potential to speed up delivery, improve productivity and modernise the sector.

The reason for such faith being placed on MMC can be attributed to three key elements reflecting the three principles driving the sector deal: Digitisation, Manufacturing and Performance.

The utilisation of pre-manufacturing technologies brings construction into the modern age by transferring production to the factory. With greater quality control and more efficient use of materials and labour, employing manufacturing techniques will boost productivity, enabling faster scheme delivery with less risk of programme disruption on site. With scale, costs can be reduced through greater efficiency in a safer, controlled environment for workers.

Digitisation may be deployed both in the production process to achieve precision assembly, and also provided through BIM and successor models, a dynamic database which is capable of tracking the unit through design, specification, procurement, construction/assembly, quality control and finishing, handover, letting/selling, residential occupation and management, depreciation and replacement and recycling and renewal. Digitisation has the potential to transform stakeholder confidence in the product including that of investors, manufacturers, builders, surveyors, lenders, insurers, managers, and, of course, consumers.

Performance will be much more closely monitored and scrutinised through digitisation and manufacturing. Through BIM, Prop Tech, big data, AI and the internet of things, performance can be tracked throughout the building's life, meaning there is a continuous cycle from design, manufacture, build, management and feeding back into design.

Moreover, for industry, MMC provides constructors and developers with wider options. By having a different profile and properties, MMC supplements existing capabilities. Developers will have more options to choose from when considering options for a development. This introduces a new dynamic into a traditionally rigid operating environment, particularly around labour and resource factors, planning and engineering constraints, and sustainability and environmental performance.

Barriers to change

Given the stated advantages, MMC can become much more prominent in the sector. However, there are obstacles to overcome before MMC becomes mainstream.

Supply chain

The supply chains for many MMC technologies have yet to develop to a point at which we can meet the ambitions for the sector. Demand fluctuations, unstable investment and construction cycles, and a fragmented housing market procurement model is not obviously a good fit with factory production. Nevertheless, as demonstrated in the paper, some offsite products and processes have had greater longevity, and have achieved significant penetration in the conventional housebuilder supply chain, albeit as augmentation of the traditional approach rather than a replacement.

Skills

The skills issue in the construction sector can also impact on the development of offsite. Assuming that there are no skills or labour supply problems at the factory end, there will still be the requirement for sub-structure, superstructure and finishing trades on site, as well as issues around utilities.

Moreover, as MMC strategies are tied into digitisation, IT literacy amongst construction workers will be a concern. Given the recent pattern of concentration and fragmentation in the sector, high levels of investment in training and education will be required, not least with regard to growing SMEs and new entrants into the evolving market.

Cost and data

From a cost, value and performance perspective, modern offsite construction is relatively untested and is still in an evolutionary phase. The data on cost of construction, value and performance using offsite is not robust yet, and as techniques evolve, cost information and performance changes, and previous data becomes obsolete. This makes it hard for the industry to estimate costs, assess benefits and plan appropriately, which is a challenge for surveyors in particular.

This is an issue for investors, lenders, valuers and insurance/warranty providers naturally concerned about product durability, value and ongoing maintenance cost. BOPAS constitutes a significant provider of confidence and assurance in this sector.

Changing work profile and inflexibility

As the objective is for up to 70% of cost to be incurred offsite in factories and at the design phase, the points at which labour is most intensively used throughout a project differs from traditional build, with the cost curve far more front-loaded.

This cost profile demands a 'right first time' ethos from initiation. This also means less flexibility to change elements of the projects later on. That is to say, as a large portion of labour and other cost is generated early, there is greater project risk earlier, which is exacerbated by uncertainty around land and planning, and development period funding.

Industry familiarity

Lack of familiarity with different offsite construction techniques can lead to risk averse decisions against its use. This is reinforced by the subcontracting model and informal networks.

Consumer perception

There is still consumer resistance, with an abiding image of post-war emergency housing rather than 21st Century technology delivering better quality, safer, and far more cost-effective homes at the same or, with upscaling, at lower cost.

Standardisation and scalability

Standardisation of different technologies is also critical to reducing complexity and achieving scalability. There needs to be a sense that consumers have a choice between contractors when choosing a technology, although conventionally there will be a natural selection of technologies leaving a handful in the mainstream.

1: Cross-laminated timber – a forward-thinking solution to the housing crisis?

It has been widely reported that the UK housing industry has failed to build anywhere near sufficient numbers of housing for many decades, despite numerous initiatives being put in place, with the overall level of house building representing a fall of nearly 40% between 1980 (251,820 homes built) and 2015 (152,380). Whilst traditional building methods form the dominant part of the house building profile, they are incapable of delivering the volumes of housing needed.

According to data collected from a newspaper article in 2016,[5] 1.4 billion bricks would be needed to build the one million homes targeted by the Government by 2020. Yet, the UK only has 628 million bricks in stock. Furthermore, 43% of contractors reported difficulties sourcing bricks in 2015, with 14% having to wait up to six months for supplies.

To add further problems, half a billion of the UK's bricks in 2014 came from Europe. Brexit will only exacerbate an industry that relies on a fragmented and inefficient supply chain that relies heavily on imports.

So-called modern methods of construction (MMC), utilising different technologies and raw materials, are therefore increasing, following in the footsteps of countries like Scandinavia and Japan, in building offsite.

Cross laminated timber (CLT) is a structural, prefabricated panel used to form environmentally sustainable walls, roofs and floors across a wide range of structures. The gluing of both longitudinal and transverse layers, which reduces the movement of the wood and allows it to span in two directions like concrete, means that CLT more than meets the standards required by modern building standards.

CLT has a wide range of applications and can be used as part of a hybrid structure or as a sole building material. Its use is well documented in almost every sector and there are numerous examples of CLT in everything from high rise buildings and large commercial office space to single-storey dwellings.

Because of its variance in thickness, it is highly versatile and doesn't sacrifice integrity in place of sustainability. Its reduced weight, when compared to traditional materials like concrete, gives it considerable advantages in terms

5 www.telegraph.co.uk/business/2016/08/25/is-a-shortage-of-bricks-killing-british-house-building-nonsense/

of total building weight and allows for additional storeys on a foundation of the same size, and/or a reduction in size or extent of the foundations.

Often referred to as 'super-plywood', CLT is typically made from either spruce, pine or larch, which is planed and kiln-dried to reduce moisture content, in a controlled factory environment.

The conditioned timber is then stacked into layers, known as 'lamellas', at 90 degrees to the layer below, and then glued together. They are then hydraulically or vacuum pressed together to create high-strength structural panels.

Being sustainable doesn't have to come at the cost of the building itself. CLT is a robust and widely useable building material with excellent soundproofing, airtightness and fire safety properties. CLT's manufacturing process means the working profile of the wood is minimal, allowing it to be used in cantilevered structures.

Being wood, fire safety is a key concern. Products can be produced to resist fire for 30, 60 or 90 minutes; whilst outer layers burn, they form a layer of char which continues to provide heat resistance to the internal layers. Unlike steel, CLT maintains its structural integrity when exposed to high levels of heat. Timber engineering has come a considerable way, and fire safety has been built into the development of these products from the very start.

CLT is becoming increasingly prominent in the UK construction industry, dominating the offsite sector as its parameters expand. Previously only used for small domestic builds, it is now demonstrating strength and durability to compete with steel in high-rise buildings. Insurable and mortgageable, it's a rapidly growing as a component in construction.

Advantages and disadvantages

The benefits of cross laminated timber are numerous – from reduced loading on foundations and infrastructure services (due to its high strength-to-weight ratio), to impressive acoustic and airtightness performance. Most importantly, a CLT construction solution provides cost and programme certainty, and programme improvement. CLT is manufactured offsite, allowing exceptional levels of precision, thus ensuring minimal defects. Improved construction and project delivery timescales lead to reduced costs and maximised efficiency on all levels. With cost and time certainty being a crucial factor in all commercial projects, the use of cross laminated timber significantly reduces risks, as it is manufactured in controlled factory conditions.

Generally speaking, building in CLT costs around the same as concrete (taking into account material and build costs). However, cost savings are made up in areas like logistics where the offsite construction methods mean that considerably fewer deliveries are needed. Furthermore, the reduced weight of CLT results in lower groundwork costs, and the fact that it is weight saving (around 80% lighter) means lightened foundations, and reduced amounts of piling, allowing buildings to be built on what would otherwise be considered poor ground conditions or complex sites.

Figure 1 **CLT is planed and kiln-dried to reduce moisture content, then stacked into layers at 90 degrees to the layer below, gluing the lamellas together**

CLT is a good carbon sink. As timber grows it absorbs CO_2 and other GHGs from the atmosphere by photosynthesis. This CO_2 is then stored in the timber as carbon. Although the weight of timber per $1m^3$ can vary by species, timber is made up of around 50% carbon, therefore a figure for sequestered CO_2 and embedded carbon can be calculated against the volume or weight of the timber. For example; $1m^3$ of 12% moisture CLT weighs roughly 450kg and so contains around 225kg of carbon. Obviously when calculating sequestered carbon, the energy that goes into harvesting, manufacturing and delivering the product needs to be taken into account. However, it is generally considered that a single five-storey, cross-laminated timber building can cut carbon emissions by levels equivalent to removing up to 600 cars from the road for a year.

There are, naturally, downsides to the material, the most obvious being a less efficient thermal mass in relation to concrete.

How, when and where it's in use

CLT has been in use since the mid-1990s. Its origins are across central Europe – Germany and Austria are the largest manufacturers of CLT – and it arrived into the UK market around early 2000. The first major CLT building in London was the Stadthaus, the first high-density housing building to be built from pre-fabricated cross-laminated timber panels. Four carpenters assembled the structure in 27 days.[6]

Proving to the market that tall structures could be built using wood alone was a turning point in the industry, and CLT has increased rapidly in the last few years.

Figure 2 **The Stadthaus, the first high-density housing building to be built from pre-fabricated cross-laminated timber panels**

Image source: Waugh Thistleton Architects and Will Pryce

6 https://www.treehugger.com/green-architecture/nine-storey-apartment-built-of-wood-in-nine-weeks-by-four-workers.html

B&K STRUCTURES
OPTIMISED OFFSITE SOLUTIONS

Case study

B&K Structures

B&K Structures is the UK's leading sustainable structural frame contractor, specialising in design and delivery of hybrid structures. In operation since 1974, the company was historically a structural steel fabrication company, primarily in retail. However, considered to be forward-thinking, the company was introduced to the concept of engineered timber by one of its major clients in 2006, supermarket giant ASDA. The company created a separate division called B&K Timber Structures in 2007, which ran alongside B&K Steel Fabrications. Then in 2010 the two businesses merged and B&K Structures was created.

Says Wayne Yeomans, Head of Sales and Marketing:

"The market was changing, and we've always been quite good at looking at what is happening out there. I think we would have naturally digressed into engineered timber, but it was great to have a client giving us a nudge in the right direction. It forces you to learn new things, which has proven to be great for us.

"We're now what we call a hybrid structures business. The way the business has changed, we have gone from being 80% steel and 20% timber, to being 80% timber and 20% steel."

B&K Structures is itself a division of Bowmer and Kirkland, a billion pound construction company, which enables confidence in an uncertain marketplace. Having significant experience in the steel and concrete industries means that the company does not suffer commercially by utilising other structural materials in unison with timber, thus making the firm ideally suited to build hybrid solutions.

Manufacture of the company's CLT takes place in a factory-controlled environment, using computer numerically controlled (CNC) digitally programmed precision joinery machines, ensuring exceptional levels of accuracy are always guaranteed. The controlled conditions under which CLT is made dramatically reduces the appearance of defects which improves construction and project delivery time, reduces costs and maximises efficiency on all levels. CLT panels can also be designed to allow for the onsite installation of bespoke windows, doors and other architectural features.

Cross laminated timber panels are prefabricated and delivered to site as large structural elements, meaning crane loads and erection programmes are dramatically reduced. The panels are installed, without the need for wet trades, with the aid of a crane and lightweight power tools. Site storage is reduced by just-in-time delivery scheduling and health and safety issues are minimised due to the lightweight nature of the product and the speed of erection. The company's building information modelling (BIM) capability also allows for pre-drilled holes for follow on trades like electricians and plumbers.

Sustainability is a considerable argument for CLT's usage. B&K's CLT is sourced from PEFC or FSC certified and managed forests, meaning that all trees used are replaced and are only felled when they have reached peak maturity. The carbon that is stored by the trees is subsequently built into the project, removing the CO_2 from the environment permanently.

Says Yeomans:

"For every tree that is felled for our buildings, four saplings get planted. After five years, the forest goes through a thinning process, and the weaker of those trees gets removed to allow the trees to become more mature. In 10 to 15 years the forest goes through another thinning process, which will potentially remove another of the weaker of those trees again. So, for every one that we chop down, at least two are going forward to become mature trees. Everything we do is being replenished, making it a truly sustainable building material."

Dalston Lane

Standing at 33.8 metres at its highest point, at the time of completion, Dalston Lane was the largest load-bearing timber structure in the world. Ranging from five to ten storeys, the Dalston Lane brief incorporated 121 residential units of contemporary-style one- to three-bedroom apartments, spread across nine floors and totalling a gross external area of 11,591m^2.

The most significant challenge of the build was creating an imposing, multi-floor building on a project that was so close to HS1 and Crossrail tunnelling. Because of its proximity, piled foundations were ruled out early on, which meant the weight of the build would be affected by the loading restrictions. The solution to this challenge was largely solved by the building materials used. Supported by a raft foundation, the robust, yet lighter, cross laminated timber structure was a major benefit.

The choice of CLT drastically reduced the weight of the building, and enabled architects Waugh Thistleton to get maximum value from the building's previously neglected brownfield plot, permitting 35% more homes to be planned within the loading restrictions.

Image source: Daniel Shearing

Says David Lomax, Senior Associate at Waugh Thistleton:

"Our project at Dalston Lane really is a proof of concept, that now working with CLT should be seen as a standard 'third way' alongside concrete and steel when appraising a project. What's more, more likely than not, it's going to win. We have a lighter, quicker and more sustainable building. Also, crucially for an urban context like this, we have a quieter and cleaner building site – fewer deliveries, working with electric hand tools rather than jackhammers. If we're going to densify our cities to solve the housing crisis, we're going to have to have the backing of existing communities and CLT can be a critical part of that journey.

"Still, none of that matters if we can't provide quality homes. Here, we've built strong, quiet, robust and airtight homes that are not constrained in their appearance or quality by the technology. We hit double the predicted air tightness, keeping heat and noise inside the flats. We're proud to have made this contribution, not just to the emerging mass timber industry, but to the happy residents within, and the wider context of Hackney."

The structural benefits of cross laminated timber include its loadbearing capacity when used as a wall or slab, together with its superior acoustic and performance properties. Cross laminated timber distributes concentrated loads as line loads at foundation level.

As the world's largest load bearing CLT building, with the greatest volume of CLT in one contiguous structure, the Dalston Lane project timber usage is calculated at 4,649m^3, with only seven tonnes of steel beams. The minimal reliance on materials like steel is a feat of engineering in itself.

In addition to the issues with piling, there was another reason to choose wood as the primary building material. Dalston Lane is in the London borough of Hackney. In 2012, Hackney Council made headlines when it mooted a 'Timber-first' planning policy, declaring:

"Hackney Council is set to be the first local authority in England to promote timber construction in its planning policy. Last week the Council hosted a Wood First conference for architects, developers and planning officials from other local authorities to encourage the consideration of timber as a first choice building material. Wood for Good, a campaign to promote the suitability and sustainability of using wood in construction, sponsored the event which examined the benefits and limitations of building with timber as well as explaining its place within local and national planning policy."

The Council was therefore keen to promote the benefits of building with wood, and made it clear it would take into account the carbon footprint of a new development to ensure it was in line with its sustainability policy. The use of structural timber would help to contribute to this.

Says Yeomans:

"Hackney's timber-first approach came about because they have quite a dense and built up area. They've got areas that they were looking at for redevelopment, and they have always encouraged new technology and haven't shied away from looking at what can be done. The timber-first approach came about because of timber's environmental credentials; sustainability, its speed of build. Speed of build lowers the disruption within the area itself, so when you are considering putting a 15-storey building in, you have to think about the local residents. If it's going to be built traditionally, all those builders are going to be onsite for the best part of two years, you're going to have hundreds of contractors around every day, trades vans parking everywhere, so it becomes a real nuisance.

"If there is a local community issue – they are the first to pick up the phone to the local authority. There are probably other factors that we are not aware of as to why Hackney takes a timber-first approach. Efficiency is definitely a driver."

Indeed, it is not clear that the policy has actually been implemented, but there are certainly a number of buildings in the Hackney area that have pioneered the use of CLT in their construction.

The environmental benefits were enormous. The build achieved 3,576 tons of sequestered carbon and 976 tons of embodied CO_2. Delivering a net carbon footprint of -2,600 tons CO_2, CLT represents a vast improvement on the net carbon footprint of an equivalent block with a concrete frame, with an estimated +2,000 tons, as the diagram below illustrates.

To put this in perspective, the carbon embodied in the building is equivalent to the emissions produced by 1,703 cars over a year. Cross laminated timber is clean to use with little onsite waste, and it is made from readily available, renewable softwood which contributes positively to high BREEAM ratings.

Says Lomax:

"It's unrealistic to think we can meet our most recent carbon reduction targets by only looking at energy 'in use' during the lifetime of the building. We've made amazing leaps in the last couple of decades in that area, but really, that has only served to highlight the importance of looking at embodied carbon – that which is emitted during the making of materials and the buildings themselves. Now that there is little space left to effectively further reduce carbon in use, there are two critical areas which form the majority

of our emissions. These are the carbon emitted via our lifestyles, and the carbon emitted to make our products, buildings and materials. As construction professionals, we have a duty to do everything we can to influence the latter, as it is directly within our control. With that in mind, it should not only be an aspiration for designers, specifiers and builders to use low carbon materials – it should be a necessity."

Adds Yeomans:

"What we proved with Dalston Lane is that it was really efficient in terms of the lesser amount of people – we had something like 60% fewer operatives onsite. If you try and equate that into actual individual people and number of vehicles coming in to the area, parking restrictions etc., it has a real impact on the local community."

By using CLT, the site received 589 fewer deliveries than that required by a concrete build. Furthermore, an additional three storeys were added because of the 8,000 tonne weight difference. Had the structure been concrete, there would have only been capacity for 106 flats instead of 141.

Says Yeomans:

"It was an efficient build in terms of the amount of people we had onsite at the time. There were on average eight timber frame erectors on that building throughout the majority of the build. If you consider you would need somewhere between 60 or 70 people onsite to erect a concrete frame, on a disruption and environmental level, that's where CLT really wins."

Although chosen for its sustainable and aesthetic properties, there was an explicit need for the project to fit in with the local environment. The building's intricate brickwork was incorporated to reference both the surrounding Victorian and Edwardian housing and the craftsmanship-like detailing of the local warehouses.

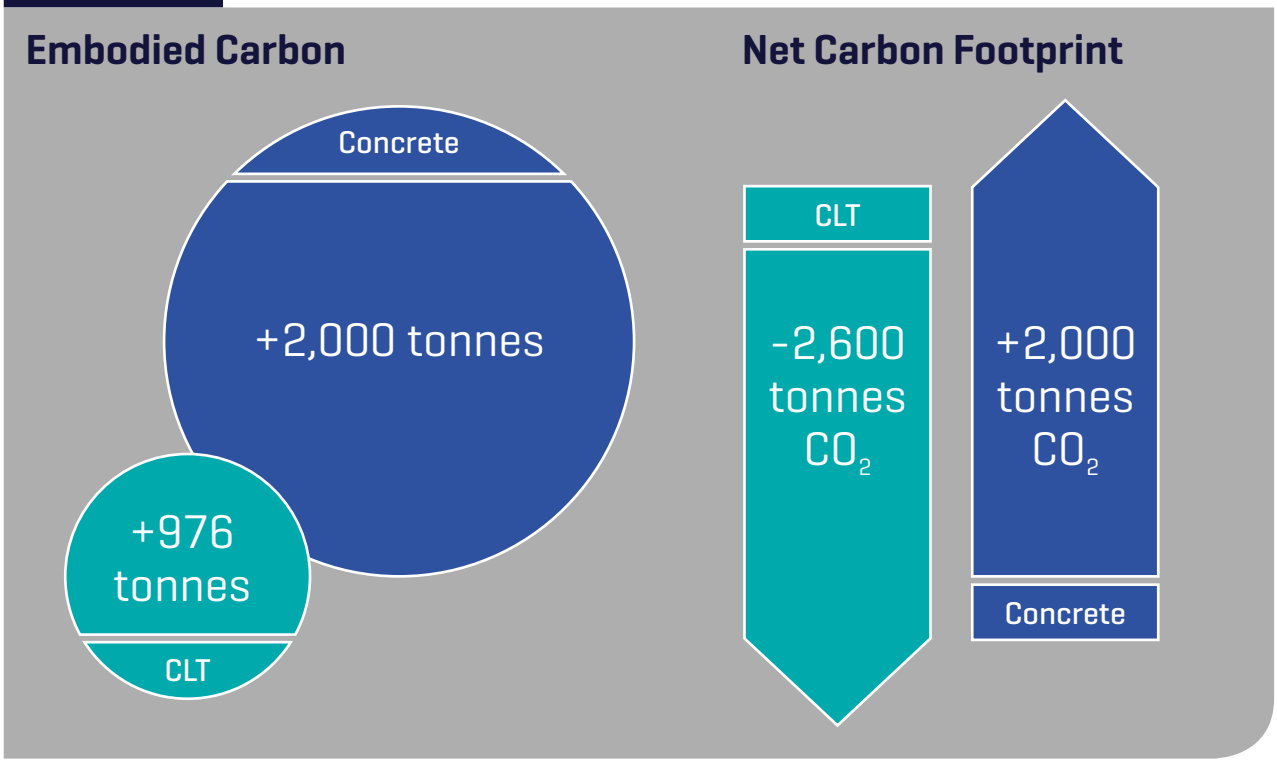
Indeed, you wouldn't know the building was made out of timber at all. Says Yeomans:

"If the average layman was to walk into the finished building and take a look around, unless somebody told them, they wouldn't necessarily know. From a perception point of view, it does its job. What is a shame is the fact that most clients would like the fact that they're living in something that's environmentally friendly, that it is a sustainable building material. If you could demonstrate to them all the benefits that we've had around the project I think they would be quite staggered by it."

The build

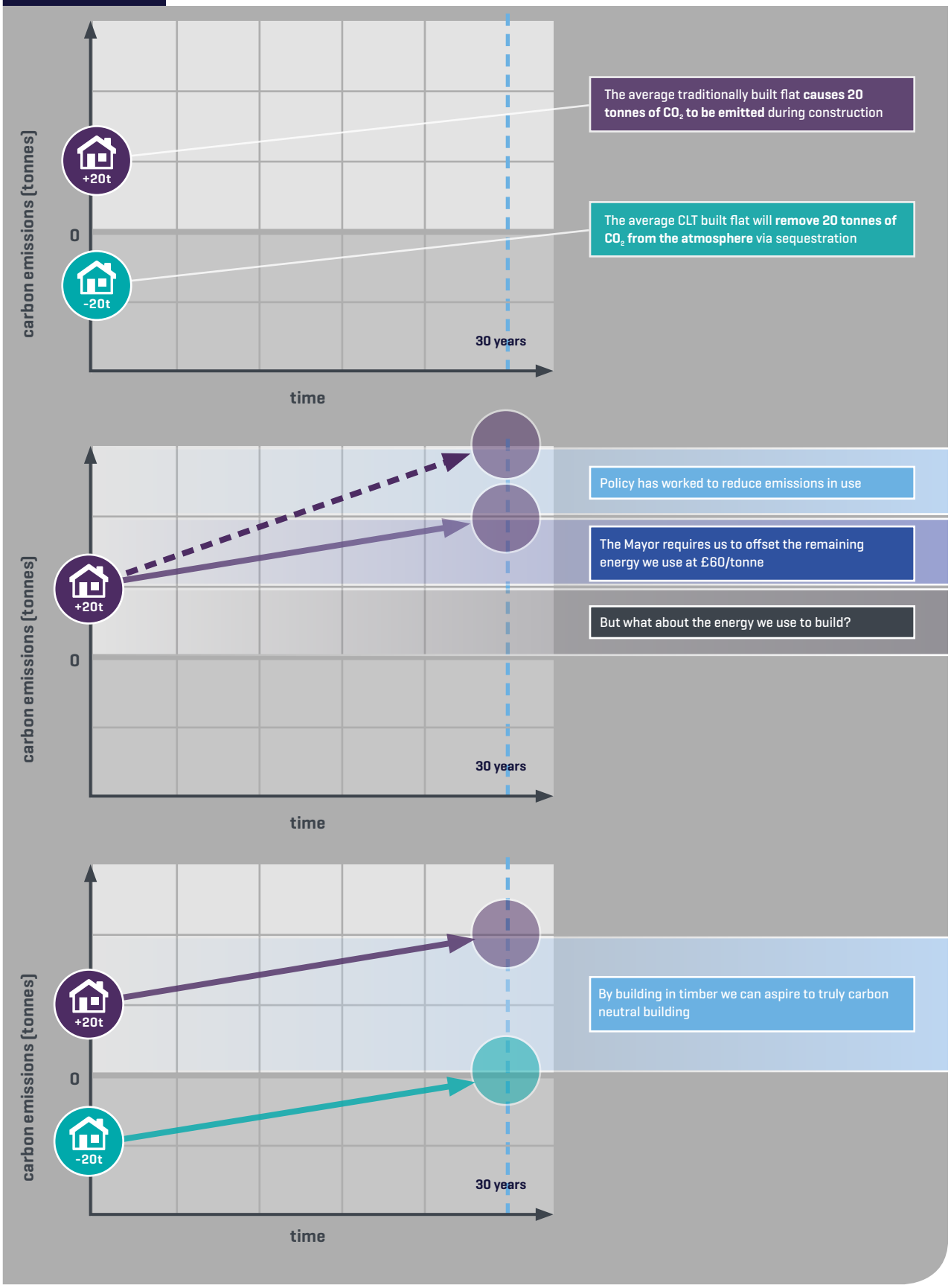
Fabrication of the CLT materials was carried out by the company's supply partners, Binderholz; this took around seven weeks in the factory. Once onsite, the overall project

Figure 3 **A comparison of the embodied carbon and net carbon footprint between CLT and concrete**



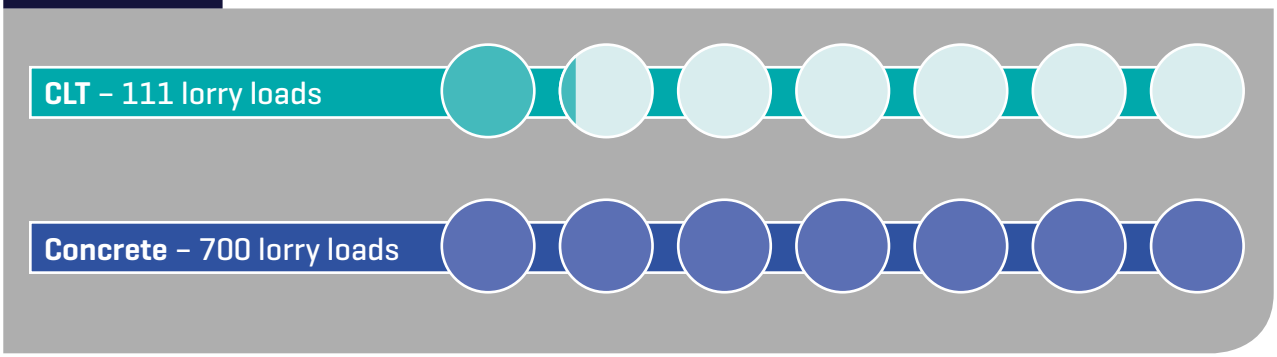
Source: Waugh Thistleton Architects

Figure 4 Carbon emissions produced during the full lifecycle of the building, including during build



Source: Waugh Thistleton Architects

Figure 5 **Delivery comparisons of CLT to concrete**



Source: Waugh Thistleton Architects

from start to finish was around 12 months, and around 34 weeks of that was for the installation of the CLT frame.

Says Yeomans:

"There are different ways of installing buildings to gain more efficiency. With Dalston Lane, a limiting factor was that there was only room to get one pair of crane onsite. That was always going to be a restricting factor; you could only have so many crane lifts per day, hence you could only install so many panels per day, so that's where the 34 weeks programme came from.

"We're currently looking at a scheme that's over twice the size of Dalston Lane in terms of the number of rooms and apartments, but the way that the site is laid out we can break it into three blocks and we can have a pair of cranes per block. Therefore, we can install over twice the size of that building in less time now by utilising efficiencies."

Assurances and warranties

Yeomans believes there is still a slight reticence in the industry to using the material:

"I think people still see it as a relatively new technology, whereas the world has actually been building out of timber since time began, it's the oldest form of construction. CLT is a relatively new form of construction, but it's still been around since the 1990s. It's tried and tested, it's been developed and engineered over many, many years. When you go around the facilities at Binderholz or Stora Enso, you see the investment that they've put into the manufacture of CLT and how engineered that product is; all the quality controls that are in place to make sure that the material is produced to the highest standard. The UK market is perhaps behind where the Europeans are in terms of our approach to different forms of construction. But we're certainly getting up to speed."

In terms of accreditation, BOPAS was a certification that the company realised it would need from the start, so it has been certified since 2014, giving assurances to the lending community that its structures will deliver a consistent performance over a determined durability of 60 years. As designers, manufacturers and constructors involved in offsite manufactured systems, B&K Structures has been rigorously audited and approved by BOPAS to maintain the highest levels of quality assurance throughout the design and build process, ensuring its construction systems are approved for integrity, durability and performance.

Less straightforward has been warranties. Although warranty providers are gradually coming on-stream, some are still wary of new technologies and building methods. Dalston Lane was warrantied by Premier Guarantee, which Yeomans maintains is one of the more forward-thinking warrantee providers. It is obviously key to giving tenants assurance that their building is protected.

As for potential lender or mortgage resistance, a 2016 report by the Building Societies Association found that high street lenders are better able to understand and provide mortgages on systems that have been subjected to some form of widely accepted accreditation, for example BOPAS.

Says Paul Philbin, Quality and Environmental Manager:

"We've not seen any resistance. From that perspective, I don't think there's any issue there. Due to BOPAS, more of the mainstream lenders are now open to providing clients with mortgages for new forms of construction. That's only been helped by more and more of these buildings coming on stream and there being more documents and evidence that these buildings are insurable and are in many ways better than traditional buildings. The more that are built, the more confidence will grow in the marketplace."

Dalston Lane has received widespread acclaim for demonstrating the benefits that CLT brings to the fast, efficient delivery of large-scale housing projects in challenging locations, and B&K Structures has received many accolades for its offsite work, including being named *'Winner of winners – private housing'* at the 2017 Structural Timber Awards.

The future

As a business that "pushes the boundaries," B&K Structures is keen to see what else CLT can do. Says Yeomans:

"It was great for the building to achieve the accolade of being the highest at the time, but it was more important to prove that it could work, and to prove that the material had the ability to go that high. The perception was that it couldn't go as high as 10 storeys, and now we're considering buildings that go much higher. That 10 storeys now seems an easy feat compared to what it was three years ago.

"How designers move forward and how technology has moved forward will enable us to really push it forward. One thing that will always limit where it goes is legislation. British standards and design standards have to be followed."

In the wake of the Grenfell Tower disaster, new systems need to be tested as a whole, and façade systems need to be considered alongside building layout. It is crucial that regulation keeps pace with emerging technology, and the government needs to keep ahead on the performance required from these systems. Panels are designed to a specified fire resistance and remain structurally stable when subject to high temperatures. CLT is the only structural timber solution to fully comply with all fire resistance REI classes (loadbearing capacity, integrity and insulation) and performance requirements without the need for any costly add-ons, building ups or adaptions.

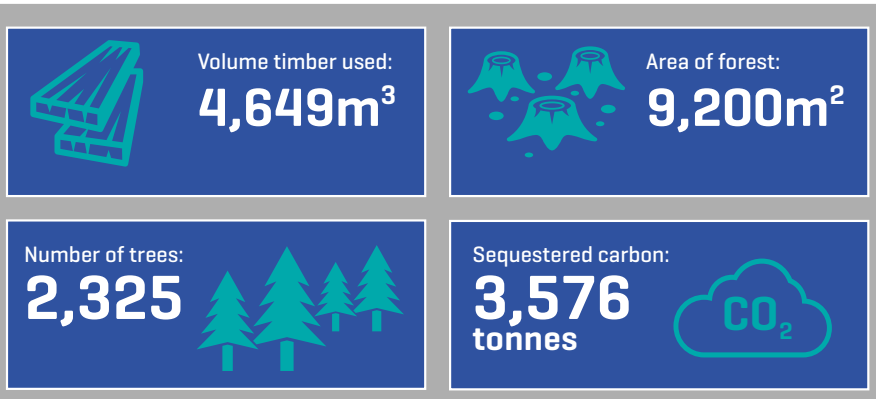
Says Yeomans:

"When you consider things like Grenfell; that had nothing to do with a timber building, but it did prove that anything can burn, given the right conditions. I think what will come out of that report will change the way we design buildings going forward, not just us but the industry as well. Our ambitions might be to push it higher, but we can't foresee what legislation might change that remit. Up until then we will continue to push the boundaries."

We are likely to see more and more construction using timber as its predominant building material over the coming years, due to its sustainability credentials and speed of use. Concludes Yeomans:

"What we're trying to do is look at how we can help clients achieve their buildings. We want to push the boundaries, within a safe remit. We realise that CLT is never going to do 30, 40, 50 storeys, but what we are trying to do is stretch its legs a little bit and see how far the material can go."

Figure 6 **Dalston Lane: timber statistics**



2: Modular construction and build-to-rent - accelerating house building

Since the 1970s, on average, around 160,000 new homes have been built each year in England. The consensus is that we need from 225,000 to 275,000 homes per year to keep up with population growth and begin to tackle years of under supply,[7] with the Government's 2017 Budget targeting 300,000 new homes per year by 2020.

In his October 2016 report, *Modernise or Die*,[8] Mark Farmer suggested that a combination of the failure to replace retiring workers (the UK faces a 25% decline in the labour force over the next ten years), and low productivity, have left the construction industry facing "inexorable decline" unless it embraces modern methods of construction (MMC).

One way of addressing the skills shortage, and encouraging greater efficiency and higher productivity in the construction sector, says Farmer, is to embrace and adopt pre-manufacturing. Much as everyday goods such as televisions, fridges and cars are built in factories, so the argument goes that constructing residential properties in purpose-built plants will be one way to accelerate construction, and create the houses the country so desperately needs.

"Modular will develop most where there's cheap land, where the local authority is pragmatic and open to innovation, and where there's a desire for quick delivery," says Farmer.

Farmer contends that it is in the build-to-rent and affordable rented sectors that offsite manufacturing is likely to have the biggest impact. *"The rental sector, where investors are looking for products at scale and quickly, is an obvious opportunity to enable investment in offsite,"* he says.

"Both affordable and PRS are acyclical, whereas private for sale is completely cyclical and wouldn't underpin the investment in factories."

Purpose-built blocks of market-rental homes are common in other countries such as the US, Germany and France, but are a relatively new phenomenon in Britain. The rising trend for long-term renting has coincided with a housing market that has out-priced the younger generation. Build-to-rent involves the construction and development of properties designed to rent out on a long-term affordable basis, and are generally offered with longer term assured shorthold tenancies.

7 Fixing our broken housing market': www.gov.uk/government/publications/fixing-our-broken-housing-market
8 'The Farmer Review of the UK Construction Labour Model': www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf

The sector is expanding across England, with 80,855 homes either completed or planned, according to recent official figures.

Among other things, build to rent can:

- increase the overall supply and accelerate the construction of new homes;
- support greater choice for tenants in the rental market;
- deliver a better quality of rental product that is professionally managed; and
- provide boroughs with an opportunity to generate a long-term income stream to invest in local priorities.[9]

Modular construction

Modular construction has been recognised for its ability to help solve the problem of a lack of housing available within the UK, designing and building high-quality pre-built homes at a faster rate.

The construction industry often faces delays caused by numerous factors, including lack of labour, or weather conditions that halt or slow down construction onsite. Modular housing provides a solution to those problems. Building offsite within a controlled factory environment minimises risk, resulting in a faster build programme, assured quality control and enhanced build performance standards.

From increased energy efficiency to reduced build time, factory-built modular homes can be designed with both occupants and the environment in mind, making modular housing solutions increasingly popular.

But for modular housing to become a scale solution to the housing crisis, a number of significant obstacles need to be overcome. Noble Francis, Economic Director at the Construction Products Association, says:

"Offsite manufacturing requires a large investment up front and returns over the long term, so you need a stable market. Following the financial crisis, housing starts fell 71% but volume housebuilders have a business model that can adjust to that kind of volatility – they can slow down or stop building – but it is much more difficult for large-scale manufacturing to adjust in the same way. If you have a factory, you have to supply it with orders, so for modular to reach scale it will require a stable market."[10]

This is where the build-to-rent sector could stimulate offsite – and vice versa. Build-to-rent speeds up the delivery of developments, as the units produced are not tied to sales rates.

elements europe

Case study

Elements Europe

Elements Europe is part of the Pickstock Group (an international group of companies specialising in modular construction, traditional construction, manufacturing and property development, with an annual turnover of circa £200m), and an established market leader in the world of modular construction. Its parent group's experience in traditional construction has shaped its approach to modular construction, ensuring seamless integration between its industry-leading systems in the factory and its innovative work onsite.

Working across the private and public sectors, it delivers a broad range of offsite construction projects – from modular housing units for the private residential sector, to student accommodation, hotels and care homes.

Elements Europe's factory production space totals 200,000 sq ft, with its principal facility located in the West Midlands. Utilising the latest technology, the company manufactures high-quality modular building systems in the factory that can then be erected onsite easily and efficiently.

A full turnkey supplier, it controls the entire manufacturing process from start to finish – from steel fabrication through to the final cleaning of the modular rooms and bathroom pods. Following this process, the quality of each and every product is checked and signed off – ensuring that all solutions are manufactured to the same consistently high standard. Once they pass quality control, Elements' in-house haulage team delivers the products to the site for installation.

Kevin Arthur, Sales Director at Elements Europe, maintains that it is this ability to provide all services from inception to completion that gives them the advantage:

"Without a shadow of a doubt it helps that we have the full process from factory to end site, including our own fleet of lorries, so we're not reliant on other contractors. Both for our hot rolled steel fabrication and our cold rolled forming, that allows us to have greater control."

9 'Everything you need to know about build to rent in London': www.londoncouncils.gov.uk/node/32494
10 Offsite hub – 'Is modular ready to go mainstream?': www.offsitehub.co.uk/industry-news/news/is-modular-ready-to-go-mainstream/

He continues:

"The original premise of the company was established as we were seeing inefficiencies in our own building sites, in the housebuilding market. We were set up initially to manufacture bathroom and kitchen pods for our residential housing arm, Hitchcock Homes. We then began manufacturing bathroom pods for third parties, particularly in the student and care home market.

"The business was set up to address inefficiency in the construction market. We're property developers, investors, main contractors, house builders, offsite manufacturers, and we have food production as well, so we've brought a lot of that knowledge into our manufacturing.

"The more you can do offsite, in a clean environment, the more you can guarantee high level quality control. Which is better than traditional construction on a building site in the pouring rain. You can not only control building quality, but also materials. On a housing site where you're building 200 homes you don't have a bonded warehouse on that site. You're relying on delivery management. In a factory environment you have goods in, goods out, a bonded store, so you have a much better level of stock control in comparison to traditional building sites."

Mark Farmer believes that the government ought to have a role to play in encouraging clients to change their behaviours and buy manufacturing-led construction rather than traditional.

He says:

"That could be about creating the right conditions, the right incentives and the right overall environment that makes clients start to change their mind about modular and think that it's a good thing and the right way forward – that it's the future of the industry."

Confirms Arthur:

"Speed, quality and cost certainty are the main advantages. There are no disadvantages if you're choosing the right product for the right project. If you're building an income producing model such as student accommodation, a hotel, a care home, PRS, you've got a huge benefit in terms of timescales as the project will be quicker to produce, so you'll get that income quicker. The cashflow is slightly different on modular, so you're paying slightly more throughout the build period, but then you get savings back having the project delivered a lot earlier."

Creekside Wharf

Essential Living chose Elements Europe to deliver its 249-unit Creekside Wharf scheme in south-east London, which, at 23 storeys, will be one of the tallest modular buildings in the UK, and one of the first build-to-rent schemes to be built using offsite construction.

Elements Europe is manufacturing 653 modules for the scheme, which make up some of the 249 one- and two-bed apartments for rent. The two- to three-room modules for each apartment are manufactured offsite and then joined together onsite at the installation stage. Each apartment includes an open plan living and kitchen area, one or two bedrooms with en-suite, and a family bathroom. The company is also manufacturing corridor cassettes within the scheme as well as the roof structure.

All mechanical and electrical aspects of the room modules, as well as decoration and en-suite bathroom fit-out, are completed within the factory, negating the need to conduct this work onsite.

Says Arthur:

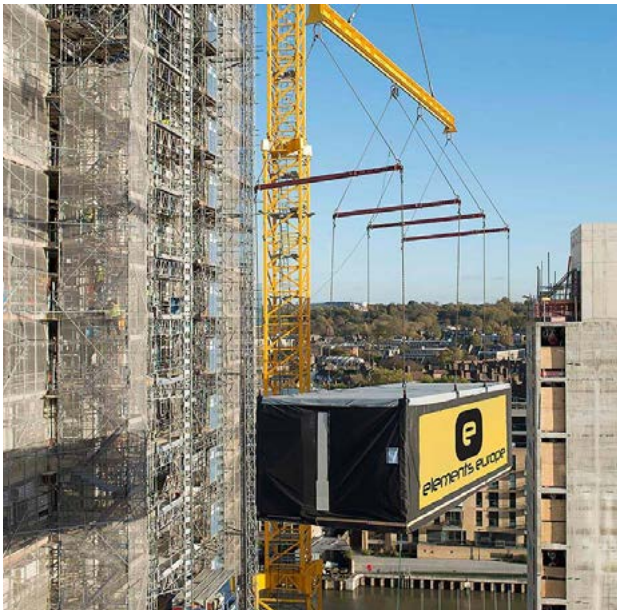
"It's probably a 50/50 split between on and offsite. The modules internally are totally completed; you'll have the entrance door, the windows, mechanicals, electricals, all the finishes on the floors and walls. To a lay person who knows nothing about construction, they would be completely unaware that it's made from modular construction, it's completely integrated."

Creating full room modules is a step up from the traditional bathroom pods the company made its name from. But they use the same technology.

Says Arthur:

"The bathroom pods are put into traditional builds as well as offsite. Our bathroom pod will go into a concrete frame, it will go into a timber frame, into pre-set concrete; the bathroom pods can go anywhere. Bathroom pods are a tried and tested means of constructing. It's very well accepted in the marketplace, whereas modular has taken a bit more time because obviously it's a larger proportion of what you're doing, and things take time to become standard."

The only restriction the company has on its module size and shape is transportation. The requirement is to remain under five metres in width and under 14m in length, but it can be any shape and size, depending on what the client wants.



Arthur maintains the market is "hot" at the moment, particularly as the Government has started to promote MMC.

"We know what manufacturing is like in the UK," he says. *"This adds value. There's obviously a large demand to deliver housing and if you're doing it by offsite means you're ticking a number of boxes. It allows you to deliver better quality homes in a quicker way whilst also underpinning the manufacture of the UK."*

According to London Assembly's *Designed, sealed, delivered* report,[11] offsite manufacturing is particularly suited to London's housing market, and build-to-rent schemes.

"OSM's positive contribution is not limited to production and performance benefits alone," says the report. *"It is suitable for all tenures, but with particular financial suitability for the rental sector. We have seen many examples of both public and private-sector developers being attracted to the counter-cyclical nature of rental homes and the delivery of a fast rental stream that OSM enables.*

"OSM homes are now a viable alternative for any potential development site, at a range of densities that can adapt to a range of local priorities. These features make this housing particularly relevant, and uniquely suited, to the housing challenges faced in the capital where it is vital that we 'sweat' all available land assets, irrespective of the difficulties presented, to meet London's housing need."

Confirms Arthur:

"Offsite is becoming more and more of the norm. Enquiry levels are at an all-time high, and there's a huge demand for offsite construction, particularly as onsite trades become more and more difficult to resource."

Accreditations

The BOPAS accreditation has been a big plus in cementing interest, and ensuring consumer confidence. *"We've had the BOPAS accreditation for around 14 months,"* says Arthur, adding that it was a prerequisite for Essential Living that this was in place before they started doing the job.

"We are very regularly audited through that, and we've got ISO 9001, 14001, 18001, we've got SCI approval for our Steel section, we've got NHBC for our Steel section, we've got BOPAS, we're CE marked, we're just as approved as anybody else on the market.

"We've not encountered any mortgage or lender resistance using OSM construction. I think it's because it's becoming a more accepted way of building. We've never had any issues with mortgeagability. Local authorities are on the whole amenable to this kind of construction. They're all struggling, so doing something along these lines is a real benefit."

11 *Designed, sealed, delivered*, London Assembly: www.london.gov.uk/sites/default/files/london_assembly_osm_report_0817.pdf

Graham Sibley of the National House Building Council (NHBC) agrees.

"We've always been open to working with new technologies and new techniques," he says, *"to ensure that new homes have the design life that is required for an NHBC warranty.*

"We see a lot of potential for using offsite manufacturing methods, right from small elements such as chimney pots, or bathroom pods, particularly in the build-to-rent and affordable housing markets, right through to whole builds, volumetric, 100% modular systems, built in the temperature-controlled, dry environment of a factory. If you can take the uncertainties and vagaries of the weather out of the way, you add in a lot more quality control measures, which mean a module won't leave a factory until it's signed off.

"When NHBC signs off a warranty, it's the same warranty regardless of the type of construction. One thing that is really important is to build confidence amongst lenders and building insurers and investors that as long as it has been thoroughly and rigorously inspected, we don't see any difference in the quality of one home over another, whatever its type of construction. And that's important to lenders in particular. We don't want to see a situation where offsite homes are seen as lower quality in some form. For valuation and surveying, it's being aware of how well it's inspected and how transparent the root of production has been, and that it's been properly assessed."

The future

"The private rent and build to rent sector is becoming bigger and bigger," concludes Arthur, *"and that doesn't mean quality or aesthetics need to be compromised. If you're unsure as to how modern methods of construction impact aesthetics, look no further than Green Park student accommodation for Berkeley homes in Bath* (see above). *That build consists of 604 modules, 468 bedrooms. That building is made from ornate bath stone, but it's modular; aesthetically it looks no different from a traditional build."*

3: Modular construction in housing and beyond

Offsite construction has been heralded as the solution to the UK's housing crisis – a quick and efficient method of constructing residential accommodation to meet an ever-growing demand. Modular construction in particular is seen as a fast and efficient method of construction, allowing quick builds, and trades to work in parallel, to ensure a building is erected at its intended site in the least time possible, causing minimal disruption.

The housing sector is not, however, the only area in which this solution is needed. Healthcare, education, and increasingly retail outlets have their own unique constraints, and modular construction is ideally poised to provide both permanent and temporary solutions.

Utilising factory-made components that can be fitted with windows, doors, and many internal fixtures and fittings dramatically reduces time spent onsite, of particular importance when disruption to residents and users needs to be minimalised.

One such area is education. For reasons of health and safety, safeguarding children, and maintaining an environment conducive to learning, disruptive construction simply cannot happen on a school premises during term-time. Schools, therefore, have to plan maintenance and new construction during holiday times, which even in the summer only stretch to periods of six weeks or less, making traditional construction almost impossible. Reducing time onsite by 70% or more is therefore the key to solving this logistical nightmare; modular construction being the favoured option.

Anyone of a certain age who attended school in the UK will remember the prefab classroom – rickety, boxy, draughty rooms on stilts that boiled in summer and froze in winter, and despite their temporary nature, were usually a permanent fixture. Modular buildings have come a long way since then, and worked hard to shed their image as second-class accommodation.

Case study

Elliott Group

Despite offering a very different proposition now, Algeco-owned Elliott Group has its roots in this era, beginning life in 1963 as Elliott's of Peterborough, manufacturing and selling mobile classrooms, due to a shortage of teaching space because of ROSLA (Raising of the School Leaving Age) that extended full-time education to the age of 16 years. Since that time its technologies and practices have radically changed, and with 50 years' experience in the education sector it is able to provide new buildings for all accommodation requirements, ranging from temporary solutions for hire, to full turnkey offerings for permanent builds.

Elliott offers a broad and extensive design and build service for the construction of new schools, classroom blocks, drama/music studios, laboratories, sports/assembly/games halls, nursery units and student accommodation and a range of other ancillary accommodation needs and external works, using steel frame offsite manufactured wall panels.

James Cowell is Elliott Group's Technical Director, and has been with the company seven years. He says:

"We provide both temporary and permanent structures. We have a fleet of around 3,000 Building Reg-compliant units, which we rent out for decant solutions. A lot of that is in education, which is still a huge market for us, where we've done everything from full school decants down to where they just need a bulge class and an extra space for one additional classroom. That's on the rental side. On the sales side, we can do anything from a single classroom of 55 square metres where they just need an additional class, right the way through to whole schools or academies.

"There is a big market for urgent solutions. Programme constraints are a big part of this. The six weeks over the summer holidays are always our busiest time – you have six weeks to essentially get decant or additional classroom space, whatever it is, into operation ready for the schools to come back in September. So speed is certainly one of the big drivers for our type of technology."

Figure 7 **Areas such as classrooms, offices and sanitary facilities are formed using Elliott's Ibex System and are fully assembled and fitted out offsite ready for delivery to site as volumetric components**

In September 2017, Elliott was awarded Principal Contractor status for the Education Skills Funding Agency Component Framework (Primary Schools) to provide offsite constructed schools. It is currently working on the first batch of nine schools, valued at around £45m.

The high level objectives of this framework are to:

- maximise offsite assembly; and
- minimise onsite disruption.

The solution is fully compliant with the ESFA's Component Primary Design Brief. The overall objective of the ESFA programme is for the initial nine schemes to be handed over ready for occupation of the schools by 31 August 2020.

Says Cowell:

"We're a full turnkey supplier, so we can act as the main contractor and principal designer. It's a full bespoke solution, so for the current primary schools that we're working on we're the main contractor, so we will design, manufacture, construct, install and commission, on top of being responsible for moving furniture from the existing school into the new school."

A typical school averages around a 70:30 ratio on and offsite. Through standardisation, the process delivers best value and highly sustainable solutions with less waste, minimising time and reducing disruption for the schools by limiting site works to site preparation, foundations and installation. The most disruptive site activity is therefore constrained to holiday periods when the children are absent.

The group's proposals have saved 45 weeks and up to £500,000 of construction preliminaries across the first batch alone.

The technology

The Elliott component solution utilises a standard platform allowing pre-defined clusters of space to be configured to suit specific project and site requirements. Elliott has created a toolkit of planning blocks to inform the 'component design' approach and ultimately acts as an engagement and construction tool. The production of both 'physical' and 'BIM enabled' models of all of the clusters streamline the design and construction process, adding significant value to programme and cost.

Areas such as classrooms, offices and sanitary facilities are formed using Elliott's Ibex System and are fully assembled and fitted out offsite ready for delivery to site as volumetric components.

Doors, windows, fixed furniture, first and second fix mechanical and electrical systems and even some types of external finishes can all be factory assembled, reducing onsite time and minimising disruption. Larger clear span, high ceiling areas such as sports halls and atriums are formed using Elliott's Hybrid system using offsite fabricated steel frame components and pre-assembled wall and roof panels.

The two systems work together to streamline the construction programme without the need to compromise on the design or internal environment.

Advantages

Speed of build is probably the primary advantage, as is health and safety, as the process essentially removes a lot of trades from site. One of the biggest health and safety risks on sites is working at height – moving that into a factory environment makes it a lot safer.

The company can install eight to ten modules per day, meaning a typical school of around 100 modules could be installed in the Easter holidays. From a logistics point of view, the amount of transport is drastically reduced. Unlike traditional construction, where constant deliveries would disrupt site activities, this is cut down to a very small number. Only what is needed is brought to site, so waste is also greatly reduced.

In terms of disadvantages, transport restrictions are the major hurdle. Says Cowell:

"We can only transport through the road networks. Generally speaking, that's not a problem with the major routes but for some projects obviously you might not physically be able to get in. That's always something that we would check very early on when we start looking at a project."

Aside from that, the only major barrier to the technology is its reputation, which is still, to an extent at least, mired in history.

Says Cowell:

"There is still a perception out there that modular or volumetric is a temporary solution. Unfortunately, people still have memories of the old days of the prefab era. That is starting to change; even over the last two or three years that perception is really starting to change and it is becoming more and more accepted as a form of construction that is equivalent and as good as traditional build. It does take some time to get the message over and it's up to us as an industry to help build that confidence in offsite technology. We need to show that we are here to stay and it is a good option."

London Academy

Located in Edgware in the London Borough of Barnet, London Academy is a mixed all-through school and sixth form for pupils aged four to 18. The school was initially intended to be built as a traditional construction project, but due to time constraints the client looked to a design solution that would substantially enhance the onsite construction period of a traditionally built project.

The detailed brief to Elliott's major projects team was to achieve an offsite solution that still maintained the prescribed performance levels and robustness/solidity of the original school that was completed ten years earlier. Elliott's approach to the design specification was to provide a modular/hybrid concept that would have the advantage of speed to complete the overall programme.

The traditionally built areas would allow a double height space of 1,437m^3 for the two-storey main hall, providing space for a games hall/canteen facility and presentation facilities. The external walls of the hybrid build were constructed from 200mm deep timbers which were then packed with insulating wool which when plaster boarded provides the building with excellent thermal efficiency.

Elliott was approached by Morgan Sindall to provide a fully designed offsite solution that would be manufactured, installed and tested to produce a fully finished and compliant building to Barnet Council's exacting standards. The school also had to achieve a BREEAM rating of Very Good, for which Elliott would have to provide the evidence in both pre-and post-construction.

Consisting of 14 classrooms, communal assembly halls and a kitchen area, the building's central atrium mirrors that of the existing main school building, and has also been designed to let in as much natural light as possible.

The scheme has also incorporated a selection of unique teaching spaces with areas such as SEN therapy rooms,

an outdoor learning terrace, central breakout space and theatre-style concrete auditorium.

The programme was the primary driver for the academy, in that they had to be open for the new school year. Elliott commenced work on the new facility in March 2016 and completed the project at the beginning of the new school year in September 2016 with a six-month onsite construction period. The offsite construction period commenced some four months earlier at the company's manufacturing facility in Bridlington with the completion of the modular units designed to coincide with the onsite install date.

The site was extremely tight, with only one entrance and exit, coming off the busy dual carriage spur road in North London. Due to the tight nature of the site, the construction of the superstructure commenced with the install of the main classrooms to the north façade, which was double height and consisted of 30 modules. The steel frame to the northern façade of the building was then installed before completing the installation of the remaining ten modular units.

After the main superstructure was built, works then commenced on completing the internal fit out of the building, which took a further 16 weeks to complete.

Says Cowell:

"There was about a six-month delay because of contamination issues in the ground. We continued with the modular manufacturing and stored the modules complete until the issues in the ground had been resolved. As soon as the foundations were in, we installed the units and hit the end date. If we'd been following a more traditional construction route, they would have missed the September open date because they wouldn't have been able to start any of the superstructure work until the ground issues were resolved. That's where you get the real benefit, where you can run things in parallel."

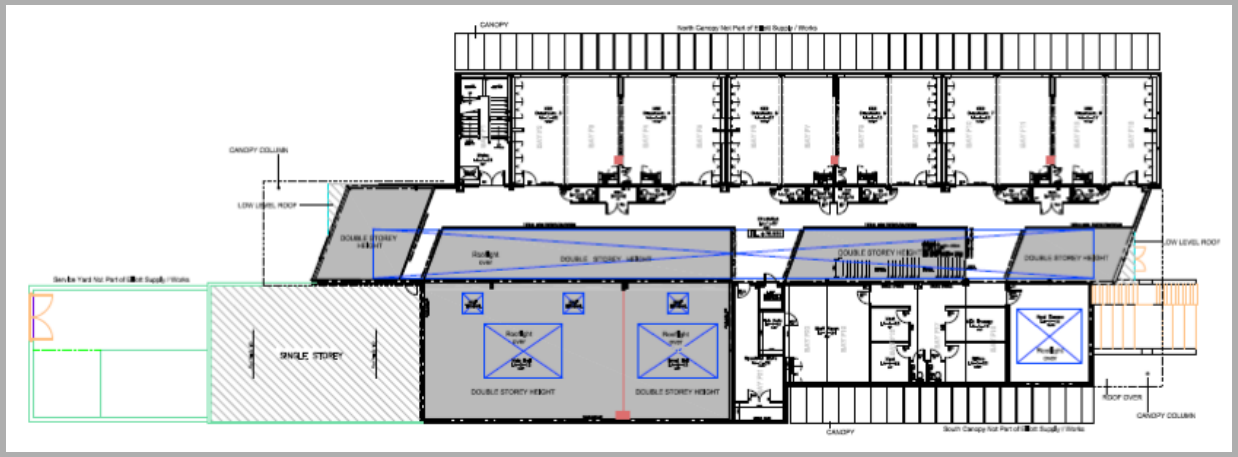
Performance

The London Academy project achieved a BREEAM Very Good rating, which was what was targeted. Says Cowell:

"The u-values essentially are engineered to meet the specific requirements of the project. The way that thermal performance is measured takes into account the whole building, M&E strategy, internal fit out, so they have full compliance with approved document L2a. If the project is in London we might have to have the 25% improvement factor for the Greater London Authority. So it's specifically engineered to meet the requirements of a particular project.

"The regulations for air tightness came in in 2003. We've not really had to do anything to our building as it was manufactured at that point in time to meet the requirements. Because you're in a factory controlled environment all the air leakage that you get from workmanship issues can be minimised due to a much more controlled environment. So there is good detailing from the design at the outset and the ability to really control the quality during manufacture. Even on our hire products we're getting average values of around 3m³ (Building Regulations Approved Document L), which is a good standard. You can push the envelope even further than that but then you have to start putting some serious money back in and it's not always the most cost-effective way of improving thermal performance."

Figure 8 **London Academy site plan**



Assurances and warranties

The company knows that attaining and maintaining leading industry standards and accreditations provide added confidence to its customers that modular space solutions are provided to the highest industry standards and are suitable for use in demanding situations. Alongside professional indemnity insurances and warranties, the buildings on the major projects that the company provides have a 60-year design life, in line with the current European norms and Codes of Practice.

The company is proud of its quality, and the standards it maintains, and regularly audits its teams and seeks feedback from customers in order to maintain and improve its market leading position. Achieving 69% on the Net Promoter Score (a management tool that can be used to gauge the loyalty of a firm's customer relationships, which ranges from -100 to +100, and where anything over 50 is excellent) is no mean feat.

Retail

Another area in which Elliott is utilising offsite construction is in the manufacture of units for the restaurant chain McDonald's. To date, the company has built around 100 restaurants, and is responsible for the design, manufacture and construction of each unit.

Elliott worked closely with McDonald's UK to evolve its design concept into highly engineered volumetric units, to deliver new restaurants in line with the fast food giant's planned expansion programme. The buildings include the dining area and toilets, staff areas including kitchen and servery, offices and storage.

The buildings are constructed in steel-framed modules with a concrete floor and a range of architectural features. The offsite method of construction enables the building to be manufactured in a factory-controlled environment to an extremely high specification and detail, with an onsite timescale of four weeks.

The buildings are delivered to site in eight fully-fitted-out modules, including all fixed furniture and signage. The modules are lifted into place and re-fitted together, following which the external façade and associated external enabling works are completed.

Says Cowell:

"With McDonald's, it's all about speed, because as soon as they take over a site they need to be serving as quickly as possible. All the while that it is a construction site they're not making any money."

Eighty-five percent of a typical McDonald's build is done offsite, but again, you wouldn't know from looking. Says Cowell, *"We've built over 100 McDonald's restaurants and I'm hard pushed to know whether it's offsite or a trad build one, and I've been responsible for designing them the last 25 years."*

Keepmoat and ilke Homes

During 2017, Elliott Group worked in collaboration with Keepmoat to form ilke Homes. The joint venture leveraged their combined experience in the design, manufacture and installation of quality residential and commercial buildings.

ilke Homes are precision-engineered offsite to ensure consistent high quality. They can install up to six homes per day onsite, delivering homes in less than half the time of traditionally built houses. The homes are fully mortgageable, with Elliott having achieved BOPAS accreditation, which has now been transferred to the ilke Homes business. The homes have all the standard warranties, including BLP Secure and NHBC Buildmark.

ilke homes are volumetric and are delivered onsite with all internal and external finishes complete, including kitchens and bathrooms, so residents can move in quickly with very little additional work required. Offering a range of customisable house types and layouts, the homes can be designed to meet the needs of individuals and the local communities they serve. Exterior options suit the local vernacular, whilst internal configurations are available for different tenures.

ilke homes housetypes	NDSS	M4(2)	Variant
60m² 2b4p 2 storey house			
80m² 2b4p 2 storey house	Yes	Yes	
80m² 2b4p 2 storey house	Yes	Yes	wide fronted
80m² 2b4p 2 storey house	Yes	Yes	rear kitchen
80m² 3b5p 2 storey house			
80m² 3b5p 2 storey house			wide fronted
80m² 3b5p 2 storey house			rear kitchen
100m² 3b5p 2.5 storey house	Yes	Yes	
100m² 3b5p 2.5 storey house	Yes	Yes	rear kitchen
100m² 4b7p 2.5 storey house			
100m² 4b7p 2.5 storey house			rear kitchen
121m² 4b7p 2.5 storey house	Yes	Yes	
121m² 4b7p 2.5 storey house	Yes	Yes	rear kitchen
121m² 5b8p 3 storey house			
121m² 5b8p 3 storey house			rear kitchen
50m² 2b4p 1 storey bungalow	Yes	Yes	
60m² 2b4p 1 storey bungalow	Yes	Yes	
70m² 2b4p 1 storey bungalow	Yes	Yes	
50m² 2b4p 1 storey bungalow	Yes	Yes	
60m² 2b4p 1 storey bungalow			
70m² 2b4p 1 storey bungalow	Yes	Yes	









The future

Modular construction is growing in scale. According to research carried out by Pinsent Masons,[12] currently around 15,000 modular homes are constructed in the UK each year. Within the UK, capacity is constrained because there are only a small number of factories that are able to produce modular housing, although the private sector has a vision for more UK factory capacity to meet demand. In a survey of 230 house builders by the Build Show, 67% said that offsite construction will play a key role in new-home supply. The reason? Speed. Says Cowell:

"There's a huge push towards offsite manufacture, or pre-built manufacture, or modern methods of construction – whatever you want to call it. Mark Farmer published his 'Modernise or Die' report a couple of years ago and that really does push offsite. The industry needs to grow with it. We are still only 5 or 6% of the construction industry in the UK. The industry needs to grasp that opportunity to move forward."

Almost all construction projects today contain some degree of offsite manufacturing, but in aggregate it remains a very small part of the industry. A 2013 paper by the UK Commission for Employment and Skills, using projected data from 2009, estimated a total market value of £6bn (equating to 7% of the total construction sector).[13] In October 2016, UK housing minister Gavin Barwell said that the government sees a huge opportunity in manufacturing houses offsite and is looking to increase access to finance for modular housing providers to help secure the delivery of more than 100,000 ready-made homes by 2020. Adds Cowell:

"Government are doing their bit and the Education and Skills Funding Agency is promoting offsite as its preferred method. It's releasing frameworks purely for the modular industry, which is a step forward. There's probably more opportunity in terms of the way we structure construction contracts as well to make it more collaborative, rather than the adversarial contracts that construction has traditionally used. We ultimately all want to get to the same position; the client wants the building; we need to make a margin; we have shareholders to satisfy; we all want to do a really good job; so we need to try and find ways to be more collaborative in our approach to construction."

12 http://constructingexcellence.org.uk/wp-content/uploads/2017/02/graham-robinson-pinsent-masons-14022017.pdf
13 https://assets.kpmg.com/content/dam/kpmg/pdf/2016/04/SmartConstructionReport.pdf

4: Timber frame – an environmentally and economically proven solution

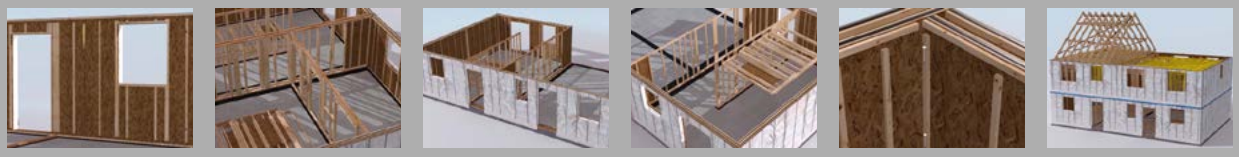
Offsite timber frame construction is an established high-value manufacturing and building method that delivers guaranteed quality, precision-engineered components to meet a variety of standards. A mainstream and intelligent way to build, it presents cost-effectiveness, speed and energy-efficiency advantages from inception to construction, while removing practices that could invite error or inconsistencies. For residential surveyors, offsite construction offers significant onsite benefits, cost certainty, and outstanding durability and robustness.

Timber frame structural wall panels replace traditional inner masonry leaf and become the main structural shell of the building, which can then be finished internally with insulation and dry lining, at the same time as completing the exterior, using conventional drained and vented air cavity and brickwork cladding, with windows and doors fitted onsite or in the factory. Alternative claddings can be applied and roofs completed.

The construction process onsite is vastly reduced, making installation easier, reducing the need for trades, removing opportunities for error, and enhancing the long-term performance of the project. Based on certified products, manufactured in controlled factory environments, it uses modern technologies such as automated production assembly lines, nailing bridges and automated insulation equipment to minimise construction risks, such as clashes with service locations and poor fitting of insulation that can lead to loss of thermal performance or condensation risks. It also utilises 3D BIM-friendly design tools to allow modelling of designs well in advance of manufacture and assembly.

In the UK, timber frame is the largest method of offsite construction; one in four homes are built this way. In Scotland, 70% of houses are built in timber frame and forecasts for England and Wales suggest this could be one in three within 12-18 months. Given its many advantages, timber frame offsite construction can deliver homes quickly, while maintaining profit margins and equity interests for constructors and investors. Timber frame also

Figure 9 The timber frame construction process



enjoys an unlimited, sustainable material supply chain, giving the potential to manufacture thousands of homes a year with considerably shorter call-off periods. Indeed, lead times can be reduced to a four-week call off, when using a standardised pallet of house styles, or typically around 12 weeks for one-off bespoke designs, from order placement to a timber frame arriving onsite. This is considerably less than traditional build methods, where material and labour procurement is commissioned late and often reactive in the process.

Timber has been used as a building material for many centuries. Advances in technology mean that timber products can achieve the required performance and efficiency standards demanded in the 21st century. Timber is graded according to its growth rate, structural properties and degrees of durability, and is managed in a sustainable supply chain, where planting and replacement matches harvesting rates.

As a natural and renewable building material, timber has excellent ecological attributes, acting as a carbon sink with low embodied energy. The energy needed to convert trees into wood and hence into structural timber is significantly lower than that required by other structural materials such as steel and concrete, giving timber-framed houses a lower carbon footprint.

STEWART Milne GROUP

Case study

Stewart Milne Timber Systems

Stewart Milne Timber Systems is the UK's leading designer and manufacturer of timber systems. With over 40 years' experience, the company specialises in offsite construction for a number of sectors including private housing, affordable housing, student accommodation, medical facilities, hotels, and education. Its market-leading build systems are precision-engineered and offer guaranteed quality with assured performance. The company works closely with architects, surveyors and design teams to deliver the benefits of timber frame offsite construction for its clients' projects.

Stewart Milne is the sole timber frame supplier to the Central Housing Consortium's (CHIC) BuildSmart collaborative framework, which provides offsite solutions for its 60+ housing association and local authority members.

Originally established in 1975, with just six employees, the Stewart Milne Group now employs over 900. The Group concentrates on building residential homes and providing timber system solutions for both residential and commercial projects. It is the largest and most recognised brand in the industry, offering clients across the UK a diverse portfolio of sustainable products, ranging from conventional open panel timber frame solutions, to more advanced closed panel build solutions, fully insulated with windows and doors pre-fitted. It has the capacity to produce over 12,000 units per annum and services cover concept, design information and technical guidance, full design service, manufacture, delivery and construction onsite.

Stewart Dalgarno is the company's Director of Product Development. He explains the drivers behind moving to timber frame:

"It's really only the private sector in England that is still wedded to brick and block. In Scotland, timber frame is the dominant solution. There are a couple of reasons for this. One is weather. The fact that you can build a shell that is wind and watertight quickly, so you can be working outside and inside at the same time is a big plus in Scotland because we are more at risk of snow and extreme weather events. You can get your superstructure wind and watertight within a week, often quicker. That allows you to be working in the dry inside, and working outside, so you're not dependent on the brickie. So, weather, bricklaying skills and productivity are key drivers.

"I think there's also an affiliation with forestry in Scotland. Timber is considered as a material of choice. Because we are affiliated more with the Nordic countries, which have colder climates, we are aware of energy efficiency; it's been driven harder in Scottish Building Standards from a thermal efficiency point of view. It's more onerous in Scotland in terms of fabric performance and the adoption of renewables going forward; we're ahead of the curve compared to England.

"There is also a skills and quality problem south of the border and to some degree that is still the case in Scotland. We're seeing changes, it's driving builders towards timber frame because it's an easy step-change to offsite, and in response to the lack of skills, post-recession and with Brexit looming, things will not get easier. The need to improve building quality, due to rising concerns and expectations from consumers; these are the key drivers."

Timber frame also offers impressive environmental credentials. One of the most effective ways to maximise energy efficiency and control build costs is to adopt a fabric-first approach. Incorporating energy efficiency into the build envelope reduces dependency on technology 'bolt-ons', thus keeping costs down and keeping homes simple to use and maintain.

Current building regulations set targets for carbon dioxide (CO_2) emissions, allowing building designers to input a range of u-values for walls, floors and roofs, air-tightness, thermal bridging etc., and then key building services performance like boiler efficiency and heating controls, to achieve the overall reduction in CO_2 emissions required. The primary factor in any building's thermal performance is the u-value of the walls, floors and roof. u-values are a measure of the heat-loss through an element, with the lower the u-value, the better the insulation and in turn thermal performance of the building. The company's open and closed external wall panel options have u-value ranging from 0.44 W/m^{2}K to 0.10 W/m^{2}K. Its floors range from 0.14 W/m^{2}K to 0.09 W/m^{2}K, and roofs range from 0.15 W/m^{2}K to 0.08 W/m^{2}K.

Airtightness is an integral part of any building's fabric thermal performance, as it considers the amount of uncontrolled ventilation through gaps in the construction. Stewart Milne's range of open and closed wall panel solutions can be specified to achieve any level of performance down to 1.5. Where airtightness above 3 is specified, the primary airtight layer can be the internal plasterboard, utilising good practice to seal all service penetrations, and sealing all external doors and windows to the timber frame. On projects with airtightness of 3 or below, the primary airtight layer should be behind dedicated service zones on the walls and roof ceilings, allowing the majority of services to be installed without puncturing the air-tight layer. This approach also ensures the long-term performance of the airtight building, where renovation works and future service installations will not breach the primary airtight layer.

Dalgarno outlines more of the advantages:

"From a cost point of view, we're certainly competitive against brick and block. We're faster, so we can build two houses as opposed to one in masonry. We're better quality, so we have fewer defects. We're less weather dependent, and less skills dependent. We've got higher thermal efficiencies under the insulation values of the fabric so it's easier to comply with Regulations. It's less wasteful onsite because a lot of the superstructure is done in the factory, so it's just an assembly job onsite. Arguably we have better safety onsite as well because we use cranes to erect it, so we have fewer falls from height, fewer manual handling issues, and fewer trips and slips as a consequence of having fewer materials onsite.

"It is more productive per head. We did some time and motion studies, comparing brick and block versus timber frame. We discovered you can build a timber framed house with the same headcount in half the time you could with a masonry one.

"So all of those are the upsides. The downside is the education and support that comes with it. It's a change, so we spend a lot of our time helping our customers through the education side of it, working with subcontractors and the design teams, to optimise the designs so they are timber-frame friendly, manufacturer-friendly, and easy to install. And then working with the subcontractors who understand slightly different site processes. Plumbing and electrics etc. We do a lot of work in terms of education – handholding and change management really – and taking people with us on that journey."

BOPAS
Buildoffsite Property Assurance Scheme

BOPAS scheme

Indeed, the journey to offsite construction has been slowed in part due to a lack of understanding and confidence in non-traditional building methods. In response to this uncertainty, the Build Offsite Property Assurance Scheme (BOPAS) was jointly developed by Buildoffsite, The Royal Institution of Chartered Surveyors (RICS), Lloyd's Register and Building LifePlans Ltd (BLP), in consultation with the Council of Mortgage Lenders (CML) and the Building Societies Association (BSA), to provide assurance to the lending community that innovatively constructed properties against which they may be lending will be sufficiently durable as to be readily saleable for a minimum of 60 years.

With offsite construction currently used for one in five new homes, industry stakeholders know it to be low-risk, durable and exceptional value. Lending and insurance authorities can now balance both perceived and accepted risks for newer offsite construction products through a dedicated guarantee programme.

BOPAS presents gold standard accreditation for offsite construction techniques, and comprises:

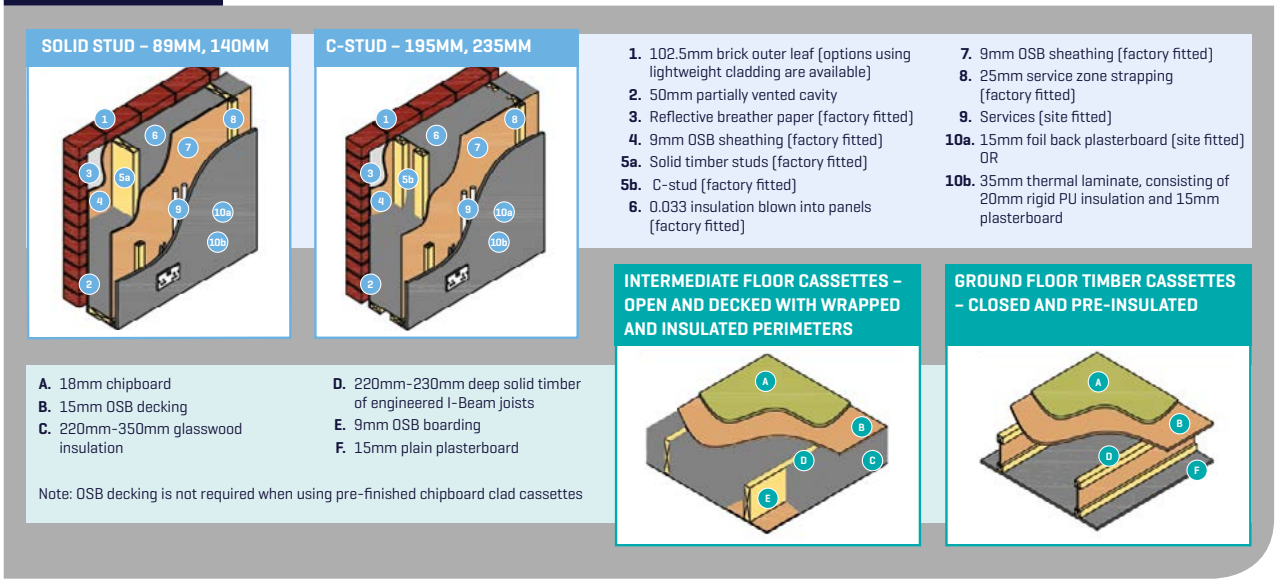
- an appraisal of durability and maintenance;
- process accreditation; and
- an online database of assessed building methodologies, registered sites, and warranted properties.

Additionally, it is designed to evaluate the adoption of best practice by offsite constructors in competency, configuration, risk, and procurement management and process control.

Dalgarno discusses how one project in particular prompted the company to achieve BOPAS accreditation.

"The Serpentine (above)*, which was part of the Design for Manufacture 60K house challenge, was our trigger point to move to BOPAS. A condition of the funding of that project, which was essentially a Homes and Communities Association (HCA) funded project, was that any new system used had to have a 60-year durability and a guarantee of 60 years' worth of mortgage and insurance. On that particular project they were looking at a German offsite product coming into the UK because they had Deutsche Bank endorsing their product and could offer up mortgages through that model. As Aylesbury (the location of the project) is about 20 miles from our factory, it seemed illogical not to be able to use UK products.*

Figure 10 The Sigma II Build System



"So, we said, we've got a product offering – our triple award-winning offsite timber frame system, Sigma II – but we don't have the BOPAS accreditation to guarantee the 60-year surety you're looking for. If we get that, would you be willing to work with us? And they said yes, because they originally wanted to have a UK manufacturer involved. We went through the whole durability assessment with Lloyds and the BLP, and got accreditation, and we saved something like a quarter of a million pounds on that particular project, by using a UK-produced solution as opposed to bringing in a German product which was initially on the cards.

"So BOPAS came off the back of that. We've done around 1,500 houses since, including the Bicester eco town. We are now dealing with many customers who are looking for higher energy efficient homes, with improved quality at affordable rates, as a consequence of having that surety."

Timber frame construction is now considered a conventional method of construction, with lenders offering mortgages at competitive rates to masonry construction. Approximately 60,000 units are built each year, demonstrating a large marketplace for lenders and a proven method of build. For the more advanced Sigma II closed panel system, through the BOPAS approval, lenders will provide mortgages over three x 20-year terms on the same rates as conventional construction. On both accounts, the company has seen very little if any higher than normal refusal rates due to the system of construction. On occasion, where more unique cladding finishes or less conventional timber frame construction make-ups are used, there may be queries, but these are typically dealt with on a plot-specific basis with the developer and client, in partnership with their mortgage provider.

Sigma II

Stewart Milne Timber Systems' Sigma II system is the only advanced closed-panel timber frame offsite construction product to achieve BOPAS accreditation. Offering an integrated approach with guaranteed performance and cost-effectiveness, this closed-panel timber-build system is the result of seven years' collaborative research and development.

It enables clients to tailor the amount of prefabrication required per project, and encompasses closed and insulated walls, free-fitted windows and doors, and insulated pre-wrapped floor and roof cassettes. All this offers residential developers a fast build with vastly reduced trades interface and risk of error onsite.

The Sigma II Build System is a fabric-first solution, promoting a 'fit and forget approach', meaning it takes into consideration the assessment of whole life cycle costing. This approach has focused on an easy to build fabric solution that provides assured performance and longevity, without risk of failure or comeback in the future. This is now recognised by policy makers as the first priority in low-zero carbon building design.

It uses conventional materials and skills with an easy to understand approach, thus requiring less supervision and construction risk. Following extensive testing, third party assessment and technical compliance, Sigma II is BBA certified and backed by NHBC's 10-year warranty.

Case study

The UK's first eco-town

Stewart Milne Group worked with A2Dominion on its development in north-west Bicester. This pioneering housing project has been billed as the UK's only true zero-carbon community, and the only eco town still to adhere to the government's original eco town policy planning statement, designed to achieve high standards of environmental sustainability. It aims to deliver the highest standards of sustainable living to its residents. With the homes designed to achieve true zero carbon rating, delivering energy efficient, good quality affordable housing was critical to the success of the project. Timber systems were therefore an ideal fit for the priorities of the ambitious task at hand. With its fabric-first design, precision-engineered, as-built performance and fully integrated offering, the Sigma II Build System was the obvious choice.

Says Dalgarno:

"Because it was being sold as an eco town, they needed to have surety that the environmental performance of the homes was there, so you had to have proof that you complied with u-values etc. As part of that we did a heat flux test, which looks at your as-built u-value compared to your design u-value on a separate project to demonstrate to the contractor that your system can achieve the value that they want. We never had to do that before, so that was unique. They wanted the confidence in the fabric performance, they wanted a system that was made in the factory to give them that confidence as opposed to relying on people onsite to do it. It had to be cost-effective, and speed of build was important because they were anticipating decent sales because there was a lot of interest in the development. They wanted to make sure they could deliver the homes.

"They recognised there were some challenges around the type of skills that they needed, to develop these eco-friendly homes. So the more we could do in the factory in terms of fitting insulation with weather seals and airtightness seals would make it simpler onsite. The airtightness requirement was quite onerous, but it was easier to achieve onsite because you're less dependent on third parties, so that was a big criteria to comply with. We also had a local connection in terms of jobs because the site was quite close to our factory, so it helped support the local community.

"BOPAS was the real tick for us because, although we were competing with other offsite systems, none of them had a BOPAS accreditation so nobody could guarantee that the homeowner would get a mortgage or insurance. Because we were one of the first ones to secure that for an advanced offsite timber-framed building, we were able to."

Stewart Milne Timber Systems designed, manufactured and installed the first 93 homes as part of the 393-home exemplar phase of the project.

With a 0.15 u-value, 3m3/hr/m^2 of air loss in accordance with best practice as prescribed in part L1a of the Approved Documents and thermal bridging of 0.04, the properties must reach Code for Sustainable Homes Level 5 through excellent heat retention and air tightness.

Much of this was achieved through the build fabric, with pre-assembled flat roof modules and insulated floor cassette edges, meaning a pair of semi-detached homes would be weather-tight, airtight, secure and fully insulated within 72 hours. Air testing was also conducted prior to first fixing, building in assured performance of the fabric.

The development will feature the UK's largest domestic solar panel array with 17,500m^2 mounted across the rooftops of all homes to generate electricity. This will include freestanding photovoltaic (PV) panels, overlaid PV panels, and inset PV tiles, with some garages benefiting from green roofs.

The development will also include a range of additional features aiming to minimise its residents' impact on the local environment. These will include rainwater harvesting systems to recycle water, home information systems displaying energy, water consumption, and real time information on local public transport; an electric car club and eco pub; optional electric car charging points; and high speed fibre optic broadband to promote home working and reduce car journeys.

Anecdotally, the company has heard from the developer that consumers are very happy with their homes, which are comfortable and high quality, with low running costs. It has had no specific callbacks relating to the timber frame since the project was completed almost two years ago.

Supply chain and procurement

The company works closely with its suppliers to ensure that the timber-based raw materials used in its products come from legal, managed and sustainable sources. Its principal suppliers of timber, engineered wood products and wood-based panels are registered under the internationally recognised PEFC (Programme for the Endorsement of Forest Certification Schemes) and FSC (Forest Stewardship Council) chain of custody schemes.

Says Dalgarno:

"In terms of our supply chain back to the forest, primarily our resources are coming out of Sweden and some out of Finland, so we've got chain of custody and a duty of care to make sure we've got traceability back to where the trees are. 60% of what we use is spruce pine and fir and it comes from Sweden, just because the quality and volume is there and it's cost efficient to do it. We've got agreements that go back 30 years with our supply chain, it's all PFEC and FSE accredited. We know where the mills are that produce it for us, and also where the trees come from that are feeding those mills. So our supply chain is very integrated, and goes right back to source, and we can demonstrate chain of custody through that as well.

"We have a duty of care to make sure that the suppliers within these countries replace the trees at the same rate that they are harvested. The current rate in Sweden is that the forestry sector is growing by the size of Greece every year (according to Wood for Good Information Sheets) including harvesting, so there is a plentiful supply of good quality timber coming through the market. They are really good at harvesting and managing their product; it's not like the slash and burn of tropical hardwood, which is a totally different ball game. The Scandinavian countries manage it really, really well.

"We work with our local suppliers in Scotland and get our engineered boards and products through UK suppliers using home-grown timber. Last time I met with the Scottish Forestry Commission they said the volume of trees is up by 60%. They've got a lot of stuff that was planted 40-50 years ago that's coming through the growing cycle at the moment, to support the UK engineered wood supply chain."

The future

When combined with a fabric-first approach, offsite construction adds value for clients and surveyors by delivering high-performance housing that requires little to no ongoing maintenance in terms of 'add on' energy-efficiency technologies. Offsite construction reduces the building design versus as-built performance gap, through factory quality control and improves process controls onsite. Rising energy bills for consumers and impending carbon emissions reduction targets for builders are a serious concern. Being able to build houses that do not require additional extensive 'eco bling' and are guaranteed to remain energy-efficient for at least 60 years is an attractive assurance to investors and owners. Stuart Milne's technical team works with clients from the concept and design stage to advise on appropriate specification, value-engineer the project from the start, and reduce waste and risk. This contributes to increased buildability, lessens construction costs, and incorporates robust and durable solutions to any project brief.

Dalgarno believes there is a lot of room for collaboration and standardisation within the timber frame offsite sector.

"Many national house builders are committing 20% of their volume to timber frame. Many are already 100% timber frame in Scotland, but they are all considering or making a strategic decision to move.

"Whereas we would normally compete for work in the marketplace against each other, it is actually better to work together to support a customer transition to timber frame. Two or three timber frame companies working together to get more timber-framed houses developed is better than competing against each other. That collaborative thinking and standardisation has probably only entered the market over the last 12 to 18 months, particularly with the private sector making a commitment to timber frame. In their minds, timber frame is the proven and available offsite solution; it's a go-to starting point. At the moment the market needs some here and now solutions, and timber frame offers that."

In fact, there is even scope for collaboration between OSM systems. Through CHIC's BuildSmart framework, Stewart Milne is working with BuildSmart's modular supplier, Premier Modular, to explore further efficiencies through combining their technologies.

Dalgarno mentions that timber frame, and offsite construction in general, is increasing around the world.

"A few years ago I was part of a delegation that visited Japan whose highly successful offsite construction house building sector is producing more homes annually than the entire UK housing market. By investing heavily in research and development, Japan is a world leader in advanced offsite construction, with large corporations and brands dominating its private house building sector, but it still only represents 15% of the overall new build market."

Japan has developed a sophisticated approach that is delivering highly customisable and durable new build homes. With an overarching focus on quality and systems assurance, the market has benefited from BOPAS-like principles to the point where offsite construction new build homes are given preferential mortgage rates and insurance terms, and attract premium selling prices.

The UK is well placed to exploit the advantages that offsite construction, and timber frame in particular, can bring, and it is hoped that introducing BOPAS to the maturing offsite construction industry in the UK will begin the same shift towards a more joined-up industry-wide approach, as it develops more advanced offsite timber frame solutions.

5: Affordable housing – how offsite construction is helping first-time buyers afford their own home

Housing affordability can be measured by changing relationships between house prices and rents, and between house prices and incomes. Since 2000, house prices have seen a boom in terms of magnitude and duration; according to *The Economist*: "Never before had house prices risen so fast, for so long, in so many countries."[14] Prices doubled in many countries and nearly tripled in Ireland.

The financial crisis of 2008 saw house prices plunge, with values dropping as much as 45% in Ireland, and 34% in the United States. However, in spite of the recession, when analysed in terms of the ratio of earnings to prices, homes continue to be overvalued by about 25% or more in Australia, Belgium, Canada, France, New Zealand, Britain, the Netherlands, Spain and Sweden.

According to the Office for National Statistics, in 1992 the average house price was £70,000, and the average recorded income of mortgage borrowers was £24,000. By 2017, average house prices had leapt to £303,000, and the average recorded income of mortgage borrowers was £63,000. This disparity in earning potential, and the price of private accommodation, has led in recent years to an increase in activity by policy-makers to create affordable housing.

A 2017 report by Trust for London and the New Policy Institute found that 24% of new homes built in London were social, affordable or shared ownership accommodation in the three years up to 2015/16.[15]

Affordable housing is housing deemed accessible to those with a median household income as rated by the government. The UK Government's definition of affordable housing is *"social rented, affordable rented and intermediate housing, provided to eligible households whose needs are not met by the market. Eligibility is determined with regard to local incomes and local house prices."*[16]

In its White Paper *Fixing our broken housing market*, published in 2017, the Government set out the measures it was taking to increase the amount of affordable housing being built in the UK.

"Investment in affordable housing is a tried and tested way of getting new homes built, and it is normally more resilient than market house-building to changing housing market conditions. 193,000 homes were built under our 2011-15 Affordable Homes Programme – exceeding its target by 23,000. Building new affordable homes also helps kick start other house-building, as it can help make sites viable and bring in investment."

14 The Economist: www.economist.com/node/21540231
15 Trust for London: www.trustforlondon.org.uk/data/new-housing-completions/
16 Gov.UK: www.gov.uk/guidance/definitions-of-general-housing-terms#social-and-affordable-housing

In 2016 the Government launched its Affordable Homes Programme for 2016-21, and announced in the 2017 Autumn Statement new funding and greater flexibility so that it now funds a range of affordable homes for rent as well as home ownership. As part of this, in August 2017, the Mayor of London, Sadiq Khan, invested £25m from his Innovation Fund into London-based developer, Pocket Living, to create at least 1,059 new homes by March 2021.

Pocket homes are sold outright at a discount of at least 20% to the surrounding market rate. They're only for first time buyers who live or work locally; what the company calls 'city makers'. These restrictions on initial sale remain on all subsequent resales and are checked by Pocket, thus ensuring that the homes stay affordable in perpetuity.

Pocket Homes

Said the Mayor of the investment into Pocket:

"The housing crisis is the biggest challenge facing Londoners today and I have been honest from the start that we won't be able to turn things round overnight. For decades, we have simply not built enough new and affordable homes in the capital, meaning that for too many Londoners the dream of buying their own home is getting further and further out of reach.

"That is why I am working with Pocket Living to build more than a thousand homes for first-time buyers, using the latest offsite construction techniques to provide attractive and affordable homes as quickly as possible. I will continue to use more of my £3.15bn of funding to invest in innovative schemes like this to build the genuinely affordable homes Londoners need."

Marc Vlessing, CEO of Pocket Living, said:

"Our mission has always been to open up the housing market to hard working young Londoners on low to middle incomes by delivering homes they can afford. This growing group is greatly in need of innovative housing solutions.

"We are proud to receive the Mayor's backing for Pocket Living's award-winning approach to design and the use of modern methods of construction to help those priced-out and not eligible for social housing to get onto the property ladder. Delivering homes for Londoners means initiatives between the public and private sector are crucial for the capital to thrive in the years ahead."

Pocket began life in 2005, created its first affordable homes in 2009, but took until 2013 to receive its first tranche of government funding and grow itself as a provider of larger affordable housing. Its primary product is a one-bedroom,

Copyright: Sarah J Duncan

one-person apartment of around 38m^2, built for people who live and work in the local area, earning under the 'affordable' threshold.

Says Sarah Davies, Head of Core Projects:

"it's a great example of a public-private partnership. We are a privately-owned business but we have public money that supports what we do, which is to provide intermediate affordable housing to Londoners, who don't qualify for social housing and don't earn enough to be able to buy open market housing."

At present, Pocket utilises two main contractors for its modular construction – Vision Modular, and Elements Europe. The company uses offsite modular construction for around 33% of its business, but expects to increase this to around 40% of its output in the future.

Says Davies:

"It depends on the site constraints and the building complexity as to which method we choose. Modular, we felt, had advantages because our product is in essence very simple; it's a one bedroom, one person home, which is composed of two modules. So there's an element of repetition there, which means it's aligned with the principles of modular manufacturing."

VISION MODULAR SYSTEMS UK LTD

Vision Modular Systems

Modular construction is ideally suited for London to get up to speed with its housing plans. Not only does it slash construction time, it provides unparalleled cost certainty, minimises waste, caters to a shrinking construction industry workforce and prevents disruption to the local area.

Vision Modular Systems' offsite construction method requires 80% fewer vehicles to site and cuts overall waste by 80%, meaning that the city is a safer place for pedestrians, and disruption to the local area is minimised. It also caters to London's chronic lack of space, as there is no need for a large site. Increased cost certainty that this building method provides also makes it an attractive prospect for consumers, investors and developers alike.

A module generally takes ten working days to be completed within the manufacturing process. Modules are steel framed with reinforced concrete floors, making it one of the most robust modular systems in the construction

Figure 11 **Pocket Living: Timeline of company development**

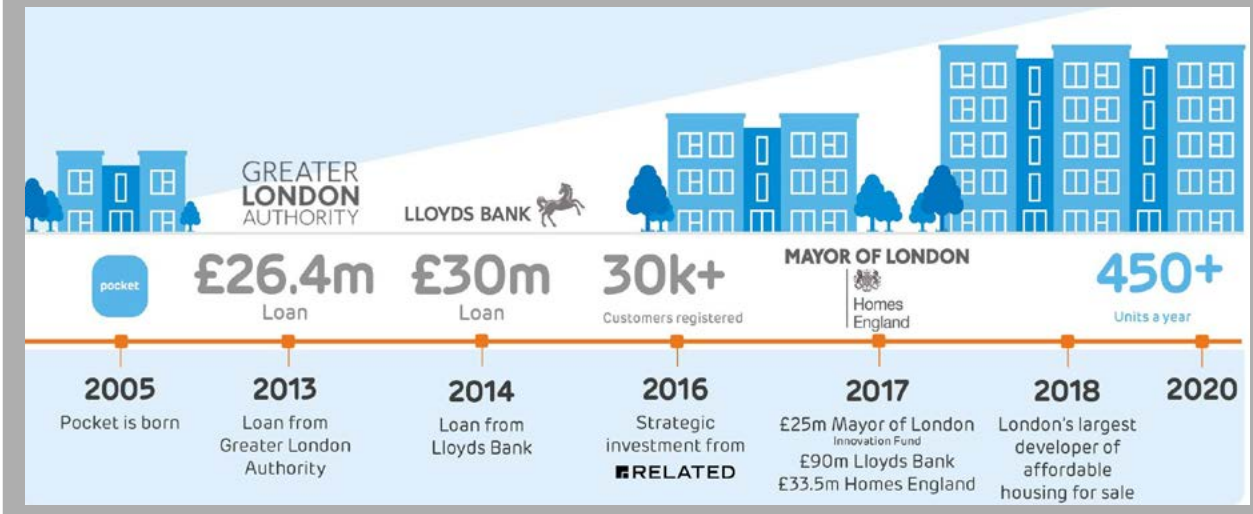
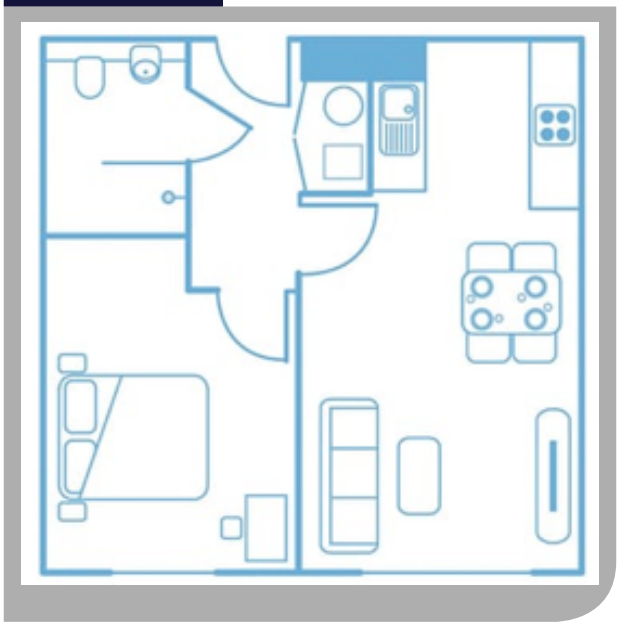


Figure 12 **A typical floorplan**



industry. Up to 90% of the gross internal areas of Vision Modular Systems' schemes can be developed offsite, although this varies from project to project.

Case study

Mountearl Gardens and Mapleton Crescent

Mountearl Gardens in Streatham was Pocket's first modular project. A development of 45 Pocket units, work started in January 2016 and finished in September, so it was a nine-month build. Says Davies:

"We saved around 30% of our programme compared to traditional build. We tendered against three traditional contractors and one modular, and pound for pound the modular was exactly the same price but offered a quicker programme, so we thought, let's give it a go. It was a three-storey building, completed very easily without incident. It was a redundant car park within an existing housing estate and we thought there was going to be some opposition during the construction phase or at the very least when the crane was there, blocking the road, but it was fine, we didn't have any complaints.

"It was a really good test, and it worked better than we expected. It got us thinking more seriously about the use of modular and led on to further buildings the following year. We're now building our fifth and sixth buildings."

Copyright: Sarah J Duncan

Mapleton Crescent started out life a little differently. A 27-storey tower of 89 homes, 53 are Pocket affordable and the remaining are open market Pocket Edition products, which are two-and three-bedroom apartments. Designed as a traditional build, it retrospectively became modular. At 450m^2, with a Thames Water culvert through the middle, the River Wandle right next door, a TFL bus stop, a UKPN primary substation serving Wandsworth, on a one-way street with a 24/7 loading bay for the Southside shopping centre, it was an extremely challenging site.

Says Davies:

"We elected to reverse engineer the design for a modular build. It was a particularly challenging build, it was the first time that Vision Modular had done two- or three-bedroomed units with more open plan areas so it took quite a lot of engineering to figure out how to do it. We spent about 10 weeks working out whether we could use modular or not. Sketching up what would the impact be to the floor plan of each unit, would we still have the floor to ceiling height, would we have the same net internal area, what would be the compromises?

"We went into contract in October 2016 with a 20-month build, which finished in the summer of this year – at least 30% quicker than the other contractors who tendered for it. We had 97% site coverage, so there was no space for materials or site set-up. Building most of it offsite made a big difference to buildability. To build it traditionally would have taken a lot longer and necessitated a more challenging site set-up, e.g. a gantry over the river, land locally for storage etc. It shows how a site that couldn't be easily unlocked by other developers was able to be used through modular."

Accreditations

Says Davies:

"If you look at the modular manufacturers around the UK, most of them are producing student accommodation, educational facilities, and on occasion elderly care homes. Very few are actually providing residential products for the open market, and even fewer have a product that is mortgageable. Because our products are for sale we need to make sure that a mortgage can be obtained on the asset. We are very much limited by the pool of contractors who have the appropriate accreditation and also have the main contractor's experience.

"There are lots of different types of accreditation but BOPAS is the one that we rely on because it confirms the product has been tested and checked and certified, and has a certain life expectancy, which means it is mortgageable.

"BOPAS is a good standard – we wouldn't want to contract with anybody who doesn't have that at the point of signing. BOPAS is highly technical, so it would be good in addition to have a broader accreditation that recognises the main contractor's ability, with a financial check to make sure they've got the cash flow to deliver the project, enabling smaller suppliers to access the market, knowing that they will be going into contract with someone capable of delivering to a certain standard."

This seems to be one of the main challenges for the company – finding an accredited and registered manufacturer that ticks all the boxes.

"One of the main challenges we have," says Davies, *"is finding modular contractors that are willing to do smaller projects; in the region of 20-50 homes. That's our biggest issue at the moment. We hope that as the market gets bigger and more entrants come into the residential side with the proper accreditation, either the ones that are already here will decide that they will do the smaller jobs, and are less choosy, or that there are new suppliers that we can contract with."*

Cash flow is also an issue. Traditionally, the construction critical path has an S Curve cash flow, whereas modular is front loaded, so more resource is needed at the outset for manufacturing and work onsite, rather than it being a steady incline upwards.

Says Davies:

"Running a project, be it traditional or modular, takes resource – from land acquisition to sales period, it's about two-and-a-half years for a typical Pocket project. If you can do that quicker, it means you recycle your people and your capital faster, you use your money for other things, and your staff can move on to other projects. It's only really optimised if the whole project lifecycle recognises the benefits that modular can offer, which starts with the planning system."

Standardisation and development

Says John Gray of HTA Architects (which has worked with Pocket on some of its builds):

"As architects, we talk to developers who are considering a project, and we also deal with the contractors and the manufacturers at the other end. Clients are increasingly appreciating the benefits of modular in terms of quality, reliability and speed, and cost."

HTA is an advocate for standardisation of the offsite industry, to encourage and promote widespread take-up of the technology.

Says Gray:

"Our view as architects is that we need to find a way to encourage clients to commit to the principles of modular without necessarily committing to a particular manufacturer. We're very keen to find ways to harmonise

the various different competing manufacturers, as they're all essentially doing the same thing, to grow the whole cake, rather than competing endlessly to get a greater share of a smaller cake. We're working with the British Standards Institute to create a modular standard for housing. It's just starting now and we hope to have the standard published in 12 months' time.

"The purpose of this is not to dictate how buildings should be designed but to use our knowledge of the technical constraints that modular brings in order to set up a performance specification such that anyone interested in designing for modular can design to this standard and be confident that there are a range of competing manufacturers out there that can deliver to that standard, which means you can commit early to designing to modular without deciding who you are going to go with. This has been welcomed by developers and manufacturers as a way forward."

In April 2018, the Mayor of London confirmed that Mark Farmer's working group would be consulting with the industry with the aim of producing:

- research identifying the greatest opportunities for standardisation of components across a representative number of different housing typologies;
- development of design principles for precision manufactured components, based on the findings of the research; and
- development of tools and designs to show how these principles can be applied in practice.

Davies adds that fast-tracking offsite construction development proposals via the planning system would also be beneficial:

"We feel that modular should have a fast track in the planning system and that the conditions should be reflective of that. The construction is faster anyway because of the nature of the programme. Planning and finance are the two main hurdles that are preventing it from further optimisation.

"It has to be Government-led. There's no other way. A local authority might decide to have a fast track planning policy in their Borough but it's only going to help if everybody is doing it. Otherwise it is adding another layer of complexity to development when there is a significant housing shortage to address. Within the Greater London Authority there should be a wider discussion… it won't really make a difference unless it's a national Government-led change."

A step-change in construction

Pocket homes are targeted at first-time buyers who want to stay in the cities in which they live and work, and get away from high rents without compromising on their living space. As such, the company is keen to ensure its homes are not just bland boxes.

Copyright: Edmund Sumner

"Although the product is very formulaic," says Davies, *"the actual home and the buildings in which they are built are unique. Each one is individually designed by award-winning architects and we find that it is important that whilst our product is within an intermediate affordable building, it should add something architectural to the streetscape."*

Gray agrees that modular or volumetric shouldn't mean bland and boring:

"We have created some buildings in the last few years that have exploded the myths of what volumetric buildings can look like. The speed of construction has been remarkable, the quality of workmanship is excellent. Our built work has been a great example of what's possible with modular. We're enthusiastic about expanding modular and volumetric builds outside of student accommodation and hotels; it's well documented for these types of building due to their cellular structure, but we're interested in seeing how it can be used for more open plan buildings in the residential sector, and championing the technology to be used in different ways."

Modular homes also offer considerable environmental advantages, which act as another incentive to cost-conscious, socially responsible young people on the first rung of the housing market. Benefits of offsite modular construction include 80% less construction waste (with 95% of that waste being recycled), up to 80% fewer vehicle movements to site, equating to less noise, dust and transport-related emissions in the area, and 50% less CO_2 produced during construction.

Pocket is now present in over half of London's boroughs, and has been instrumental in helping first-time buyers own a home near to where they have built their lives.

Figure 13 **The boroughs in which Pocket Living has created homes**

6: DfMA – how manufacturing and construction combine to create 21st century efficiency

Design for Manufacture and Assembly – DfMA – focuses on ease of manufacture and efficiency of assembly. Used for many years in sectors such as the automotive and consumer-products industries, driven by the need for consistency and quality, it is an approach that is increasingly being used in the construction industry, which is facing similar demands in the face of a major housing shortage.

Although manufacturing and construction may appear very different, there are similarities. Components of a car engine are standard across a range, with levels of performance dictated by computer software. Assembled in factories, using repeatable processes, the end product is created in one place, using a trained workforce combined with automation.

Construction, on the other hand, relies on quantities of raw materials being brought together from a diverse supply chain, to sites whose environments vary from inner cities to windswept hillsides. The end product takes many months to complete, utilising a transient and often unskilled workforce, to varying degrees of quality.

Different processes, yes; but the similarities come to light when considering the end product. Efficiency and speed of delivery are the current necessities of the construction industry – 300,000 new homes are required every year to 2020, according to the Government – and just like a standard car coming off a production line, an apartment in a residential block is very much similar to its neighbour.

DfMA, then, might be the key to constructing high-quality, standardised, efficient buildings, in a timely, and cost- and schedule-certain way. Removing the uncertainties and vagaries of inclement weather and a transient and high-churn workforce are key ways in which the construction industry can become more efficient and cost-effective, whilst increasing production to deliver the homes the UK so desperately needs.

Laing O'Rourke

Within the construction sector, market cyclicality and the pressure to match supply and demand are creating both significant challenges and substantial opportunities. Smarter processes pioneered in other industries, such as aerospace and automotive, are now being adopted by some pioneers in the UK construction industry.

Laing O'Rourke is rethinking the way it designs, engineers, constructs and operates its buildings and infrastructure. It believes that construction and engineering must break away from traditional processes to evolve and deliver projects quicker, safer and more sustainably, to a higher quality, with greater certainty.

It has successfully developed an approach to Design for Manufacture and Assembly, designing a defined set of high-quality construction products such as concrete floor-slab elements, structural columns and modular plantrooms. Manufactured offsite in a factory environment and pre-tested or commissioned before being transported to site, onsite these components are then assembled into the completed building or infrastructure asset.

Through the repeated delivery of DfMA on projects to date, the construction giant has formed a strong understanding of the tangible value that this approach delivers to its clients.

Laing O'Rourke's DfMA approach redefines the traditional phases of project delivery; agreeing and locking down the design phase much earlier to allow the manufacturing, assembly, testing and commissioning phases to be compressed and run in parallel, rather than in one long linear sequence, driving greater efficiencies in how resources are mobilised.

Benefits of DfMA

A major benefit of DfMA is a significantly reduced construction programme onsite. Says Adam Locke, Partnership and Innovation Leader at Laing O'Rourke's Engineering Excellence Group:

"We have a concrete floor solution that does not need temporary propping in the way that other floor solutions do. This in turn allows earlier access to floors for other activities, or for fit out of floors before the next slab goes on. For many of our clients, the programme savings that DfMA enables is an important driver."

Another key benefit of the DfMA approach is quality. By taking much of the construction activity offsite and into a controlled factory environment, consistently high standards can be achieved. A highly automated approach enhances quality and efficiency at every stage – both in the products themselves, which are repeatedly honed to support optimum performance, and in the production process.

"Arguably the most important benefit of DfMA," says Locke, *"is safety. By removing construction activities from the site and placing them in a controlled factory environment there is a significant positive impact on safety."*

Says Locke:

"It can provide enormous benefits in terms of productivity, safety, environmental improvement and higher quality. We're getting four times as much productivity than you would otherwise, certainly in terms of output per man hour."

Laing O'Rourke has developed a set of metrics, known as the 'pre-assembly calculator' (PAC), that enables it to measure the extent to which DfMA is being applied on its projects – and track performance against targets. The mnemonic that describes its aspirations is '70:60:30 towards 0'. In other words, 70% of any given project is constructed using DfMA, leading to a 60% reduction of onsite labour and a 30% reduction in programme – all in comparison to a traditionally constructed alternative. It is also aiming for zero accidents and towards-zero carbon emissions.

This isn't an entirely new venture for the company. Says Locke:

"We've been on this journey at least 10 years (arguably our chairman for a good 30 years of his career) and we've invested in the production capability to deliver in a different way. So this is for us nothing new, this is part of a continuum. Our approach is very much around designing for manufacture and assembly, and digital engineering is a critical part of unlocking the level of coordination and detail that is needed to manufacture and assemble effectively.

"The main reason for doing it is productivity and skills and quality. We are keen to progress building in a much more efficient manner than the traditional construction experience, which doesn't deliver the level of certainty and productivity overall. We want to change that. We're also hampered by the availability of skills, so actually investing in methods of delivery that bring some of the productivity benefits that we've seen in the manufacturing industry to the construction industry is the way that we see that going forward."

Indeed, as these other case studies show, it's definitely the way the industry is going.

Continues Locke:

In terms of direction of travel, it's going that way. We've seen the construction industry sector deal, where the government has declared a presumption in favour of more offsite manufacturing for government construction projects from 2019. There is money supporting innovation through the industrial strategy challenge fund and so there's the beginnings of support to all of that."

The method actually underpins the business' strategy.

Says Locke:

"When we look at bidding for a project now, that's one of our key considerations. If it is absolutely a traditional, straightforward project we probably won't do it. We look for where we can actually deliver more efficiently, so for us it's business as usual now. The real question is where's the dial set? Is it at 80%? 70%? 60%? and that depends an awful lot on the design and our opportunities to influence that design. For example, on the Two Fifty One project (see below) we were able to influence the design, so we were able to do quite a lot. The Leadenhall Building, for example, had around 80% of the structure manufactured offsite."

The factory

DfMA is enabled through the investment Laing O'Rourke has made in digital engineering and in manufacturing facilities, producing an often complex set of building system components in a controlled factory environment, prior to delivery to a construction site for installation.

Laing O'Rourke's main UK manufacturing centre is the 25,000m^2 Explore Industrial Park facility in the East Midlands. Here, wherever possible, defined products are created using the latest automated technologies and a high-speed production line.

The factory employs people on a full-time basis, meaning it has a stable workforce to draw on for its labour. Raj Kotecha, Engineering Project Leader – Two Fifty One, explains:

"One of the key reasons that we've been trying to measure productivity and activity as we go offsite is the churn of labour that we have. For the Two Fifty One build, for the period of about 85 weeks we needed 95 dryliners to come in. In that period of 85 weeks we've inducted 450 dryliners, so nearly five times as many people as we need. Every time we lose one of those people we lose the time we've invested in them, and the learning that we've given them. To get away from that churn, we need to make things better for them as well, as a lot of the time they leave because they're getting a better rate down the road or they get fed up with how things have been done. Our factory churn is quite stable. People quite like it because they're still working in construction but they're in one place, which is warm and dry, and they can work near their homes."

Adds Locke:

"In London there is quite a lot of competition, whereas in Worksop where the factory is, there isn't so much work. So in terms of a post-Brexit reality, we're trying to get some of the wealth out into the country; what we're doing is exporting value and wealth from London to the Midlands, which is a good news story in itself."

Case study

Two Fifty One

Part of a major regeneration of Southwark, Two Fifty One is a 38-storey mixed-use development, consisting of retail, affordable housing, and private luxury apartments. The build utilised innovative construction techniques, where manufactured components were produced under rigorous quality-controlled conditions, at Explore Industrial Park, Laing O'Rourke's UK manufacturing facility. The components were delivered daily on flatbed trailers, craned in to position and assembled into the concrete structure and façade. The pre-manufacturing strategy included use of 6,200 structural components, 1,022 facade panels, 499 bathroom pods and 62 mechanical modules. The aluminium windows and doors were already installed before the panels were placed on the building, delivering a quicker construction programme, with greater consistency and quality and a safer working environment. At peak delivery, a new floor was completed every six days, with more than 350 people employed on the project.

Levels three to nine of the build are affordable housing, and levels 10 up to level 38 are private homes. Sixty-five out of the 335 apartments are affordable; 270 are private ownership.

Says Kotecha:

"For the structure and façade, 72% was delivered offsite. Of the project-critical mechanical, electrical and plumbing (MEP) system, probably in the region of 50 to 60% was delivered offsite. The rest was done onsite and for the apartments, the general fit-out was all done onsite. But there are opportunities there for modular wiring looms, harnesses etc that we can do and we will look at more so in the future. We're also moving towards wireless technologies, which limits the amount of work we have to do onsite. So that's all stuff that will feature in some of our projects that are on the horizon over the next few years."

Agrees Locke:

"This project really pushed forward the structural and architectural elements of offsite. To be honest, in terms of the finishing and internal works, there's still something for us to go at in terms of improving productivity. If you think about getting all of the little bits, let's say for a boiler installation in an apartment, the logistics of getting all those copper pipes and fittings to the workface is actually quite a challenge. Whereas if you were doing that in a factory it's all there."

Continues Kotecha:

"So there are marginal gains. We're starting to move into a space where we should be able to deliver a crate of components for an individual apartment. So that take-off is done from a model, our factory preps lengths of pipe, bends and everything else, and sends it in a box. You land that in the structure and then the guys can go in and start fitting it."

This 'flatpack' approach certainly heeds the principles of manufacturing, with digital design very much at its core. Says Kotecha:

"One of the key things that underpins everything we do is digital engineering. So there's a massive focus on our end to make sure the models are fully integrated across our entire supply chain, and we try to instill this philosophy of 'build once in the virtual environment, once onsite'; so you build twice, and that brings with it its own set of challenges. That's probably why we've changed what others would call BIM to digital engineering and through BIM as well we try to unlock better efficiencies."

Figure 14 **The digital engineering process**

Environmental benefits

Evidence suggests that construction waste and site CO_2 emissions can be more than halved through a DfMA approach, compared with traditional practices. Laing O'Rourke has measured the following impacts:

- Site CO_2 emissions down by about 50% – typically 600kg CO_2/£100k, compared with 1,200kg CO_2/£100k.
- Site water consumption down by about 30% – typically 6m^3/£100k compared to 8.5m^3/£100k.
- Waste arisings down by more than 50%; best projects achieve 4.7 tonnes/100m^2 Gross Internal Floor Area (GIFA) or lower, compared to 10 tonnes/100m^2 GIFA.
- Reduced risks of local pollution incidents.
- Reduced risks of disturbance to neighbours.
- Decreased numbers and periods of time during which there are vehicle movements around site (and the associated noise, congestion and air pollution aspects).

The outstanding thermal properties of their buildings have actually led to some issues surrounding accreditation. Says Kotecha:

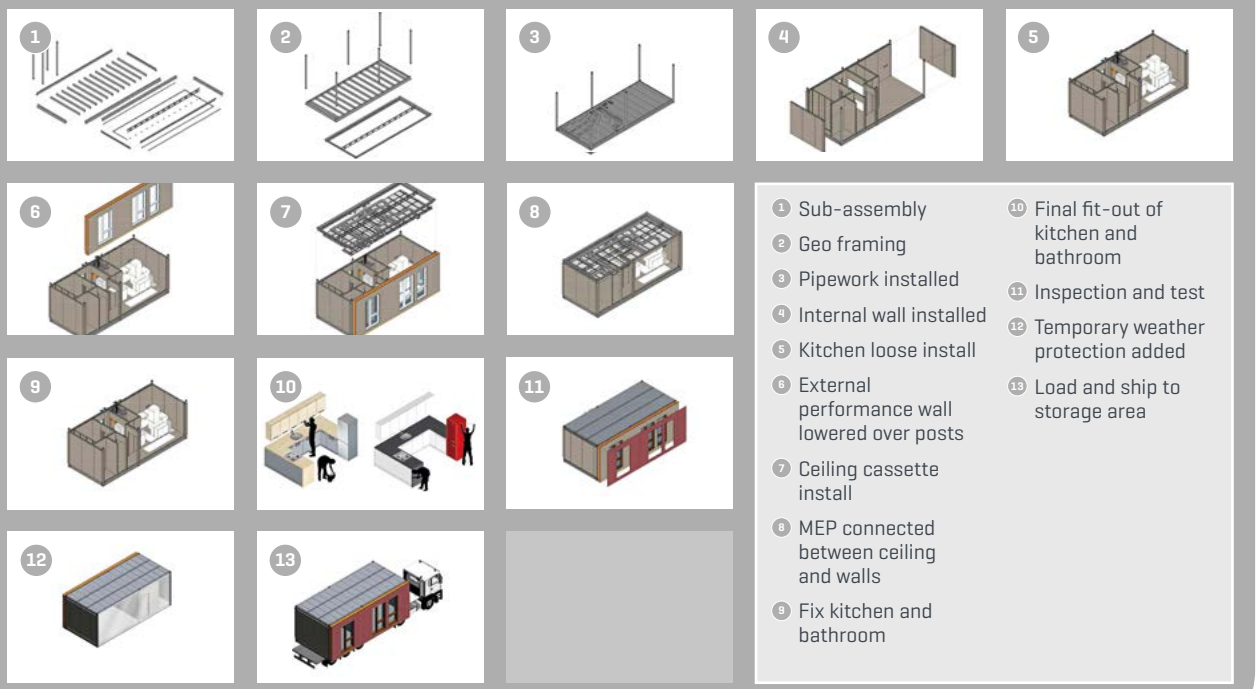
"The NHBC has a number of defined rules that you have to meet in order to get accredited. The products we've got at the moment don't do that because they don't need to; there's no need to have voids of certain sizes or cavities of certain sizes for the sake of having them.

"The requirement in actual fact is a thermal requirement. If you peel that back, and question why you need it, it comes down to making it thermally efficient. And actually that's where some of the challenge comes in to comply, because we're actually better on certain parameters.

"We're generating a matrix of what we do comply with and the bits that we don't comply with, and the reasoning for why we don't. Around 90% of it we could comply with, and the 10% is where our detailing is slightly different, because what is required as a norm isn't required in our products. When we get to conversations with insurers, mortgage brokers and people backing the schemes, they can see that it is a resilient and robust product. And we haven't had any problems with lenders – 85% of the apartments in Two Fifty One are already sold."

Laing O'Rourke's advanced manufacturing products – 'precision engineered homes' made up of volumetric modules that come together to deliver up to 20-storey apartments, delivered through its advanced manufacturing facility – are still working their way through BOPAS accreditation.

Figure 15 **Manufacturing sequence of Laing O'Rourke's volumetric housing system**



The future – Vision 2025

These precision engineered homes form the backbone of the company's future vision, making up the core of its business strategy over the next eight years.

Says Kotecha:

"We created a vision a couple of years ago to be the recognised leader for innovation and excellence in the construction industry. So we've got our precision engineered homes product, which is volumetric modules coming out of the factory, fully fitted out at a rate of one unit every 10 minutes, with an aspiration to start delivering those in 2021 and scaling up from a few hundred homes a year to up to 10,000 homes a year. That's what the capacity of the factory is based around. So we're spending lots of time bringing along the supply chain, understanding what kitchen solutions look like, what MEP solutions look like, what facade solutions look like. It changes our entire philosophy because if you think about things like a product recall, we've got to consider what that might look like, because we are selling products onto the market. If something went wrong with a component that went into one of our schemes, we would have to do a product recall. What does that look like? We're spending a lot of time on the system interfaces to avoid such a recall."

Certainly, there are huge advantages to a factory approach. Says Kotecha:

"Whereas a traditional programme will take months and months, we've done prototypes in our factory where we've put up a three-storey apartment block in a matter of weeks, and a house in a day which was habitable within a week. So it really transforms construction."

Laing O'Rourke's ambition is to build and operate a new Advanced Manufacturing Facility alongside its existing factory in the Midlands. The AMF will use intelligent design, precision engineering and fully automated processes to deliver a new range of automated residential solutions that could revolutionise house-building in the UK. With a capacity of up to 10,000 high-quality residential modules a year, it will help address the skills gap, creating sustainable engineering jobs, with a wider, more inclusive appeal, in an area much in need of employment. This, in turn, will help to alleviate the growing shortage of construction workers in major cities, where the housing crisis is most acute. It is an example of how innovation can help the construction industry continue to meet society's needs in the 21st century.

Figure 16 **Laing O'Rourke's 2025 Vision**

7: Tailor-made – how offsite construction can help fund social housing

Decades of under supply have seen a housing shortage lurch into a full-blown housing crisis in recent years. Principal to this trend is a dearth of affordable housing, so it is fitting that social landlords are increasingly leading the rebuilding effort. According to 2017's Homes and Communities Agency's quarterly survey,[17] housing associations committed themselves to £8.7bn of development spend in the period July 2017 to July 2018, in order to help fill the gap.

In late 2017, *Inside Housing* and the LHC[18] surveyed 96 housing associations,[19] seeking to establish to what extent modern methods of construction (MMC) are being embraced by social landlords. The current picture does not look that promising; only 41% of respondents said their organisations were planning to develop any homes in the next 12 months utilising methods of offsite construction, and only 11% were planning to develop more than 10% of their total pipeline using MMC.

However, when asked whether their organisation was planning to increase the number of homes it builds using offsite construction within the next three years, 59% of participants said they were, and by 2020, 51% of respondents expect their organisations to be developing between one and 30% of their total homes using offsite. A further 10% expected to be delivering between 31 and 100% of their homes using offsite construction.

After years of predictions that modular construction will be the next big thing, it appears that housing associations – private, non-profit making organisations that provide low-cost 'social housing' for people in need of a home (and the UK's major provider of new housing for rent) – may be starting to take up the trend.

17 www.gov.uk/government/collections/quarterly-survey-of-private-registered-providers#quarterly-surveys-2017-to-2018
18 A not-for-profit central purchasing body that develops OJEU-compliant frameworks in England, Scotland and Wales.
19 www.insidehousing.co.uk/home/home/shift-in-approach-53161

Swan Housing Association

First amongst these is Essex- and London-based Swan Housing Association, an innovative and ambitious developer that was first formed in 1994. The Association provides high-quality and affordable homes to rent and buy, and manages locally over 11,000 homes, with plans in place to deliver over 10,000 additional homes by 2027 as part of an ambitious corporate strategy.

Under NU living, its in-house developer, it builds homes that are environmentally, socially and economically sustainable. Utilising high quality cross-laminated timber (CLT), it is building modular housing in its own factory, using its NY build system. The generated income produces gift aid that is invested back into the Association's construction of affordable housing, care and support to the local community.

Says Geoff Pearce, Executive Director of Regeneration and Development:

"We've always been involved in regeneration, but it was in 2002 that Swan first embarked into building private sale housing, to subsidise the affordable housing that we build. By 2007 we had set up our own in-house construction team, allowing us to get close to the procurement and development process.

"We started to look at modular housing in 2015. We wanted to see if it would work on our Beechwood scheme where we had experienced delays and quality issues. It was through this research we realised we had a viable option of creating our own modular housing factory, as we could control the whole process from beginning to end and, in every other respect, we would be vertically integrated."

In the first (traditional build) phase of the Beechwood development (see below), 400 homes were created as affordable housing, but the development was beset with problems – struggles with suppliers and bad weather led to the work taking longer than expected and costing more than planned. Hence the move to modular offsite construction.

In 2015 the company decided to invest in its own modular housing factory. Initially the business case was based around just this one large project, delivered in partnership with Homes England and Basildon Borough Council, the original plan being to build 100 homes a year over the course of six years, over which time the investment in the factory would break even.

"Our ambition was always to do more with that factory as it became established," continues Pearce. *"We did some studies to work out what was the best system of manufacture, and came back with the solution of cross laminated timber modules."*

Cross-laminated timber (CLT) modular

The benefits of CLT modular units are numerous. Says Pearce:

"We wanted to have a really flexible production-line so we could produce different house types on different days, rather than have to build things in a run. The problem with steel frame is that you have to set up jigs to manufacture the frame and every time you change it, it takes a lot of time. Timber can be cut in panels to any shape or size you like, so it doesn't make much difference what size or shape of module we're producing. So it's easier to manufacture."

Another advantage was its sustainability credentials.

"When it grows, timber sequesters carbon rather than emitting it, so you end up with homes that are carbon negative for the first year of their life. It enables us to build airtight homes. It's also a much cleaner environment in the factory, so we don't have any hot works or welding going on. And finally, it is capable of going to the heights of buildings that we want to achieve."

Mark Farmer in his review, *Modernise or die*,[20] talks about pre-manufactured value. The more you can move offsite into the pre-manufactured environment, the greater the control of quality you get. Compared to traditional onsite construction, Pearce estimates it saves around 50% of construction time.

"The other thing about our product," says Pearce, *"is that it is customisable, so buyers have the option to choose their internal layout and external design. In some units they can select to have an extra bedroom, or a ground floor extension. They decide on their internal specification and also the external appearance from a pre-selected palette of materials. So it's unlikely any two homes will look the same."*

Case study

NU living and the Beechwood Village

The company's 'design your own' homes consist of modular units that are imported from Austria as CLT panels, cut and assembled in Swan's factory. Each home is made up of between two and six modules, depending on the size, which can be tailored exactly by its prospective inhabitants. Swan's architects, PTE, have created a design code from which customers can choose (online, or in the marketing suite) from a menu of external materials such as bricks, render or tiled cladding, windows, and internal layouts, including floor type and white goods, right down to tap fittings.

Says Pearce:

"We are offering prospective residents at Beechwood the chance to customise their homes. Of the 570 homes planned for the site, 251 private sale homes will be fully customisable by the buyer. Our online configurator allows buyers to choose from over a million permutations, including external materials and internal configurations. This is effectively giving the buyers a custom-build approach, as we are providing a 'Grand Designs'-type experience without the buyer having to find a plot, get planning permission and do the build themselves. This is great as it makes our homes more attractive to buyers but also gives us a chance to upsell – offering underfloor heating, wine fridges, enhanced finishes, and so on. This generates income which, as we are a Housing Association, is reinvested in new affordable homes and services for our residents."

The idea came about from an attitudes to home-buying survey, which found around 80% of buyers wouldn't buy a brand new house because they all looked the same. The company realised that if they could address that concern, they would have a marketable product. It has the added

20 www.constructionleadershipcouncil.co.uk/wp-content/uploads/2016/10/Farmer-Review.pdf

Figure 17 Some of the different cladding permutations

benefit of creating a diverse neighbourhood where no two houses are exactly the same. The experience itself is very similar to buying a new car, whereby you can choose the specification and calculate the price online.

"The aesthetic is very important," maintains Pearce. *"One of the reasons we chose CLT is because the material can be machined and planed in lots of different ways. The houses that are being built at Beechwood don't look like modular boxes. They're brick clad, they look very traditional, and you wouldn't know when you're in the home that it's a modular home. In terms of residents' choices the predetermined palettes of materials have been tested to make sure they work, and internally all the layouts have been designed by architects so all of them are functional."*

The initial phase of the infrastructure of the estate is complete; roads and services are in, and the first phase of modular housing has now started. From an initial marketing launch in late April, the company has had 37 reservations to date, with the first modules already on site.

Says Pearce:

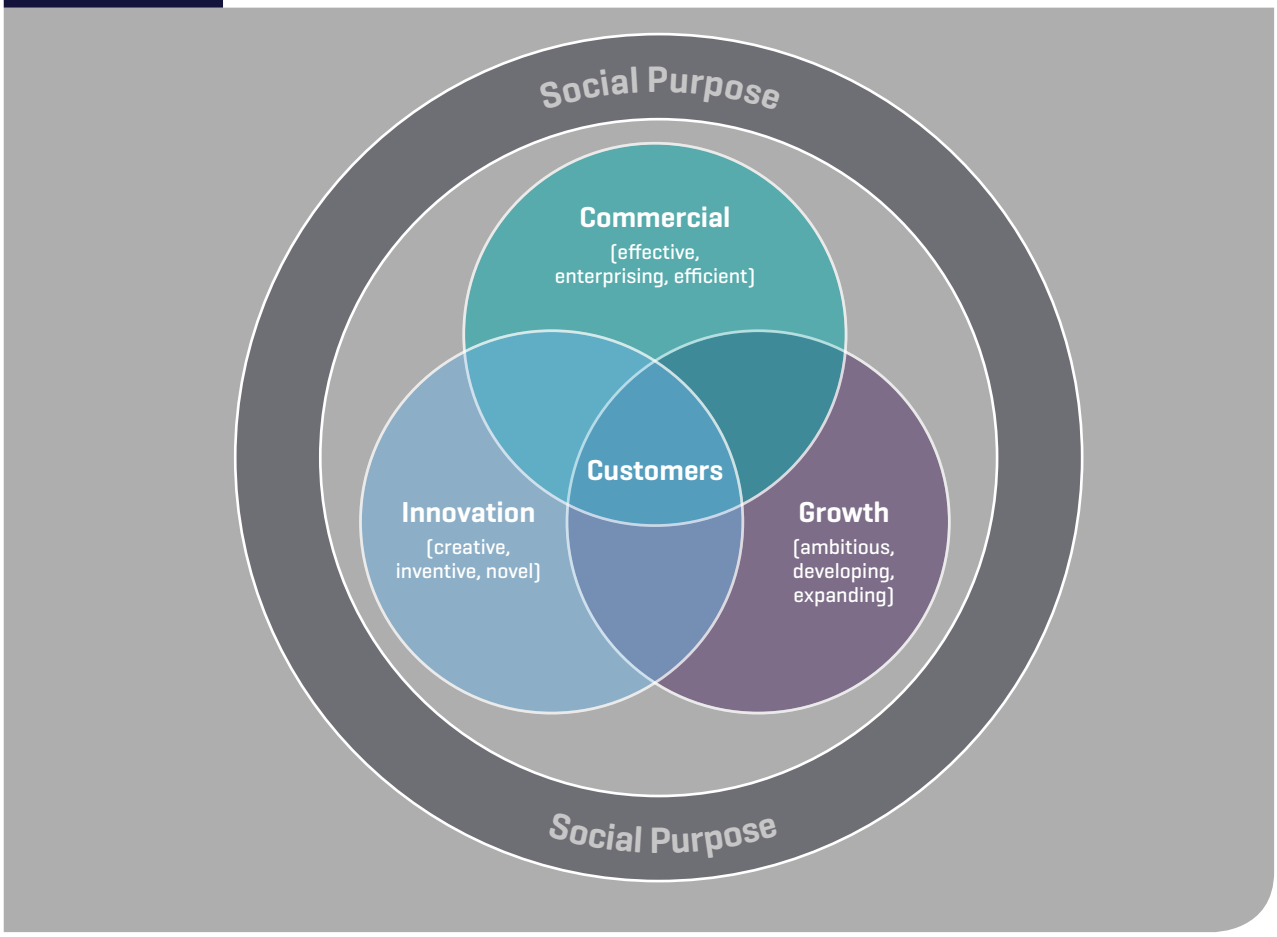
"We're now in full production; initially one a week but then going up to two a week in a couple of months and then three. These are all fulfilling orders from customers. We've got 570 homes left to build, and 251 in this current phase, which is going to be largely driven by market demand over a two-and-a-half year programme."

The move from Housing Association to housing builder

Swan has a strong social purpose; as a social housing provider it understands the importance of place, and building a community, but balances this with a commercial viewpoint that offsets its affordable housing by innovative, market-leading homes.

Ambitious and forward-thinking, the intention is for its development arm to extend beyond its own needs, and the Association is in talks with other Housing Associations, local authorities and Central Government in order to form commercial partnerships.

Figure 18 **Swan's social purpose statement**



Says Pearce:

"NU living is our construction and private sale development brand. There is potential for it to expand beyond Swan; it's something we're actively looking at. We're in conversations with other housing associations and local authorities to consider joint ventures. We're very open to that. In my role as Executive Director I need to be horizon scanning. We're looking at opportunities to roll this out on a wider basis."

Indeed, the GLA has been rumoured to be weighing up directly commissioning modular housing by producing affordable housing in partnership with local authorities or housing associations. Deputy Mayor for Housing, James Murray, recently said modular construction was *"one part of the answer"* to the housing crisis.

Says Pearce:

"At Swan, because of our secured pipeline of over 6,500 homes (to be built using both traditional and modular construction), we are able to keep our existing factory busy for the foreseeable future. However, we believe that offsite modular construction is very much part of the answer to the housing crisis, so are keen to explore opportunities for growth, not just for Swan, but potentially allowing us in future to build for our local authority and borough partners. There's been a lot of interest from LAs and Boroughs and as our aim is always to be the local partner, we're seriously looking at options for expansion in the future and have been discussing the possible benefits with Government too.

"I can't speak for other housing associations, but for me it seems to be a bit of a no-brainer. As housing associations we always have development programmes, which are relatively countercyclical (in that, if there is a drop in the market we can convert to different tenures and carry on building). We are becoming more sophisticated as clients and therefore we need more control over our developments; so as we're building private sale houses we need the ability to change and adapt programmes. The old model of regeneration for housing associations was contracting with a main contractor. That's proven to be reasonably expensive and with far less control than if you do it yourself.

"It has been quite hard changing the culture of the business to a much more transparent model on the construction side. But you get real benefits from it; it gives you the ability to have much more engagement early on the project so you can design out waste and you can make things much more efficient and much more accurate in your planning. For our modular housing factory, we invested £3 million in set up costs. All of that is held against this one project. The total project value is around £100 million, so it's 3% of the project value."

Accreditations and standards

NU, as Swan's development arm, has BOPAS accreditation – a precondition to the approval from the Association's Board and for the funders who lend against the group.

Says Pearce:

"It's absolutely vital to have some form of independent accreditation and for our properties to be mortgageable. We've had a really good experience of working with BOPAS. It's been hard work, but our buyers can take comfort from the fact that it is such an exhaustive process. There needs to be an industry standard scheme; it's important because we need to ensure that everyone within the industry manufacturing these homes uses the same stringent quality tests that we are, so that the public can be confident in this method of construction.

"You still go to debates now where participants talk about modular housing potentially lasting less time than traditional housing and I don't believe that's helpful because we're designing them to last as long as traditional buildings. Our modular homes are accredited to last for 60 years with a 12-year insurance period, as with any other traditional building. In this case we get a warranty from BLP insurance. Other warranty providers will insure our product, but as BLP is behind BOPAS, they offer a one-stop-shop, so it was easier. We've not received any resistance from lenders so far."

The future

Currently, the Housing Association's ratio of on- to offsite is quite low, because offsite is still in its infancy. *"But we're moving towards 60% offsite,"* confirms Pearce, *"that's our goal. We've got six current schemes that are in design for modular housing.*

"Over the next few years I expect to see the majority of our programme done offsite. We don't have any plans at the moment to look at anything other than CLT but that doesn't mean that won't change in the future. It's not necessarily the cheapest material and for some applications where you've got a lot of volume, other materials may be cheaper. People focus on what we make the box out of, but actually it's all the other stuff that goes into the process of pre-manufacturing a house that assures the quality. The box itself is effectively just replacing the blockwork skin on a traditional house. At the moment CLT is more than fit for purpose."

Call to Action

The case studies show the contribution MMC has made thus to the housing crisis, accommodating thousands of households in high quality homes, with added social and infrastructural value as well as the supporting non-residential uses.

However, we can do much to upscale MMC.

Skills – Modern technology needs modern skills

- **MMC specific training offer** – Government and industry must work together on the creation of apprenticeships and training products that support the rollout of MMC and encourage new entrants into construction.
- **Up-skilling existing workforce and organisations** – This must be funded and otherwise enabled strategically, including the encouragement of SMEs. This requires resourcing and incentivising new delivery agencies such as local authorities, local housing companies, SPVs and joint ventures to recognise and utilise emerging technologies.

Investment – growing the sector through investment in MMC

- **Support MMC though public procurement** – Government must support MMC through its influencing power, directly through investment and indirectly through planning, education and construction and design quality standards and programmes, including encouraging and incentivising construction of MMC factories in areas of high unemployment.
- **Private investment** – Private sector investment in MMC is already widespread; however more can be done to create an environment of cooperation and joint ventures, particularly to allow SMEs to access and invest in larger production plants. Government should consider how it can give some risk mitigation to potential new entrants and suppliers.

Guarantees – Investors and consumers needs confidence in MMC products for mortgage, assurance and warranty

- **Accreditation for MMC such as BOPAS needs to be championed and strengthened** – Stakeholders need to be satisfied that there is an industry seal of approval which gives equal or greater assurance than that of conventional home Insurers and warranty providers in partnership with lenders and investors, are critical in this regard. Accreditation models like BOPAS can catalyse MMC into the mainstream.
- **Investors and lenders must engage with the sector to recognise and calculate the long-term value of products** – Improved integration and collaboration between lenders and builders through schemes like BOPAS so that lenders better understand products and builds confidence in the quality, durability and marketability of the product. Regardless of tenure, investment approvals must become systematised, like mortgage approvals for second-hand property, despite, arguably, resales having a greater risk profile in regard of the three criteria. At the moment, second hand home sales process is clear – lenders have tolerances for bulk retail lending. Surveyors and valuers also have a key role to play, and must add knowledge of MMC technologies, especially regarding their durability and cost in use to their reporting skillset.

Standards – Regulation, standards and professionalism needs to be adapted to support MMC

- **Regulators need to familiarise themselves with MMC** – Regulators like NHBC, LABC, BBA (BRE) must skill up in the treatment of MMC by getting better familiarised with products on offer and their properties so as to provide the consumer protections to encourage confidence in the products.

There are great advantages to be gained from growing the volume of offsite-manufactured homes to significant levels. There are opportunities for all participants in the development process as it stands, and for the encouragement of new participants. The key beneficiaries however, should be those households seeking better value for money, better quality, cheaper cost in use and higher amenity in their home.

Confidence through professional standards

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