## SCIENCE AND TECHNOLOGY SELECT COMMITTEE

### Off-site manufacture for construction: Building for change

**Oral and Written evidence**

**Contents**

Accord Housing Association – Written evidence (OMC0079) ......................... 5  
Addleshaw Goddard LLP – Written evidence (OMC0065) ............................. 8  
ARUP – Written evidence (OMC0010) ....................................................... 14  
B&CE – Written evidence (OMC0016) ....................................................... 20  
BEAMA – Written evidence (OMC0052) .................................................... 23  
BLP Insurance – Written evidence (OMC0072) ........................................ 29  
Blue Lion Consultants Ltd – Written evidence (OMC0068) ......................... 35  
Bryden Wood, Rogers Stirk Harbour and Partners and WSP UK – Oral evidence (QQ 30-40) ............................................................. 42  
BSI – Written evidence (OMC0022) .......................................................... 43  
Build UK, Construction Industry Council (CIC) and Construction Products Association – Oral evidence (QQ 50-56) ............................. 47  
Buildco Offsite Architecture – Written evidence (OMC0029) ....................... 65  
Building Alliance – Written evidence (OMC0033) .................................... 70  
Building Societies Association (BSA) – Written evidence (OMC0049) ........ 74  
Buildoffsite – Written evidence (OMC0036) ............................................... 76  
Caledonian Modular Limited – Written evidence (OMC0037) .................... 84  
Carl Henry Modular Ltd – Written evidence (OMC0012) ........................... 92  
Cast, Construction Industry Training Board (CITB), Mace and High Value Manufacturing Catapult – Oral evidence (QQ 24-29) ..................... 95  
CGG OSM Ltd – Written evidence (OMC0009) .......................................... 112  
Chartered Institute of Building (CIOB) – Written evidence (OMC0040) ....... 117  
Civil Engineering Contractors Association (CECA) – Written evidence (OMC0044) ................................................................. 122  
Cogent Consulting – Written evidence (OMC0030) .................................. 125  
Concrete Centre – Written evidence (OMC0061) ...................................... 130  
Constructing Excellence – Written evidence (OMC0046) ......................... 136  
Construction Industry Council (CIC), Construction Products Association and Build UK – Oral evidence (QQ 50-56) ................................. 140
Construction Industry Training Board (CITB), Mace, High Value Manufacturing Catapult and Cast – Oral evidence (QQ 24-29) .................................................................141
Construction Leadership Council – Oral evidence (QQ 57-63) ..................142
Construction Products Association – Written evidence (OMC0050) ........159
Construction Products Association, Build UK and Construction Industry Council (CIC) – Oral evidence (QQ 50-56) .................................................................165
DIRTT Environmental Solutions – Written evidence (OMC0043) ..........166
Education and Skills Funding Agency (ESFA) – Written evidence (OMC0088)170
Elliott Group Ltd – Written evidence (OMC0027)........................................173
Mr Simon Fawcett – Written evidence (OMC0058) ....................................181
Mr Paul Fear – Written evidence (OMC0002) .............................................185
First Home Vision – Written evidence (OMC0056) .................................188
Government – Department for Business, Energy and Industrial Strategy (BEIS) – Written evidence (OMC0011) .................................................................193
Government – Richard Harrington MP, Minister for Infrastructure and Construction, Department for Business, Energy and Industrial Strategy (BEIS) and Fergus Harradence, Deputy Director, Construction, BEIS – Oral evidence (QQ 71-77)..........................................................................................198
Government – Ministry of Justice – Written evidence (OMC0081) ............218
Greater London Authority, Willmott Dixon and Legal and General Modular Homes – Oral evidence (QQ 9-16) .................................................................223
Dr Robert Hairstans, Edinburgh Napier University – Written evidence (OMC0078)............................................................................................................224
Hatch Home Accelerator – Written evidence (OMC0087)..........................230
Heathrow Airport, Professor Jennifer Whyte, Imperial College London and Professor Jeremy Watson CBE, University College London – Oral evidence (QQ 1-8) ..................................................................................................................235
Heathrow Airport – Supplementary written evidence (OMC0035) ............236
Ian Heptinstall, Independent Consultant - Written evidence (OMC0001) .....241
High Value Manufacturing Catapult, Cast, Construction Industry Training Board (CITB) and Mace – Oral evidence (QQ 24-29) ........................................247
High Value Manufacturing Catapult – Supplementary written evidence (OMC0077) ........................................................................................................248
Mr Peter Huf, Architect – Written evidence (OMC0083) ............................249
IET (Institution of Engineering and Technology) – Written evidence (OMC0071).............................................................................................................252
Ilke Homes – Written evidence (OMC0066) ...............................................257
Infrastructure and Projects Authority (IPA), Rider Levett Bucknell and Infrastructure Client Group – Oral evidence (QQ 64-70) .................................265
Infrastructure Client Group, Infrastructure and Projects Authority (IPA) and Rider Levett Bucknall – Oral evidence (QQ 64-70) ................................................282
Interserve – Written evidence (OMC0019) ..................................................283

2
<table>
<thead>
<tr>
<th>Organization</th>
<th>Type of Evidence</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPInitiative</td>
<td>Written evidence (OMC0020)</td>
<td>289</td>
</tr>
<tr>
<td>Kier Construction Ltd</td>
<td>Written evidence (OMC0024)</td>
<td>292</td>
</tr>
<tr>
<td>Kingspan</td>
<td>Written evidence (OMC0004)</td>
<td>300</td>
</tr>
<tr>
<td>Laing O'Rourke</td>
<td>Written evidence (OMC0055)</td>
<td>303</td>
</tr>
<tr>
<td>Laing O'Rourke, Severfield and NG Bailey</td>
<td>Oral evidence (QQ 41-49)</td>
<td>308</td>
</tr>
<tr>
<td>Laing O'Rourke</td>
<td>Supplementary written evidence (OMC0085)</td>
<td>321</td>
</tr>
<tr>
<td>Lean Thinking Ltd</td>
<td>Written evidence (OMC0026)</td>
<td>326</td>
</tr>
<tr>
<td>Legal and General Modular Homes</td>
<td>Written evidence (OMC0062)</td>
<td>329</td>
</tr>
<tr>
<td>Legal and General Modular Homes, Greater London Authority and Willmott Dixon</td>
<td>Oral evidence (QQ 9-16)</td>
<td>334</td>
</tr>
<tr>
<td>Loughborough University</td>
<td>Written evidence (OMC0032)</td>
<td>348</td>
</tr>
<tr>
<td>Low Carbon Construction</td>
<td>Written evidence (OMC0038)</td>
<td>354</td>
</tr>
<tr>
<td>Low Carbon Journey</td>
<td>Written evidence (OMC0005)</td>
<td>358</td>
</tr>
<tr>
<td>Mace</td>
<td>Written evidence (OMC0025)</td>
<td>363</td>
</tr>
<tr>
<td>Mace, High Value Manufacturing Catapult, Cast and Construction Industry Training Board (CITB)</td>
<td>Oral evidence (QQ 24-29)</td>
<td>370</td>
</tr>
<tr>
<td>McAvoy Group</td>
<td>Written evidence (OMC0047)</td>
<td>371</td>
</tr>
<tr>
<td>MOBIE (Ministry of Building Innovation and Education)</td>
<td>Written evidence (OMC0073)</td>
<td>377</td>
</tr>
<tr>
<td>Mott MacDonald</td>
<td>Written evidence (OMC0069)</td>
<td>381</td>
</tr>
<tr>
<td>Mott MacDonald and PCSG (Professional Construction Strategies Group) Ltd</td>
<td>Oral evidence (QQ 17-23)</td>
<td>388</td>
</tr>
<tr>
<td>NG Bailey, Laing O'Rourke and Severfield</td>
<td>Oral evidence (QQ 41-49)</td>
<td>389</td>
</tr>
<tr>
<td>NG Bailey</td>
<td>Supplementary written evidence (OMC0086)</td>
<td>390</td>
</tr>
<tr>
<td>NHBC</td>
<td>Written evidence (OMC0021)</td>
<td>396</td>
</tr>
<tr>
<td>Offsite Solutions</td>
<td>Written evidence (OMC0039)</td>
<td>401</td>
</tr>
<tr>
<td>Osborne Group Holdings Limited</td>
<td>Written evidence (OMC0023)</td>
<td>406</td>
</tr>
<tr>
<td>PCSG (Professional Construction Strategies Group) Ltd and Mott MacDonald</td>
<td>Oral evidence (QQ 17-23)</td>
<td>411</td>
</tr>
<tr>
<td>Place Venture Management Limited</td>
<td>Written evidence (OMC0003)</td>
<td>429</td>
</tr>
<tr>
<td>ProCure22</td>
<td>Written evidence (OMC0017)</td>
<td>432</td>
</tr>
<tr>
<td>Ramboll UK</td>
<td>Written evidence (OMC0057)</td>
<td>440</td>
</tr>
<tr>
<td>Rider Levett Bucknall, Infrastructure Client Group and Infrastructure and Projects Authority (IPA)</td>
<td>Oral evidence (QQ 64-70)</td>
<td>447</td>
</tr>
<tr>
<td>Rogers Stirk Harbour and Partners, WSP UK and Bryden Wood</td>
<td>Oral evidence (QQ 30-40)</td>
<td>448</td>
</tr>
<tr>
<td>Rolls Royce</td>
<td>Written evidence (OMC0082)</td>
<td>468</td>
</tr>
<tr>
<td>Royal Academy of Engineering</td>
<td>Written evidence (OMC0075)</td>
<td>474</td>
</tr>
<tr>
<td>Ryder Architecture</td>
<td>Written evidence (OMC0067)</td>
<td>480</td>
</tr>
<tr>
<td>Severfield, NG Bailey and Laing O'Rourke</td>
<td>Oral evidence (QQ 41-49)</td>
<td>485</td>
</tr>
<tr>
<td>Organization</td>
<td>Document Type</td>
<td>Page</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>--------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Severfield plc</td>
<td>Supplementary written evidence</td>
<td>486</td>
</tr>
<tr>
<td>Space Projects (UK) Ltd</td>
<td>Written evidence</td>
<td>489</td>
</tr>
<tr>
<td>SPECIFIC Innovation and Knowledge Centre</td>
<td>Written evidence</td>
<td>492</td>
</tr>
<tr>
<td>Stride Treglown</td>
<td>Written evidence</td>
<td>496</td>
</tr>
<tr>
<td>Structural Timber Association</td>
<td>Written evidence</td>
<td>499</td>
</tr>
<tr>
<td>Swan Housing Association</td>
<td>Written evidence</td>
<td>502</td>
</tr>
<tr>
<td>Tidal Lagoon Power (TLP)</td>
<td>Written evidence</td>
<td>512</td>
</tr>
<tr>
<td>Totally Modular Ltd</td>
<td>Written evidence</td>
<td>516</td>
</tr>
<tr>
<td>Trowers and Hamlins LLP</td>
<td>Written evidence</td>
<td>521</td>
</tr>
<tr>
<td>UK Finance</td>
<td>Written evidence</td>
<td>525</td>
</tr>
<tr>
<td>UK Research and Innovation</td>
<td>Written evidence</td>
<td>527</td>
</tr>
<tr>
<td>University of Brighton</td>
<td>Written evidence</td>
<td>533</td>
</tr>
<tr>
<td>University of Cambridge</td>
<td>Written evidence</td>
<td>539</td>
</tr>
<tr>
<td>University of the West of England</td>
<td>Written evidence</td>
<td>544</td>
</tr>
<tr>
<td>Urban Splash</td>
<td>Written evidence</td>
<td>548</td>
</tr>
<tr>
<td>Professor Jeremy Watson CBE, UCL</td>
<td>Written evidence</td>
<td>550</td>
</tr>
<tr>
<td>Professor Jeremy Watson CBE, University College London, Heathrow Airport and Professor Jennifer Whyte, Imperial College London</td>
<td>Oral evidence (QQ 1-8)</td>
<td>557</td>
</tr>
<tr>
<td>Professor Jennifer Whyte, Imperial College London</td>
<td>Oral evidence (QQ 1-8)</td>
<td>577</td>
</tr>
<tr>
<td>Professor Jennifer Whyte, Imperial College London</td>
<td>Supplementary written evidence</td>
<td>578</td>
</tr>
<tr>
<td>Willmott Dixon and Legal, General Modular Homes and Greater London Authority</td>
<td>Oral evidence (QQ 9-16)</td>
<td>584</td>
</tr>
<tr>
<td>WPI Economics</td>
<td>Written evidence</td>
<td>585</td>
</tr>
<tr>
<td>WSP</td>
<td>Written evidence</td>
<td>590</td>
</tr>
<tr>
<td>WSP UK, Bryden Wood and Rogers Stirk Harbour and Partners</td>
<td>Oral evidence (QQ 30-40)</td>
<td>595</td>
</tr>
<tr>
<td>Zurich Insurance</td>
<td>written evidence</td>
<td>596</td>
</tr>
</tbody>
</table>
Introduction
This response is being submitted on behalf of Accord Housing Association which owns its own offsite manufacturing business, Local Homes. We have been manufacturing a closed timber frame panel system for six years following five years experience of importing a similar system from Norway. We are in the process of moving to a new manufacturing facility during 2018 which will enable us to increase production to 1,000 homes per annum to both supply our own development needs and to other developing housing associations and local authorities.

We have also developed a “factory in a box” model to enable other housing associations and local authorities to set up their own, local factories with our support. We have created local jobs by training and employing local people, many of whom have been long term unemployed.

1. What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?
We now see the primary benefit of offsite manufacture as being the ability to deliver higher quality homes, manufactured in factory conditions and erected on site to strict quality control procedures. Secondly, there are significant opportunities to create new local jobs, particularly for unskilled people which will help address the growing construction skills crisis. Thirdly, we see the potential to drive down build costs as levels of production increase and efficiencies are realised. Fourthly, the speed of construction is improved, although in housing we don’t see this as a key driver. Finally, offsite manufacture offers the opportunity to produce new homes with a significantly reduced environmental impact in manufacture, in transport to site (fewer vehicle movements) and in use.

The potential drawbacks are the lack of understanding of clients in terms of the products and the process. More lead time is required and clients must be clear about the benefits that they want to see from offsite manufacture. Secondly, as more manufacturers enter the market, there is a risk that some may not deliver homes to an acceptable standard and this has the potential to impact on the acceptance of this type of housing from a customers and a funders perspective. This needs to be addressed by the adoption of quality control procedures and warranties. Thirdly, there is currently limited capacity in the market to support a rapid increase in demand. Finally, many housing developments are “developer led” with turnkey packages offered to housing associations and local authority clients. It is unlikely that these companies will move to offsite manufacture without some requirement to do so.

2. What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?
The most significant opportunity would be for affordable housing development to lead the market. Homes England should insist on an increasing percentage of new supply using grant funding to be delivered using offsite manufacture in order
to drive up demand and support the emergence of the offsite manufacturing industry. Such a commitment would also encourage new companies to become established if they can see a firm market emerging that is protected from the sales market.

Supporting this could be an approval process for systems and manufacturers that clients can use with confidence. This should be based upon an agreed set of standards and evidence that the Council of Mortgage lenders, LABC and others have granted approval for the system in question.

There is real confusion in terms of terminology with terms such as modular, offsite, prefabrication, modern methods of construction, volumetric and panelised all being used. There is also a clear need for clients to understand that they need to adopt a different approach to procuring offsite developments, with a longer lead in time and a close relationship with the manufacturer. In our experience real problems arise when a preferred manufacturer is selected by the client but is then employed by a reluctant contractor and the link between client and manufacturer is lost. An integrated project team approach is essential if offsite manufacturing is to be a success.

3. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

The true benefits of offsite manufacture can be achieved by “mass customisation.” This focuses on standardization of components or elements rather than standard house-types. For instance, it is possible to design a number of different house frontages whilst repeating the side and rear walls so that 75% of the structure is standardised across a new development and the remaining 25% is standardised into say 4-6 different options. Different types of cladding, windows and colours can also be used to add variety. Accord has successfully developed high quality, award-winning housing using offsite manufacture.

It would be useful if organisations such as RIBA were to run training courses to supplement the skills, knowledge and experience of qualified architects and architectural technicians to develop an understanding of how to designs with flair and variety whilst also incorporating a level of standardisation to optimize the benefits of offsite manufacture.

4. What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

Post Grenfell, it is vital that whatever systems are adopted meet agreed criteria in terms of structural integrity and fire protection. We believe that a set of offsite performance standards should be drafted and that all systems should meet the minimum threshold in terms of fire, environmental performance (including the ability to dismantle and recycle at end of life), thermal and sound, and materials. This should be warranted. The Building Research Establishment (BRE) has recently published a guide for offsite manufacture which is useful.

It is clear that trained designers may not have the relevant skills, knowledge and experience to design for offsite and so some R&D into appropriate, accredited training for “design for manufacture” as a requirement for any designers involved in future offsite projects would be valuable.
5. **What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?**

Homes England should insist that an increasing percentage (year on year) of offsite manufacture should be used on developments funded by them. They could apply the same principle to land disposals, specifying the minimum percentage in monetary terms of the cost of a new home that should be manufactured offsite.

They should also review the developer Partner Panel (currently DPP3) to ensure that panel members use an increasing percentage of offsite manufacture on projects going forward.

We strongly believe that for offsite to be a success then partnerships are required to ensure that factories are viable, that products can be improved through a process of continuous improvement and that the integrated project team between client, manufacturer and contractor is a success.

*3 May 2018*
Addleshaw Goddard LLP – Written evidence (OMC0065)

Perceived advantages of offsite manufacture for construction

1 Question 1: What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

1.1 In our opinion, the potential advantages of offsite manufacture for construction are:

(a) Cost savings (we understand that the cost of construction can be up to 10-20% more cost effective), and in our experience on the vast majority of projects in which we are involved where there is an opportunity to use modular construction or other off-site manufacturing techniques, developers and contractors explore all such opportunities in their pricing strategies for such projects.

(b) Reduced build time on site reducing logistical issues such as the longevity of stopping up roads. Obtaining consents from either public authorities or private landowners is a key concern in construction and development projects, on the basis that any matters which are outwith the direct control of the two contracting parties introduce a tangible element of risk, and therefore possible time and cost implications. Offsite manufacture is regularly seen on projects in which we are involved as a time- and cost-saver, particularly in the context of the logistical issues of delivery, unloading, and installation at the site.

(c) Consistency of workmanship due to the build being far more process built and easier ability for checking of quality offsite leading, in turn to reduced snagging and the consequential disruption to use following completion. Our experience from reviewing tender responses from contractors to development projects is that contractors are keen to highlight their advances in the off-site construction space, with large sums being invested in central facilities suitable for design, development, construction and testing. A clear selling-point of this approach from the contractor's point of view – which many of our developer clients see the benefit of – is the consistency of approach, consistency of product, ease of access to training for construction apprentices, and greater application of quality control procedures by the contractor. Each of these factors separately and together can be considered to be both a short-term commercial benefit in terms of improving cost-effectiveness and quality, but also from a longer-term perspective of improving access to training thereby reducing the skills shortage which some clients consider to be prevalent.

(d) Potential improved health and safety credentials due to less work happening on a site where other works are taking place and controlling
risk is inherently more difficult. Where the variety of necessary tasks being carried out on site can be reduced through off-site construction – e.g. to unloading, storing, installation, and testing – not only can the size of sites be reduced given the lack of the need to house construction facilities on the site itself meaning less pressure and stress on the surrounding environment and the general public, but those processes around unloading, storage, and installation can be carried out within a safe and managed environment on-site, reducing the risk of injury.

(e) It may be possible to achieve improved environmental credentials for the project due to the efficiency of the build process. Great reliance by contractors of off-site construction and modular installation on-site allows for greater emphasis on the environmental "output" of the construction process with centralisation of resource, greater opportunity for custom-made construction facilities, less requirement for "hot" works to be carried out on-site (e.g. welding, diesel-generated activities). Many of our clients express as a key concern the environmental "credentials" of tender opportunities and of packages put out to the market for contractors to tender for – our experience is that this element, far from becoming less important, is becoming a more important part of the offering made by contractors for inner-city, suburban, and rural construction projects.

1.2 In our opinion, the likely drawbacks are:

(f) Transportation/storage risk - where a significant proportion of the work is being undertaken off-site, the effect on the project of an issue arising during the transportation or storage of the modules can be significant. This can be a particular concern where the modules are being manufactured overseas where, despite the potential availability of marine insurance, the impact on the project of the loss of a vessel could be devastating for the project. The availability of insurance can have a mitigating effect, and one common view expressed by clients is that insurers are best placed to manage this risk;

(g) Insolvency risk - it can be challenging to replace a modular supplier if it becomes insolvent. Unlike projects being built on site, where a modular supplier becomes insolvent, it would be necessary to find an alternative modular supplier who is able to produce modules that replicate those used for the specific project. This may not be possible if the intellectual property used for the modules is not available or simply due to the inability for a replacement supplier to build the modules in a way that interfaces properly with those that have already been produced. This is a significant concern.

(h) Greater impact of defect – the lack of the ability to test materials, units, or "pods" in the on-site environment can mean relatively minor issues can have a highly detrimental effect on programme and costs. A good example we have direct experience of are measurements for student accommodation "pods" (where the student unit consisting of bedroom and bathroom) are constructed off-site, delivered to the site,
and installed into the building shell. An error in measurement can affect a high number of "pods" each of which would have to be reconfigured or re-constructed, whereas if construction took place largely on-site, the error would be picked up at the first opportunity and subsequent "pods" would be constructed to the correct dimensions. For modern accommodation projects for example, we are aware that the degrees of tolerance required are so precise that the risk presented by a measurement or surveying issue is very significant indeed.

(i) Review during off-site construction process – one practical difficulty can be the level of scrutiny which developer or contractor clients can exercise over the off-site construction process where distances (which clearly are often international) can militate against checking and supervising the construction process regularly and often. While contractually entitlements to inspect and review construction processes are contained in many of the published standard forms of construction contract (and regularly we are instructed to "beef up" these provisions with additional inspection rights, for example, unannounced "spot checks"), the cost of undertaking the necessary travel in order to carry out inspections (both in time and money) often act as a negative factor in a developer or contractor's client's assessment of whether exercising the right of supervision is worth doing.

Potential barriers to wider use of offsite manufacture

2 Question 3: What are the drawbacks to offsite manufacture for construction?

2.1 You refer in Question 2 to a claim that offsite manufacture can lead to greater provision of new, affordable housing. Registered providers of social housing (RPs), which provide social and affordable housing, have a financing model which is based on asset rather than project finance. This sees RPs securing funding on built and let units and using those funds raised to buy or build further units.

2.2 Therefore, post construction value and costs are important to RPs to support this funding cycle. On that basis, we see the following potential drawbacks:

(j) Repair costs and maintenance skills. The inquiry refers to the skills needed to build such units, but for RPs the cost of maintenance is important (see further in paragraph 3 below). If costs are high, the net income from the housing units will be low and value will therefore be low. This will restrict the borrowing capacity of RPs against these units, which in turn will restrict the ability of RPs to buy or develop further units.

(k) NHBC or equivalent build insurance. The units constructed would need to be supported by a reliable scheme of build insurance. Funders need to be comfortable with the build quality and that any issues,
particularly in experimental or new construction techniques, will be satisfactorily resolved.

(I) **Longevity**. Depending on the form, some units have a shorter life expectancy. This raises questions on how such units might be treated from a funding perspective, such as:

(A) If they are seen as depreciating assets, it may push their value down. This would need to be weighed up against any cost efficiencies gained in the construction.

(B) Funders generally require a dwelling to have a lifespan of the length of the loan being secured plus 30 years. This could mean as dwellings age they become more difficult to raise finance on (or are even rendered unmortgageable) and their values decrease, much like leasehold properties (which have a finite and reducing lifespan).

2.3 Additional concerns for the social housing market (and no doubt other markets) are:

(m) there are currently a number of systems being invested in and it is perhaps inevitable that some of these either do not reach maturity, or manufacturers cease trading either entirely or in particular products, and this could cause reputational concerns for RPs and their funders if systems under development do not reach a successful maturity or if production ceases and this impacts on replacement and/or repairs and maintenance; and

(n) a secondary market needs to be established for these assets before marketability can be assessed so that the value of it as security can be considered and an assessment made as to how this performs relative to traditional construction.

3 **Question 4: What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

3.1 Re-skilling is required not only in construction but also in repairs and maintenance.

3.2 Dwellings constructed offsite are perceived to be more difficult, and therefore costly, to maintain and repair.

3.3 Under the Value for Money Standard issued by the Regulator of Social Housing, RPs are under a duty to deliver value for money and this includes an assessment of the full costs and benefits of alternative delivery structures. This may be a potential barrier to RPs investing in dwellings constructed offsite - unless the maintenance and repair costs can be justified, there could be downward pressure on the RP's regulatory grading.
Government actions

4 Question 8: What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

4.1 The public procurement rules (set out in EU Directives, the UK implementing regulations and related case-law) which govern the award by public bodies of contracts above specified value thresholds already support the use of sustainability/environmental factors by public bodies when awarding construction contracts (provided that overriding requirements of transparency, equal treatment, non-discrimination and proportionality are complied with).

4.2 Under these rules, sustainability and environmental factors may be built into procurement procedures in the following ways:

(o) Pre-procurement engagement with the market
   (i) Procurement legislation specifically allows preliminary consultations with suppliers. With input from the market, sustainability considerations can be assessed and incorporated into a project from the outset.

(p) When advertising the tender (including publication of contract terms)
   (i) Potential suppliers can and should be notified of the sustainability requirements of a project, giving them the opportunity to take an early view as to whether they can satisfy them. Conceivably, these could include a requirement for offsite manufacture in appropriate cases.

(q) When defining specifications
   (i) Sustainability/environmental requirements relating to production processes and characteristics/performance qualities of products may be integrated into technical specifications.
   (ii) Eco-labels may help with drawing up technical specifications, and compliance with the technical specifications may be tested by assessing bids against the specifications underlying the eco-label.

(r) At pre-qualification/selection of suppliers
   (i) Pre-qualification requirements can include sustainability criteria relevant to the technical or professional ability of the supplier to carry out the tender. Suppliers who have breached applicable environmental obligations may be excluded.

(s) In the evaluation criteria
   (i) Sustainability criteria relevant to the contract are permitted award criteria. These may be used to award higher scores to bids that exceed minimum sustainability requirements.
Use of innovation partnerships

(i) To identify new environmentally sustainable solutions for construction needs.

4.3 Public authorities could be encouraged to stipulate offsite manufacture as a requirement of construction contracts where appropriate (and provided there are sufficient suppliers providing offsite manufacture to ensure a competitive tender process).

4.4 Short of including offsite manufacture as an express requirement, offsite manufacture may be encouraged through the use of sustainability/environmental factors in the procurement procedure if bids predicated on offsite manufacture are likely to score more highly on the basis of those factors.

4.5 While public procurement rules give considerable scope for sustainability to be factored into procurement decisions, the issue is how to promote this. Possible measures could include mandating or promoting use of sustainability criteria in technical specifications, award criteria and/or the use of life-cycle costing for evaluating the price element of tenders.

4.6 Government might also require or promote using methodologies for scoring tenders which allocate a minimum level of the total possible score to sustainability criteria (for example 10% of possible marks). This may reduce the relative importance of price in the overall assessment of bids and could drive higher up-front costs, but the use of (mandatory) life-cycle costing to demonstrate the whole of life costs of a construction project may help to mitigate concerns on this score.

4.7 With or without new mandatory requirements on sustainable procurement, public bodies should be given a clear steer on factoring sustainability and environmental considerations into construction procurements. This could take the form of encouraging public bodies to collaborate on sustainable procurement (for example through joint purchasing to achieve efficiencies and minimise waste or by sharing best practice), setting minimum targets for sustainable procurement and training (from experts) on how sustainability can be promoted through the procurement process.

26 April 2018
**What is Off-Site Manufacture**

The term Off-Site manufacture generally refers to the production of building components or assembled modules that are manufactured in a controlled factory environment before being; transported, erected, and assembled into the on-site structure or building. The amount of work or value added activity carried out in the factories dictates the level of Off-Site, and can range from 2D structural component systems contributing to 10-15% of a building to fully assembled 3D volumetric modular units which can account for 80% or more of the total value added work.

Manufacturing is inherently more productive than site based construction. So, given that this enquiry is focussed on how construction productivity can be improved using Off-Site manufacture, this report considers the higher end of the Off-Site spectrum where buildings or infrastructure are delivered with more than 70% of the value added work carried out Off-site in factories.

**Perceived advantages of offsite manufacture for construction**

Use of manufacturing principles in the delivery of buildings has long been established as a route to improved productivity, quality and reduced cost of delivery and Operations and Maintenance (O&M) for a wide range of buildings. Off-Site has (already) established its benefits in a number of sectors, including hotels, military accommodation, schools, colleges and hospitals. In these markets the combined value proposition of speed of construction, improved programme certainty, standardised quality and minimisation of disruption offer distinct and compelling advantages over traditional construction methods.

1. **What are the opportunities offered by offsite manufacture for construction?**

The general rule for anything that is manufactured in volume is that it gets better in terms of quality and performance and cheaper in terms of affordability over time. This is because volume attracts competition and suppliers then invest to achieve competitive advantage. Competitive advantage typically comes from 3 routes; cost leadership, differentiation and focus, or expressed differently product, price and service.

If volume markets for products that use Off-Site construction can be created collaborative supply chains will emerge to deliver better (quality and reliability) products at competitive prices and improved service. This could transform the UK’s new-build construction industry.

Perhaps a contrarian view, but in sectors such as housing, off-site can increase choice, flexibility and variety for consumers, as well as providing better quality.

1.1 **What are the likely drawbacks?**
Most drawbacks are based on perceptions (fears and risks) based on historical paradigms, underpinned by a general reluctance to adopt change. Themes include:

- Inability for designers to be creative; rule book approach as opposed to total design freedom
- Ultimate de-skilling of designers from creators to specifiers
- Products / systems dictating solutions, as opposed to solutions responding to need
- Early commitment to enable manufacturing removing flexibility to make late changes
- Lack of participants in the market offering similar systems leading to lack of competition

1.2 Factors influencing the ‘market decision makers’ for Off-Site products include:

- Above drawbacks
- Lack of capacity to deliver volume to common designs. The incumbent Off-Site manufacturers produce different products, so for many projects this requires single sourcing. This presents a risk that is recognised throughout the industry.
- Current Off-Site manufacturers are limited so lack capacity to respond to widespread demand, on demand. Therefore, the default, where capacity is unavailable, is traditional build methods.
- The current industry structure is design led. Architects and Engineers design to tried and tested processes. Off-Site needs a different procurement method where manufacturers can respond to a brief rather than a design. Alternatively design tools are needed to allow designers to design using modular components and sub-assemblies.
- Concerns (perceived) regarding planners, funders, developers, purchases and tenants’ acceptance of Off-site manufacturing; ‘legacy stigma of pre-fab’, not individual and enduring but a mass produced inferior and temporary ‘fix’.
- The lack of historical precedence in modularised systems and materials, in terms of their compatibility, long term durability and integrity, in short leading to scepticism or reluctance to embrace something perceived as new.

2. Off-Site manufacture can lead to....

Within construction, as with manufacturing, KPI’s vary in importance according to the type of project. However, product price, quality and service in terms of speed or reliability of delivery are generally high on the requirements list. So the list of opportunities for Off-Site manufacture includes:

- **Reduced cost** – if demand for off-site products grows so will investment in improved efficiency to achieve cost leadership. This will include increased automation and less reliance on skilled trades. **Factory assembly workers cost less than trades people and appropriate automation is much more efficient.**
- **Improved productivity** – Less vulnerability to weather, less reliance on skilled trades, less travel for workers, improved ergonomics, greater opportunities for automation, all combine to offer improvement in productivity. **By example a house typically takes 1-man year to build and a car 1-man week.**
• **Improved quality** – manufactured products are Designed for Manufacture and Assembly (DfMA). They are engineered to better tolerances and are designed to be assembled right first time. Better and more holistic design and integration delivers better products. *You wouldn’t expect a car built on your drive to be as good as one produced in a factory.*

• **Improved health and safety** – Construction injuries are between 50% - 100% higher than manufacturing and employ roughly the same number of workers. [http://www.hse.gov.uk/statistics/pdf/fatalinjuries.pdf](http://www.hse.gov.uk/statistics/pdf/fatalinjuries.pdf) and [http://www.hse.gov.uk/statistics/industry/](http://www.hse.gov.uk/statistics/industry/)

• **Greater provision of affordable homes** – Off-Site construction can deliver housing cheaper if there is surety of volume to attract investment in the areas described above. This could **improve capacity to deliver more housing**. In addition, the advantage of less time on site could reduce disruption in cities, expedite regeneration to replace dilapidated housing stock. All of which would have positive impact on delivery where affordable housing is most needed. *Reduced manufacturing costs coupled to reduced disruption costs reduce the overall costs. This needs to be coupled to appropriate financial models that consider the large variance in land values.*

3. **Potential barriers**

Given the widely acknowledged benefits of Off-Site, the question has to be addressed why is this not the norm?

• One of the drawbacks affecting the uptake of Off-Site is the fact that construction is fundamentally a risk averse industry. Virtually all of the current Off-Site manufacturers have systems that are bespoke to themselves. This presents a risk that if the manufacturer fails so does the construction project. Traditional construction does not have the same problem. If a builder fails, then another one is hired and development continues to the same design and process.

• Why don’t constructors invest in factories? – Typically investment horizons in construction are based upon the ROI from a project. Investment in manufacturing at a scale that will deliver capacity to change a market will be significant, and without **proven demand** and predictable ROI the risk of failure to achieve the required return is high. Even the largest companies have failed. [https://www.tatasteeleurope.com/en/news/news/2010/2010_living_solutions](https://www.tatasteeleurope.com/en/news/news/2010/2010_living_solutions)

• Given that no one company will change the market Widespread collaboration across the construction sector is essential to make a step change in wider adoption of Off-site. So why don’t Off-Site manufacturers collaborate to create common systems? Construction is a highly competitive and litigious industry; fundamentally the industry isn’t overly trusting of each other. At the moment Off-Site is immature and the incumbents are competing for what market there is so collaboration will require a change of mind-set prompted by a big incentive. *Platform sharing is commonplace amongst automotive manufacturers enabling shared amortisation of investment in product development, R&D and manufacture over greater volume.*

4. **What re-skilling will be required?**
It is highly unlikely that construction markets will move en masse to Off-Site. Off-Site is a manufacturing industry and in order to produce efficiently a manufacturing approach will be required. However skilled trades will continue to be required for maintenance of existing building stock.

The skills required for Off-Site are in DfMA and the industrial mind-set. As an example, Product designers differ from Architects in that they are part of a simultaneous engineering team which includes Manufacturing Engineers, Logisticians, Maintenance Engineers and suppliers. **See the illustration.**

Manufactured products are designed holistically and include suppliers in the design process. The design is often heavily influenced by parts that are available and that can be included in mass customisable designs.

Currently, to a large extent, the inefficiency and productivity losses in construction are a result of processes happening sequentially and in isolation, designers design, engineers engineer and as a result the industry delivers bespoke products and the process is inefficient. To make a change in mind-set skills training for Off-Site manufacture should include:

- Creation of a ‘manu-constructing’ workforce, not a re-skilling of a construction workforce
- This workforce would need to be skilled in understanding collaborative working to influence the manner in which their product is developed / improved (e.g. car production line – team improvements)
- Construction designers, procurement specialist and planners ALL need to be educated about and involved in the delivery of the benefits of adoption of off-site manufacturing.

5. **Can the benefits of Off-Site manufacture be realised without compromising architectural ambition?**

Yes. Mass customisation is an established term that allows manufacturers to develop a wide range of different products using a hierarchy of common components. For example, many different cars share components across multiple manufacturers and they can look and function significantly differently. Architectural ambition and advances in construction quality will be facilitated by innovation in an Off-Site manufacturing supply chain. Car manufacturers don’t develop tyres; tyre manufacturers do that. Computer manufacturers don’t design processors Intel do that. If a volume market can be established the supply chain will innovate to allow off-site manufacturers to produce mass customisable building designs.

*For volume housebuilders, there is a necessity (shareholder driven) to exploit the maximum return from their land bank to meet target market demands. As a result there tends to be very little functional difference in*
this resulting in formulaic designs to volume housing; ironically creating a demand that is perfectly matched to off-site manufacturing!

6. What R&D is needed and by whom?

Government can help by supporting R&D and investment in the development of an integrated suite of components that can be produced by a supply chain and assembled by multiple Off-Site manufacturers.

Collaborative initiatives that start with a challenge of meeting the Off-Site KPI’s that create a compelling value proposition for a market sector, e.g. housing, should be championed over those where one manufacturer wants to develop a new system alone. (Why reinvent the wheel? we have wheels, what we want is the rest of the vehicle). As described above we have enough different systems, what we need is capacity to deliver the same systems and mass customised variants and these will come from investment in supply chain collaboration.

This approach will promote collaboration and simultaneous engineering; it will allow multiple manufacturers to make the same product, de-risking the decision to go Off-Site and, with multiple Off-Site assemblers, and a competitive supply chain the capacity and benefits of Off-Site can start to be realised at scale and in multiple construction sectors including property and infrastructure.

7. Does the Construction sector deal address the issues?

We understand that the publication of the details of the construction sector deal has been postponed, however, in principle the outline within the Infrastructure and Construction industry deal sections of the industrial strategy white paper appear promising, if a little succinct. The idea of a construction industry hub that coordinates innovative approached to construction is a step in the right direction and we await details of routes to and criteria for funding through the Industrial Strategy Challenge fund.

- **Procuring for value** - Whole-life value criteria will only become a beneficial factor for selecting Off-site if the operating and maintenance costs of Off-site systems are demonstrably less than for traditional build. With relatively low energy costs and life cycle costs poorly established (benchmarked), this is unlikely to influence the housing sector.

- **Industry-led Innovation** – for construction, digital technology, manufacturing, materials and energy sectors to develop and commercialise digital and offsite manufacturing technologies, this has to be through construction sector leaders. The challenge is how industry-wide and cross-sector collaboration is achieved.

- **Skills for the Future** – the skills required for Off-site are new and will augment existing construction industry skills. An evolution into increased Off-site capacity should not be likened to the closure of steel and coal industries where overnight 100,000’s of workers’ roles became obsolete. The UK’s built environment has a functional life expectancy into the next century that will continue to demand ‘traditional’ skills.
8. **What changes could be made to public procurement processes**

The benefits of Off-Site have been known and discussed for many years. Government reports include; Latham 94, Egan 98, Barker 2004 through to Farmer 2017 and many others. Despite this, the industry has failed to adopt changes that will deliver the benefits of Off-site that are so widely accepted. The reluctance to change is a product of existing business models and risk aversion within the construction industry.

In order to accelerate the uptake of Off-Site manufacture, Government needs to drive change through a combination of support for supply chain development in off-site, and legislation to mandate the construction industry to modernise and address the huge productivity gap as described in the McKinsey Report Reinventing Construction.


21 April 2018
1. Introduction

The written evidence presented below discusses offsite manufacture specifically in the context of health and safety in construction.

Off-site manufacture for construction presumes that there is better control of hazards to health and that therefore, these hazards are managed more effectively. If this is not the case, there is little point in moving manufacture offsite in the first place. Common hazards to health in the construction sector include dust and fibres (which incorporate a wide variety of substances including respirable crystalline silica, asbestos, wood dust and general manufacturing dust), noise and vibration.

Common health conditions arising from exposure to these hazards include COPD (chronic obstructive pulmonary disease), occupational asthma, silicosis, asbestosis, hearing loss and HAVS (hand arm vibration syndrome). These conditions may take years to develop.

In addition, repetitive movements, heavy lifting and poor job design processes can lead to musculoskeletal disorders (MSDs) which is one of the most common work-related health conditions in the construction industry.

2. Opportunities offered by offsite manufacture for construction

The benefits of offsite manufacture in terms of health and safety include the following:

- Reduced likelihood of work related ill health;
- Improved productivity on site;
- Efficiencies in process, which reduces exposure to hazards by process reengineering;
- Reduced MSDs both on and offsite;
- Reduced risk of injury and accidents;
- Reduced risk of developing latent health conditions.

In addition, offsite manufacture supports the HSE’s strategy for treating health like safety; a strategy that focuses on MSDs and respiratory conditions.

Factors that are likely to influence clients, contractors and others include:

- Cost, particularly for smaller firms;
- Attitudes of project/client/site manager(s);
- The willingness of designers to use standard sizes to enable offsite to happen (e.g. if you need a variety of shapes/sizes of brick, this is less conducive to manufacture offsite).
3. What’s the evidence for improved health and safety, and, increased productivity?

Manufacturing offsite enables automation of processes such as cutting bricks, paving slabs, timbers, etc. With appropriate hazard control at the place of manufacture, health risks will be reduced. This includes:

- Reducing vibration risks to workers, as machines will be cutting materials (e.g. bricks, plasterboard, etc.);
- Minimising wood dust, general dust and silica risks, as bricks, paving, tiles and rafters and other materials are made to the required shape and size offsite rather than being cut on site;
- Lowering the risk of MSDs as the manufacturer of items can be designed and engineered.

The HSE has published research which provides several case studies on current practice and the health and safety benefits of offsite manufacture (https://www.buildoffsite.com/content/uploads/2015/04/HSE-off-site_production_june09.pdf);

A case study by WRAP into the benefits of off-site manufacture (http://www.wrap.org.uk/sites/files/wrap/APS%20-%20FINAL.pdf) demonstrated that there were no health and safety incidents and a reduction in labour requirements.

4. What are the drawbacks to offsite manufacture for construction?

There are several drawbacks to offsite manufacture for construction in terms of health and safety. Firstly, offsite manufacture may not be possible for smaller projects (particularly if a variety of non-standard elements are required) or may be cost prohibitive for smaller firms.

Because fewer tasks are performed onsite, offsite manufacture may reduce the opportunity for the rotation of tasks. There is then the potential for overuse injury when one task is repeated for too long without breaks.

Manufacturing delays may hold up a project and increase costs if the items are not ready when required. Larger items that are not being assembled on site may become more difficult, and therefore expensive, to deliver to site.

Although offsite manufacture of a particular element could result in improving control of the health hazard, if the design hasn’t been changed sufficiently and the item still needs to be cut onsite (for example), there is no benefit.

5. What reskilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

Reskilling could encompass the following:

- A new approach by designers to ‘design-out’ the risks at the start;
• Educate site managers to encourage the increase of task rotation, to prevent a rise in overuse injuries amongst the workforce;
• Project managers would need to think ahead about planning tasks to accommodate the time required for offsite manufacture so that the project isn’t delayed unnecessarily.

6. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition – if so how? *Not relevant to B&CE*

7. What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture? *Not relevant to B&CE*

8. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain what is missing?

We believe that the construction sector should focus on treating health as equally important to safety – often safety takes priority and hazards to health are not addressed. The following actions would be beneficial:

• A greater emphasis on designing out risks and hazards at the start of the construction lifecycle;
• Provision of a wider variety of ‘standardised’ products so that offsite manufacture becomes easier and more convenient for contractors of all sizes.

9. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

When procuring for public sector projects, the aim should be to use offsite manufacture where possible, resulting in a reduced need for health surveillance. This could then lead to a reduced burden on the NHS.

Government should lead a change in culture, by setting the expectation for major infrastructure projects that there are no risks to health – we should not accept that projects like these continue to damage workers’ health. When we design major infrastructure projects such as HS2 and Crossrail, we need to design out the health risks in the first place. This will not be achieved quickly, as it requires cultural and behavioural change, but it should be our ambition.

*25th April 2018*
BEAMA – Written evidence (OMC0052)

Inquiry questions:

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

2. It is often claimed that offsite manufacture can lead to:
   - lower costs, faster delivery and increased quality;
   - increased productivity;
   - improved health and safety;
   - greater provision of new, affordable housing.

What is the evidence for this?

BEAMA is the trade association for the UK electrotechnical and related industry, representing over 200 manufacturers in sectors including electrical infrastructure, smart energy, and heating, ventilation and plumbing.

BEAMA believes that off-site manufacture and assembly of modules for construction of buildings can and does offer opportunities for the market, including for product manufacturers should it continue to grow. We hope that in line with the Industrial Strategy it can benefit manufacturing and assembly within the UK, as well as growth in construction. We hope that any productivity gains achieved within the industry can lead to more opportunities for employment and development of skills in off-site manufacturing or in other areas of manufacturing and construction.

At the same time as providing opportunities to cost-effectively incorporate energy efficient technology, there is a risk that the path of least resistance for off-site/modular construction leads to the exclusion of such things. Underfloor heating may be a good example of this, where there are products that with some development work would lend themselves well to the off-site method but construction companies wrongly conclude the technology is not suited (as they consider the traditional methods of incorporating it). It is important that the environment created by Government stimulates the growth of an open-minded industry and does not inadvertently close off beneficial technologies. There are now a number of options for UFH installations, including using low profile and overlay systems, all of which could work with modular buildings and offer options for many project types. Water-based/hydronic underfloor heating has the additional benefit of being ‘renewable ready’, ie being the best emitter for low temperature renewable systems, ie heat pumps, and this fits with not only the Government’s moves to lower carbon heating within the Clean Growth Strategy, but also the link between developing low carbon technologies and industrial development made in the Industrial Strategy.

Other benefits:

**Efficiency & Predictability:**
Offsite manufacture if undertaken following a modular design strategy can lead to significant benefits in terms of efficiency & predictability. The key to realising this benefit is for the offsite principal to be involved at the outset at design concept through to detailed design. The off site approach is a design ethos and should not be considered as a VA/VE approach to reducing costs on direct material benefit. By following a modular design platform the client is able to select from a number of options / platforms to enhance select their particular specification. This approach has in reality been used by a number of industries outside of that of residential construction. By following this design ethos, covering both the design of the modular components and the design of the constructed project, benefits can be delivered by setting up of the offsite producer to tool up for the production of the modules resulting in tighter control in terms of repeatability and benefiting from economies of scale.

Assemblies are produced the same time every time. This results in reduced construction times and reduced assembly costs resulting from the investment in jigs fixtures and tolling. Work can be guaranteed to be delivered on time and to the highest quality, as the mitigating circumstances such as bad weather do not delay the project.

**Safety**
The factory environment allows for the manufacture to be set up focussing on and minimising identified H&S risks. Through suitable identification, risks can be tackled with the provision of engineering solutions and as such reduce the risks on site including:

- Manual Handling
- Hot works
- Electrical safety
- Slips, trips and falls
- Inclement conditions
- Lone working
- COSHH
- RSI
- Falls from height

Construction Industry Stats 2017:
Sustainability
Off-site manufacture allows the product to be manufactured and assembled on a purpose built production line reducing the requirement for some of the heavy machinery used in transporting material and such results in a reduction in energy usage. Transporting the finished article also uses minimal transportation and wastage is minimised as material requirements can be more accurately
calculated and giving the opportunity to gain from economies of scale via bulk buying. Packaging waste is also significantly reduced and also reduces the amount of wastage which needs to be removed from site leading to less plastics use and reduces the fire risk of site based activity.

**Less Labour**
A factory setting requires less labour and trades to be present on site. The steel construction institute (SCI) have conducted studies and reported that hands required could be reduced by as much as 75% on a four storey residential development and similar in other like builds. This significantly reduces the burden of identifying and employing suitably trained personnel and leads to a reduction in total wage cost.

We hope that any productivity gains achieved within the industry can lead to more opportunities for employment and development of skills in off-site manufacturing, in other areas of manufacturing and construction or in other related industries, or that the benefits of reducing labour needs are distributed in another fashion. We believe that all this is in line with the Industrial Strategy.

**Less training**
Transferring part of the technical product/construction elements to a factory allows more focussed specific elements of training to be delivered to manufacturing staff in a manufacturing environment. Manufacturing training is more related to specific parts of the process and as such takes less time than delivering broader constructional based training across the whole trade. More specific training given to staff within the manufacturer takes less time and as result reduces lead times and means faster deliveries with less cost.

**Less disruption to residents and community**
Onsite build and construction projects by their very nature are lengthy, complex and noisy. This can impact the lives of nearby people living in the near vicinity. This is a particular problem within areas of regeneration. Undertaking some of the activity reduces noise pollution, time and inconvenience. Offsite construction results in positive benefits to the locality in terms of time, noise, dust and general inconvenience.

**Inquiry questions:**
**Potential barriers to wider use of offsite manufacture -**
3. What are the drawbacks to offsite manufacture for construction?
4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?
5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?
6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

We believe there needs to be attention given to standards and product compliance with off-site manufacturing, given the different in supply chain and responsibilities. We are aware that BSI are looking at standardisation in this area, but we believe Government also needs to be aware of the importance of
product, assembly and system quality in any support offered to off-site manufacturing. This should help to ensure that all existing safety requirements are complied with, that existing standards relating to construction and specification of products reflects any variations needed for off-site manufacturing, and that any new standards are developed as needed so that they can be in place in time for any significant growth in this process.

Aside from standards, specifiers need to be aware of the importance of using compliant products within modules that they purchase, and to be aware that all parties are responsible for due diligence in looking up the supply chain to check the provenance and suitability of products. There is some anecdotal evidence of concerns already, so it is important that the proper safeguards are put in place, and furthermore that Building Control and other authorities are equipped to review the suitability of products in any sections of the industry where new supply chains and new types of supply chain are being developed.

Other main disadvantages to off-site construction include:

- limitations – pre-fabrications may need to be limited in size due to transportation restrictions, maximum road widths, low bridges, weight restrictions and general disruption to traffic;
- Perceived impact on design flexibility – due to the modular nature of the construction, the designer’s ability to adopt innovative approaches could be limited. The agreed design needs to be finalised earlier in the construction process and adapting the design may not be possible;
- not always a success – despite a number of successful projects, there have been many off-site failures. The majority of the failings in offsite have resulted in the projects being kicked off too late in the design phase and or lack of due diligence in planning submittal.
- investment dampened – growth in off-site construction has been dampened by high costs, fluctuating demand, concerns over mortgageability and a general lack of acceptance for the new construction method; and
- once bitten, twice shy – several house builders invested into MMC before the last recession were seriously burnt when left with empty factories as the credit crunch hit.

In order to capitalise on these opportunities, the UK needs to have sufficient capability and capacity within its construction sector workforce. This research has identified six key functions for offsite construction:

- Digital design;
- Estimating/commercial;
- Offsite manufacturing;
- Logistics;
- Site management and integration; and
- Onsite placement and assembly.

Offsite manufacture does not necessarily impact architectural flair however it does indeed require a different approach and levels of consideration within the concept development and detailed design phase. There are many sectors where a developed modular approach for mass customisation still results in a level of personalisation within the final design. This however needs to be considered within the building blocks of the individual concept design and evaluation. For
Sure, offsite construction is not a panacea. It will not be appropriate for every project. It is however an approach which should be considered with an aligned project brief and common end goal. It is our belief that such an approach can be used to support the overall productivity improvement required to meet the UK build targets. When you consider that the majority of properties are constructed by a number of large developers who build of a number of standardised build types which are replicated in developments across the country it is not such a way out thought that with a slight change in focus off site manufacture could lead to benefits in this particular part of the sector.

Studies identified the traditional thinking patterns of architects and predicted possible future roles for them as seen through the lens of architects of their personal philosophies. An alternative thinking pattern and design approach suited to OSM has been identified as a possible pathway to break through the constraints of discontinuous processes and programs of OSM. The shortcomings of traditional approaches (including process, program and lack of skills and knowledge) have been highlighted. More attention needs to be paid to architects and the philosophies that underpin their practices. They are the critical specifiers in today’s off-site construction industry.

There is often confusion between the perspective and or constraints of R&D VS Technical Management. Often innovation is hampered by the view point of the constraints of historical and or technical paradigm. Technical management and compliance is focussed on obtaining a required standard for today within known constraints, innovation is more of future perspective. One of the key investment areas within the construction industry is to challenge the norm. No easy task but whilst other industrial sectors have seen considerable development and step changes in technology the basic practices of building found today were around in the early 21st Century. A focus from compliance in technical specification to compliance in delivery and performance as design is probably the largest area which requires focus, design and investment.

26 April 2018
This is a submission by BLP Insurance to the call for evidence in respect of an inquiry into off-site manufacture for construction.

BLP Insurance is a leading warranty provider to the UK residential sector and a stakeholder in BOPAS, the Buildoffsite Property Assurance Scheme and has much experience in assessing and warranting various forms of offsite construction.

BOPAS which was launched in March 2013, was developed by Buildoffsite, Lloyds Register and BLP Insurance with RICS, the Council of Mortgage Lenders and the Building Societies Association. The BOPAS process gives an independent assessment of quality and reassurance from inception through to construction for investors, developers and owners. [http://www.bopas.org/](http://www.bopas.org/)

**Perceived advantages of offsite manufacture for construction**

The UK is facing a chronic housing supply shortage. We must deliver an increase in housing supply at a time when the average age of the construction workforce is increasing – a potential time bomb that will play out over the next 10 years with net loss of 25% of workforce.

We are finding it increasingly difficult to attract new talent into the industry and to replenish the level of leavers. This is resulting in a massive skills shortage across the industry. According to a report from the Union of Construction, Allied Trade and Technicians (UCATT) – ‘Constructions skills shortages a result of 30 years of failure’ ([http://bit.ly/1KoWh3Y](http://bit.ly/1KoWh3Y)) – the UK is facing its biggest skills shortage for a generation, with estimates showing that the construction industry needs 35,000 new entrants just to stand still. With a huge shortage of skilled workers in the UK, building firms have been forced to double the wages for tradespeople from abroad, increasing the cost of traditionally built homes.

Not only is this situation reducing output and increasing cost, quality is also suffering with an increase in construction defects and buildings not performing as designed. This is leading to consumer dissatisfaction in the quality of new homes as evidenced by recent articles condemning the quality of homes delivered by leading UK housebuilders.

The industry must look beyond traditional forms of construction. The requirement to fill the supply and demand gap must be met with housing that is both sustainable and of the highest quality. The traditional housebuilding community is neither able nor willing to change their business process and increase output to solve the problem.

There is a simple solution if the industry embraces off-site or non-traditional forms of construction and brings new players into the housing market.

We must modernise the industry in a way which will:
- Increase attraction to new entrants & offset attrition & shrinkage
- Improve productivity so we can increase output with constrained labour
Prefabrication in a factory setting is by no means a new concept and the benefits are clear: speed of construction, reliability of materials and manufacture, improved performance and potential reduction in construction costs if units can be delivered at scale and to repeatable design.

**Potential barriers to wider use of offsite manufacture**

To date, the real level of innovation and modernisation in the industry has been limited, constrained by reticence to invest in a cyclical, short term thinking sector and low levels of capitalisation. While the benefits of Smart Construction are clear, they do not come without challenges. Concerns about systematic failure, fire spread and water ingress, have been raised around the use of off-site techniques, both during and after construction. These concerns are being addressed by the Buildoffsite Property Assurance Scheme (BOPAS) which provides long-term assurance to mortgage lenders, valuers, funders, landlords and homeowners that properties built using non-traditional forms of construction will be durable for at least 60 years, without the need for disproportionate maintenance.

We are now seeing schemes being built using off-site systems that have been through the BOPAS accreditation process and benefitting from a BLP Insurance 10-year structural warranty.

Running parallel to the structural warranty assessments, BOPAS accreditation addresses the concerns of funders and valuers. It combines both the design checks undertaken as part of the BOPAS assessment and site-specific design with the workmanship checks forming part of the BLP Insurance Structural Warranty.

A summary of systems that have received BOPAS Certification, those going through the process, and the pipeline of those in discussion re accreditation can be found below.
The manufacturer’s in the table represent a mixture of established providers, those moving from other sectors and start up companies. It is imperative that in all cases the manufacturing process and the relationship with the onsite activities are closely aligned as this is often where difficulties can occur. This coordination is at the heart of the BOPAS process and which delivers confidence to the lending and funding community.

It is worth recording the type and origin of construction system that has either been approved under BOPAS or is going through the approval process.

These are depicted in the graphs below.
System Types

- Timber Frame: 11
- LGSF: 8
- Modular: 21
- Panellised: 6
- CLT: 3
- SIP: 4
The above charts demonstrate a number of significant issues that suggest that offsite, after several false starts since the 1990’s is finally fulfilling its potential.  
1/. There has been a significant growth in BOPAS registrations over the last two to three years with the potential for 2018 to outperform all previous years.  
2/. Modular is by far the most popular form of offsite construction being developed. This addresses key issues around skills shortages in traditional construction and represents a greater PMV (Pre Manufacture Value).  
3/. There is a much greater impact from manufacturer’s in the UK than from overseas which can only be positive for the UK construction sector and UK PLC.

**Government Actions**
Mainstreaming offsite manufacturing for the UK housing sector will require coordinated action from Central Government and from the construction industry. It will need both policy from Government and persuasion from clients, together with decisive action from both the private and public sectors to enable manufacturing to mobilise.

Government support for offsite manufacturing is critical in keeping the momentum going, and in its Residential policy paper (http://bit.ly/1PEt7zf), RICS urges ministers to support non-traditional construction and endorses BOPAS as an independent assessment process to ensure that such systems are durable for at least 60 years.

BLP Insurance and BOPAS are working with the Housing Minister’s MMC working group chaired by Mark Farmer to deliver a unified accreditation and warranty platform that will follow the principles created by BOPAS and which can only be of benefit to the off-site construction industry.

Finally, it is clear that traditional procurement practices are not best suited to many off-site solutions where a more collaborative and cost effective approach is required. The IPI collaborative approach to project procurement would appear to be a much better fit for clients wishing to deliver an offsite solution for their projects.
26 April 2018
Blue Lion Consultants Ltd – Written evidence (OMC0068)

Introduction

1. In an attempt to avoid providing overly generic answer’s the writer has focused on the affordable housing sector and offsite volumetric construction. The current emphasis by media and industry for offsite manufacturing is significantly driven by the current demand for affordable housing across the United Kingdom. Offsite volumetric construction is a key method of delivering offsite manufactured housing units.

2. Please note that most, if not all of the ideas and concepts discussed below are relevant to other sectors of the construction industry and apply to other forms of offsite construction.

Perceived advantages of offsite manufacture for construction

1.1 What are the opportunities offered by offsite manufacture for construction?

3. The main opportunities cited by proponents of offsite manufacture are improvements in time, cost and quality. The logic being that building in a controlled factory environment will boost productivity (by using automation, economies of scale, repetition of tasks) which in turn lead to faster delivery times, reduced costs and improved quality. Traditionally the Time/Cost/Quality triangle assumed that you can have any two out of three but not all three. In offsite manufacture the construction industry has a realistic opportunity of achieving all three; improvements in time, cost and quality.

4. TIME onsite – By transferring a large part of the construction process offsite huge savings in time will be achieved by shortened onsite project programmes. Traditionally works on superstructure can only commence when substructure/groundworks have been completed – it is a linear process. With offsite build, superstructure units can be manufactured offsite at the same time as works progresses onsite. Once delivered to site these units can be erected in under a day. This could in some cases reduce overall onsite project programmes by 30%. As build/manufacture processes are rationalised this time saving can be further improved.

5. TIME in design & procurement - By manufacturing houses rather than building houses, onsite producers will hope to offer standardised products to a point where sizes and types will be fixed. Although producers will have to adapt their product to meet market requirements ultimately the point of offsite manufacture is standardisation. This level of standardisation will deliver huge savings in the design and procurement process. For example, an Architect with a site trying to meet a specific density could approach several volumetric producers and request they offer their best product to meet the sites requirements. Upon selection of a preferred house type/types the Architect would then be able to use the house supplier’s design/product information to finalise the schemes overall design. In theory the manufacturer will have met all building regulation requirements, all design information will be readily available and most
likely show homes will be available to see. This will lead to a shortening of 
the design and procurement process.

6. TIME in project methodology and contracts stage – Following on from the 
above example offsite volumetric construction can redefine the way in 
which projects are contracted. Main contractors will be responsible for less 
work as the housing units will be sent to site complete (less the works that 
have to be carried out onsite). Although it may take some years for offsite 
volumetric house builders to be able to send houses to site close to 100% 
complete the process will still remove a substantial amount of work to be 
done on site. This leaves the traditional main contractor with a revised role 
which in turn reduces site overheads and overall project overheads that 
are traditionally added as part of a main contractor’s overheads and profit 
margin. In the long term there could be significant savings for the industry 
as a whole.

7. QUALITY – Manufacturing a house as opposed to building a house will 
encourage revised methods of working and the concept of component 
manufacturing will ultimately increase quality. It would be wrong to 
assume that by simply transferring building work to a factory environment 
will in itself increase quality. The whole ethos of product design, process 
rationalisation, de-skilling of tasks, multi-tasking trades, introduction of 
automation, use of AI, etc. will provide an opportunity for the industry to 
increase the quality of the end product.

8. Aiming for 100% defect free housing units should be a fundamental target 
for the offsite industry.

1.2 What are the likely drawbacks?

9. The drawbacks of offsite manufacture exist mainly in the short term. As 
with any new concept or change process, implementation requires a 
transition period from existing methods and it is in this period that the 
drawbacks will occur. These drawbacks will hinder adoption of offsite 
manufacture and slow progress in achieving improvements in time, cost 
and quality.

10. TRADITIONAL BUILD COMPETITION – Until there exists a critical mass of 
supply and demand within the offsite volumetric sector this emerging 
sector will have to compete with the traditional housing market. Some of 
the largest housebuilders have yet to embrace offsite manufacture and 
most if not all large housing schemes are still being built in a traditional 
way. Offsite is becoming popular with smaller schemes and general usage 
has increased steadily the past 20 years. Only when the country’s largest 
clients and housebuilders switch to offsite manufacture will the sector 
become a real and viable alternative.

11. RECORDS AND EVIDENCE – Accurate and easily obtainable data must 
exist to prove the benefits of offsite to industry and its clients. In simple 
terms if the measurable benefit of using offsite manufacture cannot be 
recorded, collated and used to prove the benefits of use than adoption of 
offsite manufacture shall be slow.

12. LACK OF KNOWLEDGE – There will exist an initial inertia for the industry 
and its clients to adopt the use of offsite manufacture. Much of this will be 
due to lack of knowledge and the natural resistance that exists within any 
organization/industry to change whether organically or by strategic 
planning and policy.
13. Currently early decision making is required by clients and designers, so schemes can be designed with offsite manufacture in mind. This is especially true at the moment whilst the sector is still in its infancy. Currently projects determine whether they are suitable offsite manufacture. Once the industry develops and advances then it would be hoped that any project could be built using offsite technology.

14. BUSINESS MODELS – Entry to the market place to supply and manufacture offsite buildings and components will be dependent upon a variety of factors including profitability. Currently the fact that the majority of major housebuilders have not adopted offsite manufacture suggests that traditional house building is still seen to be more profitable.

15. ATTITUDES TOWARDS QUALITY – Although the writer states the construction industry has a realistic opportunity to achieve massive improvements in 3 areas – time, cost and quality, the quality area is the one aspect which may be sacrificed to ensure that time and cost targets are met. To assume that build quality will by itself improve (or at the very least maintain current levels) when transferred to a manufacturing environment would be a serious error in judgement. The manufacturing industry does have quality issues across all sectors and industries.

16. Attention must be given to the ‘quality’ function to ensure it remains a real objective of offsite construction and not just words in a company brochure. The industry currently has BOPAS (Build offsite property assurance scheme) which provides the necessary assurances the lending community requires to secure loans against innovatively constructed properties however further measures should be put in place to ensure high levels of quality. Given the type of product being produced it could take several years or decades before any inherent defects/flaws come to anyone’s attention.

1.3  What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

17. Some of the generic factors are discussed in other parts of this document however some of the specific points are listed here,

18. Clients – Being the key stakeholder the client will focus on delivery time, cost and quality of product. Also the ability to carry out maintenance on offsite buildings will be key for clients. Can offsite units be adapted if required by the end user?

19. Architects – Ability to be creative with the product and produce a signature project to enhance their image.

20. Design Engineers – Ability to meet design standards and codes of practice.

21. Contractors – Ease of access to market and profitability. Ability to carry out maintenance in the event of defects.

22. Supply chain – Ease of access to market and profitability. Ability for high quantity component manufacturing items such as cupboards, kitchens etc.

2. It is often claimed that offsite manufacture can lead to:

23. Currently the writer has not seen any firm evidence to substantiate these claims. Obtaining substantiated and verified data is an urgent task.
required in the offsite industry. From experience in the industry the following statements can be made,

24. **lower costs, faster delivery and increased quality**;
25. See responses to question 1.1

26. **increased productivity**;
27. Increased productivity is generally seen as a fundamental attribute of the manufacturing process. For example, where volumetric housing units are being constructed in a production line sequence it is inevitable that the same task being repeated again and again by the same skilled workers will result in faster installation and improved process leading to improved quality. Automation will also increase this. Compare this with works carried out on site where it is normal for different gangs from the same subcontractor to carry out identical tasks in different units. It is inevitable that the same piece of work will be done differently.

28. **improved health and safety**;
29. Unfortunately, it is a well-known fact that the construction industry has a poor H&S record. Although massive improvements have been made during the past 20 years it still has much to do. The fundamental issue holding the industry back in this regard is that construction has been and still is a site-based process. Sites are never static environments and continually changing as works progress. Add to this the high quantity of labour (also changing as works progress) and it leads to an environment where day to day running of projects takes precedent over H&S matters.
30. Transferring a substantial amount of the building process to a controlled environment creates repetition from which good practice can be developed. Add the correct infrastructure and technology and H&S standards will improve.

31. **greater provision of new, affordable housing**.
32. Out of all sectors within the industry the affordable housing sector is the one best suited to take advantage of offsite manufacture. Units are relatively small in size (2-4 bedroom houses or flats) and the high quantity of units required suits the nature of this emerging market especially in the early years whilst technology is still developing.

**Potential barriers to wider use of offsite manufacture**

3. **What are the drawbacks to offsite manufacture for construction?**

33. **CONTINUITY OF WORK** – Given the large resources required to set up bespoke manufacturing facilities and the long-term commitment required to secure premises and plant, investors will require the continuity of work for a substantial period of time before entering the market. For example, a car manufacturer can continue production of units knowing that they can be stored relatively cheaply until demand is available. With large housing units manufacturers are unable to store large quantity of units for a significant period. Infact it is likely that producers would require guaranteed purchasers before commencing manufacture of new units.
Potential gaps in production would ultimately offset cost savings as producers would have to factor in down time into their overhead costings.

34. LABOUR – See response to question 4

35. TRANSPORTATION & SITE ACCESS – Getting completed units from point of manufacture to site is one of the greatest challenges the industry will face. There are 2 aspects to this, firstly the route itself may not allow transportation of large/wide loads, secondly the site itself may not lend itself to delivery of large modular units. To overcome this problem a balanced approach should be sought. For example, using off site volumetric construction in smaller component sizes. This will require additional onsite work but will still offer improvements from traditional construction methods.

36. Assistance from local authorities and Police forces would assist greatly in delivery of large modular units.

37. COST BENEFITS NOT PASSED ON – In any emerging market, a limited number of suppliers can have a tendency to hold on to costs savings and not pass on to the consumer immediately. For example, new suppliers may pass on time benefits whilst holding on to cost benefits and maintaining existing quality levels. It is when a significant period of time has elapsed, when the number of suppliers increases that all benefits are then passed onto the consumer.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

38. Moving site production to a factory based environment requires a shift in attitude and mindset. Even if work is essentially the same, the manner in which works are carried out is very different. For example introducing the production line process and work ethic to a workforce indoctrinated with centuries old site based work practices requires a degree of retraining. It is important to note that within this challenge lies an opportunity. A whole new labour market becomes available for off-site manufacture for those interested in the construction process and skills but not keen on working on a construction site. However recruiting an entire industry from scratch is a massive task within itself.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

39. The key is to start small and build on success. At the moment it is unnecessary to design complex modular structures with high architectural creativity when the industry cannot solve the relatively simple issue of building high quantity low size affordable housing (whether as houses or blocks of flats). Anything is possible and there already exists some excellent examples of complex modular structures across the world.

40. As the offsite sector becomes an established market, experience and expertise will increase. Combine this with technological advances and there should be no doubt that in the not so distant future complex modular structures will be built to satisfy the most ambitious architectural intent.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?
41. **SHARING OF KNOWLEDGE (Government & Educational institutions)** – Offsite manufacture is being used across the world with certain countries ahead in developing technologies. Sharing of knowledge would be a great way to kickstart our industry.

42. Any institutions within the UK currently working on offsite technology research should collectively share and collaborate to ensure that resources are not being wasted. An institutional forum should be set up to encourage this.

43. **DIRECT FUNDING (Government/Local authorities)** – Targeted funding towards private R&D projects would be the most direct way to promote advances in technologies. Perhaps set aside a fund of money and invite various institutions/firms such as the Building Research Establishment to focus on particular aspects of R&D. Applications could then be made for funding of such projects. The findings of reports would then be made available to the industry as a whole. Areas such as automation and artificial intelligence should be key areas of focus.

44. **EDUCATION (Government & Educational Institutions)** – As discussed in earlier parts of this document knowledge and education is key to promoting use of offsite manufacture in construction. Lack of knowledge amongst existing construction professionals may hinder the progress of adopting such technologies therefore encouraging CPD work in this area is essential. Educating the next generation of construction workers is of huge importance and this can be dealt with via school, colleges and universities.

45. **INVOLVEMENT OF MANUFACTURING EXPERTISE (Private firms)** – The construction industry should work with other manufacturing industries such as automobile and aviation industries to learn fundamentals of their knowledge and experiences.

**Government actions**

46. Further research is definitely required into how Government and other stakeholders can assist the industry in identifying the issues and then actions required to resolve them. The current offsite manufacture inquiry is an excellent first step and no doubt certain ‘next steps’ will become apparent from the committee’s findings. Possible actions that should be looked into is,

a) Looking into a designer led investigation to look into how designers can change their work to suit offsite manufacture. Designers are on the first step in the construction process and it is vitally important for them to lead the way in further studies.

b) Standardisation of the various housing association/local authority specification requirements across the country. Currently there exists a wide range of policies, regulations and reports all linked to the design of buildings. This need to be rationalized into a single or few main documents.
c) Look into ways of providing cheap funding to encourage offsite manufacturers to enter the market.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

47. Procurement of affordable housing is a key method of facilitating offsite manufacture. Local Government can implement policy changes in planning, environmental and strategic housing policy to favour offsite manufacture. For examples,
   a) Target dates set in place to achieve certain percentage of units built using offsite technologies.
   b) Key developments undertaken by Government agencies should lead the way by signing up to using offsite manufacture for their own housing developments.
   c) Forming joint ventures with offsite manufacturers to guarantee a fixed number of units over a given period of time.
   d) Stricter eco/environmental requirements that can only be met using offsite manufacture technology.

Submitted by Rajbir Singh Mudhar

26 April 2018
Transcript to be found under Rogers Stirk Harbour and Partners
BSI – Written evidence (OMC0022)

1. BSI (the British Standards Institution) is making this submission as the National Standards Body for the United Kingdom. BSI has a public function in support of the UK economy. We bring together stakeholders (including government, industry and consumers) and facilitate the development of “what good looks like”.

2. Voluntary standards offer a flexible, adaptive and collaborative alternative to regulation by providing common languages, terminologies, guidelines and good practice developed by and for stakeholders. As the UK’s National Standards Body, BSI operates in accordance with an MOU with the UK Government. Our robust standards development process requires open and full consultation with stakeholders to build consensus based outcomes. This gives standards the legitimacy and degree of market acceptance to be used for public policy purposes.

3. Over 95% of BSI’s work is on international and European standards. In its role as the UK National Standards Body, BSI represents UK economic and social interests across the international standards organisations ISO, IEC, CEN, CENELEC and ETSI, providing the infrastructure for over 11,000 experts to work on international, European, national and Publicly Available Specification (PAS) standards development in their chosen fields.

4. BSI, as the UK National Standards Body, has a public interest responsibility to develop and maintain the standards infrastructure to support UK emerging industries at home and internationally.

5. At an international level, activity in off-site manufacture is growing, particularly in China where offsite construction, referred to as “industrialised construction”, is being driven by Government policy. The activity in China is leading directly to the development of international standards. UK industry has an opportunity to lead this development to avoid being left behind and subjected to standards developed by others. It is essential that UK industry extends its knowledge base, shares good practice and agrees standards so it can contribute at an international level and compete on the global stage.

6. BSI would like to respond to the committee questions that are relevant to standards and the use of standards to support government policy in construction.

**Question 1) What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

7. Offsite construction has been shown to deliver key benefits to the industry in terms of safety and speed of delivery\(^1\). However, currently only around 10% [See Farmer, M. (2016). The Farmer Review of the UK Construction Labour Model; KPMG (2016). Smart Construction – How offsite manufacturing can transform our industry; and]
of building projects in the UK are delivered using offsite methods. Key opportunities include;

- speed of delivery, as less time will be needed on site;
- increased accuracy through use of factory/advanced manufacturing techniques;
- higher performance level of elements as design performance is more likely to be delivered;
- less snagging will be required so there will be less cost, less redesign and fewer replacement components;
- increased levels of health & safety, as less time on site, less working at height, etc.

8. For contractors, offsite methods can deliver a higher level of performance; contractors looking to demonstrate certainty in design, sustainability, and whole life performance may choose offsite solutions to achieve maximum design performance from components. Contractors may also endeavour to “raise their game” to compete with the emerging pre-manufactured market.

9. Off-site manufacture could also be a key factor in overcoming some of the skills challenges the industry faces; however, new techniques could mean new skill sets will need to be brought into the industry, for example in product manufacturing and precision design.

10. BSI is currently working with industry on a proposal for new standards around modular housing for the design industry. Industry has identified a need for design team standards in modular housing that can create system agnostic solutions that enables smaller developers to enter the market. Architects are finding it challenging to engage with manufacturers at an early design stage, and having a universal design standard that addresses the key risks in modular delivery (for example, opening up the possibility of having various manufacturers working on one design) will enhance innovation in the industry. BSI is presently gauging support from industry and government departments for this activity.

Question 5) Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

11. Standardization has a clear role to play in driving market development in this area. The Construction Leadership Council (CLC) Roadmap calls for “standardization with choice,” and specifically offsite manufacturing standards.\(^2\) Performance based standards, developed by industry consensus can significantly help to de-risk innovative offsite solutions.

12. The key aim in delivering the benefits of off-site construction is to standardise products, components and processes while still allowing the potential of bespoke design. The Bryden Wood research document Platforms;
Bridging the gap between construction and manufacturing\(^3\), has demonstrated a digital process where a designer seeks to provide an optimum functional and aesthetic solution whilst being cognisant of and adhering to a rule set “Construction Platform”. Platforms are sets of components that interact in very well defined ways to allow a range of products and services to be produced. The term has been appropriated from the software and manufacturing industries, where systems based around Platforms have both supported rapid innovation and formed a basis for exponential growth and value\(^4\).

13. For the industry to be able to benefit from the full potential of Platforms and have a high level of design freedom, interactions between components will need to be standardized. Wider adoption and development of the Platform approach by industry is likely to increase the flexibility within a standardised system and bring about greater flexibility in mass customisation design.

14. Widespread adoption and take up of Platforms will require the development of British Standards including product specifications, test methods, and process standards. Testing and certification will also be needed. One route to Standards output is through fast track PAS Standards development, followed by a longer term roll out of International Standards. A PAS is a BSI document typically developed in emerging areas due to its fast-track process with the potential to provide the base document for full British, European or ISO (international) standards. PAS documents can be funded by industry, trade associations or government departments and are commonly developed with the intention of being global in scope and application.

**Question 8) What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?**

15. Where government is a major client, there is potential to use purchasing power to encourage suppliers to adopt good practice. For example, the Government Construction Strategy in 2011, announced that suppliers tendering for centrally-procured government projects would be required to use fully collaborative 3D Building Information Modelling (BIM); this then led to increased adoption of BIM by industry.

16. BSI was commissioned by the Department for Business, Innovation and Skills (BIS) to develop a suite of consensus standards to define the processes and information management practices underpinning BIM. The resulting suite of BSI BIM standards has collectively achieved over 100,000 downloads, and according to the 2015 government report Digital Built Britain, BIM contributed to construction cost savings of £840 million in 2013/2014.

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\(^3\) [https://www.brydenwood.co.uk/filedownload.php?a=360-5aaf9367d5105](https://www.brydenwood.co.uk/filedownload.php?a=360-5aaf9367d5105)

\(^4\) Brydon Wood, University of Cambridge, *Platforms: Bridging the gap between construction and manufacturing*, 2018
17. Government should consider the opportunity to work with BSI to develop the necessary standards, guidance and tools that enable industry change driven by public procurement policies and practices in offsite construction.

**Background on BSI**

BSI is the UK’s National Standards Body, incorporated by Royal Charter and responsible independently for preparing British Standards and related publications and for coordinating the input of UK experts to European and international standards committees. BSI has over 115 years of experience in serving the interest of a wide range of stakeholders including government, business and society.

BSI represents the UK view on standards in Europe (via the European Standards Organizations CEN and CENELEC) and internationally (via ISO and IEC). BSI has a globally recognized reputation for independence, integrity and innovation ensuring standards are useful, relevant and authoritative.

BSI is responsible for maintaining the integrity of the national standards-making system not only for the benefit of UK industry and society but also to ensure that standards developed by UK experts meet international expectations of open consultation, stakeholder involvement and market relevance.

British Standards and UK implementations of CEN/CENELEC or ISO/IEC standards are all documents defining best practice, established by consensus. Each standard is kept current through a process of maintenance and review whereby it is updated, revised or withdrawn as necessary.

Standards are designed to set out clear and unambiguous provisions and objectives. Although standards are voluntary and separate from legal and regulatory systems, they can be used to support or complement legislation.

Standards are developed when there is a defined market need through consultation with stakeholders and a rigorous development process. National committee members represent their communities in order to develop standards and related documents. They include representatives from a range of bodies, including government, business, consumers, academic institutions, social interests, regulators and trade unions.

25 April 2018
Tuesday 15 May 2018
3.30 pm

Watch the meeting
Members present: Lord Patel (Chairman); Lord Borwick; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.
Evidence Session No. 7 Heard in Public Questions 50 - 56

Examination of witnesses

Suzannah Nichol MBE, Simon Rawlinson and Dr Diana Montgomery.

Q50 **The Chairman:** Good afternoon and thank you very much for coming to help us with this inquiry. We appreciate it very much. For the record, would you like to say who you and who you represent and, if you want to make an opening statement or say a few words, please feel free to do so? This will be broadcast on the parliamentary website.

**Simon Rawlinson:** I am a partner with the consulting business Arcadis, and this afternoon I am representing the Construction Industry Council. The Construction Industry Council represents professional bodies, research bodies and specialist business bodies, encompassing 25,000 advisory firms and 50,000 professionals operating in the construction industry.

As part of the Construction Leadership Council, in introducing my platform of off-site manufacture, I would highlight that the CLC has described off-site manufacture as “smart” construction. We do that because we want to emphasise that there are process elements associated with off-site manufacture, particularly in collaboration, which I will return to when we talk about business models. It is the combination of digital capabilities in the design, the control of manufacture and the manufacture itself. Of course, we do this to deliver certain outcomes, most of which are about increasing capacity and additional capacity in delivering, for example, homes and infrastructure.

**Suzannah Nichol:** I am the chief executive of an organisation called Build UK. The core of our membership is the contracting supply chain and we bring together 27 of the largest contractors in construction, some of which have given evidence over the last few weeks. Our membership includes 40 trade bodies, which represent over 11,000 specialist contractors, which make up that contracting supply chain and about 40% of the construction sector. They are the ones who physically deliver construction out on-site. They may also take a role in designing that and in maintaining it afterwards.
We also have a membership of client organisations; 15 of the biggest developers who procure or buy from that construction supply chain, and professional services that advise either those clients or those contractors. We are in a reasonably unique position to have a broad overview from the delivery side of construction—traditional through to pure off-site and on the manufacturing side at multiple levels. Alongside the CPA and the CIC, we can see the whole picture and ideally piece some of that together as we have no particular vested interest in off-site manufacturing. Hopefully, we can add to your information today rather than perhaps repeat what you have heard over the last few weeks.

Dr Diana Montgomery: I run the Construction Products Association. We represent the manufacturers and distributors of construction products, which is everything from materials that are mined from the ground through to the products used to build buildings, through to the distributors and the builders’ merchants that manage the logistics. We represent about 87% of that sector by value, so we very much speak for the whole sector.

In the same way as Build UK, we have a number of trade associations in our membership—at the last count it was about 35—which means that we have 330,000 people within the umbrella of the organisation and about 23,000 companies. Many of them are very large names that you will have heard of and there are an awful lot of SMEs. Their turnover is about £56 billion. From an off-site manufacturing point of view, we are manufacturers at heart, so we count as manufacturing. Our productivity is aligned to the manufacturing norms rather than construction.

In conversations such as this, we work very closely with the likes of the MTC and others looking at manufacturing processes—Lean, Six Sigma and those sorts of things—and we try to feed that into the rest of the construction supply chain. As Simon has alluded to, I sit on the steering group for the work the CLC does in smarter construction and innovation in buildings, looking at how we get this all moving forward faster.

Q51 The Chairman: Thank you very much indeed. I will kick off the questions.

We have had a lot of both written and oral evidence that says that we need a wider uptake of off-site construction. Everybody seems to be signed up to the idea of greater off-site construction, so the question is: why is it not happening? What are the blocks against it happening? How would a wider uptake affect the industries that you represent?

Dr Diana Montgomery: There is already quite a lot happening. It very much depends on the view you take of off-site manufacturing. We take a very broad view that it is not one particular thing. It is not just pods being craned on or complete units. It can be anything from some really good stuff, such as precast panels going into roads and bridges that improve quality, productivity and so on, through to drainage systems on motorways, through to examples that you have seen in the residential sector of complete door systems, fire doors and so on. A lot is happening where the commercial case is clear. Often that is where it is incredibly
bespoke or incredibly wide-ranging, and it can go towards lots of different solutions.

As you might have heard in the evidence, it is a manufacturing sector that supplies a very cyclical industry, and I have never worked in a sector like it. You have heard all the data about how housing fell 70% in the last recession. It is incredibly problematic for a manufacturing operation to supply into that. Any manufacturing requires capital investment to get your plant off the ground and it needs a sensible payback. If you are looking at a pipeline that looks less than six months out—the national infrastructure plan is the exception—and at short-term deliverables without that longer-term vision, it is really problematic to write a business case and get investment.

We might talk about it later. We are trying to move to a slightly more long-term view for construction, and the national infrastructure plan is certainly helping that, and starting to look at a different business model for construction where other sectors partner with their supply chain. That partnership will be really important if we want to see strides in people investing to improve productivity, safety, quality and so on.

**Suzannah Nichol:** I would support Diana in that there is quite a lot going on. I learned a new word—componentisation—which is where elements are delivered and manufactured rather than whole units. There is a whole blend of what is called off-site manufacturing or pre-manufactured value. Last week I was out on site at Wembley Park and they are doing loads of it. The balconies, for example, were delivered as a unit and just slotted on. The bathroom was delivered as a pod and just fitted in. That is off-site manufacturing.

I had the opportunity to talk with the contractor’s site manager, who said he would love to do more of it. He was very clear about what his next fit would be, but he needed to go back to the design stage for the next one and say, “You need to do this differently”. He would like to bolt the service cupboards together. He could not on this project, but he would be able to do so on the next one.

Where something is assembled probably determines whether it is off-site or not in a manufacturing environment. Various elements can be manufactured off-site somewhere and brought in or a whole unit can be brought in. It is the whole blend.

We also have to bear in mind that a substantial amount of construction work is repair and maintenance. You are about to undergo quite a substantial refurbishment here and you will see that up close and personal over the next few years. People have to think about a completely different process. They are probably not even looking at off-site manufacture, because they see themselves going in to repair and maintain. There is a huge potential. It is not directly applicable to craning things in, but there will be more componentisation.

The question is: why is it not happening at scale and faster? There are two overarching answers. As Diana has mentioned, it has to be commercially viable; no business is going to do something if the business case cannot be made for it. Secondly, the risks are still unknown, not understood, or considered to be too great to take that leap of faith from
what you know to what you do not. It is quite a big step for a business doing a big project. If you get it wrong, you are a bit too deep in and have already made some fundamental decisions.

There are different issues at different levels. You will have heard a lot of them and I will pick up on a few. The clients would have to change fundamentally the way they invest. Their investment decisions involve one supplier or a smaller number of suppliers, which is quite a risk if the market is not mature, and if you invest in one particular area and there is a problem. If you go via the traditional route, you will have lots of other options. Thus there is the risk element.

There is no real incentive for many people. It is not necessarily cheaper. They do not know what the right answer is. There are very few industry standards; you will have heard from Mark Farmer about that. If you buy a kettle, it has a plug that fits into any house. Construction does not quite work like that; there are lots of different ways of installing things, so it is really difficult. There is no right or a wrong answer and there is almost too much choice. It is not standardisation but consistency that we are looking for. For instance, when you go to buy a car, you know in this country that you will drive on the left-hand side of the road, so you buy your car as a right-hand drive. It is quite simple and you do not have to make a choice about that.

The other issue is behaviour. The industry is large. They do not trust each other and do not have those deep relationships with their supply chain. We have to deal with that and build longer-term relationships and a more mature market, so that when you are making decisions you have confidence that the market can deliver all the way through to the end. I will hand over to Simon.

Simon Rawlinson: To enable you to get through the agenda, I will make an observation about the supply chain and in particular about the off-site modular aspect of the industry. In that industry, there are probably no more than six or seven large-scale suppliers in the UK, so from a scale perspective those business have quite a nice business model without exposing themselves to a great amount of investment risk. They are quite profitable, so the incentive for the supply side to expand at the rate, which UK plc is in effect asking them to do, is not there.

Very few of those players have access to substantial institutional funding to be able to go to that next stage of expansion. Organisations have operated at that level for the last 15 or 20 years, so they are comfortable. They are busy enough to be profitable and are asking, “Do we need to expand to maintain our position?”

On the other side, as has been clearly identified, there are no real signals coming out of the marketplace that there is a big prize for them to go for. There is rhetoric about the prize, but it is not necessarily there in front of them. The relationship between the desire to invest and the clarity of the prize needs to be clear to break that cycle.

The Chairman: Thank you very much. We might come back to some of the answers you gave, but let me go to Lord Renfrew first.

Q52 Lord Renfrew of Kaimsthorn: Last week we heard from David Hurcomb
of the NG Bailey group, who rather depressed me by saying that it will be outsiders, probably from the Far East and China, who will take things forward in this country.

Do you think business models in the construction industry here need to change in order for off-site manufacture to become more widely used? If so, how do you think they need to change? How can that change be brought about?

**Simon Rawlinson:** NG Bailey is a specialist contractor, and its position in the way projects are procured and delivered illustrates some of the flaws in the business model that we operate in construction. Typically, an organisation such as NG Bailey, which does most of the detailed design work, and indeed introduces a lot of the off-site manufacture capability—the service cupboards that Suzannah described—is not appointed until the project has been let and the financial programme parameters have been set. There are lots of good reasons for that. Clients quite like to use best-of-breed suppliers, for example—their favourite designers, engineers and contractors. Also, of course, the construction industry relies on competition to demonstrate value. The idea that we are fragmenting the supply chain and the delivery of solutions gets to the heart of the problem.

Three things might change that model. The first is the need to achieve scale—the scale of people asking for the same thing. If NG Bailey is fabricating service cupboards, it wants to be doing it for multiple clients rather than one or two. It has to have access to a wide range of clients hopefully delivering standard projects. The CLC has been developing a concept called a clearing house, where you try to bring demand from multiple clients—that might be Crossrail 2 tunnel segments or Thames Tideway tunnel segments—and bringing those together so that investors have the opportunity to see where they need to build capacity.

The second thing is standardisation, so NG Bailey does not compete with other organisations such as TClarke to deliver different cupboards but they compete on value and on availability.

The final thing is the collaboration model. How do you get clients, designers, contractors and specialists to work together from the start to deliver the best outcome, but one which is demonstrated to deliver value on cost, time and all sorts of elements of performance?

**Suzannah Nichol:** The simple answer to that question is the current way we buy and deliver construction is not sustainable and the business models are not fit for purpose. We have lots of industry reports—if you piled them up, they would be taller than me—that tell us that is the case and give us lots of good and very consistent ways of doing what we need to do. However, everybody holding hands and jumping together has not quite happened yet, and they certainly do not drive or incentivise more manufacturing, more pre-manufacture value or more off-site.

The reason is quite simple: it not easy to change that wholesale, but ultimately that is what needs to happen. In off-site manufacturing there is a bit of a vicious circle. We need change to drive more manufacturing, but we also need more of the wins from manufacturing—better quality,
improved health and safety, better programming—to come out to drive the change. The question is where we break that circle.

Simon has alluded to some of the changes needed, so I will not repeat them, but one is early engagement of the supply chain, and you will have heard that from others. The knowledge is often in the specialist supply chain. It often has a really good solution or answer, but it needs to be brought in early because it impacts on everything else. If it is not, you do not get that prize. You build what you are asked to rather than offer something that could deliver the desired outcome. If your solution is not required, you do not have anywhere else to take it, so you revert back to delivering what your purchaser, client or contractor wants. It stops the innovation, so the business model does not drive that.

You will have seen all the debates about payment, the way the industry values itself and how cash flows do not work for manufacturing. High up-front investment is required in capital and in delivering that product. If you are not paid until that is on site, somebody has to fund that. At the moment the construction commercial model does not fund that, so that is a barrier too.

That is probably enough from me, so I will hand over to you, Diana.

**Dr Diana Montgomery:** One piece is that, because of the model, it is very hard to plan. The supply chain is really bad at planning. With manufacturing we like to set our business plan for the year ahead. We like to know how many panels, bricks or whatever we are going to make. Our supply chain will tell us that they want stuff on the pallet tomorrow for wherever. The ability to long-term plan comes back to collaboration and partnership. Something that other sectors do that construction does not do very well is to form that long-term relationship, so that you can share the pipeline of your own investments with your supply chain.

The other piece that is really unhelpful is if that starts, as the comments about NG Bailey indicate, you absolutely have to involve manufacturing early on to understand what the opportunities and products are. What is very disruptive is when it is value-engineered out. A manufacturer may have spent a lot of time and investment developing a product, or just upscaling it for a particular project, only to find that it has been value-engineered and a copy has been brought in from somewhere else. There is a real partnership piece that will make the difference.

**The Chairman:** Your answers, which are very good, are exciting people to ask more questions. Can I suggest that the answers and the questions are kept brief?

**Lord Vallance of Tummel:** We find it difficult to ask brief questions generally, but we will do the best we can. I still do not quite understand this market. Dr Montgomery, you said that there are things happening at two extremes. One is at the bespoke big end in one-off projects and the other is at the repetitive end, which is largely a matter of capacity. In housing, you have a few big players and an absolute multiplicity of small players. The big players like the status quo, because they make money out it and there is no need to move from it.

I am looking for where the disruption comes from. Does it come from the
SMEs? If so, how it is done? Is there some kind of intermediate organisation of scale that does large integrated manufacturing stuff but can also provide architecture, design and engineering? Is there a service company that could service a whole host of SMEs? Is that the sort of thing that might break it?

**Dr Diana Montgomery:** It is a tricky one for housing. For off-site manufacture, it would be additional to the volumes that we have at the moment in traditional build. A lot of our manufacturer members tend to invest in components and creating systems.

I am not sure whether you will get one integrator. You have heard evidence from some of those who are starting to do it. The private rental sector clearly has a longer-term objective. When we start to measure the whole-life value of a project, we start to get the ability to invest in more than just the initial building. I think Simon is dying to say something.

**Simon Rawlinson:** An example of a disrupter that you might be interested in is Coterra in the United States, which you might have come across. It was recently funded with $850 million from SoftBank, which is the large disruptive tech investor. Its model is interesting, because it can disrupt a housebuilding industry that is much simpler than the one we have in the UK, which is based on on-site assembly of timber components. It has brought in an entire manufacturing process to deliver that end to end.

The question is whether there are clients in the UK who might be able to create the volume in the right form—in other words, volume that is consistent and needs to be delivered quickly—to justify that level of up-front investment. I observe that there are probably large programmes, such as HS2, which might encourage people to invest in certain capacity involving repeat components such as trackbed, and there are large housing clients, such as some of the large RSLs, which are now moving to the scale of national housebuilders, which again might be interested in pooling that kind of demand.

**Suzannah Nichol:** To finish off, it comes down to commercial viability, and you are right: why you would change? I have three very quick examples. One of our members delivers a complete house to site. For a traditional housing project, one of our other contractors has set up a unit. Some of the houses will be traditionally built, as you can visualise. For others they will prepare a plot and put in services. The ground floor and first floor of the house arrive on the back of a lorry and the house is plug and play. You literally plug it in. Looking at the houses alongside each other, you would not be able to tell the difference from the outside. They are on sale now and the contractor estimates delivering about 2,000 units over the next year. There is a clear example of where that is being done. They are manufactured up in the north, so the contractor is providing jobs up there. The house literally goes through a process and comes out the other end. That is available now.

Other big housing suppliers are now investing in off-site facilities themselves. A large private housebuilder is doing that now. I think you will see more of that. There is the example that I talked about out on-site at Wembley. Those units are all PRS accommodation units, so an element
of manufacture is going in there rather than the complete unit. There are pockets of it happening. It is how we make that more commercially viable and accelerate that so that it is delivered at the scale that Simon talked about.

Q53 Lord Hunt of Chesterton: Simon Rawlinson, you work in a company with a lot of activities worldwide. Could you comment on the differences or benefits, comparing what the UK does and other countries? We heard in previous sessions that there seem to be ways of moving ahead faster on the continent than there are here.

Simon Rawlinson: I have done a specific study that has compared Japan and Germany. The first thing to say is that the overall value of the off-site manufacturing elements in the housing sectors in Japan and Germany is not necessarily that much larger. What is different is the percentage of manufactured value in those projects, particularly in Japan. Japan has this rather strange market where the land has all the value and the house is seen as a product that has a defined life cycle of no more than 25 years, so a house is more like a car and, indeed, is delivered by the kinds of corporations that we would be familiar with as being car manufacturers in the UK. That does not mean that they have the capacity of Toyota, for example, to deliver millions of cars, but they have the capacity to deliver an end-to-end integrated product that meets that market need because that is what people want.

In Germany, the market is completely different. It is a very regional market that works in a similar way to the way off-site manufacture works in the UK. Therefore, people do not have to invest a huge amount of capital, because they are only serving a market with a radius of 200 or 300 miles. However, they know that they have lots of customers, because a lot of it is self-build; people are buying a kit product that they are comfortable with. That is culturally embedded in the way Europe buys its houses.

We do not have that relationship between the house purchaser and what you might describe as the delivery organisation that designs and fabricates. We have intermediaries called housebuilders, and their preference is for delivering things in a different way. That is how we have got to the situation that we find ourselves in, which, as Diana rightly says, is looking at off-site to deliver additionality rather than necessarily the mainstream delivery of offices or houses, for example.

Lord Griffiths of Fforestfach: May I play devil’s advocate? From what I have heard, the business model and market structure of the construction industry, which is very divided and full of small-scale operations and so on, is also an industry that was hammered by the financial crisis, so there is a lack of capital in it. If you want a company to be an integrator, the essential condition is that it must have capital. The City of London was once divided into small, almost family businesses that have grown up as stockbrokers—Jarvis and so on. What happened was that foreign banks—American, Japanese, Swiss, continental European—came in in a major way. They brought capital and the whole structure changed.

I cannot see how in the UK, going back to Lord Renfrew’s point, there is an integrator—short of the Government, and I do not think we are looking
for that as the integrator—that could do it. As Lord Renfrew has already mentioned, that means that we are looking at China or some Far East company.

My question at the end is: can we ever have a restructuring of the construction industry in Britain without a major transfer of capital from east to west? I cannot see how we can do it by ourselves, because there is no evidence, frankly, that you can show me. If I may say so, all the evidence you are talking about is a little thing in Watford and a little thing somewhere else, which is wonderful, but in the end there is no vision for transforming the industry here.

**Simon Rawlinson:** A vision for transforming the entire industry is very difficult by reason of the fragmentation that you mention, but there are segments and sectors of the industry that are building quite clear visions of how they might do that. While I do not want to use this as the on-site reference, you should be aware of the transforming infrastructure performance strategy and the transport infrastructure efficiency strategy, which both focus on creating volume in demand to unlock the investment you describe.

We know that the UK is very good at attracting and applying capital investment, and it generally does that again by responding to pooled demand. I would not be surprised if we found ourselves at some point with decent scaled manufacturing capability aligned to the construction industry, but it needs to have a demand signal to encourage that investment through. One example of that, and I cannot name the RSL that prompted it, has signed a 5,000-unit deal with a Chinese off-site manufacturing provider to deliver those over, I think, five years, which is equivalent to a $5 billion investment in cash terms, so it can be done. The only way is if we start to pool demand, and that will start to unleash the opportunity to invest.

**Suzannah Nichol:** I always find the devil’s advocate questions the most interesting and exciting, so thank you very much. It is amazing that, despite the industry, we have we deliver some fantastic projects. You only have to look out of the window here. I cycled here and came past the Thames Tideway project. We deliver fantastic stuff despite the system, I often say, rather than because of it.

One of our challenges is that the disrupter has not happened in a way that has dramatically changed how the industry performs, behaves and builds. There are 230,000 different companies. About 90% of them have fewer than 10 employees, so the industry is built on SMEs. It wants to transform itself, and everybody would like that, but the client base is very individual.

You could say that about other sectors. We go in individually to buy our weekly shop, yet that sector seems to have delivered a different offering. Do not forget that the public sector is 40% of our client base. While there are individual clients within that 40%, you have that opportunity to make some fundamental decisions as the public sector to buy at scale, and to have some consistency of demand, design and delivery.

You could have a major impact on our schools or prisons programmes, or on a lot of homes, by pooling that demand and being really clear about
Build UK, Construction Industry Council (CIC) and Construction Products Association – Oral evidence (QQ 50-56)

the ask; otherwise the industry will continue to deliver amazing projects, and we will have to nudge it, pull it and drive it to be better, because there is a prize for everybody, but there is also a cost.

Q54 **Lord Kakkar:** To build on that, we wanted to explore how companies in this sector might be encouraged to collaborate more. If I have understood your answers so far, which have covered much of this ground, companies have to be pushed into collaboration, and that may be through government action and procurement. Are there other measures? For instance, could there be measures with regard to favourable tax treatment? Would that be acceptable in this industry? Would it put huge pressure on the already established broad range of small and medium-sized enterprises and undermine their ability to deliver? How should the industry itself encourage coming together and collaborating on this?

**Dr Diana Montgomery:** It is about procurement first and foremost. Government is an enormous procurer. Infrastructure is starting to get there. Simon mentioned the TIP programme. The Infrastructure Client Group, which is where the major infrastructure clients work collaboratively to understand best practice, has produced Project 13, which was launched last week or the week before. That starts to explore the procurement model and how that is best done, and it will start to give scale and programming.

The other thing that is very difficult for the UK manufacturing market is the fact that 80% of the products that we use here are made here. We do not import a lot, and we cannot as they are heavy and full of air, but the last thing we can afford to do is have a national infrastructure plan to try to procure all their projects within a 12-month period, because we physically could not deliver it. We do not have the plant, the people or the capacity to do so. Procurement is enormous. The Government have a balanced scorecard. If they used it, it would allow us to have a better view of real value when it comes to cost, quality and environmental impact. There is a piece about using the balanced scorecard that they have committed to.

There is a leadership challenge for the sector. You will hear from Andy Wolstenholme in a bit. There is an opportunity for the Construction Leadership Council to step up and take on that leadership piece. Certainly the chief executives around the board tables of my member companies need to feel that now is the time they can step up.

Construction is also driven by regulation. We need to be very clear and consistent. Policy changes are unhelpful. We could mention the zero carbon homes target, which changes quite frequently, and we might be about to see another one. We can innovate and deliver quality products, but you need to give us a long-term objective so that we can work to that. A consistent policy and a regulatory framework are really helpful.

**Lord Kakkar:** Does that include planning? Can the planning system change to force this type of approach?

**Dr Diana Montgomery:** From my point of view, planning is not the issue that we are talking about today. There is a whole host of other issues to do with planning, but that is not stopping collaborative partnership in
delivering the building and running the building. That, I think, is the piece.

**Suzannah Nichol:** Planning has a role to play as one of the levers. In answer to the very specific question, we have a big role to play here. Industry bodies have often worked in one direction for their members, and we need to show some real leadership and say, "Stop talking about this. If we really want the revolution to happen, if you want a better industry and this is the prize, this is the direction we need to go in”.

**Lord Kakkar:** How will that happen?

**Suzannah Nichol:** It is starting to happen. There is the fact that the three of us are sitting here and know what we are good at and we work between us. The construction sector deal is a real demonstration of the whole industry coming together. You will start to see our business plans aligned behind that sector deal and delivering the outcomes in that. We have the industrial strategy challenge fund, and we will certainly say to all our members, “Stop doing R&D on tiny scales individually. This is where the action is. If we are going to do some R&D, we do it together and we benefit collectively and collaboratively from the outcomes”.

It is about us showing leadership. It is no longer about nice things to do and guidance and information. It is about saying, “If you want a transformed industry, if you want a business in the future, this is where we are heading”, and enough of them following. The industry is really good at responding in a crisis. We have seen that over the last 12 months. There is a catalyst for change and it has the opportunity. It needs that direction and leadership.

**Simon Rawlinson:** I would make a very quick observation about the unintended consequences of things we do with the best of intentions. One example is frameworks. We establish frameworks, and quite often that constrains the kinds of answers the industry gives to you. If you have a framework that encourages people to design things before they buy and manufacture them, you get answers that are based on people first designing and then bidding. Designing frameworks to bring off-site manufacture to the front of the thinking and the front of the procurement would be a positive act which clients and their advisers—lawyers, and cost consultants such as my organisation—can do to move things forward.

**Lord Mair:** In a sense, I am jumping to the last question, but it is very relevant.

**The Chairman:** Take your question now.

Q55 **Lord Mair:** What you said about collaboration, new models and new ways of doing things makes perfect sense, but the real challenge is how you persuade clients—not necessarily government but probably government, too—who are thinking about a new piece of infrastructure to take on board everything you have been saying? We can say all these things about the importance of collaboration, and the excellent work done by the CLC is pointing the way forward, but if you are a client setting out with a new piece of infrastructure in mind, how are you persuaded?
Simon Rawlinson: Can I use an example of work that we are doing as an organisation? We are a consulting organisation and we have teamed up with one or two specialist off-site manufacturers. Before you get into a procurement activity, you try to demonstrate that it can be done and that the solution relates directly to that client’s particular needs. You give people the confidence so that they see the solution right from the start, they see that it meets their needs and they start to understand the kinds of constraints and decisions that they need to make.

A problem that the industry has at times is that it is a little like a Russian doll; you take one stage and the next stage and the next stage, and you never get the answer right from the start. Helping clients to understand the full implications and see what it looks like at an early stage makes a great difference.

Suzannah Nichol: To reinforce that—and I will never forget Sir Michael Latham who said, “Everyone must have prizes”—this has to be a win for the client. We need to be better and clearer about what the win is and what it is not if you do not go down that route. You get to the point of saying, “Why wouldn’t you do it this way?” If you want to know where to go somewhere in a London street, you do not get your A to Z out, you get your phone out. We have to move from where we are with the A to Z to getting your maps out on your phone, and the client seeing that as automatic: “Why wouldn’t I do it that way? Why am I still doing it this way?”

Lord Mair: Are you saying that it is only the uninformed clients who are not adopting off-site manufacture?

Suzannah Nichol: No. We have not quite ticked the risky bit. I was with a very educated client last week who was talking about explaining the risk to his investors, because the client is only one part in the chain. He was going from something he knows and that he understands may have problems, although they are problems that he knows, to a leap to here. There is not enough of a win at the moment. Nobody has quite felt that win enough to say, “Oh, you are still doing it the old way”. That is the bit we keep talking about, but we are not able to nudge enough people into saying, “Why wouldn’t you do it this way?”

Coming back to the homes that I talked about that are delivered on site, you need a few people to say, “I waited 10 weeks for my home and it’s fantastic”. Why would you go down the traditional route and wait for three, four or five months for a home which then has lots of problems with it when you could have one in 10 weeks? You could get married, order your house, go on honeymoon, come back and your house is waiting for you. What is not to like about that?

Lord Mair: I come back to the point about housing, which is fully understood. How do you think infrastructure differs from buildings, and from housing in particular?

Dr Diana Montgomery: It does, but in some ways infrastructure is the more developed. A lot of infrastructure is already done off-site, and with projects such as HS2 and the Thames Tideway we have certainly seen that the opportunities to manufacture off-site and bring it on-site hugely
minimise the impact on the local communities and on the project as a whole.

Infrastructure is leading in off-site manufacturing. It is perhaps not the image that is seen of it, but a lot of it is done. One of the pieces that we have been working on through the work of the CLC group on this is making sure that we have shared metrics so that we all understand that we are talking about the same things when it comes to productivity, safety and quality. It is about making sure that all the projects share that information, so if you are a client starting to think of a project and you start to see that, why would you not go there and understand those metrics?

Infrastructure is the star at the moment, but having said that it is about sharing common metrics and the old adage that what gets measured gets done. It is about measuring and finding common languages in order to understand the success of a project, not just at the point of construction but, most importantly for me, through the life cycle of the project. At the moment, we are not very good at measuring the whole life cycle.

**Q56 Lord Hunt of Chesterton:** What types of skills are needed to facilitate a move to off-site manufacture? How do those differ from traditional construction skills? What is the difference between what we are doing in the UK and what they are doing on the continent in particular? You have given us a little about what happens in Germany. How is the training different between here and on the continent? Can we learn something more?

**Simon Rawlinson:** I will not be able to answer specifically the question about the professional training process on the continent, but I will make two observations. The first is about the role of the professions in the UK and, to some extent, clients. There is a really important role in upskilling the gatekeepers, the people who have the first contact with the client, whether that is a lawyer or a consultant, who shapes their thinking at the early stages, even if that is just to keep the option open, the thinking alive, so when that client meets an inspirational contractor, for example, they are receptive to somebody coming up with an innovative idea that says, "We could do it this way". The industry too often closes options down because people like to lead with their own solutions. We tend to be solution-driven organisations rather than an outcome-driven industry. That would be my particular ask on skills.

If I were to reflect on another difference between the UK and continental Europe, and reflecting on many of the organisations that deliver particularly large-scale infrastructure, the Vincis and Hochtiefs of this world, typically they own and operate these assets, so it is in their interests to be able to maximise value throughout the entire life cycle. That gives them a very different perspective on how they specify and design these things.

**Lord Hunt of Chesterton:** Do the UK Government impress upon people that they should look to see what is happening elsewhere?

**Simon Rawlinson:** The IPA did a great piece of work in 2010 that looked at a whole lot of expertise from around the world in relation to how we
could improve value in the delivery of infrastructure. A lot of those lessons were learned. We need to reflect on the fact that there are certain constraints on the way that we operate infrastructure. We do not run highways on tolls, for example, so we do not have the same ownership interest that Vinci might have in France. There is quite a lot of openness and interchange between what is done in Europe and the UK simply on the basis of co-ownership of many of the contracting and engineering and consulting organisations that operate in this market.

Lord Vallance of Tummel: There seems to be a lack of marketing and sales. If you are going to get clients to buy into this, you need good marketing and good sales. There is a good sales pitch there if you can put it across. Where would the marketing and sales be located in the supply chain? Would they be the ones that get the benefit from it?

Dr Diana Montgomery: It is a really interesting question. I guess I would think: are we trying to sell off-site manufacturing or are we just trying to sell improvements in productivity? This goes back to the CLC saying that we need smarter construction. It is not just about off-site; it is also about doing stuff on-site better—using robotics, GPS and drones.

It is the whole gamut, and certainly it is about digitising the sector. We must be one of the last sectors to digitise. We now have BIM level 2 mandated by government. That really moved things on, but it is how we continue to move that through. That will start to integrate the supply chain. If you have a fully BIM-functional project right from design and inception, lots of benefits and payoffs—payment, lack of substitution, being able to manage that whole product—will be in improving productivity. There is not one component in the supply chain that will become the salesperson for the whole thing.

As you start to move to that more integrated model, which will be driven by digitisation and the need to improve productivity, because, ultimately, we do not have the people or capital to do it as unproductively as we are, you will then, effectively, start to get your own salesmen.

Having said that, and this goes back to Lord Mair’s question about infrastructure, infrastructure such as the Thames Tideway, Crossrail and, indeed, the Olympics are real exemplars of the industry integrating and delivering something that is substantially better than it would have been by any other means. We have good examples. We just need to be better at talking about them and moving on to the next one.

Lord Vallance of Tummel: Can I follow that up a little more? The Olympics were a complete one-off for all sorts of reasons. I am still back to this business of how you convert the clients. One of the problems is how you get them on board. Somebody has to be responsible for that. I am still back to: who does it?

Simon Rawlinson: Going back, I suppose, to the first point of engagement, typically we influence and shape how we might do things either through a project manager or an architect. You could say that they are often the best advertisers and marketers in the industry, because they are very good at communicating images and great outcomes. There is then the issue of aligning the interests of that designer with that solution. You have met one or two businesses that are very good at that
and which have differentiated themselves by being able to show that they are aligned to a new way of working. We will start to see greater recognition that delivering on a product basis greater quality has inherent value.

One thing that I continually reflect on, if one compares where we are now to, say, 20 years ago, is that probably the things of greatest quality that we see in our lives are the iPhones that we carry, the beautiful computers that we have and the watches. We are now in a productised world and we probably need to celebrate that more in an architectural and building world. That would send a very positive message.

**Suzannah Nichol:** Off-site may not always be the answer. Our client members tell us that they want buildings that work as anticipated, and that are delivered to a high standard and to the required quality and in accordance with the agreed costs in the programme. Off-site manufacture is often a solution to part of that, but it is not necessarily the only answer. It is not about saying to clients, “This is the only answer”. It is about the industry saying, “There has to be a smarter way of delivering it”.

It is a bit like in many other industries. People often use the car industry as an example. We do not make cars one by one. We used to do that and it did not go very well. It is about the industry saying, “This is what we offer”, not asking, “What do you want?”, so part of it is about the industry taking responsibility. It is not just selling to clients that it is the best thing on offer.

Again, I would liken it to when you buy something. You do not specify what tin of baked beans you want. There are beans on offer and you choose which works best for you. It is to the required standard, it has met quality specifications and there is a system to buy it. You do not have them handmade every time. The industry needs to take a look at itself and say, “How do we offer something that is smarter?” It comes back to breaking the circle and which comes first: buying it or providing it?

**Lord Hunt of Chesterton:** Perhaps you have covered this before—Lord Mair mentioned it—but I still do not quite understand the role of the Government. When there is a new project such as a prison or whatever, do the Government say, “We want to have a certain percentage of this produced by off-site manufacturing”? In what way are government agencies, and which government agencies, demanding higher standards and efficiencies? Which Ministry does it—it is not the Building Research Establishment—or do these objectives come down from each government department as they are building each little thing?

**Dr Diana Montgomery:** A number of government departments have a presumption in favour of off-site manufacturing, so for schools and hospitals that presumption is there.

**Lord Hunt of Chesterton:** What does that mean? What is the percentage outcome on that?

**Dr Diana Montgomery:** That is a very good question. There is what is called a presumption in favour and there is a balanced scorecard by which things are supposed to be procured, but there is a big gulf between what is said and what is done.
Lord Hunt of Chesterton: What is the number in terms of output?

Simon Rawlinson: The criteria are subject to a value-for-money measure and are not applied until 2019, so there is an element of the departments building up the skills to be able to do this.

Lord Hunt of Chesterton: We heard a lot about prisons before, but we never got a number.

Simon Rawlinson: I do not think anybody has said so.

Suzannah Nichol: I am fairly certain that the GLA does it, but you would need to go back and speak to Mark Farmer, as he may he have raised it. A simple example would be the same roofing contractor delivering three different roofs on three hospitals, all procured by the public sector. He would sit here and say, “You want me to look at manufacturing that in a different way, perhaps off-site or through more components. You want me to get better at delivering that, but each hospital has a completely different design and a completely different roof”. You talked about skills. We are doing a different job three times, whereas if it had been some kind of off-site or specified solution, by the time of doing the third one we would be rocking and rolling through delivering that. Instead, it is a whole new game for everybody out on site.

Lord Hunt of Chesterton: What do the Government say while this is happening? Are they monitoring this process or saying, “My goodness me, why don’t you work together”?

Simon Rawlinson: That illustrates a great challenge, because we know that health trusts are devolved, so the ability of, say, the Department of Health to influence compared to the ability of the Ministry of Justice, which directly builds prisons, is a little limited. Those are some of the challenges which the government clients face. They also have to percolate these skills down into their organisations.

The Chairman: Who do you suggest might do this?

Simon Rawlinson: To start with, you have the Treasury and the IPA.

The Chairman: No, who do you suggest should do this?

Simon Rawlinson: There are three groups of client. I would have the government public sector using the equivalent of the mandate for the BIM level 2, which is: “We’re going to test people against whether they have bought a certain level of off-site manufacture”. I would want the city authorities to start getting the people who operate within their regions, housing organisations for example, to start pooling their work, and you would want to see the large house builders in the quasi-public sector, particularly the RSLs, start doing that.

Lord Kakkar: Is not the problem that in the public sector if you are building the same building, say a hospital, in three different locations, you will have three different roofs. What would you say to a Government about kick-starting this and giving it huge impetus?

Simon Rawlinson: The first element is that you standardise what you can. There is a very good example from ProCure22, I think it was, where the contractors came together and developed a standard ward unit, so
rather than having lots of hospitals with lots of different wards they all had the same one, and everybody could start to minimise their design effort. It might still be built in situ, but it was a common component. You can do those. You might not be able to do the roof the same because of planning constraints. You need to find the things that are common and focus on those.

**The Chairman:** Why do you not say straight out that you would like all government procurement to be off-site construction?

**Simon Rawlinson:** Because the result might be the law of unintended consequences; you get suboptimal results, there is not enough capacity, or you get the wrong product. You want people to specify intelligently. Some of the evidence that you have been provided with on platform-based design and delivery, where people bring components together, which creates flexibility and ability to scale quickly, would be a more intelligent approach, rather than saying, “We want everything to be done off-site”. You need that blend. It is about an intelligent response from clients, consultants, contractors and specialists to improve productivity and the quality of outcomes. That is really what we are about.

**Suzannah Nichol:** There is also a very clear role for the industry here. We have the opportunity through things such as the industrial strategy challenge fund and use of the Manufacturing Technology Centre. A really good outcome is not just about specification. Specification is a big part of it, but I completely agree about unintended consequences. We did a lot on the schools programme, where we had more consistent schools. However, that falls away when different people are allowed to ask for it. You can have individual schools no longer having to follow those requirements.

The industry needs to be stronger and stand up and say, “This is a better outcome for you. This is the right answer to your question. This is what a good school looks like”, and finding a way of not stifling innovation but delivering really good outcomes. That is really difficult when the client says, “I don’t want that. I want my school to be individual to me or to my local area”, even if it is not the right decision.

**Lord Mair:** We are focusing on the phrase “presumption in favour of”. When the Government say to five government departments, “There will be a presumption in favour of”, there is a caveat attached to that, is there not?

**The Chairman:** Dr Montgomery, you have used that phrase.

**Dr Diana Montgomery:** I was merely quoting. This comes back to needing to do what is said. The best example, which we have talked about several times, is mandating BIM level 2, and that means that all projects have started to move toward BIM in both the public and the private sectors. The Government have the ability, by saying that they have a presumption in favour of off-site and will use a balanced scorecard to procure, to start procuring against whole life to procure better-quality buildings. As Simon said, it is not about prescribing that it has to be completely modular off-site, it is about defining, and the balanced scorecard does that very well in defining what good value, highly
productive, safe, lower-carbon buildings look like and allowing the industry to innovate to deliver that. BIM is the best example.

The next piece is taking the balanced scorecard and the presumption in favour of off-site, and I would rather it was called smarter construction than off-site construction, because that starts building all the technology, and asking government departments to report about how they are procuring against that. It is the old adage of what gets measured gets done.

**The Chairman:** Thank you very much indeed. I have let you go a little longer than I should have. Thank you very much all three of you for coming to help us.
Background:
I’m an architect with over thirty years’ experience designing all types of social housing projects. My architectural practice has always been at the forefront of innovation and I have won many design awards. We were the first practice to use Construction Management & Cost Plus procurement in delivering Centrepoint’s first rough sleepers hostel, using a fast track delivery method in the 90s for the Housing Corporation. We designed the first BREEAM rated Excellent housing scheme with low annual running costs of £170 in the 90s and we designed London’s first sedum roof social housing scheme. The first scheme to use the term ‘Modular building’ was attributed to our project in June 2000 (see press release below).

I sit on the development sub-committee of a medium sized London Housing Association, advising on scheme layouts, design and innovative construction solutions. This HA won the 2015 National Housing Awards for their project in LB Walthamstow and it also received the overall award for the best regeneration project. In LB Hackney the HA commissioned the tallest housing project in the UK using Cross Laminated Timber manufactured offsite. The project, now completed, has been featured in many press articles and mentioned at national housing conferences and exhibitions.

Having studied under Walter Segal, my architectural practice was involved in an advisory role on two housing co-op schemes in the 90s in Lewisham, using the Segal methods and working with self-build groups. Experience gained from that project and also from my initial training with the largest volume house builders ‘Wimpey’s’ & The Property Services Agency confirmed my belief that building costs can be driven down by adopting standardised solutions similar to other industries. The construction industry is the last to integrate automated methods into the delivery process. This makes it difficult for innovative solutions to be accepted within the sectors, due to a current negative, risk-averse and never been tried and tested attitude. Large construction companies influence key decision makers not to take on untried and untested risks for their own benefits.
Recent Competition:
We used our concept for our new garden FlexiVillage with offsite methods, delivered at high volume. The scheme won the readers' vote and the award for The Sunday Times 2017 'Green & Pleasant Homes Design Competition' (Logo 1). Our winning 3D image was used to launch the 2018 Sunday Times competition (Logo 2).

Innovative Building System:
Following the release of the Egan report 'Rethinking Construction' in 1988 and incorporating my many years of experience, I have been seeking alternative solutions which address how the industry can deliver buildings across all sectors more quickly, sustainably and efficiently, using standardised components. The later release of the Farmer report 'Modernise or Die' in 2016 highlights this problem further. There are still so many restrictions and barriers that I have come up against over the past decade from within the construction sector. I have found that decision makers will not accept different manufacturing techniques and delivery approaches in supplying buildings, despite our TV coverage and press articles.

This patented offsite building system is a British invention. It uses the world’s only three-dimensional, post-tension, versatile flat-pack panelised cassettes, conceived using mass-production manufacturing techniques. The similar cassette panels are used to form walls, floors, ceilings and roof. They are all connected by a common structural three-dimensional locking lug, making this construction method unique and innovative.

Our first investor was Sir William Francis, former president of the ICE. "He said that we are on to a winner and we will face severe reluctance in bringing this solution into the construction industry, because it is disruptive”.

Delivery Solution:
Over a long period, we have been gearing up and working towards being able to meet the challenge of delivering housing simply, quickly and at scale. Once the delivery process has been accepted this can be upscaled for mass production. This process will drive down costs for the benefit of clients and consumers.

Buildecos integrated delivery chain starts from the manufacturing of the panels through design and assembly to client handover of the completed project. The team consists of the manufacturing plant, the construction team and professionals from all disciplines, Architects, Structural engineers, MEP, Sustainable management and Project Managers. Projects are erected by system assemblers and completed by trained, semi-skilled labour force teams. We
estimate that each fully automated factory, once up and running, can produce at full capacity 10,000 housing units a year.

The innovative approach and delivery solution of Buildeco is focused on how buildings are assembled using standardised components, sustainable materials, reduction in material waste, reduction in the use of wet trades and the best quality materials specified for its longevity. With our integrated supply chain partners, we offer a streamlined service from inception to handover, through efficiency and the use of a common software solution, for which we have already received a £5K grant from Innovate UK.

**Opportunities:**
Transforming Construction Challenge Competition run by Innovate UK.

Having viewed the recent webinar seminar from Innovate UK and their competition launch details of £170M funding, to support the challenges in transforming construction, aimed at appointing one lead company.

The slide below was extracted from the Innovation UK competition launch presentation. It was promoting innovation within the sector and it highlighted the SPECIFIC IKC active classroom as a leading exemplar project.

**How we power buildings**

SPECIFIC IKC have developed a number of technologies that be incorporated directly into a building to allow it to generate, store and share energy (heat and electricity).

The integration of these different technologies into a building system has been demonstrated.
Photos above of the assembly of the active classroom, which used our manufactured product and assembly team.

The SPECIFIC IKC active classroom with a floor area of 210m², was assembled in 16 man days by four men, to complete the building envelope using the flat pack system. This demonstrates the efficiency and speed of the system.

**Barriers:**
We have previously made a number of applications for innovative funding in the past and submitted various calls for papers without success, as we differ from the norm, even though this is a new and growing sector with limited companies, able to supply offsite in great volume.

Government Press Release headlines below as issued on 13/12/2017:

Communities secretary says government wants to learn how to deliver NIMBY-friendly homes.

"The government will hold a conference next spring on how to improve the design quality of homes. Javid also said he wanted to see more local firms get involved with the planned house-building boom".

I posted my response to this press release (see below) and responded to a call for information on innovative solutions:

"As an architect, I’ve been trying for a decade to bring to government and their agencies attention this British invention which is disruptive. It’s the world’s only 3D building system, designed to deliver buildings utilising mass production techniques. We estimate that with the right investment Buildeco’s supply chain can deliver in excess of 10,000 homes a year in any architectural style. We will wait and see if we are invited to present at the conference". As Sajid Javid says ‘they will look at best practice from across the country and from around the world’.
Unfortunately, the conference took place on the 25th April without me receiving an invitation to attend or participate. This confirms my belief that we have blockers within the industry that still do not fully understand new advances in innovative solutions, even though we have been developing this British invention for over a decade and we have completed a small number of buildings to demonstrate this.

**Suggested Solution in addressing the Housing Shortage:**
Encouragement is required from government to trust and support small and medium sized offsite companies to compete for new commissions and not to rely on answers from the large companies. Where possible, a portion of larger sites should be allocated, enabling participation from others within this sector. An alternative approach must be encouraged through changes in the introduction of new procurement methods that include offsite SMEs. Unnecessary red tape should be removed that restricts SMEs from competing for projects, as this benefits larger companies if SMEs are excluded. Currently offsite provides a maximum of 20,000 units annually and the target is 300,000 new homes annually. However, the UK only built 110,000 units last year, so the shortfall of 190,000 is a big problem.

**Summary:**
We have developed a building system that is the most sustainable. It addresses many sectors within the construction industry, as it will drive down costs through mass production solutions and so it will be competitive. This 3D building system has many advantages: one tool is used to assemble the building, it is low tech and it is very simple to erect, using male or female semi-skilled, trained labour teams.

Past experience highlights ‘fear of the unknown’ by officials in recommending disruptive solutions.

*Author: Audley English RIBA, AA Dipl.*

*26 April 2018*
Building Alliance – Written evidence (OMC0033)

The masonry industry is recovering from the largest and deepest recession in living memory. In 2008 new homes starts fell from 180000 to 80000 over night with a massive loss of production capacity and 400000 people leaving the industry in just one year.

As the leader of the “Get Britain Building” campaign we have led the economic recovery. It is a fact that for every £1 invested in new homes our economy enjoys a £2.84 return. That is because we make it here and the multiplier effect of real manufacturing as opposed to assembly is of great economic and social value to the country.

We are currently witnessing Government sponsored market interference on an unprecedented scale. That is supported by significant tax payer’s subsidies and “Homes England” funding is now being limited to projects that feature modular or off-site construction. This practice is anti-competitive and unfair to the British Masonry Industry.

The Government is not qualified in such matters and should remain material and system neutral, but instead seems to want to adopt the role of Principal Designer, a role future Governments might come to regret if we experience more disasters such as the tragic events of Grenfell.

This action by Government, is in support of materials and systems that are almost exclusively imported and will undermine investment in British Manufactured masonry products that are preferred by consumers, cost some 15% less, are non-combustible and flexible and are built to last 150 years.

It is important to note the following

- We cannot grow structural timber in the UK so 100% is imported, much of it coming from Russia
- Lightweight steel is also likely to be imported due to a massive excess in world capacity, created by China who produced 800 million tonnes in 2016 against less than 8 million produced in the UK. We are no longer a significant player in the commodity steel market and exist only on added value products.
- Currently we make 80% of the product that is used to build new homes in the UK,
- Any change will be substitutional, in Scotland the masonry industry has been all but wiped out and replaced by imported timber frame kits.
- There is no evidence to support the business case for such a move and the outcomes will be homes built to last just 60 years.
- British manufacturers are already subject to some of the highest energy costs in the world. This action in taking public money to support imports is extremely unfair and unwise.
- In 2010 the “Homes and Community Agency” scrapped its incentives for off site as it was driving lightweight timber frame construction, that is more likely to overheat in the future leading to health issues and premature death as the ageing population increases.
Masonry construction is tried and tested and results in hundreds of thousands of downstream jobs which will be lost because of this action.

It is incredulous that the Government shows no interest in supporting and developing one of our last great manufacturing sectors as we head to Brexit. Instead we are investing public money and time to directly encourage a move to imported off-site building solutions that will significantly increase the fire risk to an ageing population and offer poor quality housing for future generations.

It seems that we are happy to ignore the many mistakes and learning from the recent past where the same off-site solutions have under-performed. The use of Government incentives to promote imports is to the detriment of our economy and its citizens. The voice of the masonry industry is not being listened to and the people that work in the industry are being subjected to very unfair and unwise interventions.

**What are the opportunities offered by offsite manufacture for construction?**

The use of offsite components such as precast concrete in some high-rise structures and the use of some off-site units such as roof structures and brick arches can work to augment traditional build and add value.

It is the case that the masonry industry offers a range of tried and tested additional solutions such as storey height aerated concrete elements, clay blocks and thin joint masonry but the reality is that the vast majority of solutions, driven by Government policy will be assembled from imported steel and timber.

Lightweight Off-Site Construction as a replacement for masonry in mainstream housing is a retrograde step which is bad for our economy and the residents of the new homes.

**What are the likely drawbacks?**

- A further deterioration in our trading deficit which, despite the current currency advantage, peaked at £58 billion in January 2018.
- A suspension of investment in British manufactured masonry and associated products leading to long-term irreversible reliance on imports.
- Lost manufacturing jobs and skills.
- Young people will be deterred from taking up vital trades such as bricklaying leading to long term skill shortages with no opportunity to recover.
- More serious fires and loss of life, made worse by the risks associated with an aging population unable to get out of burning homes as quickly as they need to.
- Overheating due to lack of thermal mass in a warming climate.
- Higher cost to the NHS driven by poor indoor air quality. In Scotland were timber framer has replaced masonry we have the highest rate of teenage Asthma in Western Europe.
- Higher costs.
- Less flexibility.
- Higher stress on cash flow as offsite systems must be purchased in advance and can’t be as easily flexed to match demand.
Need to replace more often due to 60-year design life leading to a much-increased carbon impact
Reduced opportunity to adapt and extend homes as needs change as "kit and modular construction is not designed for this
Significantly Increased build costs

What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?
Professional decision makers should be empowered to make objective decisions in a free market. The use of Government funded incentives, bullying and unfair procurement rules to try and force the use of off site is anti-competitive and unacceptable. The history of such interventions such as the one to push diesel cars is littered with unintended consequences.

It is often claimed that offsite manufacture can lead to: • lower costs, faster delivery and increased quality; • increased productivity; • improved health and safety; • greater provision of new, affordable housing. What is the evidence for this?
None it is simply not true but is instead propaganda, pushed by those with vested interests.

It is a great shame that the Government attributes no value to investing to support efficiency improvements in traditional construction. We believe that the use of digital technologies can add significant value though the design and build process and in the operation of homes but there is no interest in helping us to develop this.

Potential barriers to wider use of offsite manufacture
The widespread use of offsite in domestic housing is not cost-effective and will be rejected by most of the private sector.

3. What are the drawbacks to offsite manufacture for construction?
Fire, cost, flexibility, adaptability, longevity, overheating, poor indoor air quality, consumer preference ignored, quality problems and restricted design options.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?
There is very limited off-site knowledge and skills and a lack of understanding of the risks of retrofitting to offsite-construction which can have significant consequence’s increasing fire risk and undermining the performance of the building.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?
No we will re-visit the design problems of the 60’s

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture
R&D incentives provided to Offsite must be matched to the masonry sector. Already a series of anti-competitive incentives and grants have been provided with little or no return to the tax payer, the masonry industry is currently
involving in new capacity but the lack of any support and the negative messages promoting a move away from traditional construction will cause long term irreversible damage.

We hope the House of Lords Committee will allow the Masonry industry to provide oral evidence and that you will properly evaluate the economic, safety and employment impacts that this unfair and very unwise action by Government will cause.

26 April 2018
Building Societies Association (BSA) – Written evidence (OMC0049)

The Building Societies Association (BSA) represents all 44 UK building societies. Building societies have total assets of over £374 billion and, together with their subsidiaries, hold residential mortgages of over £297 billion, 22% of the total outstanding in the UK. They also play an extensive part in the self-build and custom build market, with societies representing 25 of the 28 lenders currently active in the self-build market.

This response highlights additional restrictions not specifically identified in the Call for Evidence, such as a reluctance on the part of mortgage lenders to provide loans for homes built using methods or materials that go beyond traditional brick and block.

Barriers to the provision of finance on residential developments using MMC

The BSA has long campaigned for increasing the supply of new build housing and for successive Governments to make the provision of housing a key priority. In 2015, the BSA published a Housing Manifesto that identified Modern Methods of Construction (MMC) as a particular area that should be focused on by Government to boost the supply of new homes.

Given building societies’ historic strength in self-build and custom build, where buildings often incorporate elements of MMC, many societies have been more open to new build properties that incorporate elements of MMC.

However, a report published by the BSA 2016 about MMC titled Laying the Foundations for Modern Methods of Construction, identified a number of challenges facing lenders when it comes to providing funding for MMC.

Primarily the concern of lenders is around the accurate valuation of properties using MMC and the existing provision of building warranties to ensure lenders and borrowers have cover in the wake of something going wrong with a building.

Key findings included:

- That there is a lack of information and comparable evidence for MMC properties at the moment, something which is a vital element for any accurate valuation
- Some construction methods are so new there is little or no historical data demonstrating how they will age and their likely lifespan. Lenders and valuers will be naturally risk averse to anything that could affect the future saleability of properties.
- The introduction of new materials and multiple innovative construction techniques creates uncertainty about the risks posed and the performance and desirability of these buildings in the longer term, especially when properties do not easily detail what methods/techniques have been used.
• There were also concerns about the provision of warranties and whether existing industry measures such as the **Buildoffsite Property Assurance Scheme** (Bopas) are adequate.

The BSA made a number of recommendations in the report, in particular that it was an opportunity for Government to bring the different parts of the market together. The Ministry of Housing, Communities and Local Government (MHCLG) has now done this, with an industry technical group working to address a number of the issues that we identified around adequate warranties (the BSA is a member of this technical group).

Other recommendations made in the BSA's report include:

• An MMC hub to provide a single point of factual reliable information that is available to lenders
• A property logbook for homes so consumers know what their home is constructed from and what work has been done to adapt and improve it.
• Information about the construction type of the property should be made easily available to lenders.
• Standardisation of terminology - the offsite industry should be looking at where it can collaborate to standardise systems. This will make it far easier for other sectors, including lenders to quickly understand and underwrite the risk.
• Updating the RICS UK secured lending section of the Red Book to include valuation guidance relating specifically to MMC properties.

Since the report was published in 2016 the BSA has been actively working with the Government to bring different elements of the sector together.

We have also continued to work with our own members and their valuation partners to understand underlying concerns about MMC. Many have cited that a lack of knowledge within the valuation sector continues to be a key obstacle.

To that end, we have arranged site visits with members and valuers to Legal & General’s offsite factory near Leeds to better understand off-site manufactured housing. The BSA and its members also visited the city of Almere in the Netherlands last year to see how MMC developments work in practice and understand lenders in other countries are more comfortable with MMC.

*26 April 2018*
Buildoffsite – Written evidence (OMC0036)

Background on offsite methods

There are many forms and descriptions of offsite construction but the common denominator involves elements of construction projects that would normally take place on a construction site using a set of commodity products, being manufactured in factories using modern manufacturing methods and technologies. Given the right investment and with sufficient market demand there is no reason why the manufacture of offsite elements should not match the levels of productivity achieved in the automotive, aerospace or consumer goods industries.

There are numerous forms of offsite construction but the common examples include walling, flooring, ceiling and roofing systems, building services, glazing and cladding systems, modules/volumetric and pods. The degree and quality of fit out will depend on client requirements. Understanding of offsite terminology is generally poor across many in the client and traditional contracting community. Buildoffsite has produced Guidance on Terminology

To date very few buildings and structures are constructed wholly through offsite methods. Most construction projects will include some use of offsite methods to deliver elements where quality, accuracy and assured delivery are business and project critical. However, in most cases much of the construction will still be delivered on site by constructors through traditional methods.

How big is the offsite industry?

Frankly we don’t have access to accurate numbers. Government stopped collecting data some years ago. It would be most helpful if robust data was available. However, Buildoffsite’s experience in this area has demonstrated that efforts to collect and analyse such data need to be well designed to avoid double counting projects e.g. from customer, main contractor and specialist contractor perspectives

We believe that almost all offsite production is being applied to new build projects. Our best guess is that over the last 10 years or so the use of offsite construction has grown from virtually nothing (around 2%) to approaching something like 10% of the new build market. Rapid growth is continuing as the industry and clients become more aware of the benefits of offsite methods and more comfortable to switch over from traditional methods.

Background on Buildoffsite

Buildoffsite is a unique non-commercial organisation set up almost 15 years ago with the support of Government to promote improved understanding of the potential for offsite solutions to increase the quality, sustainability and performance of the UK construction industry and delivered built assets in all markets. In line with the rapid increase in client and industry acceptance of the
benefits of offsite solutions the Buildoffsite role is now also focusing on enabling the innovative use of offsite solutions to meet the developing needs of clients.

The Buildoffsite Membership brings together organisations from across the supply chain and the client communities to share knowledge and best practice in the use of offsite construction methods, to collaborate on innovation, to showcase leading edge examples of game changing applications of offsite construction and also to challenge the supply chain to continuously improve. Buildoffsite promotes the intelligent application of offsite solutions through its programme of events, through publication (all media), in discussion with a wide range of industry and public organisations and through industry activities.

Our work to help make the case for offsite solutions also regularly embraces the issues and questions raised by the Select Committee.

Our Evidence

Informed by our 15 years of experience working with some of the UK’s most innovative construction clients and offsite suppliers we would like to respond to your invitation to submit evidence - as follows:

**Question1:** Construction is a manufacturing industry and for the most part the construction process is still dominated by traditional construction trades working on site. The inevitable consequence of reliance on traditional methods is the intractably low levels of productivity of the industry, inconsistent and often poor first time quality of build and buildings and structures and a performance in use that often fails to match the performance requirements set out in project specifications. The construction industry is still characterised in terms of projects that generally run late, generally overspend and deliver poor value for most clients.

Alongside the adoption of digital engineering, DFMA and lean production methods, the adoption of offsite construction methods with manufacturing taking place in controlled factory conditions offers the best opportunity to ensure product quality, predictability of cost and delivery, minimise waste of all types and to boost productivity. **Lower costs will follow as designs are refined, supply chains invest and the offsite industry is able to operate at scale.**

The primary drawback is that investing in offsite factories is an expensive business that may be difficult to justify when in most cases sales are not assured. Multiple routes to market are essential for such enterprises to be sustainable.

**For the shift to offsite there needs to be a compelling reason to change.** In many cases the offsite proposition has not been sufficient to convince a risk averse and sceptical industry to try new solutions, except in areas where there is a compelling business need e.g. Prisons/Airports/Utilities – looking to minimise site labour for security reasons. Retail, hotels and student living – where highly repeatable designs are acceptable and rapid completion to a high standard is a business imperative to deliver revenue flows as soon as possible.
The Buildoffsite website (www.buildoffsite.com) contains case studies that demonstrate that offsite enabled construction is considerably faster and of better quality than comparable traditional forms of construction.

**Key influences on the decision to use offsite:**

- The cost and availability of **good quality traditional labour** is an increasing problem for contractors. As skilled labour becomes scarce and costs increase: the attractiveness of offsite solutions which minimise the residual need for onsite traditional labour is increasing.
- A client requirement for rapid project delivery will drive the take up of offsite.
- The need for improved security (fewer people on site) and safety will drive higher levels of offsite.
- A client need for higher build quality and greater assurance of performance tips the balance towards offsite. Particularly for clients who have a long term interest in the performance of their assets, their longevity and performance in use. **An emerging industry and public policy issue is the disconnect between design performance of traditionally built assets and performance achieved in practice.**

An offsite approach will ensure a much closer link between digital models and as built construction with implications for certainty regarding performance of the completed construction in use. Materials and other wastes will also be substantially reduced.

The widespread use of offsite methods along with digital engineering, a DFMA approach to design and construction, and the application of lean production techniques to drive efficiency into construction processes provide the key to bring about a step-change in industry productivity.

**Drawbacks:**

- The up-front cost of setting up a factory with no assurance regarding sales
- Ongoing lack of awareness of offsite solutions and the value to be gained from rethinking the design and construction process among clients, designers and constructors
- Unless driven by a demanding client there may be few incentives for designers and constructors to change practice – particularly if market conditions are benign and decision taking individuals are unwilling to adopt new ways of working.
- Getting the best out of offsite solutions requires a more planned, better organised, more intelligent approach to design and project delivery.

**Question 2:** For the most part there is plenty of evidence for faster delivery, improved quality and lower construction cost through published Case Studies.

However, increased productivity may be more difficult to demonstrate because in most projects the specific benefits of offsite may be masked by the overall performance where the bulk of the construction is still being delivered by traditional means. Achieving increased productivity in a factory environment is easier to achieve with the availability of substantial production runs which may be available only on the largest projects where the client (usually through a main contractor) is willing to enter into a long term supply relationship eg Hinkley Point C. Factory productivity is driven by good manufacturing systems design
which is well aligned with market requirements. However, even the most productive factories cannot remain viable if there are significant boom / bust periods in construction.

Regarding Health and Safety the HSE has indicated that they regard an offsite approach to construction based on fewer people working on site, reduced requirements for working at height and a factory approach to construction as most likely to deliver substantially improved H&S outcomes – including improved occupational health. This accords with the evidence from UK manufacturing industries.

The use of offsite methods is likely to have the potential to increase housing supply where the benefits of offsite approach can be delivered at scale.

For established social housing investors (eg Homes England, LAs & HAs) willing to take ownership of the full investment, rather than relying on private developers, there will be a direct cost benefit from offsite solutions as repetition of build improves delivery and leads to reduced programme and cost.

The link between construction methods and affordability of housing is complicated and is unlikely to be impacted significantly as a consequence of the selected construction method. However, build quality and performance in use are likely to benefit from offsite enabled construction. Efficient construction is a means to delivering value from a land bank for many developers. The lower the construction cost for a given market price, potentially the higher the land value rather than a lower price for a building.

**Question 3:** Offsite methods are unlikely to be cost effective alternatives for traditional methods for one-off small scale projects or where the design is still to be settled (until there are a range of suitably configurable products and systems available in the market that can be economically manufactured with small batch sizes). In particular this is likely to be the case where clients and constructors are less interested in the wider benefits of offsite but are focused mostly on first price.

There are probably still too few offsite manufacturers able to offer customisation to meet the specific needs of projects although this situation is changing as more agile manufacturing techniques are being introduced.

Capacity and resilience of the offsite supply side is also a potential drawback. The offsite supply side is still small although new entrants are coming on stream. Clients and constructors will usually look to manage risk on the largest projects by contracting with suppliers who have the capacity and balance sheet to give confidence that they will be able to deliver the contract. As a relatively new industry there are still too few offsite suppliers able to operate at scale.

Current forms of contract that provide for offsite suppliers to be paid only when the works are complete can also create significant financial difficulties for smaller manufacturers.
Design and build type contracts put the detailed decision making in the hands of the main contractor and sub-contracting work to a manufacturer may lead to reduced margin opportunities for their business ie self-interest working against best methods.

Clients and their commercial advisers tend to ask for designs, which can be constructed by multiple suppliers using traditional methods so as to ensure competitive tension. This puts the offsite suppliers at a disadvantage as they need to respond with a redesign and a “non-compliant” offer in challenging tendering time frames.

Routinely tendering packages can effectively prevent clients and supply chains working with each other to improve productivity and performance over time. Supply chain development is under-developed in the construction sector, probably due to the nature of contracts used and the way in which clients need to demonstrate value for money in regulated industries.

Increasing interest in collaborative forms of working is a positive trend in this area. The Government could drive supplier development through its contracts in a similar way to its stimulation of the use of Building Information Modelling (BIM) in public construction projects.

**Question 4:** The use of offsite methods is not simply an alternative to traditional means of construction.

The use of offsite methods in association with a DFMA approach to design and construction and adoption of lean methods for project delivery have in combination the potential to bring about radical transformation in the productivity of the UK construction industry.

With an industrialised approach, shifting away from artisan trades, there is the potential for much more rapid training of ‘assembly’ operators that skilled crafts people. This is achievable in a matter of weeks versus the years for tradespeople. The reskilling that is required will have as much impact on clients, designers, consultants and constructors as it does on the industry work force. Increased awareness and understanding of offsite needs to embrace the entire industry if the use of offsite is to increase on site.

The Professional Institutions are starting to introduce an awareness of offsite into professional training and development but more needs to be done. CITB are also looking to increase the provision of offsite training at management and technical level. Buildoffsite is supporting these developments and is involved in the Offsite Management School - now part of The Supplychain School.

**Question 5:** There is plenty of evidence in the form of Case Studies that provided there is early project engagement between the design team and offsite suppliers the relevant architectural ambitions of the client and the design team can invariably be met. Clients can play a key role in establishing positive relationships and Buildoffsite has produced guidance for clients.
However, it needs to be noted that many elements of the construction will not necessarily require special architectural consideration. For example many house builders have a “type approved” catalogue of house designs, which could be delivered using offsite methods.

Similarly the repetitive nature of student accommodation, hotel rooms and prison residential wings has meant that offsite manufacture has been the dominant delivery method in these markets.

Factory production should be capable of delivering optimised solutions combining different materials and associated technologies. This should unlock design flexibility and innovation.

Many very tall buildings (towers) and long buildings (e.g. airport piers) contain a lot of repetition of structure and content, which in turn opens up opportunities for offsite manufacture and associated cost savings.

The paradigm that offsite will stifle aesthetics is as untrue in construction as it is in the fashion industry: There will always be an appetite for iconic ‘haut couture’ buildings but that should not mean that there is not a high quality aesthetic on the high street for mass scale housing, schools and infrastructure.

This can be achieved by the supply chain investing time to understand what their chosen markets value in terms of design before the tender stage and demonstrating how their technical solutions can be customised to supply. There is no one offsite solution for all construction projects; just as there is no one solution for clothing retail.

**Question 6:** Offsite manufacturers and technology providers such as those offering digital engineering technologies are already investing significantly in offsite methods and manufacturing capacity. Research is needed to provide evidence of the tangible benefits of offsite methods compared to traditional methods. Buildoffsite is currently involved in an evidence gathering and assessment project in collaboration with the Construction Industry Research and Information Association.

**However, it is often the case that even an authoritative evidence base is insufficient to convince clients and their consultants to change.**

There is a sizeable programme of University led research into the use of offsite methods and in product technologies that are most suitable for incorporation into offsite products. Similarly research is being carried out in collaboration with the National Composites Centre and the Manufacturing Technology Centre.

The biggest single investment is required to support awareness raising and skills development in all sectors of the market. Skills such as Systems Engineering’s ways of defining performance requirements for contracted work packages could help transform the open-ness of tender opportunities.

We believe that if the UK invests successfully in developing Intellectual Property in design, engineering and manufacturing systems there will be a substantial
international appetite for export of services and technical know-how. Notwithstanding commercial challenges in the domestic market in many overseas markets the UK is seen as a global leader in the development and implementation of offsite construction capabilities. For many years Buildoffsite has been supporting international collaboration.

**Question 7:** Based on a clear understanding of the challenges facing the UK construction industry the Government’s Construction Sector Deal provides a mechanism to support collaborative research that the offsite industry and the construction industry at large will be able to benefit from. Buildoffsite will be looking to play a role in supporting offsite suppliers to establish consortia to tap into this funding to drive innovation and increased productivity.

Government could review how regulators for major infrastructure sectors assess value for money of investments in constructed facilities, the types of contracts used and the promotion of medium term supply chain development processes that have been well proven in other sectors.

Much product development in the construction sector is initiated by lower tier suppliers or the major materials suppliers. The Government should continue to support such R&D through R&D Tax Credits, Patent Box, Innovate UK funding competitions and through the use of selection criteria for Government projects.

Project managers and commercial advisers need to be well educated in this area as they are often the ultimate gate keepers who make the assessments and manage the risks associated with adopting innovation.

Government could support innovation that combines different and new materials technologies and methods to accelerate the progress of DfMA.

**Question 8:**
Current procurement practice in both public and private sectors tends to perpetuate traditional solutions; this is because tenders are written as a technical ‘input’ specification: e.g. ‘We require a 56kn power floated concrete floor’.

Shifting procurement to an output / outcomes specification will enable more sustainable and cost-effective offsite solutions: e.g. we require a high quality surface finish for a school floor with a design life of at least 25yrs and a whole life cost of below £XX m².

Public procurement rules tend to favour the comparison of quoted prices rather than probable (invariably higher) out-turn price. Offsite has been demonstrated to be more predictable in terms of price, time and quality than traditional delivery methods, but this is not generally reflected in selection criteria.

In practice the form of contract often provides for payment to suppliers on completion of the works. This practice in combination with the need for offsite suppliers to finance manufacturing and material investments over a potentially long period can discourage the offsite supply side from competing. This is an area that requires more attention.
Often the use of offsite and other innovations needs **to be incorporated early** in the project planning process. Once main contractors have been appointed, the potential opportunity to improve productivity etc through the incorporation of offsite construction will have already been constrained.

The Government should consider more ways of incentivising main contractors to support and introduce innovation to projects (in a generally risk averse and conservative sector).

The Infrastructure Industry Innovation Platform (i3P) initiative is a good initiative involving public sector clients but is arguably late for some of the participating projects to gain direct benefit or for some suppliers to develop solutions quickly enough to respond to invitations. Product and system development cycles tend to last a couple of years or more, rather than the weeks and months that projects can accommodate, particularly when durability and certification aspects are factored in.

25 April 2018
Perceived advantages of offsite manufacture for construction

Q1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and supply chain in deciding whether to choose offsite manufacture?

1.1. **Opportunities:**

Construction output in the UK is more than £110 Bn per year and contributes 7% of GDP. The sector employs over 3m people (approximately 10% of the UK employment). It is facing a combined problem of an ageing workforce and shortage in the recruitment of young talent, as outlined by Farmer report. The productivity of the sector is very low as compared to other sectors in UK and even few larger European countries. This is one of the major reasons why the traditional modus operandi still exists and generally the sector struggles with a complacent mind set. The structure of the construction sector structure is skewed towards handful of large and powerful players, who have limited interests in adopting (or even invest in) modern technologies and resistance to change.

However, the introduction of BIM has made some inroads amongst all stakeholders in the industry, although the full potential of this technology hasn’t been explored. For example, most large house builders (private and public) are still yet to adapt BIM extensively, as their maintenance department are not linked to these information platforms which otherwise could have driven better proactive maintenance programme rather than reactive workloads. The Offsite sector extensively uses BIM for its manufacturing process, and can offer benefits on whole “asset life cycle”. Clients are able to access this information and develop smarter built and maintenance programme, if they wish to.

The other benefit is quality. Given that offsite is a manufacturing process, it brings stricter quality control during the build process. Buildings delivered through traditional built faces projects delays and snagging issues. The recent demise of Carillion testify the consequences of project delay, while quality issues of some of the National House building companies confirm that traditionally built products cannot guarantee a consistent output. Given huge pressure on delivery of new homes, these issues will become more and more common unless we start building them in a manufacturing environment.

Finally, offsite will enable diverse workforce and improved productivity. The Construction sector is facing acute shortage of skilled workforce due to ageing workforce and failure to attract young talents. A controlled work environment delivers safer workplace, and modern methodologies attract a wide range of skill sets. It also enables workforce to be multi-skilled. With less dependency on weather, the build rates are higher resulting in higher outputs and productivity. Usage of BIM will require new set of skills under different working conditions – which will help to attract younger talents and diversification of the construction workforce. Operating within a factory controlled environment allows for some of
the assembly process to use lower skilled operatives therefore reducing the need for skilled and more expensive labour. This helps deliver a lower cost product and makes OSC more affordable.

1.2. **Drawbacks:**

1. The biggest drawback is the perception of offshore and bad legacy of pre-fabs (especially in the housing sector). Nicky Gavron in her report pointed out that last time we came anywhere near to reaching high housing targets was in the late sixties and seventies, when “prefabs” contributed significantly to supply. Over 425,000 homes were built in 1968, and much of this was substantially manufactured offshore. However, many homes were used beyond their usual life expectancy period – resulting in a bad reputation for “prefabs”.

2. External cladding – There are very few limitations to the choice of cladding material. The main question at this stage is can the cladding be fitted in the factory. There are obvious advantages to fitting the cladding in the factory, however some cladding (either in terms of material or format) is best installed on site. At the very least we would aim to install any sub frame (wall tie channels etc) in the factory.

3. Upfront higher capital costs – This is often perceived as greater risk for the lenders. As construction process are carried out in the factory, Caledonian Modular segregates materials by means of a vesting procedure, purchased with advance payment from clients, in order to mitigate any perceived risks of bankruptcy. Step in agreements can also be negotiated to mitigate client risk.

4. Restriction of transport networks – For example, the height of the modules needs to be less than 4 metre in order to transport them under the old railway bridges. Similar issues apply for urban regeneration sites where access restrictions often dictate the shape and size of the modules, which in turn affects the commercial viability of the project. We are currently undertaking a project for Watford Borough Council where following a transport assessment the design was modified to reduce maximum module sizes and ease access into a tight garage infill site.

5. Availability of tall cranes – With more and more taller buildings being planned in the cities, we find restricted applications of robust volumetric modules which are made from hot rolled steel (like our system). There are not many heavy cranes available in the UK market, who can lift modules which can weigh as much as 17 Metric Tonnes to height beyond 17 floors.

6. Small production run – Established manufacturers like Caledonian will not be able to economically produce small batches of different sized modules, as the factory production facilities are geared towards large, repetitive batch sizes. For example, our latest £50m Hinkley key worker accommodation project involves delivery of 1400 modules, but of only two different sizes only – which helped to adopt lean production arrangements and deliver considerable value engineering and cost savings.

7. Local employment – Unlike in situ construction process, the bulk of the construction process happens inside the factory, hence we often find
situations where we are unable to meet local employment conditions. Given
the high set up cost for a volumetric factory, setting up a local factory is not
always economically feasible unless clients commit to a long-term order
pipeline. Therefore, local planners and politicians need to consider holistic
picture when considering modular projects. When using OSC our installation
operatives and contracts management teams are all site based and rent hotel
rooms, use local leisure facilities and make an economic contribution to the
local area.

1.3 Stakeholder engagement:
Uptake of the offsite methodology depends on the early adoption rate of key
stakeholders (i.e. architect, planners, builders, surveyors). In the housing sector,
for example, many architects are trying to shoe-horn modular units to fit into
traditional design – indicating a distinct lack of understanding of modular friendly
design amongst these practices. Some practices are sceptic or even negative on
offsite, as they believe that it will compromise design flexibility. Lack of
understanding also lies with the planners, building reg. and quantity surveyors as
they are not used to this type of delivery method.

The volume house-builders, on the other hand, are worried on long-term
commitment to cope with demand fluctuations in the market and holding unsold
inventories. The financial sector too has shown scepticism on offsite
methodology, and mortgages or development loans on modular projects are hard
to get.

End-clients are worried too. Latest research (2018) from Ecobuild points out that
a fifth of the population think prefabricated housing is poor quality, with one in
six claiming it is old fashioned. Nearly a fifth doesn’t think a modular home would
last as long as a traditionally built house.

In a nutshell, all key stakeholders need better understanding of offsite
methodologies – hence, industry-wide training and knowledge sharing initiatives
can be a good starting point. Caledonian has already initiated several workshops
within the housing sector and architectural practices to remove the barriers.

We are helping to overcome this lack of understanding by using CPD seminars
and have developed a number of presentations which we aim to deliver to clients
and consultants nationally with the aim of changing the perceptions of the
modular industry and what we can offer. We are keen to educate the wider
industry and promote awareness of off-site volumetric modular solutions as a
viable alternative to traditional solutions across most industry sectors.

Our factory is our shop window and we regularly arrange visits for clients,
consultants, subcontractors and have even hosted groups of school children
escorted into the factory to see their new school being constructed. This creates
a great deal of excitement ahead of delivery.

Q2: It is often claimed that offsite manufacture can lead to:
• Lower costs, faster delivery and increased quality
• Increased productivity
• Improved health and safety
• Greater provision of new, affordable housing
What is the evidence for this?
Caledonian has a wealth of experience constructing bespoke new buildings over £3.5m; we work across all industry sectors and offer an infinitely flexible system which can be tailored to suit any client requirements. At our facility in Newark we design and manufacture buildings from raw materials and as such can accommodate any size, shape or architectural feature into our designs. A few examples below, all within the value scope of this framework lot demonstrate our capabilities and experience.

Farnborough Academy – Comprising of a full height assembly hall (portal frame), science labs, music rooms, dining hall and commercial kitchen plus full M&E services which included a CHP system, underfloor heating, and all interior design. 7000m2 full secondary school.

RAF Lyneham – 1145 bed MOD accommodation over 12 blocks total 36240m2. Designed fully using BIM principles to improve co-ordination, tolerance and factory accuracy. 6 bedrooms per day delivered over a 9 month period. (Steve Tate – Contract Manager)

Hinkley Point – 1500 room key worker accommodation for Hinkley point power station in Somerset. 44 blocks on 2 sites, each block installed and completed in 6 weeks. High level of finish (96%) and fully externally clad in the factory. (Steve Tate – Project Director).

ACS Cobham – High quality boarding accommodation, full turnkey project with extensive groundwork’s and traditional masonry cladding constructed in a live operational environment. (Steve Winterbottom – Contract Manager).

Hillingdon Hospital – 3100m2 Acute medical facility and endoscopy suite. Factory installed micro-concrete floors and lead-lined walls. Angled and wedge shaped modules to ensure the footprint matched existing.

Named examples: Caledonian were contracted to deliver the last project on a tight secondary school site in Clifton in Nottinghamshire in a very demanding time scale without compromise to the quality, design and performance of the school. Working with the clients design team, the original architect’s intent was preserved whilst turning into a buildable project that met all the statutory guidelines and financial constraints set by the BSF.

The building was manufactured whilst the site works and foundations were being prepared. Delivery of the building sections took place during normal school operation and site works were progressed with a full on-site team using programming tools and schedules to co-ordinate the various sub contract packages integrating the soft landings process to enable management of commissioning processes to ensure a smooth and successful handover to the client. Having commenced on site in January the building was handed over complete for occupation in August.

Potential barriers to wider use of offsite manufacture

Q3: What are the drawbacks to offsite manufacture for construction?
Please see Q1 section 1.2
Q4. **What re-skilling of the construction force is required to facilitate a change to more off-site manufacture for construction?**

In 2017, CITB published a report identifying 6 key functions within the offsite sector. Modern design demands more digital skill sets and full understanding of BIM – but unfortunately not many architects and designers are up to date with the technology advancement. Few clients complained that even younger construction professionals have not received adequate training on modern construction process during their learning journey.

As a business, Caledonian experiences limited training and qualifications specific to offsite sector, and there is a shortage of trainers and trainees. Particularly important were the design, commercial/estimation functions, as any mistakes can lead to costly rectification process. Therefore, Caledonian has developed our own in-house programme in association with our education design partner. We work closely with local schools and FE colleges to provide placement opportunities, usually focused around live projects which are visible in the community. Each of the offices typically provides 4-5 work experience placements for 14-18 year olds in architecture, technology, landscape, and interior design every year. Most recent placements in the London office have been from Twyfords School, Hanwell, Reeds School, Cobham, Charterhouse School Surrey, and Maiden Erlegh School in Reading.

We would be keen to work in partnership with the participating authorities, to develop a bespoke employment and skills plan following CITB guidance to guarantee specific, measurable employment and skills targets. This will include work experience, construction curriculum support, graduate training, apprenticeships, training and job creation all recruited from the local area.

Q5. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

Any manufacturing process gains high productivity by adopting mass standardisation of products. The process of offsite manufacturing will no doubt increase the productivity of the construction industry, but a step further would be standardisation of design and specifications. Borrowing from the experience of education market, whereby the nodal body is considering an advanced version of “aggregator” model i.e. procurement of total number of “standardised classrooms” instead of “project specific design and build” approach. The implementation of a standardised design solution across numerous schools has resulted in the development of a Caledonian standard product which we now offer as an “off the shelf” solution to school expansion. We have recently secured a place on a national EFA modular schools framework as part of which we have designed a series of compliant standardised components that can be assembled to form a complete primary school or delivered as a stand-alone units. This has helped for schools to plan and procure module units, as and when they need. And at the same time, Caledonian benefits from a large batch size order to produce the units economically.

It’s a simple statement but we need to operate effectively then concentrate on efficiency.
We would urge the House to lead the adoption of more standardised approach especially with his involvement in the planning process – this will help the offsite sector to deliver more homes in a shorter timescale. The standardisation will also help end clients to reduce the risk of development and maintenance over long term (a key reason for hold up, as cited by many public sector bodies)

Realising that a one size fits all approach won’t work, we are also happy to work on bespoke projects with more complex design requirements. As an experienced manufacturer of bespoke off-site modular buildings we have an established design department operating from our head office at Newark. This department is supplemented with a supply chain of consultants familiar with our systems, processes and ways of working. Agility in manufacturing is a philosophy we adopt as we wish to grow the business and become the Off Site Manufacturer of choice.

Evidence:
Hinkley Point Key Worker Accommodation – We are currently delivering this project via a full design and build (above ground) procurement route. We were procured directly by the client and novated with full design responsibility for all above ground works. Developed in BIM to a level 2 standard the Caledonian team is taking responsibility for the co-ordination and federation of the BIM model. The level of factory finish on this project is unprecedented with modules complete internally and with factory installed cladding. As an indication of the extent of design work involved over 1500 fabrication drawings were produced from the fully federated BIM model.

Design development was managed through daily co-ordination meetings with Clients representatives co-located into our facility significantly accelerating the decision making process. A full scale mock-up was constructed and a sample room created ahead of any manufacturecommencing ensuring every component had client approval.

ACS Cobham – This project was procured on a full turnkey basis involving design, co-ordination and construction of a complex semi-basement ground floor, traditional core elements, module room elements and traditional masonry envelope. Initially working as a specialist, the main contractor pulled out of the project and we negotiated with the client on a full turnkey basis from a design progressed to RIBA 3.

The building was of a very high specification and the as a full turnkey project required significant substructure, enabling works, cladding and soft landscaping.

In a nutshell, as a bespoke manufacturer with full design and build responsibility the earlier our involvement can be facilitated the more efficiency we can introduce to the scheme. Ideally we would be involved at concept design stage with the ability to influence the fundamentals of the scheme providing maximum benefit for client’s investment in an off-site solution.

Q6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?
On every scheme we deliver, our approach is to maximise works offsite in order to reduce the overall time on site, therefore manufacturing and constructing most of the works in a controlled environment.
Caledonian Modular Limited – Written evidence (OMC0037)

Caledonian operates from a 40 acre site located in Newark, Nottinghamshire ideally situated adjacent to the A1 providing excellent transport links to London and the South. All manufacturing is carried out at this facility with the support of commercial, design and procurement located in our adjacent head office.

Our manufacturing facility comprises of 4 factories with 2 linear buildings providing “flowline” capabilities for standardised designs and 2 open plan factories for “static” build requirements where projects are bespoke or more complex. As a market leader we strive to push the level of finish we achieve in our modules to maximise the benefit of investing in an off-site solution.

R&D efforts are being targeted towards how we maximise factory processes to minimise time and man power on site. Currently extensive work is targeted toward our buildings external finishes. There are very few limitations to the choice of cladding material however the main question at this stage is can the cladding be fitted in the factory. There are obvious advantages to do this in the factory, however some cladding types (either in terms of material or format) are best installed on site. Although, we aim to install any sub frame (wall tie channels etc) in the factory for such cladding materials, ideally we would like to produce modules which are fully fitted in the factory.

We would strongly urge that the present supply chain of construction industry gets acquainted with the offsite manufacturing process, so that they are able to innovate and/or adapt their products which fit the purpose of offsite manufacturing and robust transportation requirements.

Strategic partnerships within our supply chain are important and our suppliers work with us as part of the team. Working collaboratively is vital to support our R&D and project development.

**Government actions**

**Q7. (if published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?**

We are in touch with many large housing associations, council development bodies and other public bodies (e.g. Transport for London). The demand side response is still at “nascent” stage as many end-clients are still “thinking” about this delivery method. The historical image of “pre-fab” is holding them back. We urge the House to provide substantial financial incentives (beyond Innovation Fund & Accelerated Construction Programme) to kick-start the acceptance of precision manufactured homes. This will also boost requirement of different skill-sets suitable for factory environment, and attract young talents and diverse workforce to the industry.

**Q8. What changes to the made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture**

The capacity of established module manufacturers in the UK is still massively under-utilised. Facilitating procurement process to deliver standardised units
using “aggregator” model will be of great help to the industry. However, we would like to emphasise the need for a visibility of pipeline over both short and long term basis – so that established manufacturers like ourselves can bring substantial investments to grow their production capacity in a significant way. The new players will also be able to attract long-term investment (less cost of capital). End-clients will benefit from “economy of scale”, enabling quick delivery of “affordable” good quality homes.

26 April 2018

Footnote:
This document has been prepared by the Caledonian Modular Business Development Team that lead the company’s strategic development. We are a source of industry Knowledge but we are still keen to learn more about what the industry’s and governments drivers are as this will help shape our business going forward. Please help us to help you.
Perceived advantages of offsite manufacture for construction

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

a. OPPORTUNITIES: “Deliverability”;
   i. Affordable residential housing
   ii. Filling the UK housing shortage needs
   iii. Providing jobs in highest areas of unemployment
   iv. Positioning offsite factories where there are skilled people
   v. Better comfortable working environment for employees
   vi. Efficient production line techniques can be employed
   vii. Develop efficiency by standardisation of many elements
   viii. Robotics can be used to complete repetitive actions
   ix. Potential to develop specialist factories as part of supply chain
   x. Just-in-time delivery schedules can be employed for materials
   xi. Bulk delivery of components and materials possible
   xii. Reduction of pollution due to less transport movements
   xiii. Factories can be positioned to take advantage of both road & rail
   xiv. Intermodal transportation can be used by designing to ISO sizes
   xv. Reduce negative impacts around building sites
   xvi. Certainty of development completion timescales
   xvii. Reduction of delays caused by bad weather
   xviii. Ground works completed at the same time as the building is built
   xix. Centralisation of components and materials
   xx. Inclusion of more recyclable & sustainable materials such as steel
   xxi. Opportunity to supply modules both B2B and directly B2C
   xxii. Websites can be created where people can “design your own home” and a full quotation automatically created (excluding the cost of land) and payment taken.
   xxiii. The cost of a modular home does not vary because of the geographic final location, the only geographic variable is the cost of land.

b. DRAWBACKS: “Education”;
   i. Resistance by traditional (House) builders
   ii. Resistance by the brick & slate industries
   iii. Acceptance by the public
   iv. Acceptance by the mortgage market
   v. Incorrect perception that this is lower quality construction
vi. Memories of post-war “prefab” housing.

2. It is often claimed that offsite manufacture can lead to;

a. lower costs, faster delivery and increased quality;
b. increased productivity;
c. improved health and safety;
d. greater provision of new, affordable housing.

What is the evidence for this?

a. lower costs, faster delivery and increased quality; Generally through centralisation of labour and materials with reduced transportation of employees and materials. The key to faster delivery is that groundworks and the creation of the building take place in parallel resulting in a potential saving of 50% of the time required to complete. As all buildings are completed inside factories the conditions are totally controlled; heating, lighting and employee’s facilities. With the availability of specialist equipment, leading materials available and production-line techniques the highest quality can be maintained.

b. increased productivity; Due to the totally controlled working environment potential stoppages and downtime due to weather are eliminated also better working conditions leads to happier more productive workers.

c. improved health and safety; Once again through the controlled working environments possible matters such as visibility is increased, errors caused by cold or wet hands avoided and systems and processes can be put in place more easily in a factory environment.

d. greater provision of new, affordable housing; As our evidence is titled offsite modular construction of housing is: “Faster, Better, Cheaper & Greener!” Generally taking 50% of the time, Higher quality in structural and thermal qualities, due to time saved, transportation reductions, reduced financing periods and quicker delivery to the open market a minimum of 25% can be saved which can be ‘passed on’ to the open market & local government (Only land value will fluctuate around the country). Modular construction will allow a wider range of housing solutions, infilling on small sites (uneconomic for traditional builders), self supporting housing using air-rights (over shops, commercial buildings, carparks), both temporary and permanent housing (Houses and flats) can be provided to suit special situations or local authority requirements. Land can be developed quickly and efficiently avoiding the requirement for land banking to create a “pipeline” of developable land.

Potential barriers to wider use of offsite manufacture
3. **What are the drawbacks to offsite manufacture for construction?**

   a. We do not see any drawbacks to the efficiencies provided by this method of construction.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

   a. A large part of the industry will have to get used to working inside in clean and efficient factories.
   b. The industry will have to get used to using new more efficient materials.
   c. Builders will become more technical and use more specialist tools and automated systems on production lines.

5. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

   a. Due to the wide range of construction materials and finishes architects will be more liberated and have a wider scope for design creativity.
   b. Many more ecological and energy saving technologies can be incorporated into the very fabric of the buildings, even becoming part of the structure.

6. **What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?**

   a. Entrepreneurs running private organisations will be the very best to develop this opportunity.
   b. Passion, dedication and competition within the market place will produce the best results.

*This submission has been made by:*
*Carl Henry, Carl Henry Property Limited*

*24 April 2018*
The Chairman: Welcome to our inquiry and thank you for coming today to help us. It is important that we hear from you. Starting from my left, please introduce yourselves for the record. Please feel free to make any introductory remarks. Mr Farmer, I will start with you.

Mark Farmer: I am the chief executive of Cast, a specialist real estate construction consultancy working primarily in the residential sector but having input and involvement across the construction sector, including infrastructure. I am co-chair of Constructing Excellence and I authored an independent review of the construction sector back in 2016 entitled Modernise or Die.

I am a strong advocate of off-site manufacturing, and no doubt we will develop that further in discussion. Some of the findings of my review from 2016 clearly suggest that developing new ways of designing and building is an integral part of how we are going to overcome the challenge of building new homes in particular but also other critical infrastructure.

Steve Radley: I am director of policy of the Construction Industry Training Board, the industry’s training board funded by the levy. We have three primary roles, which are all relevant to this inquiry: supporting the sector to recruit and retain people through careers work, helping the industry to develop the appropriate standards and qualifications, and influencing training and development. This is primarily through three mechanisms, all of which are relevant: partnering with employers, training providers and other organisations; providing funding for companies to train and for programmes; and carrying out research. Increasingly, a lot of our research is looking at future opportunities and future skills.

Mark Reynolds: I am the Chief Executive of Mace Ltd. Mace is a privately-owned consultancy and construction company. In addition, I am part of the Construction Leadership Council, responsible for Skills work stream. I have also been a part of the Project 13 executive group
Dick Elsy: I am the chief executive of the High Value Manufacturing Catapult. Our job is to develop advanced manufacturing technologies and processes for the high-value manufacturing sector, characterised by complex and high-volume manufacture, aerospace, automotive, rail, defence, and food and beverage. We were approached 18 months to two years ago by the Construction Leadership Council, following Mark Farmer’s report, to understand how the disciplines from high-volume and high-value manufacture could be transferred into the construction industry for productivity gain and to meet the targets set in the strategy document Construction 2025.

Since that time, we have helped to develop technology route maps with the Construction Leadership Council and to develop the recent construction sector deal. While doing that, we have engaged with leading construction companies and their supply chains on many projects to demonstrate what is possible, including the use of digital tools and information management, robotics, automation and, the topic of today, off-site manufacture. These demonstration projects have crystallised the view that the concept of that cross-sector knowledge transfer is fully workable and will lead to the kinds of productivity and cost-improvement gains that the industry needs.

The Chairman: Thank you. What is our productivity level in construction compared to other countries?

Mark Reynolds: The statistics are that we produce between 15% to 25% less than countries.

The Chairman: Which countries?

Mark Reynolds: Germany, France.

The Chairman: Is that solely down to not being able to do more off-site construction?

Mark Reynolds: Partly. It is also partly about efficiencies in health and safety. We have much more stringent health and safety requirements, which slows the process down and certainly makes it far more rigorous. There is an element of having a production-based approach, certainly for design efficiencies, and a system-based approach for materials, components, sub-assemblies and so on.

The Chairman: On the components of productivity gains—you mentioned design and other areas—how much would off-site construction contribute
to improving that productivity?

**Mark Reynolds:** I think it could contribute up to 50% increase and maybe higher.

**The Chairman:** That suggests that the other areas of design and so on contribute very little to productivity.

**Mark Reynolds:** Design is an important element. They are all integral. If you design for manufacture, it will improve stringencies on health and safety, because you reduce the number of people on site and the inefficiencies of delivering that on site as well as making it more standardised.

Q25 **The Chairman:** We have heard a lot about the benefits of off-site construction. In fact, I think we are sold on it after the positive comments that we have heard. What are the barriers? Clearly all of you want more off-site construction. As you have said, Mr Farmer, you are a champion of off-site construction. What are the barriers to more construction being done off-site?

**Mark Farmer:** There are several barriers. There is a supply chain issue in the capacity and structure of the off-site market as it currently stands. I work primarily in the residential sector, so my focus is on housing and high-density apartment schemes. Currently, the off-site market in the UK is fragmented. It is effectively a cottage industry—it has certainly come from that perspective—where individual businesses have finite capacity. Developer clients and housebuilders who want to engage with that method of building have often struggled to align with the right partners and to understand how their demand can map on to availability in factories. It has been fairly sporadic in matching supply and capacity.

There is also a basic issue that goes to the heart of a key barrier to uptake in off-site. There is a big issue with how we organise ourselves as an industry around procurement with a fragmented model of architects bespoke designing something that is procured through a competitive process that in turn is tendered for by an ad-hoc manufacturing supply chain. It is not the best way of advancing off-site.

If we are going to move forward in off-site manufacturing, there is much work to do on more integrated procurement. There is a big debate about procurement in the construction industry, which has been flagged up by all sorts of other instances in the last 12 to 18 months. We need to move to more collaborative procurement so that design for manufacture and assembly—DfMA—a term you have probably heard several times in taking evidence, can be promoted properly. That is a different and more collaborative way based on trust. There is not enough of that in our industry, so it is a big barrier at the moment.

**Mark Reynolds:** We also have to look at how projects are funded. If you look at the beginning of the whole process from concept design to developing that into funding, many of the large institutional funders just want to see tried and tested solutions. If they are not proven, it will be a “not invented here” syndrome. We do not have a process of doing prototyping, and as a consequence we learn on the job. Therefore, it is difficult sometimes to get funding if you are trying to do something new.
If you are trying to sell that to some clients, it is difficult. As Mark said, it is then about the design process. The traditional RIBA plan of work process which the industry follows does not really accommodate a manufacturing construction solution.

**Q26 Lord Borwick:** I want to talk more about the drawbacks of the off-site manufacture and the barriers. You have mentioned some of them, but are there others that you want to bring out to show why it is not taken up more widely?

**Dick Elsy:** As an industrialist looking into this sector, because we are bringing the disciplines from automotive and aerospace to the sector, it requires a mindset change. There is a cultural shift in thinking from this rather sequential approach to a more integrated one. The sorts of things that we are looking at are, for example, the use of digital tools, so there is one version of the truth from the first strokes of the architect’s pen on a screen through to the completion of that design, the tendering, the procurement processes, the physical build itself and onward in to the ongoing maintenance of the building there is single database, a constant hand over of baton all the way through that chain.

That requires quite a different mindset, which will be a challenge to accept, but the beauty is that this is ubiquitous in aerospace and automotive. They are used to doing it. The great thing is that the sector wants to change and to learn. I do not see it being a barrier, therefore, and the first-mover advantage people, who I have met through the Construction Leadership Council, are determined to change. There is therefore a strong push to make that cultural shift.

**Mark Reynolds:** May I add to the point about the successes before we come back to the barriers? Pre-assembly, mechanical electrical plants come in as modules. This has been a huge success in the industry and taken many hours out of on-site labour process and improved safety. The starting point is throwing away the design, which is a traditional design. If a client spends £1 million on design for 30% to 50% to be thrown away in order to start again, they do not see that as an added-value process. You have to accept that you have to move back to move forward in order to make those savings. There are challenges and concerns about developing the designs only to start again and move forward in a different way, and people are reluctant to do that.

**Lord Borwick:** One of the problems is that it is such a diverse industry. We are asking these questions not only about housebuilding but about multi-storey office buildings as well as hospitals and prisons. They are so utterly different in their funding, their maintenance and the nature of the client. We are trying to come up with questions that are relevant to totally different industries. Is that a fair analysis?

**Mark Farmer:** Within construction there are lots of sub-asset classes. There are differences in building construction and infrastructure, certainly physical infrastructure such as roads and railways. Social infrastructure is more about buildings, so we are talking about schools and hospitals. Housing is obviously a very clear asset class as is commercial construction—offices, shopping centres, hotels and so on. You need to break it down into bite-sized chunks.
One of the key things here, which Dick and Mark have alluded to, is the mindset shift towards process-led thinking in construction. The construction industry is very unstructured. It has developed an historical model that is not well suited to efficient working. The learning that we can take from other manufacturing based sectors, such as automotive and aerospace—although I do not want to overdo that comparison, it is well worth making—is about process. When you look at all those different asset classes of construction types and apply process to all of them and recognise the differences in technical build, the design challenges or the rules by which they are built, you can do something very differently.

There is a fundamental shift here, which has been covered several times already starting with the role of the client. A lot of this starts with clients and how they commission their projects. Rather than going to a designer and saying, “I want a design that meets this fairly open brief”, a set of rules is established, whether it be for commercial office building or an apartment building, by which it codifies and parametrically defines how you would go about designing that and you enable it. It is like the product-platform thinking that you get in the automotive sector. We can replicate that in construction. Lots of people think it is unachievable, but it is, and I think we are going to get there.

**Lord Borwick:** Which parts of the industry are perfect for off-site construction and which parts are rotten? My immediate belief is that prisons are perfect for this, but maybe that is to suggest that prisoners do not deserve good architecture.

**Mark Reynolds:** There are many areas. Prisons is a great example, as are schools, and housing at all levels, be it low-density, high-density. They are all equally important. Mark’s point about creating a platform, whether it be a commercial office or a house or a high-rise residential facility, is that it has repetition in it in some shape or form. It is about creating those platform sub-assemblies, components and systems. If you can create something with sub-assemblies and sub-sub-assemblies that come together, it is much easier. You get commonality at the sub-assembly level, which will start spreading across schools and hospitals.

To give you an example, bathroom pods have been very common in high-volume, multi-storey residential developments. They were not commonly used 15 years ago. There were productivity and capacity problems. Today, they are used commonly. You now see utility cupboards used commonly on developments. The utility cupboard could be adapted for a school or for a prison. These systems and components can become common platforms. Their advantages are that they are a common product that can be bought off the shelf, used many times and plugged into a building. You can plug into the design, which means that you are using a system-based design rather than a designer designing over and over again from first principles.

**Dick Elsy:** There is a misconception that this modular off-site construction leads to portakabin cities. The analogy that I would draw is from the automotive industry, an industry that I am familiar with. When I started in the 1980s, every car was different and the industry suffered from every car being engineered differently. Now there is incredible commonality of components and systems in cars. The Volkswagen Group has an MQB platform. This is a single platform, including common parts
such as brake systems, axles and engines, which serves four brands and 25 different products. The products all look different. The different brands appeal in different ways, so that architecturally to the consumer they are very different products, but they share this very high common core with all the benefits that Mark has just talked about: high-volume throughput, high-quality parts and certified bits. It can be made to work. That is the best analogy I can make.

Baroness Young of Old Scone: I am curious about the housebuilding industry, because it seems that with some exceptions it is driven by high-volume housebuilders who have a vested interest in not building very fast. It must be the only part of the construction industry that thrives on going slow. I wonder whether that means that this approach is doomed to failure in the volume housebuilding industry unless—you talked about a change of culture—we get a major mindset shift. Discuss.

The Chairman: I might add that Mr Farmer and Mr Reynolds both have experience overseas. To link with that question, how does that experience compare here?

Mark Farmer: I will answer the question about housebuilding incentive first and then open it up to overseas benchmarks. You are right to say that there is not necessarily an incentive in the private for-sale housebuilder model to move fast. One of the benefits of off-site is speed. We are seeing very clearly, and it has been magnified in the last 18 months, that we have a big issue in this country with quality. It is becoming more apparent that the big housebuilders recognise that that is becoming a reputational and brand risk for their businesses. Even though the speed piece might not fit with their core business model with a risk of having unsold inventory, if they are delivering products ahead of their sales rate, that could be an issue.

Increasingly, there is recognition and evidence of top five volume housebuilders actively looking at off-site manufacturing solutions either through partnership with existing manufacturers or in some instances looking to vertically integrate and set their own factories up. The Berkeley Group is an example of that. Some of you may be aware that Berkeley is building a factory in the Thames Estuary that will be for its own products and pipeline, and that is borne out of the risk. If you speak to its board you will find that it saw the reputational risk from poor quality because of the skills constraints that it is now seeing and the variability of the outcome of traditional build.

On the overseas piece—I think it was mentioned in the previous session—there is no stand-out country that is doing something remarkably different across all parts of housing. There are some well-known examples of single family housing being done in a more manufactured way. Germany is an example of a country that has single family homes that are seen in many respects as premium products, such as the HUF Haus. Many of you will be aware of that. I cannot point to any international exemplar of high-density apartment-led schemes being delivered in a manufactured way. Japan is another example of a lot of single family housing in a pre-manufactured way. We have an opportunity, if we embrace it and do it well and in a considered way, to be an international leader in this market.
Mark Reynolds: To add to the point that Mark raised, this is low-volume, low-rise, which lends itself to setting up an off-site manufacturing facility. I will take car plant as an example. The analogy is the assembly area and, as you said in the last session, the constraint is that you have to put it on the back of a vehicle and transport it down the road. There is no reason why we cannot create those sub-assembly areas locally in a pop-up factory close to the large-scale development. Low-rise, low-volume is very different to high-volume, high-rise. They are different solutions that do not do the same thing.

On the second part of the question about the situation internationally, if you look at different places around the world, whether it is in the Middle East, which thrives on low wages and lots of people who are not treated in the same environment as they are in the UK, you have to be careful. The quality of the type of work done in different locations in Germany or France is equivalent to the UK, but in Russia they only build a grey box, which is basically blockwork and a façade, and it is left to the individual to plaster the walls, do the electrics and the kitchen and bathroom. It is a very different market. When you compare housebuilding in one country to another country there are different products and different solutions that make a vast difference.

Lord Kakkar: Can you give me a sense of the elements that might be constructed and applied to different types of buildings? What kinds of things could be done on a very large scale, the kinds of things that a pop-up factory might do or indeed the factory that you spoke about in the Thames Estuary might be doing?

Mark Farmer: Lots of methodologies coming forward are applying different solutions. The factory I mentioned in the Thames Estuary that Berkeley is bringing forward is a volumetric solution. The intention there is to three-dimensionally pre-construct an entire apartment or part of an apartment or part of a house. That particular solution will be for houses and high rise. They are using steel so that it has structural integrity to go higher. They are looking at that as part of the core piece of their business plan. That is the extreme end of the pre-manufactured spectrum.

Taking Mark’s point about sub-assemblies and the hierarchy of how you pre-assemble parts of buildings, there are certain elements of commonality that will move beyond asset classes such as building structures. Moving towards more pre-manufactured structure that will invariably involve things like pre-casting concrete rather than in-situ pouring concrete, which is highly prevalent particularly in housebuilding.

It is a very labour-intensive part of how we build structures, and it could be broken down into something that is a lot more pre-manufactured and platform designed. As we move into different asset classes and look at the difference between housing and commercial offices, there will be a divergence in the type of sub-assemblies. There will be elements such as engineering infrastructure and risers, staircases, lift shafts and so on that go into the central parts of buildings. There will be an office version, a hotel version, a residential version, and multiple platforms between each of those. As you move into the fitting out, it will become even more divergent, because you only have kitchens and bathrooms in residential;
you do not have that in commercial. It becomes a matrix of options, breaking buildings down into bits.

As Mark also said, there is a big debate as to whether you do it in a central factory, highly pre-manufactured, or whether you use flying factories or pop-up factories, collocated to site, or even, at its most extreme, form the factory environment at the workface. Mark has done that with his own business. It is a matter of technical detail as to how you break it down but the key thing is consistency. Platform approach and commonality, as Dick said, is what they do in automotive, rather than reinventing. I work on many schemes where we might have a 100-unit apartment scheme and there might be 85 different bathroom types. It makes no sense. It is not driving value; it is because of the individuality of the approach to design.

Mark Reynolds: Can I elaborate on that and give you an example? In a multi-storey building of over 32 or 34 floors you could engineer that so that you can get another floor within the building without affecting the overall height, that can be constructed. The building that Mark mentioned was what we call a jump factory where we built a large factory on top of the building. We were able to construct the floor, cladding, walls, structural walls, columns, staircases, prefabricated bathrooms, utility cupboards and service modules, horizontal and vertical, in 38 hours. I have never seen that done anywhere in the world. It can be done and we need to understand how we standardise that and take that forward as an industry and work together.

The client who we worked with bought into the concept. We had some failures on that project and we had some successes. He has given us a similar building and we have taken that lesson forward and on to the next scheme and we will take those lessons into other schemes. The point we are all making is that it has to be engineered at the beginning. It has to be based on a system and sub-assembly base and then you can create that manufacturing. We have not spoken about the skills of the workforce and it does change the mindset of both the management team and the into-the-site installation team because they become an assembly team, which is much safer and much more productive.

Q27 Baroness Morgan of Huyton: Can you talk through for us the change of the skill base that you would need for more off-site and the advantages and disadvantages? We know that there is a skill shortage in current construction that arguably is going to get worse because of the age profile and probably Brexit. We know we have a problem but what new skills will be needed and where do we get them from?

Steve Radley: As well as skills challenges there are some big skills opportunities here. If we get the initial entry level training right, whether that is apprenticeships, T-levels or degree courses, we could have a much more productive workforce. There are different roles in construction that would be affected in different ways, and in some cases new roles are being created, but there are some skill needs that are in common, such as team working, multiskilling, quality management, better understanding of digital skills and better communication. Some of these are regarded as soft skills. If we are developing the training and the upskilling to deliver
those skills we have the opportunity to create a much more productive workforce. If it is a better working environment on-site and off-site, it will help the industry in its recruitment and retention challenges because it will be a more attractive industry to work in.

In some cases, there may be benefits for some of the problems that the construction industry faces more than others, such as mental health and, in extreme cases, suicide, because we will be working in a less stressful environment. Another of the advantages of off-site is that you do not need all of the workforce together on one site. You can do the work where the workforce is located, so there is less need for young people to be away from home, living in rented accommodation and so on. That tends to be associated with high levels of stress and, in extreme cases, suicide.

If you look at the specific challenges, it creates new roles for on-site assembly and there is a lot more emphasis on precision, using things like BIM, logistics management communication. If you look more at the off-site environment, people working in the factory, it is about producing those components, fixing, tiling and wiring those and bringing them together into modules and having a better understanding of digital skills and the ability to work in a production line.

At the other extreme, it is about enhancing the role of, say, digital designers. In those cases, you need to understand 3D modelling and have the ability to use modelling to design and test processes and modules. It creates a range of new skill needs and opportunities and what we need to think about is how we build these into entry level training such as developing new trailblazer standards that reflect some of those specific skills but also some of the skills that I have talked about that are in common. We also need to look at the new T-levels, which are going to be coming into force in a couple of years. One of the emphases there is on multiskilling so that, particularly in the first year of training, you get an understanding of a greater range of trades. That will be important for developing some of the skills that we need to make off-site construction more successful.

**Baroness Morgan of Huyton:** Are the T-levels being developed for modern construction or for existing skills? Who is in the driving seat?

**Steve Radley:** They will be developed for a mixture of the two. In terms of who is in the driving seat, it is up to employers to work closely with government and training providers to make sure that the right content is developed in training. It is a CITB role to make sure that we have sufficient trainers and assessors to deliver that. One of the key elements is ensuring that we have sufficient employers that are able to provide work placements for three months in those areas. The T-levels we get will be very much dependent on employers getting involved. The T-levels you get will be the T-levels you deserve if you put in the effort to influence them.

**Baroness Morgan of Huyton:** Is that happening? My impression is that post-2008 there was a complete crash in training and that people have been reluctant to come back to the table.

**Steve Radley:** T-levels initially will be fairly low volume. This will be a gradual rollout over the next five years or so. In the shorter term, the
primary route for construction to bring people in will be through apprenticeships. We have seen strong growth in apprenticeship numbers in the last few years. While some people have commented that, with the apprenticeship levy coming in, apprenticeship numbers have dropped off in other sectors, they have held up very well in construction. There is an increasing understanding among construction employers that if they are to get the skills they need and to become more productive they need to invest more in training.

Mark Reynolds: I think we need to be honest with ourselves when it comes to training. The industry dropped to something like 7,000 apprentices during 2007 and 2008. It is nearer 23,000 today. There is an aspiration from the Construction Leadership Council and the industry to get that up to 30,000 apprentices a year. There is a reluctance on T-levels because of the demand placing young students in to the workplace for three months, which is a challenge and needs to be addressed by the industry. We should not hide the fact that that has not been resolved yet.

On the question about changing for the future, we have had various discussions among ourselves in the industry about how people adapt their workforce. There are some good examples around, such as NG Bailey, which has taken its business from being an on-site to partially off-site where it has been building modules in its own manufacturing centres. It evolves those skills, so you start as a specialist and evolve into a generalist doing multiple skills. It does not go necessarily for specialist training because it starts off with that specialism. We will see both specialism at the beginning and going into generalisation so that it will be easier in the future. It comes down to how people design things, so they are plug and play designs for manufacture. Dick probably has better references for that from the automotive industry.

Dick Elsy: With all the industries that we serve, and now supporting construction, one of the biggest challenges is advanced skills. The further education colleges are taking apprentices to a certain level. In the industries that I serve they (the apprentices) know how to operate a lathe, but they do not all know all the digital tools and techniques. There is quite a big void above that. We are trying to plug the gap working with DfE, which is a challenge since skills separated from BEIS into DfE, and there is a lack of understanding about these advanced skills. Construction will face the same challenge, but it will join us in being a powerful force in calling for funding principally to put into development of the curriculum and standards and so on. The colleges can then distribute all of that and get on with it. That will be a challenge, however.

Baroness Morgan of Huyton: To what extent has the work been done to demonstrate how the skills need to change? Is that out there or is that quite vague at the moment? Mr Radley, you gave us a load of stuff, but I am not clear whether in 10 years’ time, for example, we will need to shift to needing X number of these people and this is how we are going to take it forward.

Steve Radley: We have done detailed work in this area. We have defined six key roles within the industry and some examples of those are the ones I have talked about already, such as on-site assembly, off-site assembly, digital design, site managers and that type of thing. In each case we are
asking ourselves what the new skills are and which of the roles are going to change. For a site manager, for example, there is going to be a lot more emphasis on quality management, behavioural change and getting people to work together effectively. Probably in the more advanced forms of off-site that is going to be a more general manager role where you have the ability to manage from start to finish, from conception to completion of the project.

It is going to require new skills but also the enhancement of existing ones. One of the challenges is to influence the design of new courses. For example, a new digital engineer apprenticeship has been developed. In many cases it is going to be about embedding these off-site concepts in existing courses. For example, Mark talked about DfMA. We need to make sure that is mainstream in a range of digital design courses already.

Mark Farmer: There is a particular piece of work going on for London (Transport for London / Greater London Authority) linked to future homebuilding skills. It is quite a difficult area, because you are trying to forecast future skills needs. They have to be demand-led, so, ultimately, running courses for these new developed skills in the different areas that Steve has mentioned has to be embedded in the fact that employers want those skills.

That, in turn, is reliant on us changing the way that we build. The London work is looking at housing and making projections as to what proportion of our new build housing in London in the future over the five-year timescale will change towards more modern methods and more manufactured approaches. It is quite high level, because you have to model what skill profile that looks like such as how many traditional tradesmen, how many assemblers and logisticians doing different things in different ways, how many DfMA specialist architects will be required. We are not going to transform our skills base in this country unless it is demand led. That is where the Government’s role and some of the policy announcements made in the last nine months about starting to initiate some level of change, where it is within the Government’s control, are very important. This is particularly the case with major capex programmes in the five government departments that were announced in the Budget as moving to a presumption towards modern methods.

That is a good start in trying to start shaping the level of demand that the FE-HE providers can respond to, because they know that this is coming from the Government’s own programme. Hopefully that will spill into housing and commercial buildings and so on.

Q28 Lord Hunt of Chesterton: What wider actions are needed from the Government and from the sector on skills to meet the changing needs of construction? One of the issues seems to be related to the Treasury and the fluctuations. One of the interesting things that we have heard from Mr Elsy relates to a catapult programme in which you are bringing together vehicles, aerospace and construction. There have been some reports about some catapults being more successful than others. Would you like to comment on the catapult model in this programme? How has that contributed?
Dick Elsy: The catapult programme is about bridging the UK’s fantastic science base. We spend a lot of money on the development of science, but we have a market failure in the UK in that we do not exploit enough of it as manufacturing value-add. The job of the catapult programme is to bridge that gap and bring more science through for industrial solutions. The catapult that I run, High Value Manufacturing, has been very successful in doing that.

In the first six years of operation, we have leveraged off £330 million of government funding, a total of £1 billion of R&D activity with some fantastic new processes and new factories built, and inward investment off the back of it. It is a very successful model. We are looking to apply that well proven model in construction, and if we are successful in the construction sector deal bids we hope to provide a place for constructors to come and develop.

Lord Hunt of Chesterton: Is the structural side a separate organisation from the aviation and vehicles side?

Dick Elsy: No, it is all one. We are multisector. We are sector agnostic, although I am describing advanced manufacturing, typically aerospace and automotive, food and beverage, rail and marine. Construction is now joining that. We are uniquely sector-agnostic, so the tools and techniques we use are freely available, because they are being supported by a government contribution to the construction industry. About a third of our funding comes from government.

Lord Hunt of Chesterton: Do the apprentices in construction go and visit the factories?

Dick Elsy: They will be. We have experiments running now with most of the major manufacturers. We have had school children coming to see things being assembled by robots, glass cladding on buildings, the construction of entire roof sections of buildings done robotically. Those are available to see and we have been engaging with youngsters on that. We are at the foothills of developing those techniques, and key to that will be bringing the youngsters and reskilling people to show them what this new world looks like to get them comfortable with it and to get the skills developed. There lies the challenge. We cannot do it all in our facilities because we are busy with delivering the technology.

Lord Hunt of Chesterton: How much of the money for this comes from government and how much from private industry?

Dick Elsy: About a third of the money comes from government to provide core capability, keep the lights on and buy the equipment, and a third from industry for using the equipment and the final third we win on collaborative projects. The projects have to be innovative, competitive and collaborative to win them. It is a very good model.

Baroness Young of Old Scone: Is there one thing government can do to break this cycle of not having enough skills or not moving fast enough, where people are not firing up to it? When we heard evidence last week, we felt that this thing was stuck in a loop and that nobody could break out of it. If government could do one thing to break out of the loop, what would it be?
Mark Reynolds: I have a couple of suggestions. First, the sector deal is really important to the construction and infrastructure industry. That will be enabler, as Dick says, for the three-thirds approach, so that people then start doing it. Also, HMRC could take a different approach. It is about being an enabler and helping organisations. If you are investing £40 million to £50 million a year in R&D projects, there is no reason why those R&D tax credits could not be increased. For some reason, HMRC has taken a dislike to construction over the last six months and has been more stringent.

The Chairman: Is the construction industry more disadvantaged than any other industry for R&D?

Mark Reynolds: I cannot comment, as I do not work in any other industry.

The Chairman: Would it not strengthen your case if you knew that you were disadvantaged?

Mark Reynolds: Pharmaceuticals do very well, I believe, but other industries get a hard time, such as IT. We probably sit at the bottom of the food chain. Automotive, aviation and pharmaceuticals do very well and have probably been playing the game much better than us over the last 10 years. HMRC should be working with industry on the R&D tax credits and demonstrating the benefits, because there are real benefits to be accrued to industry through doing that.

Dick Elsy: If I have an observation as an industrialist, the Government are a big procurer of construction infrastructure projects to get behind this. I see that the construction industry is determined to change. There are some frontrunners in their determination to change, and I am sitting next to one of them. It is encouragement with the new wave of government construction projects not to mandate but to encourage the use of this new approach. It is a pretty obvious thing to do.

Steve Radley: I would like to underline that point, because there are a lot of things that the CITB and industry can do by way of running careers campaigns to advertise the new roles, to influence training provision and get qualifications right, persuade training providers to put these courses on and help them to develop trainers and assessors. If they do not have the confidence that the work is going to be there all of this will be fruitless. Giving a push to that employer demand side is crucial.

Mark Farmer: Times three on that. Demand planning is at the heart of all this. We suffer from being a highly cyclical industry. It is at the root of our struggles. We have configured ourselves as a flexible, resilient industry, but with the skills constraints that we have coming forward that is going to be increasingly difficult. Anything the Government can do in relation to their direct spend programme and the National Infrastructure Construction Pipeline is an important piece of that uncertainty. We need to think beyond parliamentary cycles, we need long-term certainty.

In the housing sector it is slightly more difficult, because the only tools in the armoury from the government’s perspective is land, but there is still an ability to influence there. From a housing perspective, which is the market I concentrate on, that cyclical can be a real barrier to people
wanting to change the way they do things. If there is any way in which policy can support countercyclical demand stimulation for housebuilding, at least the industry knows that there is a floor of minimum demand that gives some certainty in relation to investment in different techniques in manufacturing.

R&D has been mentioned, and I agree with Mark’s point about the HMRC piece on that as well. There is definitely a role for government to initiate and underpin that change, albeit that we still need private sector take up as well.

**Lord Vallance of Tummel:** Can we take housing, which is relatively simple? I think you mentioned that you have a 50% increase in productivity. You can get improvement in the quality of what is done. Presumably you could also significantly reduce the costs here. I still do not understand why the private sector on its own or some disruptive courageous folk in the private sector cannot do it. I am slightly uneasy about the idea that if the Government did this or that it would all come good. Is there nobody who would break ranks and say, “Yes, we are going to do it. We are going to deal with the lack of vertical integration”, or whatever else it may be, “and we are going to cut prices of all this”. Can it be done?

**Mark Farmer:** There is definitely disruption afoot. Regarding the pace at which the private sector moves to this model, I have already mentioned some of the drivers for change, which are probably more negative drivers—people being forced there because of their concerns over their brand or reputation for poor quality work. Those that are not in that mindset will have their hands forced, because there are going to be new players coming in. Some of them will be technology platforms rather than housing, construction or manufacturing platforms with a slightly different approach that can aggregate in a different way in bringing the supply chain together. There is a whole piece on digital enablement in this which is implicit in what we are talking about. It is probably more the subject of the previous panel session. That disruption is coming.

You have already heard evidence from one of those disruptors, which is Legal & General. It is adopting a certain approach, which is not the only approach that can be taken, to disrupting the market. An institutional fund comes in, looks at the industry and says, “We’re not going to do it that way. We’re going to set a factory up and do it in an integrated way”. There are going to be lots of those kinds of models that will emerge and destabilise the market hopefully in a positive way.

We do not want negative disruption where people feel threatened or businesses go bust because something else has happened. We need competition in the market, we need the market to evolve, but it needs to be done in a positive way so that everyone responds to that in the right way.

**Lord Vallance of Tummel:** There are economists who say there is creative destruction.

**Mark Reynolds:** We are at a tipping point in the industry. I played a small part in the Egan report 20 years ago. Digital technology has moved on. Never has the industry been joined up with an MTC with its training
body as much as it has through the Construction Leadership Council, through the Infrastructure Client Group and coming up with a number of issues and the same common language. It is about that commonality.

We have seen that even the demise of Carillion had relatively little effect on the industry, and that was the second largest player. The industry needs to move forward together. The disruptive player is not going to change things. There is not going to be a 30% market in the UK for any organisation. The industry collectively needs to move forward in the way that automotive has done; you have a collective system components delivery system where you are all working together.

**Q29 Lord Mair:** I would like to go back to skills, following on from that point. It is very encouraging that the high-value manufacturing is involved in construction and particularly in the context of off-site manufacture and all the things that go with that coming from the manufacturing sector, from the automotive sector and other manufacturing sectors.

On advanced skills, which we have been hearing that young people need to be much more adept at, if there is more off-site manufacture in the construction industry, are there lessons from the automotive sector and the manufacturing sector that help can help delivery of these new young people with these skills?

**Dick Elsy:** For sure. We have a list of the roles that never existed before and that we now need. Those have been developed by the work that we have been doing with the sector thus far in our facilities. We have talked about digital lead architect, digital design manager and automation engineers to understand how to control the robotics and assembly technicians. We are now looking at tools such as augmented reality to deskill things to project workplace instructions into the workplace. There is an enormous amount of technology that can be applied to that in addition to the physical skills required.

**Lord Mair:** Click or tap here to enter text. Do you see one big advantage of that is that young people contemplating coming into the construction industry will be potentially much more fired up by that kind of technology?

**Dick Elsy:** Definitely.

**Lord Hunt of Chesterton:** Are there more women? One of the points that has often been made is that women are reluctant to go into the construction industry because of the environment.

**Dick Elsy:** Software and automation is knowledge-based as opposed to a physical thing, so yes.

**Lord Hunt of Chesterton:** Is there empirical evidence that it is changing?

**Dick Elsy:** We always struggle in the technology arena and we are working on it. We are beginning to draw more and more women into our R&D capabilities, so our numbers are going up. The ratios are still not right.

**Lord Hunt of Chesterton:** So is it 20%?
Dick Ely: Just over 20%.

Mark Reynolds: Could I give an example of that, because you have raised an interesting point that goes back to the subject of digital. I was on a project recently and we had initiated a whole BIM strategy—I will be quick with this—taking BIM from concept right through to operational maintenance and asset maintenance. We implemented the strategy four months ago and the team were given training three weeks ago. I was sitting with a couple of financiers in front of four people under 25. The BIM co-ordinator was a woman, who was probably between 23 and 25, and she was running the federated BIM model. The guy who was running the site activities was checking everything as in an automotive production line process, so we had things out of tolerance being checked, conformance logged, cleared and moved forward. Everything was tracked through the process. The planning manager was slightly over 25. It was so impressive. The two financiers said to me, “Your people are very young, aren’t they?” That is what we have to do. It is a completely different skill set. They went through the normal construction management training and were doing completely different skills in a matter of weeks.

Lord Mair: Who should take the lead on the delivery of those skills? Who should be providing this new generation of bright young people coming into the industry?

Steve Radley: There may be a lesson from the manufacturing sector. In a previous life I worked closely with automotive and aerospace, and I found in those industries that even though the companies were competing with each other, there was a lot more collaboration in identifying what the skills were.

One of the issues in the construction industry is that it tends to have a very disjointed approach to training. One of the key things is for employers to join together and ensure that they are training to common standards, having set out the skills that are needed. With the Construction Leadership Council and the CITB working closely with it, we have the opportunity to get that right. Ultimately, it is up to the employers working together to identify what skills are needed and work together to influence training providers and people who create qualifications to ensure that those are reflected.

Mark Reynolds: I was a real sceptic of the Trailblazer programme until I joined the CLC and saw the skills. It is quite impressive. When we understand what the Institute for Apprenticeships—the IFA—is trying to achieve and what industry should do in order to develop those Trailblazer programmes for themselves and work together with other organisations, we will become quite a powerful force.

At the moment, we are still finding our way and a bit disjointed. The concept is fine. We need to find a number of ambassadors to drive it through and get some successes. I was talking to someone at a groundworks organisation last week. He had done all the right things, but nobody had helped him to engage with the IFA. That is the missing piece of the jigsaw.
Mark Farmer: On the question about who should drive this, I agree that whatever we do needs to be created with industry. The standards that we set have to be things that the employers are buying into. My only build on that would be that there needs to be a bit of tension around what is coming over the hill by way of new innovations, new things that perhaps the employers cannot see themselves yet. That is where applied academic thinking and forward look as to how technology in particular is moving can be helpful.

There is lots going on, particularly in the artificial intelligence space that I can see having all sorts of impacts. In some respects, that alone might dwarf the movement to manufacturing that we have been talking about. In reality, it will complement it, but there are lots of things coming that might be ahead of the employers’ thinking as to how that might be applied in their business. There is a little bit of tension there and that forward look is what is needed.

The Chairman: Gentlemen, thank you very much. Our session has come to an end and we appreciate your coming today. It was an interesting session. Thank you.
CCG OSM Ltd – Written evidence (OMC0009)

In response to the recent call for evidence relating to Off-site manufacture for construction, please find answers to the 8 questions as detailed below. By way of introduction and to clarify our position within the off-site manufacturing industry I have provided a brief summary of our business.

In 2010, through private investment, we developed and opened our own Off-Site Manufacturing facility, CCG OSM – a bespoke 130,000 sq. ft. £12 million centre of excellence where we design and manufacture the iQ closed panel timber system across a 3-lane, semi-automated production line. Since implementation in 2010 we have delivered over £85 Million worth of off-site product across a variety of construction sectors throughout the UK (predominately Scotland). With over 60 staff, CCG OSM is now one of the UK’s leading off-site manufacturing plants that produces a product unmatched for its quality and the level of design specification on offer to our clients across the public and private sectors.

1. 
   a. **Opportunities offered by off-site:** The UK Construction industry is by and large not susceptible to change, however as a whole we have continued to fail to achieve targets and there is still a significant shortfall in the demand for housing across the Nation. In order to start to deliver there must be a ‘step change’ within our industry and how we construct buildings. Traditional methods of construction are heavily reliant on skilled labour which is diminishing and presents a huge challenge. Off-site manufacture can offset this skill requirement by allowing operatives to be trained to undertake specific processes / tasks in a controlled environment. The advancing technology with equipment, machinery and robotics also offsets the necessity for certain training and labour aspects. Our iQ system is flexible by nature of design, is governed by strict quality control procedures, gives predictability and certainty of output both within the factory on during on site erect and offers significant programme savings whilst creating a safer working environment. Further to this our timber based system can be specified to achieved the highest building performance criteria to align with Government agenda for lowering carbon emissions and improved sustainability agenda. Our approach is to optimise the fabric of our system and obtain the most efficient thermal and air tightness strategy before considering ‘bolt on’ utilities.

   b. **What are the likely drawbacks?** Drawbacks within the off-site sector can be largely down to lack of understanding of the system. There is currently a great emphasis on the Design for Manufacture and Assembly (DfMA) of buildings and this is being driven with the requirements for Building Information Modelling (BIM) coming into play. Often the on-site assembly of an off-site system can lead to the failings and this is where there must be a joined-up approach and the full DfMA must be considered. The most efficient off-site system can fail at this first hurdle if the site is not up to speed or prepared for the delivery. Off-site also requires a different approach from the design
teams and supply chain. Multiple aspects which are not on the critical path for sign-off and approval on a traditional construction project need to be finalised at an earlier stage in order to ensure maximum value within our off-site system. Architects and engineers must fully understand and be attuned to the design programme and milestones to ensure successful delivery.

c. What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture? In our experience factors likely to influence the choice of off-site manufacture are as follows (not in specific order):
   i. Capability to deliver OSM as part of full construction turnkey contractor or act as sub-contractor
   ii. Flexibility and adaptability of system / product. Offering architectural design flexibility and also suitability of product across variety of sectors (i.e. low rise, medium to high rise, education and health care etc)
   iii. Procurement options
   iv. Opportunities / limitations of the OSM system (i.e. dimensions, materials, building performance specification, structure and fire performance)
   v. Programme savings

2. It is often claimed that offsite manufacture can lead to:
   - lower costs, faster delivery and increased quality;
   - increased productivity;
   - improved health and safety;
   - greater provision of new, affordable housing.

What is the evidence for this?

As part of the City Legacy Partnership, CCG OSM delivered 237 units across the Athletes Village for the 2014 Commonwealth Games held in Glasgow. These 237 units were fully completed in 292 days ready for handover. Coupled with the speed of construction each unit was designed to allow flexibility of use – during the international sporting event the units were required to be utilised in ‘Games Mode’ sleeping up to 12 athletes, post games the units were then transformed to ‘Legacy Mode’ providing a mix of 2, 3 & 4 bedroom houses. The design brief and environmental strategy set by the client was to achieve a Zero Carbon strategy and 60% reduction on the 2012 building regulations, this was achieved by focusing on the fabric of the system in the first instance. This was achieved by optimising the envelope performance to provide approximately 30% reduction in Co2 emissions based on a typical house. A further 30% reduction was driven by the use of renewable technologies available at the time such as MVHR and PV roof panels. This coupled with the use of a local CHP plant servicing the site reduced the CO2 impact by over 100%. This project was delivered ahead of programme within the budget set by the client and is just one example of the use and deliverability of our OSM capabilities across the affordable housing sector.

3. What are the drawbacks to offsite manufacture for construction?
a. Lack of understanding from design teams leading to poor relationship and interaction with off-site provider. This in turn can create a bad stigma and misconception with off-site. It should be noted that the benefits of OSM are significant but ultimately OSM will not improve an inherently bad design.

b. Key relationship and interaction required between off-site manufacturer and principal contractor. If the site is not fully aligned with the requirements of the off-site system then the value added benefits of pre-fabrication can quickly be lost and the programmes savings diminished.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?
   a. Direct off-site manufacture: Skills shortages within the workforce is a serious concern and is only showing signs of worsening in the short term. Off-site can offset this requirement by training operatives to undertake specific tasks and processes relative to their production line. The training can be undertaken ‘in house’ and provides development opportunity for operatives within the business to continue to learn and grow their skills and experience. At CCG OSM we have developed, in partnership with Edinburgh Napier University, Herriot Watt University and the UK Commission for Employment and Skills (UKCES) specific training modules for each area and process of our production line. This documentation is used for all new employees within our business and is similarly rolled out to each existing operative as part of their continual development plan. In addition to this we are also currently collaborating with local colleges and Energy Skills Partnership (ESP) Scotland to develop industry specific training content for Off-site manufacture. ESP is a collaboration of Scotland’s colleges and industry partners established to increase Scotland’s capability and capacity to deliver the right skills for the energy, engineering and construction sectors to meet industry demand. An Off-site Manufacturing action group has been formed with representation from the Structural Timber Association (STA) and Construction Industry Training Board (CITB) in order to develop specific college course content for off-site timber frame manufacturing and onsite assembly.
   b. Ancillary re-skilling:
      i. Designers / Technicians
      ii. Surveyors
      iii. Project / Contract Managers

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how? There are many aspects of standardisation that can be implemented within off-site manufactured systems without hampering the architectural ambition. Within our business we have standardised the wall panel build ups based on achieving varying levels of thermal, air tightness, fire and structural performance. This drives efficiency both within our production line due to the repeatability and consistency, in addition this provides a platform for our buying department on which to broker supply chain partnerships based on economies of scale. Our closed panel timber frame system differs from a modular or volumetric system where typically the units are limited to
rectangular boxes generally governed by the dimensions of transportation which can in turn restrict the design flexibility. The iQ system is panelised and therefore individual elements up to 3.2m x 10m are connected together on site to form the superstructure. This allows for more design flexibility in comparison to a modular / volumetric system. A common misconception of off site is that all units have to look the same. Indeed, there are obvious benefits in standardisation but this can and should be balanced by offering flexibility in external finishes and detailing which play a large part in overcoming these potential concerns. Our closed panel system has been developed with this in mind and we have produced specific detail packs to reflect the type of external finish; be it facing brick, render or rain screen cladding.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture? I believe that there is sufficient evidence and examples of offsite systems being utilised both within the UK and oversees in order to confirm the benefits versus traditional forms of construction without the need for more R&D.

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing? Comments below relate directly to the ‘sector deal’ objectives as set by Government:
   a. 33% reduction in the cost of construction and the whole life cost of assets - whilst cost is an aspect which needs to be controlled and managed to ensure market value. It should also be recognised that with off site manufacturing systems the cost can also come with a certainty of supply and surety of delivery. There is an industry perception that projects need to be tendered in order to ensure market value and often drive costs to a minimum, however this will ultimately detract from quality and deliverability as projects typically have to be value engineered after this process in any case. By establishing supply chain partnerships, the client provides themselves with a certainty of supply and longevity, whilst also having the added benefit of being able to work with the off site provide at an early stage within the design in order to ensure a joined-up approach and that the benefits of the system are driven from the outset. Price checks can be put in place to ensure that market value is being adhered to.
   b. 50% reduction in time taken from beginning to end of new build and refurbished assets – off site systems will bring significant programme savings in comparison to traditional forms of construction. However, if statutory approval processes driven by local authorities and public utility procurement are not managed and held to account within realistic timescales then the most efficient off-site system in the world will still not address the nationwide shortfall in housing.
   c. 50% reduction in greenhouse gas emissions in the built environment - recent building regulations are leaning towards renewable technologies rather than maximising the benefits of the fabric of the building. These need to be realigned and polices put in place so that tax levy or funding can be accessed to positively promote this strategy. Consideration however should be given to the overheating of buildings,
driving to push thermal performance and airtightness should also be reviewed hand in hand with ventilation and overheating.

8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?** Any funding should be used directly within the industry as opposed to develop or create new innovation centres / hubs. More often than not, funding opportunities are limited or capped relative the size of the company (be it turnover or number of employees), in addition to this innovation funds tend to look for significant technological advance or systematic changes within the construction industry. Off-site systems are well established and my view is that funding needs to be provided to companies looking to make the capital investment in the equipment and infrastructure required to take the industry forward. This investment coupled with a Government led policy to back and support MMC over traditional forms of construction with levy or tax reliefs will see growth and uptake within the industry and as a result drive forward the ‘step change’ that is needed within our industry to improve construction output and also the quality thereof.

_Sent by: David Crawford, Business & Operations Manager_  

_16 April 2018_
1. Introduction and general comments

1.1 The Chartered Institute of Building (CIOB) is at the heart of a management career in construction. We are the world's largest and most influential professional body for construction management and leadership. We have a Royal Charter to promote the science and practice of building and construction for the benefit of society, which we have been doing since 1834. Our members work worldwide in the development, conservation and improvement of the built environment. We accredit university degrees, educational courses and training. Our professional and vocational qualifications are a mark of the highest levels of competence and professionalism, providing assurance to clients and authorities who procure built assets. We welcome the opportunity to respond to this inquiry and are happy to be involved in the debate as it develops.

1.2 Even with increased or maintained levels of manpower, there is a general consensus that substantially increasing the number of homes, other buildings and wider infrastructure built a year will not be possible without embracing new technology.\(^5\) If a wholesale switch to off-site construction is to be successful, customers and investors will need to be reassured about the new products. New competencies and managerial skills will have to be nurtured. A number of guaranteed projects will be needed to create market certainty for off-site manufacturers to scale up production capacity. We welcome the construction sector deal commitment for a presumption in favour of off-site manufacturing from 2019.

2. Defining off-site construction

2.1 Some in the construction sector use the term ‘modern methods of construction’ (or ‘MMC’) in place of off-site construction for brevity and understanding rather than accuracy – for example, several 'modern' methods of construction have been used in practice for many years, but are not widely adopted by the sector.

3. Off-site construction

3.1 Off-site construction, and MMC more widely, offer alternative solutions that could:
- Reduce the amount of labour needed on site;
- Reduce health and safety risks during the build process;
- Raise the overall quality and energy efficiency of the finished building;
- Help control overall costs;
- Reduce production waste;

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• Encourage the wider take up of digital construction tools and techniques such as Building Information Modelling (BIM) within the sector, which is part of the Government’s *Digital Built Britain* strategy.

3.2 Even relatively small changes to design such as use of timber frame or precast panels could reduce requirements for labour. "Analysis of data suggests that a well-established timber frame product could reduce labour needs by 25% compared to a conventional housing construction." This is also important in the context of the recent 25 Year Environmental Plan, which commits government to increasing the amount of home-grown timber for us in construction, and in stimulating innovation with products such as cross-laminated timber. There is evidence that off-site wall panels are replacing the need for bricklayers on some projects. Contractor Laing O’Rourke also estimates that using MMC could bring a 30% reduction in programme time, compared to traditional methods.

3.3 Houses are among the most homogeneous products produced by the industry, particularly mid- to high-rise developments. There is scope to develop new products and processes that increase productivity. This can also apply to other relatively homogenous builds such as hotels, some retail etc.

3.4 The off-site construction sector in the UK was valued in 2013 as around £1.5bn, but has the potential to achieve value of £6bn if the market conditions are right. Evidence from UKCES also suggests that modern methods of construction could potentially contribute an extra 60,000 homes per annum.

3.5 A vibrant home-grown off-site sector would have the opportunity to compete on the global market. The sector is currently dominated by companies from Austria and Germany. Japan, China and the USA are ramping up activity. High quality examples of prefabricated products being imported into the UK include SvenskaHomes and Huf Haus from Sweden and Germany respectively. Polish company BUMA also exports a steel framed modular product into the UK. If the UK lags behind international market leaders, this could be a missed opportunity to develop home grown skills and intellectual property rights, protecting direct and indirect employment in the sector and stimulating economic growth.

3.6 Evidence has shown that there are no national regulatory barriers to increased use of off-site manufacturing in house building. Constraints are often based on commercial or supply-side challenges, as well as an aversion to risk. We need to bear in mind that the cost of materials used in the construction of new homes represents only a small proportion of the overall cost; savings from the implementation of new solutions or processes are likely to be modest in most cases, meaning there is no real financial incentive to introduce them.

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6 Arcadis, *People & Money: fundamental to unlocking the housing crisis*, June 2015
7 UKCES, *Technology and Skills in the Construction Industry*, September 2013
8 *Laing O’Rourke look to refresh DfMA*, Offsite Magazine, Spring 2017
9 UKCES, *Technology and Skills in the Construction Industry*, September 2013
3.7 Against this backdrop, though, is evidence from house builders themselves that they would not be able to build more than 150,000 units a year via conventional means, assuming they have the resources available immediately. Volume house builders tend to phase production with sales, making demand erratic. Scaling up production can be seen as risky, and high profile market failures can make investors nervous to invest. In addition, the general public could be reluctant to buy properties that use off-site methods, possibly due to perceptions of prefabricated houses supplied in the post-war era.

3.8 Construction is a risk-averse sector. Its fragmented supply chain acts as a disincentive to investment. It has the lowest spend on research and development than any other sector in the UK, currently estimated to be running at 0.1% of output. Consequently, there are problems in getting products to the market and scaling up production. So we have to ask the question of whether current business and financial models are fit for purpose in being able to deliver the houses, buildings and infrastructure that the UK needs. We need to diversify tenures and supply, bringing in new entrants to the market.

4. Off-site construction and skills

4.1 The move away from traditional build methods to adopting premanufactured elements presents new training challenges which are underestimated by the industry at present. This is likely impact most heavily on professional roles, as trade skills in terms of joinery, plumbing etc. do not differ extensively from their current on-site role. As off-site requires integration between design, construction, manufacturing and engineering disciplines, professionals will need to work in a more interdisciplinary way, embracing wider areas of knowledge than previously. The roles most likely to be affected include design and architecture, engineering, BIM modelling and supervisory project management.

4.2 Managers will need to manage a greater number of variables and diverse teams, bringing together on- and off-site activities. Other hybrid roles may develop, such as an overlap between managerial and professional levels, or technical sales roles where commercial and technical skills overlap. Site managers will need to deepen their logistics competencies. This suggests that behavioural development is as important as skills development for education and training providers. There will be a need for leaders and managers to develop softer collaborative skills such as problem solving, team working and communication alongside their technical competencies.

4.3 However, at present, current training for off-site skills is inadequate. There is a disconnect between industry and training providers and industry and academia. Because of the bespoke nature of off-site systems, most of the training is carried out by companies in-house and lacks consistency. With low margins and tight schedules, organisations lack understanding as to where

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11 UKCES, Technology and Skills in the Construction Industry, September 2013
the skills and knowledge gaps lie for offsite production. Although most of the construction industry consists of SME subcontractors, they are predominantly not involved with off-site technology, and lack the resources to become involved.

5. Productivity and measurement

5.1 There is a further, often undocumented, side effect of moving more construction work to an off-site, factory environment. This lies in the way the Office for National Statistics (ONS) measures construction output, which at the moment only includes onsite activity. By moving construction/house building work off-site and into what is technically defined by the ONS as the manufacturing sector, it is likely that what we see as construction output and its productivity will actually decline or remain stagnant, providing policy makers, industry and the public with an obscured image about the sector. So paradoxically, one could be theoretically building more productively to a higher quality, with innovation in design, product manufacture and construction management, while the statistics suggest the industry is actually becoming less productive.

5.2 We therefore recommend support for a built environment ‘satellite account’ dataset from the ONS. A more complete and consistent set of data like this that measures the entire delivery and maintenance of the built environment would provide significantly better understanding of how construction in its entirety delivers value. It would better capture the impact of the industry as a whole and enable more informed and holistic policy making, as well as provide a truer picture to potential employees of the future about the wide array of roles that the industry provides.

5.3 The CIOB itself has held preliminary discussions with the ONS about such a satellite account, but it will require cross-industry and government support to ensure such a move happens – the National Productivity Investment Fund, for example, would provide a solid and relevant platform to support this work.

6. Case studies and best practice

6.1 The Buildoffsite Property Assurance Scheme (BOPAS), launched in 2013, provides long term assurance to mortgage lenders, valuers, funders, landlords and homeowners that properties built using non-traditional forms of construction will be durable for at least 60 years, without the need for disproportionate maintenance. BOPAS was developed by Buildoffsite, Lloyds Register and BLP Insurance with RICS, the Council of Mortgage Lenders and the Building Societies Association. It gives an independent assessment of quality and reassurance from inception through to construction. Some schemes that have received BOPAS accreditation have also benefitted from a BLP Insurance 10-year structural warranty. Twelve manufacturers have already been approved under BOPAS and a further 12 are going through the process.

6.2 Laing O’Rourke has invested heavily in Design for Manufacture and Assembly technology, establishing a factory at the Explore Industrial Park in Nottinghamshire. As well as manufacturing many components for Custom
House Crossrail station, the factory has also supported residential projects, including Elephant Road, London and Two Fifty One, Southwark. Laing O’Rourke is planning to build an advanced manufacturing facility alongside the existing factory, using intelligent design, precision engineering and fully automated processes that could revolutionise house building in the UK.\textsuperscript{12}

6.3 Legal and General launched a business in 2016 to deliver pre-engineered homes more quickly and cheaply through the largest modular housing construction factory in the world. Using pre-assembled and fitted out cross laminated timber frames, this lean approach dramatically reduces time on site and subsequent need for manpower on site, improving predictability, cost, quality and time. The Farmer Review says that the factory “represents one of the biggest potential disruptions in the UK residential sector with a manufacture approach being used at an unprecedented scale.”

\textit{26 April 2018}

\textsuperscript{12} Mark Farmer, \textit{The Farmer Review of the UK Construction Labour Model}, October 2016
Civil Engineering Contractors Association (CECA) – Written evidence (OMC0044)

1. What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

Construction methods can take a variety of forms: wholly in-situ construction; assembly on-site; manufacture on-site; or, wholly off-site. CECA is supportive of moves towards off-site build, but notes that it has both risks and opportunities which must be analysed on a case by case basis. In our view, the overriding factor must always be to develop the optimum solution for a project, which sometimes may be a combination of on and off-site construction methods.

Furthermore, as we have long argued, it is vital that there is a long-term, certain, pipeline of work for contractors and their suppliers to invest in the capacity to deliver any project, and especially so for off-site build. Investing in off-site build requires a great deal of workload certainty as it is designed in and its logistics arranged much earlier in the process and it requires a substantial investment of both time and money.

Opportunities: Off-site build has the potential to enable effective quality control and enables parallel operations to occur, reducing the overall duration on-site, and as such driving cost savings for customers and contractors, and reducing the impact on the ultimate customer, e.g. the travelling public etc. Our members agree that off-site build can drive improvements to health and safety on site, but it is important to also note that those safety risks are simply being transferred to the manufacturer, albeit within a more controlled environment.

Drawbacks: Off-site build requires early engagement to maximise its benefits as it needs to be incorporated into the permanent works design at an early stage. It may not always be possible due to other constraints, including ensuring the right financial structures are in place and where specific alignments may already be determined as part of the enabling Planning Approvals (DCO, Hybrid Bill etc). However, a number of potential problems could be mitigated by designers and manufacturers engaging with contractors at a very early stage. Notably, before Orders are Made. Furthermore, up-front planning for each programme stage is vital to ensure smooth delivery of any off-site project.

2. What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

CECA believes that a variety of methods are suitable for construction projects. As we have previously indicated, the use of off-site build is dependent on when parties are engaged, how upfront investment is incentivised and what constraints are already embedded into the project. Often there are physical constraints making off-site build a less preferable solution. As such, we would strongly advocate that off-site build is only used appropriately and with proportionality
and takes into account: availability of supply chain and certainty of work, providing the necessary return on investment.

3. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

CECA agrees with the above statement, but only if schemes are designed from the start with off-site in mind. CECA members have indicated a preference for off-site build hybrids which enable architectural features to be built into the project.

4. **What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?**

CECA members have long argued that innovation in infrastructure is about improvement and collaboration. But it is often very difficult to identify the impact of its value.

Our sector has historically been slower than others in maximising the opportunities arising from innovation. While construction spend on R&D has risen quite fast compared with the average for UK plc, it still remains at a lower level than in other sectors.

Understanding innovation’s value is vital in a fast moving business climate where markets and technologies are continually evolving.

While there are notable benefits to off-site build and R&D investment some of which we have identified above, CECA believes the risks of innovation for contractors include:

- Threat of competition;
- Unclear commercial returns;
- Lack of finance;
- Uncertainty over the ownership of any intellectual property;
- Fear of negative impact on project (commercial, financial, time / delays, not delivering to specification);
- Not tried and tested so clients may not agree to accept handover of assets / project on completion immediately; and
- Industry’s shallow margins minimise the ability to allocate resources to dedicated innovation.

Therefore, in order to invest substantially in innovation, CECA believes that civil engineering contractors must develop a clear business case, which is underpinned throughout by client and Government support.

5. **What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?**

CECA believes that there must be a top down approach led by customers in order to drive innovation in supply chains and incentivise contractors to consider off-site build where appropriate. To this end, we are fully supportive of Project 13,
the work led by the Infrastructure Client Group which is creating a community of infrastructure owners and suppliers committed to change and to driving productivity through new methods of working.

In order to maximise the adoption of build off-site it is vital that its benefits are listed and quantified for use when appropriate during procurement processes.

In order to facilitate the ambition outlined above, CECA believes that public procurement processes must also allow for times in their programmes for the development of concepts to allow for off-site construction and the investment to do so.

26 April 2018
1: What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

Offsite manufacture will not solve a construction crisis, but it will prevent a catastrophe.

The previous ‘offsite boom’ lasted circa eight years, until the start of the recession in 2008, but even up to this point the sector had only achieved (optimistically) a circa 7% share of the then £110billion construction sector in the UK. There are several reasons for this relatively small market share but we can conclude that there are two primary reasons; the perceived increased capital cost of offsite construction methods and the under-capitalisation of the sector.

Offsite manufacture for construction involves interchangeable terms referring to the part of the construction process that is carried out away from the building site. This can be in factory or sometimes in specially created temporary production facilities close to the construction site (or field factories). Systems in the offsite portfolio include Cross Laminated Timber, Glulam, Hybrid, LGSF, MEP, Pods, Precast Concrete, SIPS, Timber Frame, Volumetric Modular.

Currently, offsite accounts for circa 10% of the total construction output and is applicable primarily to new-build application rather than retrofit applications. The offsite sector supply-chain and technologies are beset with a series of constraints that must be considered, accommodated or over-come for it to become an established sustainable solution and to obtain a significant double-digit market share.

The house-building sector appears to be grabbing many of the headlines – primarily due to offsite construction being seen as a potential solution to the housing crisis – but offsite construction is also rapidly expanding in other non-residential applications such as hotels, student accommodation and more latterly the schools sector, with over 450 new schools and classrooms required per annum to the 2020 horizon under the Priority School Building Programme (PSBP). This demand has seen a ‘pull’-away in offsite manufacturing capacity from the house-building sector and therefore restricted some of the available capacity being tapped in to by the residential developers. The offsite manufacturing sector is in danger of overheating and this is a significantly negative factor in influencing clients, architects, design engineers and contractors as lead-times extend.

As the construction process has evolved – so has design. Architects, designers and engineers have to orchestrate a collaborative design protocol and help to conceive products for a manufacturing process, as well as know how to integrate them into a design i.e. there is a greater emphasis on Design for Manufacture and Assembly (DfMA) which need to be better understood. This re-skills rather than de-skills the design process and in the context of architects can often be perceived as a threat to the role of the architect, thereby engendering a negative mindset towards offsite manufacture for construction.
Manufacturers know how the materials and processes they use best come together, how to control waste and quality, and how to learn from previous experience. By understanding the purpose of each component and working collaboratively with the manufacturer, architects can take these virtues from the factory to the building. When architects realise, and not all do, how to design for and with manufacturers, they can design buildings that are easier to build (assemble) with less wasteful of resources, more enjoyable to use and more valuable to their owners.

2. It is often claimed that offsite manufacture can lead to:
   • lower costs, faster delivery and increased quality;
   • increased productivity;
   • improved health and safety;
   • greater provision of new, affordable housing.
What is the evidence for this?

It is clear that the drivers for change vary but most would cite predictability (of cost and programme), improved quality (reduced snagging) and a direct method of addressing the skills shortage as the primary reasons for embracing offsite manufactured solutions. There is generally a very limited understanding of the offsite sector and a lack of tangible evidence to support the performance achievement claims of the sector – too many of the benefits of offsite construction are anecdotal. Even bodies such as BuildOffsite cannot ‘underpin’ many of the offsite sector arguments with ‘hard facts’ and often bases communications output on unsubstantiated information. This is a significant achilles-heel of the offsite sector and one that Government can help to address by developing independent evidence of the real benefits using recent live projects.

Cogent Consulting are currently undertaking a report to provide impartial, quantifiable evidence to evaluate the capability, capacity and viability of the offsite sector.

Potential barriers to wider use of offsite manufacture

3. What are the drawbacks to offsite manufacture for construction?

Lack of investment is frequently linked to a lack of certainty of demand or continuity of business. Construction is typically a project-based activity and thus the customer base can be difficult to maintain as key ‘customers’ move from one project team to the next. Whilst parallels are often made with the automotive industry these are very tenuous links as the offsite industry does not ‘tell’ the client what they want, it responds to designs and concepts developed by unrelated (and often uneducated in respect of offsite manufacture) architects, engineers and contractors.

The key issues of standardisation, capital investment in semi-automation and the cost premium are part of the same equation and have a direct correlation. That is, with more standardisation there is a higher likelihood of a production process being repeatable and therefore automated, with automation comes investment in machinery which increases efficiency levels and provides cost reductions. Cost
reductions present the opportunity for more volume and with more volume, more automation is required and therefore more efficiencies are found.

Whilst this is an obvious cycle it is one that very few UK-based offsite manufacturers have been able to capitalise on and so the level of investment in UK offsite manufacturing resources is woefully low, resulting in an industry that has businesses that are best described as ‘building sites under a roof’.

There are estimated to be less than 20 businesses in the UK offsite manufacturing sector that we would say embrace a ‘world-class manufacturing’ ethos and have received the levels of investment required to ‘break the cycle’ outlined above. These businesses have therefore prospered and are set to capitalise on the return of the market. As such, the primary drawback of using offsite manufactured solutions is the associated risk with the financial fragility of the supply-chain.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

The resurgence of offsite has seen a blurring of the lines between manufacturing, engineering and construction - creating the need for new skills and redefining existing ones. We need to not only train new entrants in a range of new skills, but also upskill our existing workforce. The digitalisation of the construction industry and the link that provides to offsite also offers a chance to attract a new cohort of skilled workers.

One of the key recommendations within the Farmer Review was the need to comprehensively review the Construction Industry Training Board (CITB) and institute a reform programme. In response, the CITB have recently issued its own report - Faster, Smarter, More Efficient: Building Skills for Offsite Construction, which is a research summary, and action plan. The report recognises the changing dynamic that faces the UK construction industry, and the growing appetite to utilise offsite construction. Reinforcing Mark Farmer’s observation that new methods of construction will require new skill sets, if the expectations are to be realised, and the benefits and momentum of offsite construction are to be achieved. The report identifies that the successful implementation of offsite techniques will require an integrated understanding of both offsite and on-site implications and the need to redefine current roles.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

More often the offsite manufacturing operation is responding to and accommodating the demands of a range of ‘stakeholders’; planners, clients, architects and residents for example, and as such the ability to deliver high levels of standardisation (at a footprint level), is eroded. The focus is therefore likely to need to be on the levels of ‘invisible standardisation’ (sometimes referred to as ‘mass customisation’) that can be achieved. That is, standardisation at an elemental or component level, and it is these ‘product characteristics’ that need to be appraised in detail when making an assessment of which material or offsite system type to select and implement.
The emergence of BIM (Building Information Modelling) which is now starting to influence the genuine adoption of Design for Manufacture and Assembly (DfMA) which will significantly aide the offsite manufacturer’s ability to address the standardisation issue. BIM will permit greater opportunity for further upstream integration of components and systems and will therefore no doubt generate new types of offsite manufactured technologies. The recent development of the DfMA Plan of Work overlay document produced by the RIBA, shows a direct correlation with upstream architectural design activity and demonstrates how the design team can contribute to the process. As well as delivering projects faster, lowering costs and improving quality, the use of DfMA techniques will also result in better operational and in-use outcomes. Fundamentally, DfMA requires the design team to shift their thinking away from traditional means of construction to scenarios where buildings are assembled rather than constructed, and where opportunities for ‘offsite construction’ are maximized without hampering architectural ambition.

**Government actions**

6. **What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?**

R&D is required in area of complementary systems to the primary portfolio of structural offsite technologies e.g. cladding and façade systems, fast-track roofing technologies and pre-engineered foundation systems. Many of the current offsite manufactured systems revert to traditional construction processes on site to complete the building structure/envelope and this needs to be addressed if the maximum benefits are to be fully realised. Transferring more of the site-based activity in to the manufacturing operation is not necessarily the most effective solution to this observation and as such a greater focus on site-based innovation to complement the offsite technology is required.

7. **(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?**

The construction sector deal will help modernise the industry and recruit and train the next generation of high-skilled construction workers, but it should not lose sight of the fact that the offsite manufacturing sector also have skills challenges and needs to recruit/train the next generation of manufacturing engineers, capacity planners, DfMA experts, continuous improvement and lean manufacturing experts etc. With the current emphasis there is a danger that the skills and recruitment challenges of the traditional construction we simply be transferred to the manufacturing environment rather than addressing the route challenge which is how do we make the construction sector a more appealing industry in which to develop a rewarding career?

8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?**

The most significant and impactful change that could be made to public procurement processes relates to the aggregation of demand and a greater focus
on standardisation at a component level in order to leverage greater efficiency in procurement via integrated supply-chains. Significant economies of scale are realisable through tighter specification control and a more prescriptive and consistent approach to performance parameters. An expansion of consortia or framework-based procurement initiatives will encourage economies of scale and minimise procurement complexities. Greater production volumes of standardised offsite manufactured technology will increase productivity performance and permit the step-change that other high-volume manufacturing industries have realised e.g. the white goods and automotive sectors.

26 April 2018
Concrete Centre – Written evidence (OMC0061)

Who we are
The Concrete Centre provides guidance for engineers, architects and other members of project teams on design of projects using concrete in all its forms. Concrete Centre experts are involved in standards committees, research & development and input into construction industry guidance and best practice. It is a not for profit body, part of the Mineral Products Association the trade association for the aggregates, asphalt, cement, concrete, dimensioned stone, lime, mortar and silica sand industries.

The Mineral Products Association (MPA) is the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries. With the affiliation of British Precast, the British Association of Reinforcement (BAR), Eurobitume, QPA Northern Ireland, MPA Scotland and the British Calcium Carbonate Federation, it has a growing membership of 480 companies and is the sectoral voice for mineral products. MPA membership is made up of the vast majority of independent SME quarrying companies throughout the UK, as well as the 9 major international and global companies. It covers 100% of UK cement production, 90% of aggregates production, 95% of asphalt and over 70% of ready-mixed concrete and precast concrete production. Each year the industry supplies £20 billion worth of materials and services to the Economy and is the largest supplier to the construction industry, which has annual output valued at £144billion. Industry production represents the largest materials flow in the UK economy and is also one of the largest manufacturing sectors. For more information visit: www.mineralproducts.org

Commentary
1. As identified in the call for submission and other services offsite manufacturing for construction is not new. In the subset of construction within our expertise, precast concrete has been successfully used for decades not just as concrete cast in a factory, but also with value added elements also fitted in the factory.
   i. In the case of building cladding, precast concrete cladding wall panels which are full storey height, having the external aesthetic finish such as bricks incorporated in the factory along with windows is commonplace. In recent times, the best-known example would be the Olympic village which was constructed using these cladding offsite elements
   ii. In the case of building structures, offsite manufactured elements – columns, walls, beams, slabs and volumetric core elements are all used in the UK. There are a range of supply chain avenues for this to occur: for example, conventional insitu concrete building contractors choosing to precast some elements; specialist frame contractors who design procure and install precast elements to form the whole structure; and main contractors who win projects on the basis of using precast concrete. Cooling/heating pipes and other services can be cast into slab elements in the factory. Portcullis House utilises offsite manufactured precast concrete.
iii. Foundations can also be precast. Offsite precast concrete piles and ground beams are used, although the former is restricted by ground conditions.

iv. In the case of infrastructure, offsite manufactured precast concrete elements are extensively used across all aspects of energy, water/drainage, communications, and transport. Examples include precast concrete tunnel linings, rather than site placed concrete, which are utilised with TBM machines and precast elements which are used to minimise road/rail closures. Precast elements for the public realm (e.g. station platforms) can be prepared in the factory with tactile surfacing for the disabled.

2. Offsite manufactured precast concrete can deliver the following benefits: increased speed of installation, higher quality, reduced site operatives, reduced noise, less site waste.

3. Offsite should not be seen as a panacea for all ills of construction or seen to be applicable in all cases.
   i. Offsite manufactured products using any materials requires more lead in time prior to start of construction. Overall procurement may be longer when lead in times are accounted for.
   ii. Transport from factory to site may be significant and may result in greater overall transport. This is particularly the case if components are produced at many factories, transported to an assembly plant and then transported to site.
   iii. Without repetition, offsite precast does not gain from economies of scale and we understand this is also the case for lightweight offsite systems.

4. There are procurement and construction risks to adopting new forms of offsite construction: untried, few standards, single or few suppliers, low resilience of materials to fire, water and physical damage.

5. Precast concrete reduces these risks because: it has been around for a long time and lessons have been learnt; standards have been developed and refined; a mature robust supply industry has been developed which protects clients; amongst the inherent properties of the main material concrete are resilience to fire, water and physical damage.

6. There are in use performance risks to adopting new lightweight forms of offsite construction: lower resilience to overheating, lower resilience to flood damage, increased risk of fire damage, increased risk of water damage.

7. Concrete and masonry have inherent properties that enable designers to deliver sustainable projects with the highest resilience to overheating, flooding, fire and water.

Question responses

Perceived advantages of offsite manufacture for construction

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely
to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

1.1 The term offsite covers such a broad range of solutions – by definition, the only thing in common being a high proportion of content being made in a factory. It therefore follows that there is a high degree of generalisation to cover this breadth of benefits. In turn it follows that in the generalisation the benefits across a range of solutions all are aggregated and communicated, when any one solution may only have a subset of such benefits.

1.2 Opportunities include speed on site, less waste, quality of product, improved health and safety. However, some or all of these may not be realised, with some offsite solutions, and on some projects.

1.3 Drawbacks can include a lack of design standards, higher cost if insufficient repetition, increased procurement/delivery risk from procuring from a small immature supply chain, increased risks during construction due to limited fire and physical resilience, lower in-use performance and reduced longevity.

1.4 The majority of clients are driven by cost and time. Typically, capital cost, although some clients consider whole life cost. Risks are costed, so these factors are not given zero weight, when cost is the metric. Time for transport infrastructure closures or education facility start of year/term makes time a factor in itself. Time until completion at which stage income can be received can be costed.

1.5 Architects, design engineers, contractors and the supply chain have their own agendas but in most part are driven by serving the client’s agenda.

1.6 There are the exceptions where clients are driven by other factors e.g. sustainability (many definitions may be used for this) or the project team influence choices based on their own agenda or passions.

2 It is often claimed that offsite manufacture can lead to:
- lower costs, faster delivery and increased quality;
- increased productivity
- improved health and safety;
- greater provision of new, affordable housing.

What is the evidence for this?

2.1 Precast concrete has been used to deliver lower cost, faster and higher quality building projects. However, this does not mean that this would always be the case, and on-site casting of concrete has also resulted in lower cost and faster overall construction periods for other projects. It is a case by case situation that is best left in the hands of construction professionals and clients.

2.2 We are not aware of credible productivity metrics that have been used to compare like for like projects with different construction methods across many projects.

2.3 We are aware of health and safety improvements in offsite and non-offsite methods of construction within our remit.

2.4 The continued greater provision of affordable housing can be achieved using on site masonry construction alone or with a majority of masonry
concrete and some offsite construction. Masonry construction remains the cheapest form of construction, can surpass all in-use performance requirements, is long lasting and resilient to future climate change.

2.5 There simply is not the capacity in the offsite sector to deliver all the affordable housing needed, nor is it conceivable to think that it could be developed, unless the government chooses to distort the market.

2.6 Precast concrete is manufactured in the UK from, in the main, UK sourced constituents. This is markedly in contrast with lightweight timber and steel offsite solutions that are either imported or fabricated from constituents and components that are mostly imported. This results in lightweight offsite solutions being prone to currency fluctuations and the CO2 emissions resulting from transportation over long distances.

**Potential barriers to wider use of offsite manufacture**

3 **What are the drawbacks to offsite manufacture for construction?**

3.1 A drawback of increased offsite manufacture will be an increase in imports (unless the offsite solution is all precast concrete). This runs counter to the Construction Strategy that targets a decrease in imports of construction products by 2025.

3.2 The vast majority of UK homes are constructed from fire and flood resilient, durable, energy efficient, cost effective masonry solutions using UK produced products.

   i. A drawback is that in low rise housing an increase in offsite (unless the offsite solution is all precast concrete) will reduce longevity and long-term value.

   ii. A drawback is that in low rise housing an increase in offsite (unless the offsite solution is all precast concrete) will reduce flood resilience. The British Standard states (BS 8550) that concrete and masonry solutions should be used for flood resilience.

   iii. A drawback is that in low rise housing an increase in offsite (unless the offsite solution is all precast concrete) will reduce fire resilience. Concrete and masonry does not burn. Government statistics show that offsite timber solutions suffer more extensive damage from fire. ([Analysis of fires in buildings of timber framed construction, England, 2009-10 to 2011-12; Department for Communities and Local Government; December 2012](#)).

   iv. A drawback is that in low rise housing an increase in offsite (unless the offsite solution is all precast concrete) will increase the import of construction products or constituents. For example, construction grade timber is imported.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

4.1 We have engaged in communicating the most efficient and sustainable concrete and masonry solutions since 2003. We equip designers to appropriately choose masonry, insitu concrete and precast concrete for
projects and to understand the manufacturing methods and how to incorporate them effectively into design.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

5.1 Standardisation does not have to hamper architectural ambition if appropriately used with a budget that supports high quality design and quality finishes.

5.2 The benefits of standardisation and factory manufacture rely at an economic level on a high level of repetition and simple geometry which in turn can lead to monotonous and cheerless design.

5.3 To mitigate this, good design and high-class finishes will be required, which in turn may dilute the economic advantages.

5.4 Within the UK, cost plan/budgets, public perception and the planning environment could preclude the use of such repetition and scale where smaller scaled solutions would be favoured such as masonry. This relates to good design.

6 What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

6.1 No comment.

Government actions

7 (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

7.1 Government needs to give greater clarity on forward programme of government project spend and allocation. It must also ensure its agencies also provide clarity and deliver according to promised allocation.

7.2 Government needs to provide a clear direction and stick to it. When there was clarity in relation to increasing sustainability standards for homes (Code for Sustainable Homes) with levels set for forthcoming years well in advance, the industry did respond. In some cases, the decision was made to meet future standards now, because there was clarity of the future. It is disappointing that responsible sourcing ambitions set in 2008 for 2012 have never been revisited (Sustainable Construction Strategy 2008). It is pleasing that Hansford 2025 targets are likely to be maintained in the construction sector deal. It is hoped that government procurement will reflect targets for UK sourced construction products and materials.

8 What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?
8.1 More economic and sustainable practices could be encouraged by implementing a balanced scorecard approach to procurement with recognition of the value of local products. (refer Crown Procurement Service)

8.2 More economic and sustainable practices could be encouraged by introducing employer requirements for responsible sourcing of construction products in accordance with BES 6001 or similar.

8.3 More economic and sustainable practices could be encouraged by introducing employer requirements for a longer service life and whole life cycle analysis in infrastructure and building sectors. For example, in the drainage sector, at current replacement rates pipelines need to last for 100’s of years and yet are specified to last for a small fraction of this. An improvement would be to increase to a longer specified service life that incurs little or no additional cost.

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8.6 More economic and sustainable practices could be encouraged by introducing employer requirements for designers to be cognisant of climate change and future risks from an increased incidence of overheating and flooding.

8.7 More economic and sustainable practices could be encouraged by ensuring that new jargon such as the ‘circular economy’ does not result in unintended consequences. Circular economy thinking encompasses maximising resource efficiency, minimising use of virgin materials, maximising re-use and recycling. These are all laudable. However, this thinking can erroneously lead to short term buildings made from a kit of parts that can be re-purposed. In some instances, this may be the right solution, but in many cases, it is better to have a long-lasting shell that can be re-used many times over as the finishes and interior are updated. It is also the case that for a growing society we need virgin materials to provide for increasing total overall needs. Incorrect application of recycling zeal can lead to perverse less sustainable outcomes overall: for example, the use of recycled aggregates that have travelled a greater distance than 11km will only increase the carbon footprint when local virgin materials are available.

26 April 2018
Constructing Excellence is a platform for industry improvement to deliver excellence for clients, industry and users through collaborative working. Constructing Excellence has a national corporate membership spanning the construction supply chain from client to supply chain, as well as a network of associated regions and clubs across the England and Wales.

‘Increased standardisation and pre-manufactured content’ is a core part of our vision. In 2017 Constructing Excellence launched an Offsite Manufacturing & Technology Group that works across the construction supply chain to look at the issues affecting the implementation of Offsite Technology and suggest solutions to overcome those barriers. The group uses practical demonstrations and visits to delve into opportunities and benefits around offsite technologies.

A poll of over 100 participants at the December 2017 Constructing Excellence Annual Conference revealed 61% of respondents were positive that their organisation were in a good position to exploit the full benefits of offsite manufacturing and technology, whilst only 11% felt negative. This may reflect the positive and forward-thinking organisations that engage with Constructing Excellence rather than the industry as a whole.

Constructing Excellence firmly believes that offsite is only part of the solution. It needs to align with a shift in industry procurement towards whole life value and incorporate high value manufacturing techniques and digital technologies – doing what is currently done on sites is not going to effectively deliver the high quality buildings and infrastructure that the UK needs.

What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

Opportunities

Fully embracing offsite manufacturing and digital construction has the potential to transform the construction industry. Increased productivity will come from greater utilisation of capital, elimination of waste in the supply chain, reduced time on site which will lead to greater predictability.

It has the potential to alleviate the industry’s skills shortage by creating new job roles that are more attractive to the emerging workforce. There is a fear that the push towards offsite and associated automation that may lead to job losses. However, evidence from the manufacturing sector suggests increased automation mean a higher level of training and therefore opportunities to improve the workforce skillset and flexibility. High quality production and just in time service also require resources and training in Quality Assurance, planning and Health & Safety to support the supply chain.

Drawbacks
A clear message from Constructing Excellence members is that **early decisions** on offsite are required in order to deliver real value for clients.

The industry in its current form cannot deliver the full benefits of Offsite manufacture for construction. Existing procurement and contractual relationships are not geared up to recognise the full benefits of offsite manufacture. To realise its full potential clients need to have long term relationships in place with offsite providers and decisions need to be made much earlier in the process.

**It is often claimed that offsite manufacture can lead to: lower costs, faster delivery and increased quality; increased productivity; improved health and safety; greater provision of new, affordable housing. What is the evidence for this?**

Constructing Excellence has 18 years of industry performance data and benchmarking, which it continues to collect. The offsite theme group is developing a set of KPIs for projects delivered using offsite techniques in order to benchmark performance against traditional build methodologies.

**What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?**

Construction supply chains are often fragmented and inefficient. Across the supply chain construction product manufacturers have the opportunity to change the perception of their product from simple commodities. In order to add more value they need to get closer to their clients to really understand their requirements and how they define value, in much the same way as the automotive sector has done. This would require a movement away from traditional supply chains towards more integrated supply chains.

The existing contractual and procurement model does not encourage offsite delivery. When clients procure traditionally they are effectively limiting and even excluding the potential use and benefits to be derived from offsite approaches. The existing supply chains could take a flatter more integrated form, much in the way that has happened with the automotive and aerospace sectors. Factors such as increasing digitisation through Building Information Modelling (BIM) and the potential use of smart contracts could help enable this.

Greater **standardisation and harmonisation** of offsite approaches de-risks the implementation of offsite as clients are not limited to a single supplier on a particular scheme and also makes servicing and maintenance easier.

There is a need for verified and comparable evidence of the performance of offsite solutions in design, construction and operational phases. Constructing Excellence is working up a set of Key Performance Indicators (KPIs) which integrate with its existing KPIs to enable comparison across traditional and offsite methodologies.

Generating a **pipeline of repeatable projects** and elements that can unlock long-term investment and enable the industry to build on knowledge and transfer
learning more effectively between projects. The government presumption towards offsite is a very welcome intervention to help achieve this.

**What are the drawbacks to offsite manufacture for construction?**

Many of the perceived drawbacks of offsite manufacture for construction are linked to the current contractual and procurement processes, which do not allow offsite to operate at its optimal levels. The effective implementation of offsite requires decisions to be made and confirmed at an earlier stage, effectively applying manufacturing principles to offsite. Moreover, in order to benefit from the economies of scale, offsite manufacture needs to deliver cost savings; the supply chain requires greater certainty of demand and longer term commitment from clients.

**What re-skilling of the construction workforce is required to facilitate a change to more offsite manufacture for construction?**

- More design for manufacture
- More manufacturing based jobs, including automation and digital technology
- Different skills on site in terms of logistics and assembly

**Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

Offsite manufacture opens up new possibilities for building design. It requires a new way of thinking in terms of design for manufacture and indeed, design for customisation, something which has been embraced by other industries without hampering design ambition. New skills are needed to deliver effective design for manufacture.

**Generative design tools and a platform based approach** with a pallet of products will help allow construction to start full advantage of manufacturing and its added value. This relates to the work that Constructing Excellence Members have been doing in the education space to identify a kit of parts for the education sector that can be configured to suit the specific site and client requirements, whilst still meeting Education Funding Agency requirements at higher spec and lower costs.

Finding ways to enable **early manufacturer engagement** whilst remaining compliant with European procurement regulations. This will enable tenders and procurement to be delivered in a way that supports innovation and SME involvement.

**What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?**

R&D needs to focus much more on higher technology readiness levels. Seeking practical implementable solutions and capturing learning on real projects. These include:
• Performance indicators for offsite manufacture, which map on to existing industry performance indicators.
• Developing standards to de-risk the implementation of offsite for clients and ensure consistency and maintainability. This is both on the technical and contractual side.
• Research into performance in use to ensure that offsite is delivering the quality and value required.
• The integration of digital technology into the design, manufacture and assemble process.
• Research into the application of high value and precision manufacturing techniques and principles on the delivery of buildings and infrastructure.

What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?

Procurement processes are in place to manage risk, and particularly in the public sector to ensure fairness and transparency. It is doubtful whether existing complex supply chains can be open and whether they do deliver transparency and that current processes were skewed towards traditional delivery. It was considered that existing procurement procedures can get in the way of early manufacturer engagement and therefore limit some of the advantages of offsite. Moreover, passing risk down the supply chain has the effect of multiplying risk. Informed and enlightened clients have the power to change this and change the attitude to risk.

Long term relationships: Suppliers invest in production facilities on the basis of long-term and certain demand based on standardisation and systemisation, making it easier to make long term investments in manufacturing facilities. Long-term relationships with clients, it can take 2 years of discussions with end clients before a part gets put on the production line. The steel industry is not without risks but those risks are clearly identified and understood so therefore investments can be justified. Short-term procurement models don’t support long-term engagement with supply chains. Contracts need to change to support better, fairer payment mechanisms.

26 April 2018
Construction Industry Council (CIC), Construction Products Association and Build UK – Oral evidence (QQ 50-56)

Transcript to be found under Build UK
Transcript to be found under Cast
Tuesday 15 May 2018

Members present: Lord Patel (Chairman); Lord Borwick; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 8  Heard in Public  Questions 57 - 63

Examination of witness

Andrew Wolstenholme OBE.

Q57  **The Chairman:** Good afternoon, Mr Wolstenholme. Thank you very much for coming to help us with this inquiry today. Would you say who you are for the record and what your current position is and, if you wanted to say anything to start with, please do so, otherwise I will go straight to the questions.

**Andrew Wolstenholme:** First, thank you very much for giving me the opportunity to come here today. I am Andrew Wolstenholme, the ex-chief executive of Crossrail. I find myself in a curious position because as of now I do not have a position. I am about to take up the group managing director role of maritime and land for BAE Systems, so a slight shift in sectoral balance.

I have just come from the Department for Business, Energy and Industrial Strategy where I got an update on something that is extremely exciting and will act as a catalyst for much of what you have been talking about, which is the construction sector deal. If I may say so—and apologies if it is not my position to do so—it is a slight frustration that this sector deal has not yet been announced, and over the course of this questioning I would like to tell you a little about the three elements of it.

The central one is an industry-led innovation programme with manufacturing sitting at its heart. I came in a few moments before the end and heard some of the debate and dialogue going on, and I would say this is a very important strand of UK plc. Infrastructure and construction represents around 8% of the UK’s GDP. We represent somewhere around 10% of the employment opportunities. For rather too long now, this sector has not attracted the sort of debate we are having here today, so thank you for the opportunity, and over the course of the questioning there are very many points of a very positive and constructive nature that I would like to draw out.

**The Chairman:** You are a key witness in lots of ways but if I might start with a question given your statement: do you have any idea as to when the sector deal is likely to be published?

**Andrew Wolstenholme:** I know that it has been signed off by all the respective stakeholder groups. I know that, unfortunately, it has got stuck
because Judith Hackitt is going to issue her report soon around the tragedy this time last year in north Kensington. I also know that it got stuck because of the inconvenience of the activities around Carillion’s failure. All I would say is that we cannot wait too much longer for this important sector deal to come out. In politics there will always be a reason why you should not push the boat out a bit, but if there is any help or support that this Committee can give, I would very much welcome that.

**The Chairman:** What kind of support can this Committee give to expedite that process?

**Andrew Wolstenholme:** My expertise is not in bringing statute to the start line, as it were. We need to do whatever we can to convince BEIS that now is the right time to deliver this sector deal. If anyone around the table could influence that it would be welcome. If it is not the position of this Committee to do so, I apologise, but we need this thing to be out because, in many ways, it is the catalyst that is going to unlock much of the intent and the opportunity to go down much more of a manufacturing route.

**The Chairman:** Let me come to a different question. Is it correct that you currently lead the Construction Leadership Council?

**Andrew Wolstenholme:** I am the co-chair of the Construction Leadership Council.

**Q58 The Chairman:** We are told that this leadership council is crucial to encourage wider use of off-site construction and that it needs to take the responsibility because it has the authority to drive this process. Is that correct and, if it is, how do you intend to do that?

**Andrew Wolstenholme:** About two years ago I was asked by Sir David Higgins, who was the chairman of the Construction Leadership Council, to take over the co-chair role. If you look at my background, I have been in the major programme sector for about 30 years, originally as a consultant with a group called Ove Arup, then with the airport operator in those days known as BAA, and subsequently with Crossrail. On each of those occasions I spent about seven years looking at infrastructure and critical assets from different directions.

This sector has lacked a very simple and compelling agenda with a very strong business case to go with it. I asked a private consultancy to help put some numbers together. If you look at the simple facts, here is a sector that represents around 8% of GDP and 10% of employment. If you look at the pipeline of critical assets ahead, we have somewhere between £450 billion and £550 billion. The analysis that was done showed that on our current levels of production and productivity, we will be somewhere between 20% and 25% short of resources or raw productive outputs. The start point from the CLC was to put forward the thesis that unless the sector came together around a compelling and simple agenda that could attract the attention of a very diverse sector and industry against one set of initiatives, we would, like many others previously, fail to get critical change across the different parts of the sector.
The sector, as you have learned, represents housebuilding into private commercial developments into public sector social and economic infrastructure. This is a huge opportunity and the question for this sector is: what is it that brings the common denominators together? We went out to a leadership group, and some of the individuals who were here a moment ago helped me do this, to try to get the three strands. I looked first at the automotive and, secondly, at the aerospace industry. Aerospace has attracted £4.5 billion of match funding from government over the last 10 years. The two things that aerospace has focused on are wings and engines. We do not make complete aircraft here. The two things that the automotive industry is focusing on right now are driverless and battery—in other words, power plants beyond those that are carbon dependent. I asked myself the question: what are the wings and engines of this sector? What are the three things that make it very simple that everyone, from a housebuilder to someone building a school, a hospital or a major programme such as Crossrail, can hang on to? The three strands were, first, the definition of the outcomes at the front, so using digital technologies to deliver better, more certain outcomes. A car, for instance, has a digital model that is 98% mature before you start manufacturing possibly 10,000; a building’s digital model is probably less than 60% mature before you start building, so it is absolutely vital that you get the definition and the outcomes understood before you start what we traditionally call build.

That gives you two opportunities. The first is to improve the productivity of delivering the asset and that may take two, three or four years. For Crossrail it has taken about eight years. There is a huge opportunity to improve productivity. Why do we want to improve productivity? First, it brings that asset to market quicker; secondly because it relies less on the resources we are currently importing from eastern Europe—and I suspect there will less of them in the future, certainly post Brexit—and, thirdly, instead of constructing on-site by importing those skills, it provides high-value manufacturing jobs in the areas where jobs are needed most. The opportunity through digitalisation is to improve productivity. Manufacturing is part of that and I have given you some very good examples.

The third opportunity—and I am going to point to Lord Robert Mair here and the fantastic work that he has done at Cambridge University, and forgive me, Robert, for introducing any conflicts here—is the opportunity to understand how that asset behaves over its entire life cycle. Bombardier has a train set on Crossrail that pretty much diagnoses and self-analyses on an hour-by-hour basis the state of that infrastructure. Down the road in Derby, Rolls-Royce also, incidentally, knows exactly what its engines are doing hour by hour. Unless you digitalise at the front end, you lose the opportunity, first, to improve productivity through the delivery, and, secondly, to introduce smart technologies, monitoring and datasets to the life of that asset. In infrastructure and building we have missed the opportunity to deliver both of those, principally because of the slow uptake of digital technologies at the front end.

The sector deal is about three things: better and more certain outcomes for the delivery of digital technologies, improved productivity by the introduction of manufacturing, and improved life cycle performance by the
introduction of smart technologies, including sensor technologies. All of these are available and we are at the forefront of a potential revolution that can take us back into a leading role, not only nationally but internationally across the different marketplaces there will be post Brexit.

**The Chairman:** What state is the UK in regarding the digitisation of the construction industry?

**Andrew Wolstenholme:** It may come as a bit of a surprise to learn that we are not badly placed. The Government have done a very good job in promoting what is called BIM—building information management. It is probably the wrong word, but it has gained some traction and it is here to stay. I call these digital technologies. It is mandated at BIM Level 2 that public sector programmes use this. If you go around the world—and I have not done much international travel as I have had my head down on Crossrail for the last seven years—you will see it is the envy of many other nations. America has technology that is much better advanced but is unable to deploy it on programmes. We are very good here, even though we rock ourselves quite often, at working collaboratively in projects to make sure that the technology is spread across all the different departments. If you only have 10% of the project using the same technology, you will get 10 different interfaces. If you have, as they do in the car industry, one model that represents the concept design of that car, and it goes right the way down to looking at what rivets you use and how the different componentry comes together, that is the environment within which you have the opportunity to go away and manufacture.

In my time at Crossrail and terminal 5, we have been promoting a collaborative way of working to make sure there is the opportunity for the digital model to speak a single language across the whole of that project. Where you have that, you have the opportunity to talk about manufacturing.

**Lord Griffiths of Fforestfach:** It is a great pleasure to ask you questions. You have described yourself as a revolutionary.

**Andrew Wolstenholme:** I have?

**Lord Griffiths of Fforestfach:** Yes. You have said you were one of the people leading this revolution, which is terrific news.

**Andrew Wolstenholme:** With many others in this room, I am sure.

**Lord Griffiths of Fforestfach:** I have two questions. The first is because of what you said at the beginning. I can see the case for the sector deal being spelt out as soon as possible. Where do you think the capital to support it will come from? A lot of evidence we have taken is to do with buildings going up whereas you have been at the horizontal level. My second question is: what have you learned from that about a model of construction which might be relevant to us?

**Andrew Wolstenholme:** Let me start with that one because I was anticipating something along those lines. You can see what we have done on Crossrail. I started when the programme was 4% complete and it is now 93% complete. It will open in December and it will transform London.
Some 42 kilometres of bored tunnel has been done completely through a manufacturing process. There is no need to worry about certain elements of this. This is not off-site manufacture; this is on-site manufacture. A tunnel-boring machine only has two roles to play. It takes away around 6.5 million cubic metres of clay and replaces it with off-site manufactured concrete segments. It does this with a team of somewhere between 15 and 20 people. This is a factory working 24 hours a day under London building a tunnel and it is completely manufactured. If you look at what we need to tie these running tunnels together—these are 7 metre diameter tunnels—to the passenger spaces, to the concourses, to the various escalator barrels and all the rest of it, you do not have a machine as a tunnel-boring machine; you have to hand spray concrete. It is called a sprayed concrete lining. When I was at Heathrow you had a pack of strong people holding nozzles. Today these are people dressed as if they were space people—men and women—operating robots in a manufacturing process. We are manufacturing the principal elements of Crossrail.

If you look at how we introduce the technology into the tunnels, for the running rail, of which there are 50 kilometres, the sleepers were built in a factory, the running rail was built by the steel industry and is handled by specifically designed componentry. In introducing the notion that our supply chains should look very carefully at the IP and innovation models they carry, we persuaded people to introduce robotics into our tunnels. The joint venture of Alstom, Costain and a French railway engineering group, for the first time, brought in robotics to the tunnels to do simple activities such as drilling holes. There happened to be three-quarters of a million holes to drill. There is a social side to this because instead of the 28 people who would otherwise be needed to drill the holes, this now needed a gang of two. There is plenty of opportunity on linear programmes.

If I look at things such as High Speed 2, I am quite sure those technologies will be taken forward and the opportunities will be built upon. I have just come back from Sri Lanka on a slight break and every time I passed over a bridge in Sri Lanka it was a government bridge. The handrails and the components were identical, and that was British engineering in the 1880s. I very much hope that High Speed 2 will adopt a standardisation process to copes with those linear components that have the opportunity of being different through lack of climate control, lack of direction of travel. I very much hope that we can finish the job off and ensure that every opportunity to standardise and to build off-site is taken, creating higher-value jobs in regions that do not have them.

We surprise ourselves when we talk through this commentary by how many of these things are delivered on-site. I want to give you one example, if I may, and I do not know if you have heard this one before. There were two platforms built on Crossrail, one at Tottenham Court Road and one at Liverpool Street. They were identical platforms, about 250 metres long, times two because there is a western and eastern-running tunnel. They were both built by the same employer, Laing O’Rourke. This gives you one answer as to why you do not mandate it and this has to be a value-driven equation. At Liverpool Street we had a huge hole in the ground at Finsbury Circus. It used to be a bowling green in 1880 and we
are going to put a bowling green back there, but it is now a huge hole in the ground. Logistically, we were able to put a huge gantry crane over the top of it and lift huge components down, weighing about 18 tonnes each. These components were the platforms and they were built in Derby. On site we had seven people and the skills of those seven people were not traditional concrete-laying skills. These were people who understood logistics, assembly and manufacturing-type techniques. They walked along large craneages that lifted big components in place and they put them in place against the digital model. In Derby, there were 27 people with high-value manufacturing jobs and it took 27,000 man hours to build this platform.

If you go to Tottenham Court Road, with exactly the same platform, there were 67 people on site, around 40 of whom were eastern Europeans, all of whom were good construction workers, but because the logistics of Tottenham Court Road did not allow us to put large components down, they were constrained into doing it traditionally. It took 67,000 man hours against 27,000 man hours. You can stand back and ask, “Why are we doing this?” It is not just the pursuit because off-site is fun; it is because you solve a production issue, you solve a resources issue and you inspire your supply chains to innovate and to research and develop the ways of doing that. One way of unlocking this is, yes, to have clients who are engaged and enlightened, but, secondly, to try to create an industry where it is worth their while to put some of the very thin margins that occur back into researching and developing these techniques. Unless you create the business model that allocates some of the win to the client, some of the win to the supply chain and some of the win to the stakeholder part of this, you will never get this model to work.

I look at Skanska’s model. It was a huge exponent of helping me deliver an innovation programme. We asked Skanska to share its IP and we match funded Mike Putnam’s own money, to encourage people to find the solutions in getting this more productive way of doing it. Off-site was a very valuable solution here. We have to break the current paradigm. If the public sector wants to procure for the lowest cost, we will never get out of this loop of hysteresis we are in. If the public sector wants to stand back and say, “We want to create more value over the whole life of an asset”, it is going to do it by mandating a direction of travel, and perhaps even a percentage of research and development in that programme for which they will have to match fund.

On Crossrail let me give you a very simple example: we said for every £3 million of work we would like you to put forward an apprentice. It was in some ways distorting the market. I ask myself: are we pleased that Crossrail has 1,000 apprentices right now? Can we not take that sort of behaviour and match it elsewhere? The market responds by the client asking some pretty bold questions. We are now in a cycle where public sector clients, in particular, should put down some very strong indicators about the percentage of manufacture they would like off-site, and perhaps a suggestion that they will match some of the R&D that is going to be put in, which is what the automotive and aerospace industries did, and certainly by saying, “For a percentage of the work we give you, we would like you to employ an apprentice”. By asking these questions on a level playing field, the market will have to respond.
Lord Griffiths of Fforestfach: We heard earlier it is a fragmented industry with 230,000 companies. When you first started you said the sector deal is fantastic, and we are prepared to accept that. Where will the capital come from to back it?

Andrew Wolstenholme: There are three elements to the sector deal. The first is the most difficult and requires no money. It requires leadership and behaviour change. It requires public sector clients to write something different in their procurement strategies around the presumption for off-site. We need to be able to measure every project and work out whether the industry is getting more productive by doing more manufacturing and whether we are getting more highly skilled because we have a greater percentage of apprentices. This is not going to happen a week on Tuesday. The next thing the leadership council needs to do, plus Tony Meggs at the IPA, is to have this very simple and straightforward measuring process. The first element does not you cost you any money; it is a behavioural change.

The second element is already funded and this comes with the industry-led innovation programme, and it is the innovation challenge fund. About £170 million has been committed on the presumption of match funding by the industry. This is fairly small beer. Let us call this £400 million that did not exist currently. This is a sector that invests less than half of 1% in R&D. To make meaningful change, you need to convert that to somewhere around 3% or 4%. This is what the automotive and aerospace industries have done. If we put in 3% or 4% R&D money, by focusing attention on a few things and doing them well, we can begin to see results. That money has already been committed but we have not yet launched it.

The third level is skills for the future. At the moment, there are two ways in which you raise money for that. The first is a levy through the Construction Industry Training Board—the CITB—which has had quite a rough ride recently because the industry has questioned the value that it provides, and quite rightly, because there needs now to be modernisation of the CITB, which is happening.

The second element is the Government’s apprenticeship levy. Some organisations will be required to pay at least 1% toward apprentices. We are saying let us work out a better way of spending that 1%. That is not new money; it is smarter ways of directing that 1% towards the skills we need for the future.

Where does the capital come from? First, it is around procuring for better value and is about understanding the risk out there, understanding a total value outcome as opposed to a low-cost outcome and somehow representing that through consistently procuring public sector programmes in the future. That is probably the most difficult one we have to do. On the one hand, it is saying, “Am I going to distort the market by telling people what to do?” For a moment in time I believe we have to be pretty bold in that. The central and exciting one is about using the very limited resource we have sitting on people’s balance sheets and government match funding it. That is where the £190 million is coming from. The third one is about money currently in the system being used better.
Baroness Young of Old Scone: Could I take that a tiny bit further? We kind of think that if the economic case was powerful that private sector clients would go for it and there would be an indubitable case. You seem to be saying that this will only get legs and run if the public sector gets behind it. Is that absolutely the case?

Andrew Wolstenholme: It will not happen across the whole of the sector unless the public sector, which by a country mile is the largest construction client, understands the part it has to play. I have explained my career. I have not worked for very many people, but one of the very informative times was working with BAA—the British Airports Authority. In those days, we owned seven airports in the UK and three internationally. I was there with Sir John Egan, who came from Jaguar Land Rover, who absolutely understood the manufacturing process and had just gone through the crisis of the UK car industry. Unless that industry changed, it would have been obliterated. He brought in that sense at BAA. He wrote a report called Rethinking Construction. He brought much of the technology and the process management from automotive into the industry and so BAA, a private sector organisation, because there was a very powerful business case for it, introduced a lot of standardisation, digitalisation and off-site manufacture. At terminal 5, 85% of the mechanical and electrical services were built either on the Firth of Forth using oilrig technologies or further downstream using off-site manufacturing technologies. There is an example of the private sector. There are many others.

If you look at the regulated utility industry, smart regulation can be a huge benefit in being able to pull supply chains and utility owners into delivering better performance, for instance at the start of a quinquennium to the end. These are private companies responding to smart regulation. There are many great examples—private asset owners, for instance, BAA, private sector property companies, British Land, Land Securities, Stanhope. All previously have understood the value in getting their product to market, have worked with a limited number of suppliers and have invested vertically through the supply chain. They take a team of players, invest in those players and use them on projects over and over again. Where you have consistency in the process and in the team which does it, you can see great examples of where value is brought to bear.

I feel the public sector now has an opportunity to lead on this. The big one-offs—the Olympics, the terminal 5s, the Crossrails, hopefully the High Speed 2s—have an opportunity and a responsibility to work this sector at what I call an enterprise level. The problem is that if you have discrete investments called projects, there is very little opportunity to work at an enterprise level in the same way that the automotive industry has worked over decades. They have improved manufacturing not because they have had one car to build but because they have had 10 series of 100,000 cars to build. Organisations such as the Construction Leadership Council and the Infrastructure Client Group—and I am very pleased that the small innovation programme we produced on Crossrail called Innovate 18 has become an industry platform called i3P—are enablers and critical components of an industry that has not found it easy to work as one hybrid enterprise model. It has only ever been encouraged to start and finish a project and try to make 1% profit on the next one. We need to work out the wings and the engines—the digital, the manufacturing and
the through life—and, whether you are a housebuilder or a public sector or private contractor, all of those things are going to bring long-term value.

Q60 Lord Borwick: Can we talk about the business models in the construction industry? A big contractor works off a remarkably little amount of capital and has an enormous turnover. With off-site construction, is he going to need more capital than he had before and does his cash flow change with this? It would seem to me that with properly organised off-site construction he would end up having to pay a lot earlier for the products that he sells to the client at the end of the process.

Andrew Wolstenholme: I think that is a very good question. In a sense, this goes to the heart of it. Mike Chaldecott is a member of my Construction Leadership Council and he looks at housing. The housing crisis has meant the Government have demanded 200,000 units a year. It is fair to say that over the last 10 years, I am not quite sure, and do not quote me on the figures, it has been somewhere between 100,000 and 120,000. How do we develop another 80,000 houses per year? Some people feel that there are simply not enough bricklayers and plasterers, and I am sure that the lack of resources is part of that. Some people know that the housing developers are rather smarter than that and they are holding on to a land bank and waiting for the market to come back before they start investing. You can look at the one or two organisations that are putting a huge amount of their own capital into the factory output to deliver houses, and imagine you are that chief executive or managing director and you are going to the bank saying, “I would like to borrow £50 million, £60 million, £70 million, £100 million to deliver this output”, and they say, “What is the guarantee on your market? How can you make sure that this is a good capital asset to invest in over the next 10 years which we the banks are exposed to?”, and they will say, “We can’t because the housing market is cyclical”.

The secret in getting the investment in the market is to understand from the supply point of view how you provide a regular pipeline against which you can invest and develop the overheads that one contractor alone is unable to deliver. You have to take a slightly different market view on this. I am afraid this is one of the inhibitors. If I can cite Laing O’Rourke, Ray O’Rourke is inspirational and has invested tens of millions of pounds of his own money and he is uniquely positioned in being able to deliver things off-site. He would love to invest in a housing factory, and has all the skills, capabilities, technology and leadership to do that, but is that going to be a good investment in a market which for many reasons is out of his control? My personal view is these overheads have to be owned probably by a co-operative more than by a single unique organisation. The Government have to understand the value of a consistent pipeline.

I am disappointed that my next job does not start a week on Monday and is not called Crossrail 2. We have the machinery, expertise and momentum built up in the sector and, all of a sudden, we will stop. All of those technologies and resources are going to be dispersed elsewhere, some internationally. If Crossrail 2 was part of a pipeline—and forgive me, this is difficult—and national infrastructure programmes had a pipeline that was consistent and optimised, two things would happen in the sector.
The first is they would feel less exposed to investing their capital in the equipment needed to keep these things going, and, secondly, they would have a resource platform that was not cyclical and imported; a resource platform again owned by the organisations that were delivering that capital output.

**Lord Borwick:** Is it not inevitable in the housebuilding market particularly that it starts, stops and stutters because of the planning system and because of so many people wanting to be involved in the details of the house and whether or not houses are built in that particular area? Does this not therefore suggest that if it is hard in the infrastructure sector to achieve this consistently, it is going to be nearly impossible in the housing sector?

**Andrew Wolstenholme:** All of these are constraints, which is why Mike Chaldecott has not looked at trying to anticipate the technology. He is asking what the circumstances are around which people would invest in that capacity. The circumstances are consistency of pipeline, access to finance and some sort of consistent behaviour around housing authorities, public sector housing or even private sector housing specifying what that house should be able to do over its life cycle. With a relatively small amount of recalibration of these things, I think one would be surprised by the opportunity that was exposed.

**Lord Borwick:** Do you have any idea about the quantum of money that would be required for this extra capital to transform the housing industry?

**Andrew Wolstenholme:** I do not, but we could take it within the Construction Leadership Council and do some sort of equation around it. Consistency of pipeline is a very interesting question of whether that costs you any money. Yes, because housebuilders would not traditionally expose themselves to a market for which house prices were reducing and for which there was no immediate uptake. They do that because it is in their economic interests not to be exposed to that shortfall. There must somewhere be a cost to this, but it would be an interesting piece of work to do.

**Lord Hunt of Chesterton:** You began by comparing aerospace and wings and engines. As you know, with aerospace, you have Rolls-Royce with the golden share and the aerospace without the golden share. We are no longer a dominant partner of Airbus and we do not know what is going to happen. Rolls-Royce is a good example of where there is very strong UK investment by the Government that works. The car industry is largely owned by foreign companies. Do you see massive national investment as being required?

**Andrew Wolstenholme:** Again, these are good questions. It is always interesting to talk about the mechanics of off-site, but understanding the circumstances of where that happens naturally as a consequence of the market is what we should be talking about. If you go to the advanced manufacturing centre at Coventry, one of the seven government catapults around manufacturing, you will see that Rolls-Royce’s logo is in six-foot high letters. You will also see it is not alone and even though Rolls-Royce holds huge respect in international markets and has the market share that it does, it realises that it can only operate if the industry around it
operates at enterprise level. That is why you have 50 or 60 different logos sitting around Rolls-Royce representing its supply chain, all trying to find that answer in collaboration together. That is why the Government have decided that if you match fund this, the industry will respond in kind. The consequence of that is continuing to have, whether it is golden or not golden, a share in the global market and very focused high-value resources sitting around an industry that is high in R&D and easily exportable. It requires the sort of support that I am sure all other international aero engine manufacturers have: this collaborative enterprise model where Governments match fund.

These industries do not operate on their own, in the same way that the pursuit of battery or driverless technologies is not going to come from Jaguar Land Rover or Ford, or whoever our wonderful foreign-owned car operators are which still hold the technology. It will not be done unless the sector operates as an enterprise platform. That is why the Construction Leadership Council’s agenda is very important, because it is beginning to define the three prerequisites we need to become more productive, more international, more high-value skills orientated and more exportable. Those three prerequisites are: digitalisation at the front end to understand the outcomes, the manufacturing elements, of which off-site is one, and through-life performance through the digitalisation of assets.

You have the most phenomenal project ahead of you in this Palace of Westminster. Several billion pounds will be spent on this and it is a fantastic opportunity to almost hold the international market of undoing and re-doing these buildings. You need to absolutely understand almost shift by shift what you are going to do by digitalising this complex building. Behind some walls there is probably 350 year-old plaster and horsehair and behind other walls there are complex mechanical and electrical componentries. Unless you completely digitalise that and have the opportunity to do a lot of this work in factories around the country, for which you will be an exemplar and role model, this will be very complex indeed. The length of time that you are debating about whether you stay in the Chamber or leave is a difficult inconvenience, and the only way you can minimise that is by absolutely understanding the outcome, the process of politics when you get your new parliamentary building and the process of delivering that, as much of which must be done off-site as possible.

Q61 **Lord Mair:** In the earlier session we heard evidence about this issue of five government departments saying they will adopt a presumption in favour of off-site construction by 2019 where it represents best value for money. What does the Government need to do to advance that case? They are saying a presumption in favour of off-site manufacture but it does not feel like a really big push; it is not mandating. What are your views about that?

**Andrew Wolstenholme:** Two or three questions come up, all of which are relevant here, and one of which is around the business case that makes it compelling that the right way of delivering this particular asset is to introduce manufacturing—and the presumption is off-site manufacturing. Over the next generation of asset development we need
to be able to measure the outcome of that. This will really accelerate. At the moment, we should rely on the market leaders, but over the next half generation we need to be able to prove convincingly that those organisations and supply chains that deliver efficiencies on-site—and that could be through off-site manufacturing or taking a smart logistics process or robotics process—have the opportunity to either make more profit or share the savings.

If you look at housing in particular, with a very small local architect who has just invested in off-site manufacture for wooden-based houses, he thinks he can take 35% to 40% of the time off. It takes him just weeks to put up a house once he is out of the ground, and he is pretty close to understanding the percentage cost reduction. He has to figure how much he retains himself and how much he gives back to the market. This needs to be a combination of taking the benchmarked examples and breaking them down into the different components to prove the value equation. It is setting up a long-term set of key performance indicators across the industry rather than measuring, post-Egan and Rethinking Construction cost, profit and time to market. Time to market is important, but let us say we start to measure this sector’s ability to export, to off-site manufacture, to take up a percentage of apprentices and to invest in research and development. These are very different key performance indicators. These are indicating smart modern sectors rather than ones that have no opportunity of investing in themselves.

First, the public sector has to ask the right questions. Secondly, it has to illustrate this on an annual basis by exemplar programmes that are leading the way. Thirdly, the market has to follow by having a set of KPIs that makes it very difficult for supply chains in the future, because otherwise they would go out of business, not to follow a more value-driven outcome, which, incidentally, will give them superior profits.

**Lord Mair:** Do you think all that leads to a change in mind set about procurement?

**Andrew Wolstenholme:** I do. We have been back over many years talking about the value of the work you have done at Cambridge. On its own, a smart sensor providing valued information is worth nothing, unless that information can be locked into a life cycle model, or can be locked into a delivery model. Unless the client asks the right questions, he will never get that. If I look at the letter that was written to me by Chris Grayling, Secretary of State for Transport, he absolutely supported what we are doing on the CLC. If I look at the Ministry of Justice around their prison programme, there is absolute support. There is an energy around education and health, too. With the Infrastructure and Projects Authority, we are beginning to get an organisation and a realisation that a set of processes at IPA level and change programmes in each individual government department that are consistent with the CLC and sector deal, these are all pushing the barge in the same direction. This is a very exciting opportunity, but it starts with an alignment of each of the different spending departments understanding the same type of question that you need for the supply chain which is very diverse, to give you the same market response.
We heard about three different roofs going on three identical hospitals. That is because there is lots of variation in how the questions are asked. If we can begin to get some consistency in how these questions are asked, the market will begin to understand at an enterprise level that there is a more efficient way of producing it. There will never be a single set of solutions. The direction of travel will be towards buildings that have a higher percentage manufactured and a higher percentage that is built by robots and a higher percentage that is built off-site and, therefore, has a much better opportunity of beginning to export not buckets of concrete but the expertise as to how you create this. I am very pleased to say that Crossrail International is something that the Secretary of State for Transport Chris Grayling has supported. What is of interest to international markets is not how to physically do the work but how to bring this to market, how to set up apprentice programmes and how to set up off-site manufacturing in the environment within which it is. There is a really inquisitive interest as to how you share some of these technologies.

Lord Hunt of Chesterton: My questions are to do with skills. What types of skills are needed to facilitate a move to off-site manufacture? You have told us a lot of marvellous examples in your work on the tunnel for Crossrail. How do these differ from traditional skills? What organisations will be responsible?

Andrew Wolstenholme: Skills for the future is a very important strand within the Construction Leadership Council. It is very interesting that if we demand more of the traditional skills, we have completely missed the point. When we talk about skills, we probably think of traditional apprentice-type skills; skilled and semi-skilled trades. We should also consider the skills of a civil servant who is presented with a procurement problem and a risk profile, and who needs to understand them. I am delighted to say that the Said Business School is providing some sort of skills opportunity for civil servants, not just to be good at delivering policy but at understanding how to manage portfolios of risk. You can look at that as one set. Another set is clienthood skills, and again understanding the risk profile and the different ranges of procurement opportunity you have. We need to attract in this sector the sorts of skills that go to Google and Amazon. The digitalisation of those sectors has been enormously successful and progressive. We need those skills to be attracted by our universities. From a university perspective, we need to understand how graduates are trained. I went back to Southampton University the other day and there was still the same machine that bent a beam today that was there 35 years ago. We need to do that, but it needs to occupy slightly less of the curriculum. There are the clienthood skills, the civil servant skills and the graduate skills. Do not in any way think that any of those people are let off the hook.

When you go down into the trades, in this building you are going to need stone masons. I happen to know that on your critical path is the question of getting enough stone masons because there is a lot of stone masonry. In a housing site, I would expect that over a 10-year period you would have a smaller proportion of bricklayers and a bigger percentage of people who understand manufacturing skills back in the manufacturing
departments, and fewer plasterers because the walls are going to be preassembled in prepacks in factories.

When you look at the 67 people we had at Tottenham Court Road, those 67 people were bar benders, putting steel in reinforced concrete, shutterers, support labourers with wheelbarrows and brushes; they were skilled and semi-skilled. The seven people we had at Liverpool Street were people who operated robotics, logistic equipment and on the just-in-time model. There needs to be—and I will use this word—a revolutionary shift in understanding, and part of what we within the sector deal are doing is trying to identify, through something called Trailblazers. If you have a Trailblazer, you can draw down some of that half a per cent from your apprenticeship levy and get modern apprentices from it. We need to identify through Trailblazers what those skills are, probably starting from the top and going right the way through a vertical section of the supply chain. I kid you not that we need people who can mend robots, because brick walls in the future will be built by robots. It will not be the lack of skip loaders; it will be the lack of people who repair the robots. Let us think radically about what we need for this sector and how to revolutionise what we do best to a world-class standard.

I have been around the world a lot and there are very few programmes in Asia or in the Middle East or in America that do not have a British architect or engineer. We are world class at this and where we have exemplar programmes, this is the envy of the world. We have to be positive about the sector deal, back it and do whatever we have to do to get it launched. We must rely on the industry to respond to subtly different procurement questions and allow the market to be able to cause the adjustment that we so badly need right now.

**Lord Vallance of Tummel:** Earlier on you said that a major block on progress in the housing market was its cyclicalit for one reason or another. Does the sector in any way try to handle that problem? Are you trying to deal with the cyclicalit? There are ways of dealing with cyclicalit. There are other cyclical industries. You can go right back to the Milk Marketing Board. Are there governmental ways to try to deal with this or how do you take the risk out of it or spread it in a more fair way?

**Andrew Wolstenholme:** We have to draw a line around those things that we are responsible and accountable for. I am not responsible or accountable for Brexit, for economic fluctuations or fluctuations in the housing market. We try to point the mirror back and say, “If you did not think it was a significant part of the future model, the cyclicalit is a fundamental reason why the capital is not going in to the capability of putting in manufacturing components”. The answer is no, we are not accountable or responsible, and we are not trying to change the cyclicalit. That is because of market forces, land ownership and planning as well as resources. Mark Farmer wrote a report with the awful title of *Modernise or Die* and pointed out that, unless we took up some of these important themes, we should not anticipate huge fundamental sustainable change within this sector. In some ways, it is never going to be perfect. There will never be a Crossrail 2 or Crossrail 3 or High Speed 2 that completely follows it, but there needs to be the capacity and the pipeline in the industry to make it a first choice, and to make housebuilding attract
not just those who build traditionally with brick—who are very important—but those who see there is a technological, design and market challenge to it. In that sense, market share and market cyclicality are very important issues.

**Lord Vallance of Tummel:** I buy all that, but I come back to the earlier question and that is: if cyclicality is such a significant block, is there anything that you can do about it and who should be doing it? If it is not you, is it government departments?

**Andrew Wolstenholme:** I have heard of a political aspiration of 200,000 houses built every year. That seems to be a level output/outcome, which must mean that at some point there will be a set of tools that creates the opportunity to level out the cyclicality. I do not, with respect, think it is the construction sector’s responsibility to do more than point out why investment is not being put in. You have organisations such as Legal & General. Legal & General is a pension fund manager. Why is it that it is investing in the prepack housing market? It is because a lot of the long-term stable monetisation they are getting is from the investment in housing and the income that it gives.

Someone said that ownership is very important. It is really interesting if you look at Bouygues or VINCI from France, or Ferrovial from Spain, why is it that their balance sheets are 10 times bigger than any UK contractor’s. It is because they own long-term assets. They do not make much money out of building toll roads or toll bridges or car parks, but they gain a market stability and a balance sheet strength by holding an asset that is worth a monetisation over its entire life cycle. PFI gave the opportunity for the UK contracted infrastructure market to gain a critical mass on its balance sheet. I know I am digressing here, but if Carillion had had a balance sheet the same size as Skanska or Bouygues or VINCI had, I doubt whether the adjustments they had to make in their cash would have been necessary. There is a value in having balance sheets that allow you to invest in research and development, take risks over a life cycle and have a monetisation that allows the market to be able to support and capitalise you at times of leanness. Our own industry, because this sector has been designed this way over many decades by both the private and public sector, has ended up too small and too vulnerable to market changes. That is a reason why the housing market and the UK construction industry cannot bridge some of these cyclical events.

**Q63 Lord Mair:** That leads me to ask about R&D, which you just mentioned. You said earlier that with the very thin margins of our construction industry it is quite hard to imagine the private sector putting money into R&D. There is a big difference between those large French and Spanish companies that you mentioned. Do you see that as an intractable problem in the UK and that the likelihood of getting the private construction sector putting a lot more money into R&D is quite low?

**Andrew Wolstenholme:** The other day I spoke to the ex-chief executive of 3M, the organisation that is famous for Post-it stickers. They have delivered endless revolution and innovation and I asked what the critical mass was around an organisation or part of a sector that would allow it to
grow disproportionately. He said that you need to reach 3% or 4% of turnover investment. How do you mimic that in this sector, which traditionally invests less than one half of 1%? You do it by having one or two clients such as Crossrail which get the ball rolling, which insist that their supply chain, if they are going to be part of the party, match fund that. We are talking about very low levels of funding. I asked Skanska over the duration of our programme to put in £50,000, which Crossrail matched. We had a pot of low millions of pounds, but that pot of low millions of pounds created an environment where it was okay to pass different ideas around. People became rather excited about the reward and recognition they got for something that was done very well in Tottenham Court Road on a Friday suddenly being the way of doing things at Liverpool Street the next Monday. There was a way of this good news travelling.

If we look at the sector deal, for which there is a limited amount of money, let us say £190 million, and double that in match funding, and the organisations that collaborate around the sector deal look at focusing the limited amount of money in three or four areas—we are suggesting digital, manufacturing and through life performance—if we can get a portfolio of programmes in the same way that automotive and aerospace did, to be able to focus this limited resource in these areas that manifest themselves in 2%, 3% or 4% R&D—this is the thesis—you can very quickly, I hope, get critical mass in those certain areas. It is through those benchmarked programmes, with consistent application of the right questions from procurement, and a five-year programme as to where the best value is spent, that you are going to get this sector believing that. A focus on R&D will come up with a long-term sustained solution and value that is good for our home market, our local job market, and it is exportable.

**Lord Mair:** The sector deal is going to be asking the private sector to put in £250 million.

**Andrew Wolstenholme:** The i3P, which is this industry-led innovation model, still chaired by Andy Mitchell, who is the current chief executive of Thames Tideway, was asked to do a study as to what money exists on people’s balance sheets for R&D. That is where I have quoted this half of 1% from. We know this money is out there. We have to be able to bring together pools of expertise around projects which they are prepared to invest in and the Government will match fund. If these are well chosen projects, some of which should certainly be around the long-term life asset of infrastructure, private companies and public sector spending departments will realise that this is long-term value and the procurement model should accommodate this in its next round of infrastructure investment.

**Lord Hunt of Chesterton:** A cousin of mine wrote a book on economics. He was a BBC economics correspondent. I read his book and I said there was something wrong with it—I like to do that—and I said, “It’s got no reference to the cyclical behaviour of economies”. Different economists have different views about this. Could you give him a hint about what we have learned from recent events in economics that Governments should take into account?
**Andrew Wolstenholme:** All I would say is that having the fantastic opportunity to run Crossrail, and, incidentally I am also just about to join the board of High Speed 2, I would ask: what is the big "why" of Crossrail? Why have we done it? It is because London’s population is currently at 8.6 million and predicted to be 10 million by 2030. If it is to remain a capital city, it needs long-term investment. This long-term investment far outbridges political cycles and, to a very large extent, far outbridges economic cycles. Unless one understands the real long-term value of economic infrastructure, we will not prepare UK plc to have the connectivity and the transferability that it needs; not for this decade or the next decade but the next 50 or 100 years. If you look at the wisdom of the people around this room and the reason why London is a capital city. it is because, for example, Bazalgette in 1863 built a sewage system that would last for 100 years and Brunel built economic infrastructure not for a return in three years or a market return in the next quarter. Politicians must understand the economics of infrastructure and the opportunity and ability it brings for the value of the nation. In a sense, until we put some of this into a special case, we will never make the long-term decisions to develop and enhance our prosperity for the future. Apologies, I am not trying to knock economics, but political and economic cycles are too short.

**The Chairman:** On that note, Mr Wolstenholme, thank you very much indeed for coming to help us today. It has been an enormous help and you have been a fantastic witness.
Construction Products Association – Written evidence (OMC0050)

1. The Construction Products Association (“CPA”) represents the UK’s manufacturers and distributors of construction products and materials. Our sector directly provides jobs for 333,000 people across more than 23,000 companies and has an annual turnover of £56 billion, accounting for more than one third of total UK construction output every year. The CPA represents 87% of the industry by value, and is therefore its leading voice.

2. Approximately 80% of all construction products used in the UK are made in the UK – this reflects a sector that plays a central role in nearly every construction project in the country.

3. By definition, offsite manufacture for construction is led by and based upon the expertise, resources, capacity and input from manufacturers themselves, and as such our members are essential to its success. Many of our members, in fact, have well-established, commercially successful offsite products and services which clients, architects, engineers and contractors are using.

Q1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

4. One of the biggest opportunities for offsite is to increase productivity and bring construction closer to the productivity achieved by the manufacturing sector, through the use of tools and techniques such as LEAN/six sigma/TQM and investment in people, digital, robotics and ultimately AI.

5. Such factors explain why UK manufacturing is outperforming the rest of the economy in terms of productivity. In Q2 2017, manufacturing productivity was 12% higher than the UK average, versus productivity in the construction sector which was 22% lower than the UK average.

6. Increased productivity could be equally available to construction; however, the productivity gains in manufacturing have involved significant investment, up-skilling of the workforce and a consistent market allowing a return on investment.

7. Given that offsite is inherently manufacturing, it requires high, upfront investment for a long-term rate of return, often over 10 years, which will only occur if demand is not volatile and uncertain. Addressing the cyclical nature of the construction market, therefore, by ‘smoothing’ or making more level and transparent the pipeline of projects, is crucial. Take-up of offsite will only occur en masse with consistent, coherent Government policy given that the public sector accounts for one-quarter of total construction output.
8. When the commercial drivers dictate that offsite will provide better margins and profits than the current model, then the wider industry will choose it as a solution. Related to this are factors such as the short-term outlook of contractors with their low margin business models; ‘value-engineering’ by contractors, usually at the client’s behest; the fragmented nature of the supply chain; and reliance on semi-skilled third party labour, which is cheaper than investing in-house and developing talent.

9. If successful for the construction industry, productivity gains would bring increases in quality, reduced cost, more reliable and timely deliveries, and an increased value and investment in innovation, as is borne out by the globally competitive nature of UK manufacturing sectors such as automotive and aviation.

10. At present, however, the construction sector is fragmented, and so whilst the Government is making significant investment in infrastructure it won’t see the productivity gains that it might unless the client leads an integrated supply chain approach which allows up-skilling of the workforce, digitisation and support for a consistent market over a ten year + timeframe to allowing a return on investment made.

11. The track record of the National Infrastructure and Construction Pipeline to date has seen significant delays in funding for a number of projects such as roads and rail with changes to how much will be spent and on what – this backdrop does not give confidence to invest in capital intensive plant and machinery.

12. That said, some projects like Crossrail and Thames Tideway Tunnel have moved forward within the planned timeframe and the client has ensured investment in skills and the supply chain which has paid dividends. Indeed, for infrastructure projects, there are clear demonstrations of significantly higher ‘pre-manufactured value’ than has typically been seen elsewhere.

13. For housing, much work is being done by a working groups of the Construction Leadership Council led by Mike Chaldecott of Saint-Gobain. They have mapped the opportunities for offsite manufacturing to deliver the increase in homes needed and have a number of work streams looking at dismantling the barriers to offsite, not least from the mortgage and insurance industries.

Q2. It is often claimed that offsite manufacture can lead to: lower costs, faster delivery and increased quality; increased productivity; improved health and safety; greater provision of new, affordable housing. What is the evidence for this?

14. Many of our members, in fact, have well-established, commercially successful offsite products and services, for which they have evidence of the benefits. Such products and services range across the housing, building and infrastructure sectors including but not limited to: roofing, flooring, wall and panel systems; timber frames; facades; door and window units; plant
modules; prefabricated pipework and mechanical and electrical systems; steelwork supports and frames; and various precast concrete solutions.

Q3. What are the drawbacks to offsite manufacture for construction?

15. As referenced in Q1 (above) manufacturers need greater visibility and surety of demand to commit to the necessary investments in capacity and industrialised capability. The Construction Leadership Council has outlined how this drawback can best be addressed by working with market sectors that are more likely to adopt smart construction methods such as offsite than others, particularly in the housing sector. The Government, public bodies, local authorities, housing associations and the build-to-rent sector, for example, “offer a substantial pipeline of development... which if it were nudged towards smart construction, would create a volume and certainty of demand to sustain investment and significant growth in productivity and capacity.”

16. Other drawbacks which must be addressed include the lack of development of industry level guidance, and common standards; the lack of skills; lack of familiarity for innovative offsite solutions, the general absence of collaborative contracts and models; and the lack of familiarity outside the manufacturing sector with materials and manufacturing processes, design and components.

17. Presently, there is also a perceived drawback amongst clients, builders and architects that implementing offsite is seen as taking on additional, unnecessary risk, including a lack of proven products and methods; an insufficient number of suppliers; or undercapitalised manufacturers who may not have longevity as suppliers.

Q4. What re-skilling of the construction workforce is required to facilitate a change to more offsite manufacture for construction?

18. The shift from a site-based, contractor-led model to a factory-based, manufacturing-led sector, is already seeing new roles developing that cross traditional boundaries, such as information managers or multi-trade onsite capability to connect disparate manufactured building systems onsite.

19. The construction sector is already competing with other sectors such as automotive for high value skills ranging from engineers to information technology professionals. Demand for other skills such as materials science, design for manufacturing, and logistics will only grow.

20. Whilst the focus for future skills development is likely to be for highly skilled roles, the potential for automation through Industry 4.0 within the manufacturing sector provides a significant opportunity for UK industry to optimise production processes, and enable offsite production to remain in the

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13 Demand creation, investment and volume surety, Construction Leadership Council, November 2017, page 5, found at http://www.constructionleadershipcouncil.co.uk
UK. The development of future skills around offsite is further outlined in our report The Future of Construction Product Manufacturing\textsuperscript{14}.

**Q6. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

21. Standardisation and factory manufacture can be of great benefit to architectural ambition if approached in the right way. Good quality architecture that provides practicality, durability, efficiency, and aesthetic delight is created by applying control and well-balanced relationships to a clear understanding of the outcomes. Currently, without the benefits of a standardised and manufacturing-driven industry, the outcomes (no matter how well intended) are subject to randomised change, chaotic delivery and very poor quality control.

22. Standardisation does not limit aesthetics; it creates a framework within which good design can flourish. In fact, there is every evidence that the lack of standardisation and applying ‘traditional construction’ has resulted in very poor outcomes and nonsensical waste.

23. Using digital techniques – where design can be developed holistically and informed by factory protocols – can result in pre-determined, robust components. All processes of assembly and quality control can be worked through prior to any deliveries to site. This results in all decision making being completed offsite. Site work itself is then strictly limited to assembly, thereby mitigating the on-site operations risk as far as possible. Live feedback through the digital model and database makes possible immediate quality control and progress checking, further minimising any possibility of the ‘as-built’ final product deviating from the design intent.

**Q7. What R&D is needed, and by whom, to realise fully the potential benefits of offsite manufacture?**

24. In general, 70\% of all R&D across the UK economy is undertaken by manufacturers\textsuperscript{15}, and we have reason to believe much is already being done in the offsite sector by construction product manufacturers here (and more particularly globally). That said, innovation through R&D is expensive, and there is currently little transparency of demand or a stable pipeline of projects or contracts to strongly support further investment in this area. Again, clients and Government could make a huge difference. Already the five Government departments which have a declared preference to offsite have raised this up the agenda, but the investment case needs long term certainty of a project pipeline.

\textsuperscript{14} The Future of Construction Product Manufacturing, Construction Products Association, 2016, found at http://www.constructionproducts.org.uk/publications

\textsuperscript{15} Manufacturing: statistics and policy, House of Commons Library, January 2017, page 12
25. More specifically, construction product manufacturers have advocated greater R&D in the areas of robotics and 3-D printing. R&D consideration should be given to how offsite relates to the circular economy; i.e.; how technology, design and standards can be developed to realise cost effective, high quality, durable, low energy, flexible, multifunctional, re-usable products and materials (i.e., fully utilising circular economy thinking) through offsite manufacture.

26. Alongside this, Government needs to continue spurring the digitisation of the sector to support the ‘smart’ technologies, methods and infrastructure which support offsite. It may also consider how the existing R&D expertise and knowledge can best be shared, perhaps via a virtual platform.

Q8. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

27. To encourage offsite manufacturing, we believe the sector deal for construction should address the volatility of demand for construction, for example by ensuring that Government delivers its existing National Infrastructure and Construction Pipeline. The Pipeline should offer greater transparency and clarity about projects beyond those supported only by Government funding. Such actions will offer greater certainty to manufacturers and thereby encourage investment in planning, skills and capacity for innovative products and methods such as offsite.

28. The sector deal should also promote projects and models of best practice which implement and rely on a culture of collaboration and partnerships, which we know to be a key element of offsite’s success.

29. The sector deal should not be determining the winners in the offsite sector; rather, it should allow a level playing field whereby the market will decide which products and technologies are successful.

30. The sector deal’s success should not be measured by conceptual or start-ups brought to market, or additional institutions or “shiny new centres”. Rather, a greater emphasis should be focussed on pushing greater awareness and knowledge about existing offsite solutions further down and across the supply chain and address the barriers of the wider industry to use and benefit from the centres and technology and expertise already on hand.

31. An advantage to offsite is the reduction in waste and carbon emissions. We suggest the sector deal should prioritise how Government and industry can partner to support clear and tangible steps towards the sustainability ambitions of Construction 2025.16

16 Construction 2025, Department for Business, Innovation and Skills, July 2013, found at https://www.gov.uk/government/publications/
Q9. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate offsite manufacture?

32. UK construction product manufacturers invest significant time and money into reducing the environmental impact of their products and materials, providing third party accreditation and undertaking local hiring, training and supply chain initiatives that have a meaningful impact on their communities. Such work and expense are not undertaken by most overseas companies simply importing into the UK.

33. To ensure that projects are procured not just on lowest cost but also recognising the value of sustainability – environmentally, economically and socially – Government should demonstrate that it will now embed a ‘balanced score card’ approach with ‘whole life values’ into its procurement decisions.

34. More generally, procurement reporting needs to make a clear shift from anecdotal to evidence-based measurement, to ensure that Government departments are held accountable.

26 April 2018

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DIRTT Environmental Solutions – Written evidence (OMC0043)

DIRTT – an acronym for Doing It Right This Time – is a Canadian company which provides an innovative construction process utilising 3D, video game technology and in-house manufacturing to build customised interiors, rapidly, cost-effectively and sustainably. DIRTT has worked with 7000 clients internationally in commercial, residential, healthcare and education sectors (and retail, hospitality etc). We have worked with nearly 200 of the Fortune 500.

DIRTT now has an office and team in London and would be pleased to provide more information.

Responses

1. **What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

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<th>Benefits</th>
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| Safer working conditions | • Controlled environment of a manufacturing facility  
• Eliminates variables like weather and visibility and key hazards of traditional construction—i.e. equipment accidents, falls from heights, etc. |
| Efficiency | • Using machinery to create components minimises the likelihood of human error  
• Replicable, mechanised process minimises error and optimises efficiency |
| Speed | • Reliable timeline because of replicable process with small margin of error |
| Quality assurance | • Quality of work can be guaranteed by applying machinery and minimising opportunity for human error. Quality assurance will not affect timeline. |
| Faster Installation | • Significantly less onsite assembly; components arrive to site with elements preinstalled (electrics, insulation, plumbing), only connections and plug-and-play to happen onsite. |
| Less labour required | • Fewer skilled labourers required onsite = cost savings  
• Simplification of installation process = less training required for labourers compared to traditional construction |
| Less disruption | • Speed of installation means clients/residents can move in faster  
• less downtime for businesses  
• Minimised noise and air pollution, traffic  
• Less disruption for local residents |
| Sustainability, less waste | • Reusable components result in less material going to landfills when reconfiguration is required  
• Less heavy machinery and energy required than traditional onsite construction |
2. It is often claimed that offsite manufacture can lead to: lower costs, faster delivery and increase quality; increase productivity; improved health and safety; and greater provision of new, affordable housing. What is the evidence for this?

- Increased ability to reuse components rather than buying new. (I.E. DIRTT’s proprietary ICE software contains a feature called ICE cycle, which allows a designer to input any DIRTT components and use them in creating a new space.) This results in cost savings over the lifecycle of a space as older components will always be able to fit with newer components
- Controlled facilities allow us to eliminate variables like weather and visibility. It also minimises some of the main safety issues like the potential of falling from heights, heavy machinery and crowded workspaces
- Digitising construction and building offsite streamlines the process and minimises the margin of human error to provide reliable processes, costs, timelines and outcomes
- Virtual and mixed reality applications (like DIRTT’s ICE VR) allow the space to be experienced at every step of the design process. Changes can be made before components are manufactured, this eliminates rework/change orders and streamlines the process.
- High quality spaces can consistently be delivered under tight timelines. The speed of manufacture and installation eliminates costly delays that come as part and parcel of traditional construction. These delays severely
inflate project costs resulting in final numbers being several times that of the original estimate/budget.

• A better understanding of the materials and quantity that are required to build each component in offsite allows manufacturers to buy in bulk for increased cost savings.

3. What are the drawbacks to offsite manufacture for construction?

The main drawback to offsite is the lack of knowledge and limited number of experts that exist in the field to take a project from start to finish. Because of the general resistance within the construction industry to move toward a new method, we have a lot of adjustments to make in training experts and educating the wider industry on positive impact of offsite.

Since most of the process occurs in a controlled facility rather than onsite for all to see there is an apprehension about whether the end result will happen on time or even if it will meet expectations. If seeing is believing, it will require offsite manufacturers and main contractors to successfully deliver projects on a consistent basis in order to rewrite that apprehension and make it the new norm. Until the industry has successfully mitigated this fear of a new and relatively unknown process, there is likely going to be resistance to offsite as a whole.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

There will need to be certification schemes to train installers in specific manufacturer installation processes or labourers will need to go to work directly with the manufacturers. It will likely require a reappropriation of the labour force. Equally, certified installers are likely to be a requirement on each jobsite for insurance and warranty purposes, as is the case with DIRTT.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

If anything, offsite construction allows for a higher degree of precision and is increasing the scope of what is possible in construction. DIRTT’s proprietary software, ICE, supports a high degree of customisation—from dimensions to aesthetics. For example, DIRTT walls are highly customisable tiles that snap into an aluminium frame. While there are physical limitations on the maximum tile size, all tiles and cabinetry can be customised to fractions of a millimetre. Additionally, interchangeable components allow for endless combinations and finishes. DIRTT in the US and Canada is now manufacturing timber structures. If anything, the high degree of precision made possible by mechanising the process allows highly complicated structures to be assembled quickly and with minimal labour. Additionally, custom cut mirrors or glass (in traditional construction would be done onsite and be costly) can be done quickly and easily in a controlled manufacturing facility.

DIRTT was consulted for Mark Farmer’s Modernise or Die Report. As Farmer indicates, “If you buy a new car, you expect it to have been built in a factory to exacting standards, to be delivered on time, to an agreed price and to a
predetermined quality. This needs to happen more in construction, so that the investors, developers or building owners hiring construction firms increasingly dictate the use of modern methods of delivery and invest appropriately in the skills agenda to grow this part of the industry…” This is a similar line of thinking to DIRT’T’s ethos. DIRT’T’s technologically-focused process is akin to a car assembly line – but is much more conducive to customisation.

26 April 2018
What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

Modern Methods of Construction (MMC) is expected to deliver opportunities and benefits at three different levels: to the Department, to HMG as a whole and to the UK economy as a whole.

First, the Department will benefit as it will enable us to control unit costs in the medium and long-run, in a market where construction inflation is expected to be above 4% because of skill shortages and volatile demand in the sector.

Second, HMG will benefit because the processes and the technologies used for schools can be directly applied to hospitals, care homes, housing, hospitals, GP practices, care homes, jobcentres, community centres, exactly as the same platforms are used by car manufactures to produce sedans, station wagons and SUVs for different market segments.

Third, the whole economy will benefit as off-site construction is the main mechanism through which the construction sector can fill the productivity gap it has accumulated over time. These efficiencies could place UK PLC at the forefront of MMC and off-site construction.

The benefits of off-site construction (including modular) potentially include faster construction speed, consistent quality (factory-controlled environment) and programme and cost certainty. The challenge is that the market is relatively unestablished, but a long-term investment programme will offer the certainty the market requires to expand and to revolutionise the infrastructure sector.

MMC (off-site volumetric construction) is not suitable for all buildings. It only works efficiently where there is standardisation and repeatability of product or the size of the project is significant. It is not suitable / efficient for smaller bespoke buildings.

What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

The key factors likely to influence off-site manufacture are

- Consistency, standardisation and repeatability.
- Volume and a longer term pipeline to generate investment in production
- Quality and continuous improvement
- Investment in staff and the development of factory based workforce
- Economies of scale
- Reduction of build time on site

The key factors not to choose off-site manufacture could include:

- Higher initial costs
- Specialised knowledge and expertise required
- Complex coordination and logistics
- Limited flexibility in design
- Potential safety concerns
- Environmental impact considerations
• People understand the traditional market (and are suspicious of an evolving modular market)
• Tier 1 contractors resistance to change from a regional to a national delivery model
• Be-spoke designs
• Refurbishments!
• Small pipeline, lack of standardisation and repeatability
• Potentially off-site will be more expensive in the short term until investment maximises automation

The approach the ESFA is taking removes the need for in-depth bespoke design as we are looking to standardise the design across each type and phase of school (infant, primary and secondary, Special needs schools). The key factor that will influence clients, is the reduced spent on site construction the school. This is current an issue that can cause problems and causes disruption to the school day. From a contractors perspective, they need the volume and repeatability.

Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

In the education sector we use a standard output specification. You would not be able to tell whether one of our schools is built traditionally or via off-site construction. The external cladding treatments are the same and each school is subject to the same planning conditions whether modular or traditional. The ESFA has no requirement to ensure schools provide an architectural ambition. In order to ensure we provide sufficient new schools and new pupil places we have to ensure our procurement of new buildings provide the department, HMT and the tax payer with good value for money. However, they will always be instances where traditional build and design will provide the best solution.

For bespoke one off buildings off-site may not prove to be the best option.

What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

A key factor will be to agree a set of standards, sizes and components that can be used by the industry. Once a standard is agreed and applied, and a set of components is approved (for instance window sizes and design, frames and structures, M&E solutions, etc). This will mean that manufactures can use their manufacturing lines for any public building (schools, a health center, libraries, housing) but using a set of standardised components to ensure quality. This is a similar process used in car assembly plants. This will help us move to a position where one manufacturer builds class rooms, one Halls and kitchens, one toilet blocks and one staircases and these are assembled on site.

The ESFA is working closely with the off-site construction market and the Manufacturing Technology Centre, Coventry (MTC) to ensure that we can all progress to a common long-term objective of building schools via DFMA (Design For Manufacturing and Assembly). R&D work is also currently being undertaken by the ESFA to look at the next generation/steps in more standardised design. There will probably be on-going R&D to ensure that the market can evolve with
any changes in either the ESFA requirements or advances in technology that can improve the efficiencies of the DFMA process.

What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?

In the short term the ESFA will look to review how we currently procure our school buildings and consider the option of procuring on a national basis, by type of school, rather than procure regionally, as is the current position.

This could be for instance

1) Procure 50 primary schools nationally with a single supplier or 2 x suppliers
2) Procure the manufacture of components, and assemble these on site or in a factory via a nominated supply chain and a contractor(s)
3) Get a single factory delivering public buildings

This may have identify efficiencies and enable the capital programmers to provide better value for money. In the longer term, if can standardise and harmonise the design of off-site modules across Govt Dept, then we may wish to consider cross Govt procurement of modules that could be used for schools or hospitals or prisons etc.

12 June 2018
Elliott Group Ltd – Written evidence (OMC0027)

Introduction

a) Elliott Group has over 50 years’ experience delivering temporary and permanent off-site solutions to market sectors that include education, health, industry & commerce, construction, infrastructure, petrochemical, utilities, retail & events. We are strategically located across the UK and offer a design & build full turnkey service.

b) As leading delivery partner for the Education Skills & Funding Agency (ESFA), Elliott are currently in contract to manufacture and deliver 14No modular primary schools (value c£75m) across 3 of their frameworks. We are also awaiting the outcome from the recently submitted tender for the Component Secondary Schools Framework, value £200m.

c) Elliott are the sole UK provider for the McDonalds restaurant chain and are approaching our 100th order. The relationship and working ethics and processes developed with this established Client has proved invaluable in applying the knowledge gained to solutions and processes in various other construction sectors. Indeed, this knowledge was relevant to our success on the Component Primary Schools Framework, value £95m.

d) With funding secured from Innovate UK, we are working in a collaboration agreement entitled ‘SEISMIC’ (Standardisation of School Components). In association with two other leading modular construction delivery partners, several leading UK consultancies, the ESFA and the Manufacturing Technology Centre, our aim is to ‘digitise modular construction to productionise the delivery of school construction in the UK delivering significant savings to the UK taxpayer’.

e) Over the past 2 years Elliott have supported the establishment of Ilke Homes, affordable off-site housing solutions and that are now on the market. Support encompassed seconding technical and managerial personnel to develop the product and also, in setting up the manufacturing facilities for delivery.

https://www.elliottuk.com/  http://www.ilkehomes.co.uk/

The Elliott Definition of Off-site Manufacture

- Volumetric modular building solution
- Construction in a controlled environment delivering consistent quality (1st time)
- Efficiencies in production through manufacturing techniques (driving value)
- Based upon component solutions / repeatable solutions
- Speedier delivery when on site (maximise what can be done off-site)
- Safer delivery through the entire life of the project

1. What are the opportunities offered by off-site manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose off-site manufacture?
a) Whilst the growth of the construction industry has been significantly behind that of the general economy over the past 20 years there has still been an increase in construction employment opportunities which has unfortunately failed to have any positive impact on construction delivery productivity. Off-site manufacture has the opportunity to address both this and the current nationwide skills shortage and, if approached correctly, this will significantly increase construction productivity. (Productivity of manufacturing based personnel typically ~85%, that of on-site workers ~60%).

b) There is significant work required to promote / actively market the benefits of modular construction and to overcome the stigma of low quality post Second World War prefabricated housing and temporary classrooms as this still deters Clients. The perceived and/or technical limitations must be understood by Clients including specification, the ability to deliver a 60 year design life whilst enabling controlled architectural flair.

c) Off-site manufacture offers a sustainable alternative to traditional on-site construction. It offers a deliverable solution to the Built Environment challenges we are facing across all market sectors (Education, MoD, MoJ and Housing) through the benefits in quality, productivity, time and costs that will be achieved by increasing the scale and application of off-site modular manufacturing.

d) It is a construction method that enables us to better control material procurement (and manage associated lead-in periods) and through exemplar manufacturing techniques, minimise material waste (typically 70-90% less than traditional build).

e) Repetition, standardisation and ‘volume’ will ultimately drive economies and bring down final costs. This ‘volume’ needs to be demonstrated by way of a forward visible pipeline and is an absolute must in order for modular suppliers to make any business investment decisions in expanding off-site manufacturing facilities.

f) Selecting the correct modular option for its intended end use is key as many alternative solutions exist. It must also be understood that not all schemes are suitable for modular and that a traditional solution may be preferable in delivering an efficient and effective design solution.

g) Engagement at an early stage is therefore critical to success and an early design freeze will eliminate the expense and disruption of late Client variations. The issuing of late instructions has made the traditional construction process complacent in terms of both cost and programme. In 2015 only 69% of traditional builds were completed on budget and only 40% on time (*KPMG Explore Offsite 5th Dec’17). This compares to 99.7% on time and budget within the same year for modular construction (*Smart Construction Report, April 2016).

h) We also need to help Clients to understand the need for and the benefits that will come as a consequence of modifying existing procurement processes to better support and align with efficient modular delivery.
i) By way of example, the 9No schools in our current ESFA Primary School component framework has demonstrated savings of 45 weeks and up to £500,000 of construction preliminaries when compared to traditional build. Developing 18m long modules has helped drive down cost with further efficiencies in transport (and therefore reduced environmental impact). We have evidenced the buildings at 79% completion before leaving the manufacturing facility however are challenging this continually as works progress.

j) By maximising off-site construction the time on-site will be minimalised and disruption reduced. For the education sector, disruption is minimised by limiting site works to site preparation, foundations and installation and constraining the most disruptive site activity to holiday periods or to times of reduced activity when the pupils / employees are absent.

k) The Farmer report states:
   “It (off-site manufacture) challenges the contractual structures we operate in.”
   “It (off-site manufacture) reduces the work needed on site, which reduces the number of subcontractors needed and calls into question the role of the tier one contractor.”

Factors in selecting off-site manufacture?

l) Government, off-site manufacturers and its campaigning groups all play a part in promoting well considered, design led and compliant modular product offerings that challenge the pre-conceptions that exist. Yes, concrete floors can be delivered in a building with a design life of 60 years!

m) An understanding of the flexibility inherent with modular design is required. Modular does not directly relate to a restraint in architectural flair however an understanding of boundaries within which to work is necessary. Clients need to think modular from the outset and design as such.

n) A Client’s budget is important. There is a misconception that off-site construction is more expensive than traditional construction and analysis has demonstrated that off-site construction can produce savings of 7% during a project (*KPMG’s ‘Smart Construction by Joshua Southern 2016’).

o) Speed of delivery on site is a key factor in determining to procure as modular or otherwise. This must be managed in conjunction with factory lead-ins as factory slots need to be booked in advance and are therefore dependent on factory capacity.

p) By the entire team buying into a `component design’ approach we can create variable ‘solutions’ that will support lower costs, faster delivery and increased quality.

q) In particular, the benefit of early assured delivery may influence enterprise supported by private investment and/or borrowing (retail / hotels / leisure) as early assured delivery, building occupancy creates earlier revenue.
r) Elliott work as both a Principal Contractor (full turnkey) and also as a Sub-contractor to Tier 1 Contractors (where the main contractor is responsible for preparing and delivering the groundworks package for the off-site manufacturer to provide the building element), as reflected in the Farmer report (*quote detailed above Question 1 Item K*).

s) Contractors need to be accepting that the gearing of off-site schemes with earlier design freeze and production slots compared to the more fluid mobilisation of traditional construction needs to be taken into account.

t) Off-site manufacturers will run at a higher level of margin to traditional contractors and, with the recent demise of Carillion, off-site manufacture with increased margins must benefit the longer term development of the construction industry.

u) In planning for an increase in off-site manufacturing capacity, stress is placed on the manufacturers’ resources and the supply chain. To plan effectively, the off-site industry are requesting commitment and vision into client’s pipelines. Investment into our supply chain can then be de-risked, realised and capacities increased.

2. *It is often claimed that off-site manufacture can lead to: Lower costs, faster delivery and increased quality; Increased productivity; Improved health and safety; Greater provision of new, affordable housing. What is the evidence for this?*

a) No more strongly is this demonstrated than in the relationship we hold with our retail partner, McDonalds for whom we have rolled out 100 UK restaurants, with a total value of over £100m, over the last 6 years. The repetition in turnover of this work evidences an ongoing ‘open and honest’ relationship with work secured on a negotiation basis. In addition it enables us to demonstrate our desire to continually improve upon what we do and how we deliver it for our Client. We continually innovate with evolving designs based upon only 3No standard layouts that are manufactured for the individual restaurant and with variants of only one or two storey, or for 100 or 140 covers in the restaurant. This is true standardisation and it is an aspiration that we should emulate in other areas of the built environment, particularly with regards to education facilities. We are currently reviewing one such store design and have demonstrated cost savings (superstructure) of 12%. This has been achieved by leading the design ourselves i.e. not the Client’s architectural lead, in order to better space plan the restaurants around the component principles of modular construction to aid buildability, increase efficiencies and drive out cost. Ongoing specification reviews and continual development of the M&E design strategy to incorporate modern technologies and support potential savings.

b) Through continual value engineering, enhancing manufacturing efficiencies, driving innovation, we have effectively delivered inflation neutral schemes year on year.
c) The trust between both parties has led us to a ‘stock pile’ scenario where stores are manufactured, stored in our yard and are called off on an ‘as and when’ basis. This is a very simple contract to administrate and the level of consultant input (thus fees) is minimised dramatically. Were the UK public sector procurement to emulate this concept, the benefits would be enormous.

3. **What are the drawbacks to off-site manufacture for construction?**

   a) In order for construction to fully embrace off-site construction a fundamental change in industry attitude and process in the method of construction procurement is required.

   b) The mobilisation process for a design, manufacture, install and construction is inevitably different to that of a traditional contractor who has limited design and no manufacturing skills or responsibilities.

   c) As our evidence provides, off-site construction requires earlier design freeze (which can be considered a positive) enabling alignment with manufacturing capacity. Clients need to understand the benefits that will come from being clearer on their requirements earlier in the delivery process. Late changes create complexity and increase costs in both modular and traditional build projects. Late changes drive inefficiencies and need to be avoided.

   d) Individual local authorities spend significantly on their procurement and contracting policies which in turn can be important mechanisms for advancing other regional public aims. Many cities, counties, give a preference to local businesses in their procurement decisions as a means of supporting and growing their local economies and surrounding and regional education centres. Off-site, by its very nature carried out often 100’s of miles away from the eventual delivery site, off-site could therefore impact on local skill base and regional wealth creation.

   e) Factory capacity limitations exist, however visibility of sustained pipeline will enable modular suppliers to draw up business plans for factory investment. Without visibility and certainty, this will not be possible.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

   a) The delivery of off-site manufacture requires a different skillset spread across its operatives at different periods in the process. In the factory, labour and semi-skilled operatives are required, with skilled operatives being required on site to complete the works i.e. connections and certifications. The same core demand for numbers will therefore remain the same, will increase with increased throughput, however the skill profile will change. This can only help in todays perceived skills shortages.

   b) While training to be a specialist in on-site construction can take time, training operatives to perform their role in an off-site build environment is simpler and faster. Transferring the construction process to a factory setting converts building into a manufacturing/assembly process, and each worker need only learn their own small skill in the production line. Less training means faster
delivery thus value and savings. This can have both benefits and drawbacks for the UK workforce.

c) There is also an industry acknowledgement of skills shortages in specific trades i.e. bricklayers, electricians and joiners. Government support in re-skilling the existing and new workforce should be considered if the potential workforce is to be realised and production capacities achieved.

d) Manufacturing operatives from other industries may need to be encouraged to transfer to the off-site industry.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

a) It would be wrong to suggest that off-site buildings are the cure-all solution to the challenges facing the construction industry. To successfully effect this form of construction the building has to be transportable requiring unobstructed road links and accessibility on site. This cannot always be achieved. There will also always be certain building forms whose scale, time and budget, will drive it towards a traditional solution.

b) Our own permanent off-site solutions, specified by architects, have a breadth of external finishes and concrete floors permitting much architectural flair, a requirement that we recognise and always has our fullest support.

c) In being able to respond to localised planning conditions and/or existing campus design it is vitally important that off-site construction provides the same flexibility associated with the aesthetics of traditional construction.

d) Our experience in working with clientele over the long-term such as the McDonalds Restaurant chain, mentioned in our introduction, best supports the case for the benefits of standardisation and factory manufacture, coupled with individual design elements.

e) With component standardisation, now being promoted through the ESFA reductions in build programme, improvements in feasibility design, material costs, and labour costs are being realised without reducing the appearance of the completed scheme. This is the basis of the component solution design principal which has a demonstrable track record of success through achieving planning permission for all 9 schools with all ESFA key stage dates met.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

a) SEISMIC, as noted above, is an on-going and ambitious project to utilise digital technology and a highly skilled team to productionise the delivery of school construction in the UK. In just 12 months, SEISMIC aims to create a harmonised digital modular design library which can be used to configure any new school project. This will undoubtedly bring a level of certainty to the school community, the supply chain and the UK taxpayer which has never before been realised.
b) However, wider industry collaboration is required. In order to drive the ‘modular revolution’, we must all come together to dispel the myths and stigma that modular construction has. This is at all levels of the industry and across all disciplines.

c) We would encourage support from Universities and the Manufacturing Technology Centre to assist us in tapping into new material developments that may enable faster, smarter, leaner modular construction activity.

d) It is fortunate that some Government bodies have, by the nature of the frameworks put in place, driven R&D by encouraging the main modular suppliers to question the effectiveness of their designs and imploring us to design pure component solutions. Elliott are very proud to share that we have achieved this ‘fully component solution’ for both primary and secondary schools.

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain / what is missing?

a) We acknowledge the Government’s recent rise in interest for off-site manufacturing however the main modular suppliers are most probably 2 to 3 years ahead of this interest in terms of the developments they have made. It is the Government who must amend current working practices to help us deliver on the significant promises we can make.

b) Procurement processes must be simplified and we must be treated as a modular contractor and not the current relationship that is adopted with Tier 1 Contractors. Ours is a different business model.

c) Government must make the workload volume attractive to us in order for us to invest to meet the demands that they anticipate to be delivered through off-site manufacture. ‘Batch’ projects, as opposed to one off scheme release, is imperative.

d) Government must urge the education sector to focus on the skill requirements necessary to drive growth. Training and apprenticeships are needed in key trade works packages.

e) We would encourage the formation of a suitable structured body representing ‘modular off-site’ who can voice the feedback from the key suppliers as to how things can improve. Please embrace the propositions tabled in order to drive efficiencies.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

a) We note in response to question 7, the need to implement ‘batch’ procurement. Transparency of pipeline is the key single item that we cannot currently visualise and, without this, we cannot invest in manufacturing
plants. The pipeline is spoken about however, until this translates into live projects, this is but a paperwork exercise.

b) The structure / shareholder requirements of a modular supplier are different to those of a Tier 1 Contractor and this must be acknowledged. This is in terms of investment requirements, resource requirements and also, margin return as a manufacturer.

c) It is harder for us to ‘flex’ to demand capacity peaks and troughs therefore sustainable and consistent workload is required.

d) As a modular off-site building solution provider we design, manufacture and install the project. Traditional construction embraces only one part of this process. Government processes must be adopted to suit.

e) There is a desire from the off-site industry to support in driving this forward and to help UK economy grow as a result.

25 April 2018
Off Site Manufacture (OSM) in Construction

**Perceived advantages**

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

No one should assume that the construction industry in UK does not already use Off-Site manufacture (OSM). The strength of the pre-cast concrete beam and pre-fabricated timber roof-truss (to name but two) industries in UK shows that this is already happening, but more can be done.

The major opportunities lie anywhere that is amenable to standardisation. Tower blocks are likely to be suitable because their regular floor plan should offer opportunities to standardise the units that comprise the rooms – and especially more complex rooms like bathrooms and kitchens. However low rise construction can also benefit because careful design offers opportunities to combine ‘modules’ in different ways to produce houses with common features, but which make better use of the site layout.

Factors that improve the chances of people choosing to use OSM include experience, communications (understanding) and availability but most of all cost. Any contractor given a proper choice between methods will choose the cheapest. However off-site manufacture will not automatically happen if the architect has not considered possibilities for prefabrication in his design.

Factors that work against OSM include the division of labour and contract timing. Where an architect is appointed by a client or local authority without any responsibility for actual construction he is likely to omit aspects that favour OSM. If he is appointed directly by the builder or contractor in a “Design and Build” relationship, that will automatically produce pressures that favour OSM.

Other factors that might help include favourable planning or tax treatment for OSM projects. We probably have to acknowledge that the market has produced as much OSM as it’s ever likely to under current constraints. However if additional incentives (including competitions) from local authorities or Development Corporations were available they would shift the balance towards longer term relationships, and more extensive appointments that can support private investment and facilitate OSM.

This might lead to an OSM ‘grading’ scheme similar to that for energy efficiency appearing with more favourable treatment being given to those schemes with a higher OSM component.

Drawbacks to OSM. Drawbacks are usually the other side of the standardisation coin. Standardisation can produce awful ‘soviet’ style blocks that are ugly to look at and where nobody wants to live. Most people who have the chance to choose
where they live will be interested in what it’s like to live there. This problem can be solved while still allowing for standardisation by experienced architects working for a builder who are sufficiently skilled and imaginative in their designs.

2. It is often claimed that offsite manufacture can lead to: • lower costs, faster delivery and increased quality; • increased productivity; • improved health and safety; • greater provision of new, affordable housing. What is the evidence for this?

As above, the relevance and suitability of Off-site manufacture will depend on the project objectives. It will not be suitable for every project, but where demand for housing and speed dominate it is likely to excel.

An excellent example of off-site manufacture for accelerated housing construction are some of the tower blocks recently erected in China. An article in the Guardian in 2015 describes how a Chinese construction firm (Broad Sustainable Building) was able to erect a 57 storey skyscraper in just 19 days. It provides 800 apartments and office space for up to 4000 people. Other examples are appearing.

Of course this was preceded by years of meticulous planning and design and months of intensive pre-fabrication of more than 2700 modules. But it shows that it can be achieved.

**Lower Costs:** A considerable proportion of construction costs goes into simply maintaining the construction site itself so any reduction in the time this is required significantly reduces costs.

**Increased quality:** The modules are usually built in a relatively controlled ‘factory’ environment where workers are sheltered from bad weather and warm with access available at ground level. This compares with more traditional methods where workers would be subject to the weather over many months at height on a skyscraper which is accessible only via temporary elevators. Conditions for doing the work and inspecting it for quality control in the ‘factory’ environment mean that the product is likely to be of much superior quality to that provided traditionally.

**Improved Health and Safety:** A similar argument to that above applies. Where access is good, communications are good and workers are not subject the worst of the weather, they are likely to make fewer mistakes and be safer.

**Potential Barriers**

3. *Drawbacks*. Drawbacks are described under 1 above.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

It is probably not correct to put re-skilling of the workforce before the basic contractual incentives described above. If the financial incentives are there, the industry will re-skill by itself. If any re-skilling is required it is possibly in the building and procurement departments of major clients and local authorities who
need to understand and leverage the influence they hold over the way their projects are built.

OSM is likely to lead to greater demand for high technology skills associated with machine control and automation for the ‘factory’ environments that will be needed. In that sense the UK will need to produce more technicians with these skills. Current efforts for the UTC’s to develop their offering need to be encouraged and amplified otherwise the current deficit in traditional building skills will simply be replaced by a similar deficit in higher technology skills.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

As indicated above there are some architects and designers who can manage both standardization and architectural ambition. However these features may not always be on the same project. Clients who want bespoke buildings will pay for them. Clients under stronger pressures for lower costs and faster delivery will work out ways of incentivizing their delivery teams to suit.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

One of the problems associated with trying to make OSM adoption more widespread is the current gap in design data standardization. This is somewhat similar to the problem experienced when comparing products from different manufacturers. Their brochures and catalogues describe their products in English but except where a parameter (eg thermal efficiency) is covered by a given standard they often use different terminology. If it includes a ‘performance table’ they will list different parameters. Thus it’s quite hard to know how they really compare. Building Information Modelling (BIM) is a technology that is gradually making its mark on the industry and will help this, but slowly. It’s a step in the right direction and needs to be encouraged, but unfortunately even the current BIM initiative doesn’t go far enough to really nail this problem down to the point where the selection, production and delivery of material components in a building can be fully automated. Currently this is still a very manual activity (in the design office). Suppliers and manufacturers are doing their bit, but (understandably) are generally focused on their own commercial advantage. Data standards do exist in many areas but are not widely adopted. So commercial interests, ignorance and lack of understanding of the need currently hamper a UK wide initiative here.

This is not a small problem. The work required to achieve this objective across the whole UK Construction industry supply chain is worth studying by a combined team comprising persons drawn from:

- Architects with experience of OSM
- Major building component suppliers
- Major MEP (mechanical, electrical, process) suppliers and designers
- A university with a track record in this kind of activity and especially data management
- A major design-build contractor
The study should be led by one of the building institutions eg CIOB.

26 April 2018
I have been employed in the construction industry as a site carpenter for over 35 years, I also have a HND in business systems analysis.

- What are the opportunities offered by off-site manufacture for construction?
- What are the drawbacks to offsite manufacture for construction?

**OPPORTUNITIES.**
Off site manufacture of component parts does increase speed of construction. For example no one today would consider making doors and windows on site.

**DRAWBACKS.**
1. Prefabricated modules often involve the use of large lorries and cranes for delivery to site, access to sites and disruption to the UK road networks could be a problem.

2. The construction and running costs of prefabrication factories are high. This often means that only large corporate companies can afford to invest in such factories. Small and medium sized companies would effectively be locked out of this industry.

3. Prefabrication factories do not need their workers to be registered with schemes like the construction skills certificate scheme (cscs), nor are they subjected to many of the new strict HSE CDM 2015 regulations. Indeed many prefabrication factories require hardly any skilled labour, as much of the work is done on automated production lines. See link, legal & general. (No construction experience necessary). [https://www.legalandgeneral.com/modular/our-product/](https://www.legalandgeneral.com/modular/our-product/)

This creates an unfair competitive advantage for prefabrication factories over traditional build.

4. The construction leadership council has now put qualification requirements on cscs card holders. See link. [https://www.cscs.uk.com/about/clc-one-industry-logo-2/](https://www.cscs.uk.com/about/clc-one-industry-logo-2/)

Many of the board members of the construction leadership council (CLC) are CEOs of corporate companies that have invested in, and profit from prefabrication. There is a conflict of interests in this arrangement. By increasing cscs requirements the CLC have created a labour shortage and increased the labour costs of traditional builders, making prefabrication a more attractive alternative for clients.

5. Land equates to approximately two thirds of the cost of a home. No real long term cost benefit will come from reducing the cost of building homes via prefabrication. Any cost saving would be lost by an increase in land prices due to speculation. Simply put, by decreasing the cost of the built asset the land asset price would increase.
6. Prefabrication does not use the local supply chains, so local building supply companies would also suffer economic damage, putting many people out of work.

7. The construction industry is susceptible to booms & busts, traditional building companies can survive these busts because they employ subcontract self employed labour that can be shed in times of economic downturn & hired again when the bust is over. When a factories shut down, in many cases they never reopen again. This push for prefabrication could leave the UK without the ability to build it's own homes or infrastructure by destroying traditional building companies & skills.

8. Productivity in the traditional construction industry has been held back by regulations like IR35 false self employment tax rules that have forced contractors to hire their labour via employment agencies & umbrella payroll companies that have added extra layers of unproductive costs to the industry.


- What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

Lower costs and increased speed of delivery can be achieved with prefabrication.

- Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

Unfortunately, no. Prefabrication relies on standardisation for speed of manufacture and while one building may be considered unique thousands of them are not. Standardisation also standardises any structural issues as seen in the 1960s prefabricated tower blocks.

- What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

This can only be done on scale by corporate companies. They will of course only invest in prefabrication if a market has been created for their product and they are given competitive advantages over traditional build.

- What changes could be made to public procurement processes to encourage more sustainable practises in the construction industry and facilitate off-site manufacture?

Personally, I believe off-site manufacture of entire buildings will be a disaster for the UK, for the reasons already given.
The issue of affordability of homes, is not the fault of the construction industry. This fault lies within the UK banking system. New bank credit is being created for existing homes this has created unsustainable house price inflation. Existing bank credit should be used to fund purchasing of existing assets not new bank credit. See bank of England article “money creation in the modern economy. https://www.bankofengland.co.uk/quarterly-bulletin/2014/q1/money-creation-in-the-modern-economy

7 April 2018
First Home Vision – Written evidence (OMC0056)

First Home are a team of experienced developers and construction specialists, delivering a completely new concept for lower-cost homes. Clean, green and space-efficient apartments built using Cross-laminated timber, which provides a quicker, cost-effective building process. First Home have designed the ‘Treehaus’ apartment, utilising the off-site manufacture of bathroom pods, utility cupboards, and CLT panels to deliver efficient and affordable homes to live in, with far less environmental impact. During the design process the team has discussed extensively the use of CLT panels, and other modern methods of construction, with key stakeholders of the construction industry, and run a quarterly Modern Methods of Construction forum to openly discuss new ideas and key challenges faced by designers, developers, suppliers and contractors.

Klas Nilsson, First Home Chairman’s Statement:

"The housing crisis of today is on a scale we have never seen before. Our ambition is to design and deliver thousands of high quality homes at affordable prices. With 5 decades of prime residential development and having delivered some of the most iconic schemes in London – I wanted to use that experience to enable high quality and exceptional design to be part of today’s solution.”

1.1 There are a number of common misconceptions associated with the use of CLT, which are applicable to most modern methods of construction. The perceived drawbacks are generally:

- Longer lead-times to procure goods manufactured off-site
- Coordinated designs are required at the early design stages, which can be more time consuming
- Un-willingness of key stakeholders to adapt and embrace change
- The perception of timber with regards to fire safety
- The risk of using one manufacturer for a contractor
- Lack of flexibility within the design once manufactured components have been ordered
- Design limitations due to transportation constraints

1.2 Having undertaken 24 months of Research & Design, First Home have uncovered a number of benefits when designing and building with CLT:

- Ability to meet Part L sustainability building requirements
- Ability to achieve increased air-tightness, enhancing building performance and U-values
- Enhanced well-being for occupants
- Reduced weight of super-structure, which creates the potential to work on constrained sites
- Up to 50% quicker than traditional construction
- Up to 90% less waste compared to traditional construction
- 80% fewer vehicle movements reducing the impact on the environment and the local community.
- Less labor intensive than traditional construction
- Safer working environments
- Quality control and improvement of finishes, due to controlled factory environments
- Precision engineering, with as little as 2mm tolerances on CLT sites
- Less storage of materials on site
- Cost Assurance
- Offsite testing of key plan

1.3 The above provides great financial assurances for investors; design benefits for architects and consultants; improved working conditions for tradesmen and a simplified construction methodology for contractors.

2.1 Sophisticated 4D Building Information Modelling (BIM) software can simulate a traditional construction programme alongside a construction programme using Cross Laminated Timber, and generate the estimated overall reduction in construction programme. Time saved on site reduces overheads and profit, prelims and on-site attendance, thus reducing the overall build cost.

2.2 Live CLT construction sites in London highlight the efficient build process, reduced labour force, and improved site conditions.

2.3 First Home have worked closely with Quantity Surveyor’s to create a robust Cost Plan, analysing key comparisons between Traditional Construction and Modern Methods of Construction (predominantly CLT). The reduced weight of CLT alone provides a significant cost saving due to the reduced provisions for pile foundations. Reduced construction costs can be returned to the occupier, making the apartments more affordable without sacrificing quality.

2.4 HSE guidelines report that on average 2.2 million working days are lost each year due to workplace accidents and injuries. Off-site manufacture reduces the amount of work undertaken on site, and provides safer environments to work in. Removing the requirement of wet trades on-site provide a cleaner environment to work in, and reduces inaccuracies. Increased quality and quality control of materials is achieved through controlled environment of the factories in which they are built and assembled.

2.5 It has been proven that children are more focused, less stressed, and experience less conflicts working within a Timber environment, as shown in a study by the Human Research Institute from 2009. Similar studies have shown that timber buildings provide healthier environments to live in, and that residents are happier and calmer in these buildings where the homes are well ventilated and have fresher and healthier air quality. Man-made materials such as plastics and concrete used in buildings can emit toxins over time into the environment.
3.1 The perceived drawbacks to offsite manufacture are outlined in Paragraph 1.1.

4.1 CLT panels are assembled on site by a team of tradesmen, generally with a background in carpentry, following a relatively short period of training in CLT installation. The same tradesman can be utilised to undertake the fit-out of the apartments, providing multi-disciplinary learning in construction. Risk assessment and site logistic roles are also required on site.

4.2 It is First Home’s intention to develop the Treehaus Academy, providing the opportunity to reduce the skills shortage and enhance quality through construction and off-site manufacture. To entice the younger generation and existing tradespersons who have left traditional construction, we have to highlight the benefits of working with Cross Laminated Timber and offsite-components:

- Cleaner working environment
- Less exposure to Hazardous Risks such as concrete
- Less noise exposure
- Greater quality of installation
- The opportunity to work within a factory environment and not on a construction site
- Pride in the delivery of quality products

4.3 The high level of engineering when using Cross Laminated Timber and other off-site manufactured products is achieved through the use of “Revitt” or “BIM”, and is key to the successful production. This provides a greater appeal for people who have studied engineering to utilise this skill within construction.

4.4 With the new incentive by local authorities and government of the building University Technical Colleges, which are sponsored by the Main Contractors such as BAM / KIER / BAA, can only be beneficial to the Construction Industry and show that there are other facets to the industry, besides working on site.

5.1 Design constraints associated with off-site manufacturing are often due to transportation constraints and limited dimensions. Despite Cross Laminated Timber panels having a maximum transit dimension (2.95m x 16m), the form of the CLT structure when assembled is not limited to orthogonal boxes. Geometric forms, shapes and even curves can be achieved using CLT, provided this is considered in the early design stages. With the use of CLT, the architectural intent and design can be further expressed through the external façade, detailing, internal finishes and key amenity spaces such as landscaping, roof space and play areas.

5.2 Constructing with CLT panels also lends itself to standardised design, due to the ease of stacking the structure and service risers. Standardisation of
design provides a host of benefits during the procurement and construction phases, leading to greater assurance of costs and programme.

6.1 Over the last 24 months, First Home have primarily focused on the Research and Design of CLT construction, working closely with a team of architects and consultants, and engaging with key members of the supply chain to create a robust housing solution which is practical, affordable and leads to reduced energy costs.

6.2 We have prepared a detailed Cost Plan; 1:1 design details for a Prototype apartment, including the design of the prefabricated utility cupboard and bathroom; a detailed construction programme; and refined construction methodology.

6.3 It is the First Home aspiration to be on-site by 2019, to realise Research & Design undertaken to date. This body of work will be published, using the first live site to highlight key challenges faced during design, procurement and construction, with future recommendations for client’s, designers and suppliers interested in CLT construction.

7.1 The government and key stakeholders need to embrace off-site manufacture, and gain a better understanding of the benefits of Modern methods of Construction. The following could facilitate the change in mind-set towards MMC:

- The government should be assessing the infrastructure required, and in place, for the production of CLT within the UK and assessing the viability of reviving the Scottish forest industry to both increase job opportunities and reduce the carbon footprint required to transport the CLT. This review should extend to other off-site manufacturing.
- The Government need to be further educated on modern methods of construction through forums with the construction partners, as well as delivery and design teams. Only then can they gain an understanding of the key legislative challenges and barriers to the use of modern methods. Through these forums the government will also have a better understanding of the key constraints that Traditional Construction faces in terms of late deliveries, poor weather disruption, and lack of resources on site.
- Reducing constraints through the planning process and embracing modern methods of construction as an alternative construction methodology will enable the faster production of homes, creating great homes and sense of place.
- The building regulations, such as Part L, need to factor in modern methods of construction into their assessment criteria. Local authorities could produce design guidance note that takes into account off-site manufacturing, which could be created in conjunction with the specialist manufacturers.
- There should be specific papers and updates on a regular basis identifying the clear benefits of off-site manufacture
- The release of government / local authority major land sites, and redundant offices, which developers and house builders can purchase, with agreed density and delivery targets which align with the increased speed of construction.

8.1 Changes needed in procurement processes to facilitate the delivery of off-site manufacturing:

- Embracing a collaborative approach towards procurement of Modern Methods of Construction and offsite manufacturing
- Establishing framework agreements with local authorities and government
- Due to the early design requirements to achieve off-site manufacturer in-line with the delivery programme, key stakeholders and developers should understand the benefits of the Construction Management procurement route, and how this can encourage knowledge sharing and lessons learned through design. This procurement approach would be more beneficial and effective than Design & Build where the risk sits with the main contractor, which can lead to conflict through the design team and delivery team.
- As part of the Construction Management procurement route there can be as many as 15 different contracts that can expose developers / Construction Managers to risk of failure through the supply chain. Therefore ensuring that contracts are flexible and financial support is available.

8.2 Despite construction reports, such as the Farmer review, being issued over the last few years, Modern Methods of Construction has still not been fully embraced. The government should be promoting the Modern Methods of Construction supply chain for pushing the boundaries of technology, and providing cleaner and more efficient buildings that are far more sustainable than traditionally built homes.

26 April 2018
Introduction

The Government welcomes the enquiry into offsite manufacturing for construction being undertaken by the House of Lords Science and Technology Committee, and the opportunity to respond to this. Construction is a key sector for the UK economy. In 2016, the wider construction sector, which includes contracting, construction products and associated professions such as architecture, had a turnover of £370 billion, generating £138 billion in GVA (9% of UK GVA) and employed 3.1 million workers, or around 9% of the UK workforce. The sector underpins the whole the economy, through building and maintaining the infrastructure, buildings and homes that the UK needs. Therefore, a productive and sustainable construction sector can make a significant contribution to growth and prosperity in the UK.

The wider adoption of digital and manufacturing technologies is vital if the construction sector is to be made more productive, sustainable, and be able to adapt to the changing demographics of the UK workforce. The adoption of these technologies will also enable the sector to maximise its contribution to supporting economic growth in other sectors, which rely on construction outputs, and to reducing carbon emissions and supporting clean growth across the UK. Through the Transforming Infrastructure Programme, the Construction Sector Deal and its investments in construction projects included in the National Infrastructure & Construction Pipeline, the Government is committed to working with the construction sector to achieve these ambitions. The Transforming Infrastructure Programme sets out an ambitious approach to improving the delivery and performance of infrastructure, through benchmarking of contractors and infrastructure, strengthening commercial relationships between clients and the construction supply chain to improve the sustainability of the sector and increasing the use of technology to make infrastructure delivery more efficient and ensure the smart operation of infrastructure assets.

Perceived advantages of offsite manufacture for construction

1. **What are the opportunities offered by offsite manufacture for construction? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

The McKinsey Global Institute has estimated that productivity gains of 50 to 60 per cent could be achieved through the adoption of digital and manufacturing technologies. These could drive better project planning and management, accelerate the building phase by enabling production of the building to proceed in parallel with site preparation work, enable more efficient and better integrated supply chain management practices, produce buildings to consistently higher quality standards and reduce errors made onsite, and offer improved and safer working conditions in a factory environment. These productivity gains would also make the sector less dependent on labour-intensive modes of production.
The adoption of offsite manufacturing technologies will also contribute to greater sustainability through minimising materials wastage (which at nearly 120 million tonnes of waste per year, accounts for almost a third of the UK total) as well as delays due to error, supply chain inefficiencies or weather that are regular occurrences in on-site construction. Buildings account for an estimated 40% of UK energy consumption and 19% of UK greenhouse gas emissions, technological developments in the construction sector have the potential to make a substantial reduction to the UK’s carbon reduction targets.

The factors affecting the choice of construction methodology vary between firms who have different priorities. The Construction Leadership Council’s Innovation in Buildings Work Stream assessed the barriers to increasing uptake of offsite in the housing sector (defined as a form of smart construction) and concluded that among the primary influencers to all players was high perceived risk of new methodologies, alongside 10 further barriers. The National House-Building Council reported that for house builders and housing associations the top consideration for adopting offsite was speed of delivery. Other considerations included, improving build quality, tackling the skills shortage, reduce costs and improve profitability and improving health and safety, among others. This survey also found the main barrier to uptake was high (or the perception of high) capital cost.

2. It is often claimed that offsite manufacture can lead to: lower costs, faster delivery and increased quality; increased productivity; improved health and safety; and greater provision of new, affordable housing. What is the evidence for this?

There is some evidence from the housing and infrastructure sectors that the use of offsite construction methods have significantly reduced the time taken to build new homes. Anglian Water have estimated that their adoption of offsite technologies has reduced the need for onsite labour by 70% (with a corresponding 70% decrease in the frequency of accidents), costs by 20% and a 50% reduction in embodied carbon. The Y:Cube development by the YMCA in Mitcham (London) estimates that the use of offsite techniques reduced the costs per square foot of development by nearly 50%, and reduced the time taken to complete the project by 40% compared to onsite construction techniques.

Offsite construction methods are potentially well suited to the affordable housing market, as well as the wider social and private rental markets. The increased speed of delivery, greater certainty of project timescales, certainty of cost and quality of build match these subsector market drivers. Offsite construction methods in themselves will not result in an increase in the number of new homes

18 Construction Leadership Council – Innovation in Buildings, Workshop Report and Road mapping, April 2016
http://www.constructionleadershipcouncil.co.uk/workstream/innovation/
http://www.constructionleadershipcouncil.co.uk/workstream/innovation/
built, as this depends on investment decisions by clients. There are very few offsite construction companies who act as a developer, e.g. purchasing the land and building homes themselves. If affordable housing clients specify the use of offsite, this may result in rapid delivery and enable homes to be built more quickly.

**Potential Barriers to wider use of offsite manufacture**

3. **What are the drawbacks to offsite manufacture for construction?**

The Government believes that the potential benefits of offsite manufacturing significantly exceed the potential risks. The benefits include greater speed, because more work can be undertaken in parallel rather than sequentially (e.g. products can be manufactured as groundworks are undertaken), fewer defects through manufacturing components in controlled conditions rather than onsite, and less risk of delays in the process of creating new built assets due to factors such as the weather. These factors also mean that the cost of construction, as well as the risks associated with onsite construction, are reduced and certainty is increased. For these reasons, five Government Departments (the Department for Transport, the Department of Health, the Ministry of Justice, the Department for Education and the Ministry of Defence) have adopted a presumption in favour of offsite manufacturing for suitable projects from 2019.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

Even with rapid adoption of off-site manufacturing, demand for traditional construction skills is unlikely to decline in the medium term. In the longer term, the overall effect of increasing adoption of off-site manufacturing will be to reduce the sector's dependence on labour and shift the skills mix away from these traditional trades. Off-site manufacturing is likely to generate greater demand for digital design and modelling skills, programming skills, engineering and maintenance skills (including robotics) and the logistical skills necessary for efficient factory and onsite operations.

5. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

The adoption of digital and manufacturing technologies will enable the development and production of standardised components for a range of built assets. Architects will be a key participant in the development of these component sets, and also in designing the configuration of buildings that will use them, to take account of the locations where these will be assembled. The development of component sets will not of itself restrict the scope for innovative design or other forms of innovation. It is likely to be possible to use digitally designed components in a range of different buildings, making these easier to design. It will also be possible to adapt components based on the specific requirements of a project or assessments of their performance when incorporated into built assets, and through manufacturing processes rapidly prototype and test these. Therefore, whilst these technologies will require all professions and occupations relating to construction and the built environment to
adapt the way they currently work, this is likely to be a driver, rather than an inhibitor, of innovation.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

Realising the benefits of digital technologies and offsite manufacturing will require greater investment from both the construction sector and the Government, as well as related sectors such as the digital sector, where this is developing applications for the construction and built environment sectors. Despite its size, the construction sector invests less in R&D and innovation than other sectors. According to ONS statistics, business expenditure on R&D in the construction sector in 2016 was £211m, 0.9 per cent of total UK business R&D. This compares to investment of over £3.3bn by the automotive sector, and over £1.9bn by the aerospace sector.

The Government is taking steps to encourage greater investment in R&D. The Transforming Construction Programme announced at Budget 2017 will see the investment of £170m of funding from the Industrial Strategy Challenge Fund to support the development and commercialisation of digital and manufacturing technologies for the construction sector. The Government estimates that this will leverage around £250m of private sector investment in R&D. This will support:

- digital transformation, based on improvement information management, integrating aspects of Building Information Modelling (BIM), sensors, data analytics and smart systems technologies
- manufacturing technologies and information-enabled production systems, which will develop new product platforms for built assets and new manufacturing technologies; and
- energy generation and storage technologies for buildings, new energy generating and storage technologies for buildings, reducing running costs for building users and carbon emissions.

The first competitions under this programme, to create a Core Innovation Hub focused on digital and manufacturing technologies, and an Active Building Centre focused on developing energy positive buildings, were launched in March 2018.

Government actions

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

The Construction Sector Deal aims to address the key barriers to improved productivity in the construction sector, through taking forward work linked to the five Industrial Strategy themes of Ideas, People, Infrastructure, the Business Environment and Place. These include:

- **Ideas**, through the Transforming Construction Programme;
People, driving greater investment in skills, through increasing the number of construction apprenticeships and enhancing the ability of the sector to recruit and retain skilled workers;

Infrastructure, harnessing the planned £600bn of public and private sector investment in infrastructure over the next 10 years to drive value-based procurement and support the adoption of new construction technologies and techniques;

Business Environment, improving the sustainability of the business model in construction, through encouraging better supply chain relationships and reformed payment practices; and

Place, taking account of the economic importance of the wider construction sector to all regions of the UK, and the contribution that it can make to driving growth and prosperity in all regions.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

The way Government procures construction projects can influence the speed of emergence and adoption of new technologies, and encourage more economically and environmentally sustainable practices. Offsite construction techniques change the business model of the sector from a service model to a manufacturing one; requiring significant capital investment. Unless there is a strong pipeline of future demand, firms are unlikely to make this investment and take on the commercial risks of adopting this new business model. The Industrial Strategy White Paper sets out the Government’s strategy to ensure broader outcomes are considered in the early stages of policy and programme design, with outcomes such as impact on local jobs and apprenticeships, regional re-balancing, strength of supply chains, and environmental impact and whole life value considered. These outcomes can then be carried through all subsequent parts of the design and procurement process. Once the initial assessment of desired outcomes has been made, off-site manufacturing could help to achieve them.

The Government has already encouraged a more strategic approach to procurement through Crown Commercial Service’s balanced scorecard. This is a procurement approach which balances cost against wider social, environmental and economic themes using a set of Key Themes and can also be used to encourage better working practices. It should be applied to all construction, infrastructure and capital investment procurement with a value over £10 million.

23 April 2018
Watch the meeting

Members present: Lord Patel (Chairman); Lord Fox; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Maxton; Baroness Morgan of Huyton; Baroness Neville-Jones; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 10 Heard in Public Questions 71 - 77

Examination of witnesses

Richard Harrington MP and Fergus Harradence.

Q71  The Chairman: Good afternoon, Minister and Mr Harradence. Thank you very much for coming today and for taking time to assist us with this inquiry. You are our star performers today, so we are looking to you for all the answers.

Richard Harrington MP: I shall do my best.

The Chairman: Before we start, all the questions are addressed to you, Minister, but you can decide whether you are going to answer or you want Mr Harradence to answer.

Richard Harrington MP: Lord Chairman, I have always disapproved of Ministers who bring officials with them to Select Committees, but such is Fergus’s speciality in this sector that I thought it might be a good idea if I brought him with me in case you had any additional questions. But I will not be ducking out of them myself.

The Chairman: Thank you. We normally do not allow Ministers to be accompanied, but for the very reason you mentioned, this time we have made a concession.

Richard Harrington MP: Thank you.

The Chairman: We know both of you, but before we start perhaps you can introduce yourself for the record. We will then move on to questions. If you want to make an opening statement, please feel free to do so.

Richard Harrington MP: I am the Minister at BEIS with responsibly for business and industry.

Fergus Harradence: I am the deputy director for construction in BEIS.
The Chairman: Do you wish to make an opening statement, Minister?

Richard Harrington MP: If it is acceptable, Lord Chairman, I would like to go straight to the questions, and I am of course happy to expand on anything.

Q72 The Chairman: If I may, I will kick off with the first question. What policies might the Government enact to improve or increase the use of off-site construction? I would like your comments on how you think that might be done. Do you think the Construction Leadership Council might have a role to play, or will it be all mapped out in the construction sector deal? Perhaps you might also tell us when we will get that deal.

Richard Harrington MP: If I may, I will divide the question and deal first with the Construction Leadership Council. Its title sounds rather stuffy compared to the organisation that it actually is. It has a very clear strategy to push on-site construction to off-site construction. I think the Americans would call that a mission statement. A core part of its very existence is to promote construction in factories for reasons of cost and the environment. Those are the two things.

It is independent of the department, although I co-chair it. Traditionally with these councils there is a Minister and an elected leader from the industry itself. I have not been to one yet, because I took on responsibility for construction only quite recently. There is one in the first week of July, which I will co-chair. The department provides the service itself, including the administration, but it is an independent council.

Leading on from that, and to answer your question about how else the Government can influence it, one of the main things is the fund of £170 million, which we call the Transforming Construction programme. It is precisely to transform construction from the traditional: what we would all accept as building site-type construction, with all its skills, or shortage of skills as it often is, the price of which has gone up dramatically.

Having first got involved in construction myself when I was 23 and in business, I know that the price has hugely outstripped inflation. I am a little out of touch now, because I have not been in business for 10 years, but even in my time it went up from about £40 per square foot to £200, or to £250 per square foot in some more complicated central London sites. That is because of the cost of materials and labour and all the on-costs, many of which are improvements to do with health and safety and that kind of thing.

The Government’s policy is that there are so many reasons why we should move to factory-based construction, which by the way is not new. Many structures that we are familiar with, such as Paddington station, were built predominantly in factories. This has been going on for more than 100 years. People will remember the huge construction of prefabricated houses after the Second World War, all of which were built in factories. This is not new, but of course it is the technology that is changing.

It is not widely known, although it is public, but half of the BEIS budget goes on research and development, one way or another. Incidentally, the
Government – Richard Harrington MP, Minister for Infrastructure and Construction, Department for Business, Energy and Industrial Strategy (BEIS) and Fergus Harradence, Deputy Director, Construction, BEIS – Oral evidence (QQ 71-77)

The other half goes to nuclear decommissioning, which is spoken about even less. All the different funds that the budget goes to, such as the industrial strategy challenge fund and the Transforming Construction programme and so on, are research and development based. That is the Government’s key role, apart from the direct involvement of government contracts, which perhaps I could come to in a moment.

The Chairman: In responding on the question about government contracts, you might address the issue of contracting for value rather than capital cost.

Richard Harrington MP: I can happily do that. I should perhaps mention the sector deal, which you brought up. As I am sure members are aware, sector deals are an important part of our industrial strategy. They are intended to get a lot of different companies and stakeholders involved with government.

It is a move away from previous generations, when the feeling was that government should be directly involved in industry, with civil servants and Ministers literally talking about taking stakes in businesses. I remember in my childhood, when I was doing A-level economics, visiting the NEDC as it was called then, or the development council. It was very impressive to us sixth-formers, but basically it was a room full of people deciding what stakes in businesses to take, with politicians actually interfering, usually for political reasons. I am not making any party-political point, and that is still how it is decided in a lot of parts of the world.

It moved from that to a general belief that government could not really get involved in industry because the market itself would decide. That was discredited as well. The industrial strategy is not the first that Governments have had in their history, but it is based on this partnership. So government puts money where it thinks it will add value rather than investing in individual businesses, and research and development is typically part of that.

To get on to the relevant point, the sector deal is a deal between the sectors, broadly speaking. We try to do it not just through the big companies but through different organisations such as construction, the council, the Nuclear Industry Association and so on. I could go through all the different sectors, which hopefully represent the whole of industry and government. It is typically an arrangement whereby each side has a clear offering: government will do this if industry does that.

It was hoped that construction would be one of the first ones to come about. It is in the first batch, but it is fair to say that it has taken longer than people originally thought. Let me explain why. In the first instance, most industries do not have people trained to write a sector deal. Maybe they should, I do not know. Some got through it by hiring very expensive and competent people to do it. Sir John Bell chaired the life sciences one and Peter Bazalgette did the creative industries one. But many industries do not have that level of access to people who are used to the way that government works, so it takes longer. We have officials who can help, and obviously we help them do it because we want them to do it, but there were no prizes for being first. It is not a race. That is one reason.
Secondly, the industry itself had to decide what it wanted in particular. Usually it is a combination of skills, a deal for skills. Construction is a lot more complex than most, first because it has its own methods of recruiting apprentices, which it always has, some of which work and some of which do not. There are some fundamental problems with skills so that contracts tend to last for shorter periods than apprenticeships, et cetera.

Then there is the question of how government should be involved in off-site construction, which is what we are here to talk about today.

**The Chairman:** When do you think it might be published?

**Richard Harrington MP:** I am going to use a Civil Service word, which I will probably get into trouble for, but if I say “imminently”, I hope that will be acceptable to the Committee.

**Baroness Morgan of Huyton:** We were just told by previous witnesses that they thought it was finished at Christmas.

**Richard Harrington MP:** The draft may be finished, but I am afraid it has to go through all the different departments and approvals and write rounds and everything. It is my job to get them through, and I am very happy with the construction one. The press say that you are “hauled” before Committees, so if it is not published imminently, I could do with a good hauling. And I would willingly accept it.

**The Chairman:** Will it be in the next Session of the Parliament?

**Richard Harrington MP:** I would hope that it would be in this Session, Lord Chairman.

**Lord Hunt of Chesterton:** Presumably you discuss it at the committee you are going to be at in July.

**Richard Harrington MP:** Yes. I have a weekly meeting with officials on how these deals are going along to discuss what we need, what the industry has said and so on. If there has been disappointment at the time period, I do not apologise for that. What I apologise for is if members of the industry perhaps thought it would be an easier process than it has been. I hope it is worth waiting for. Anyone can organise a drinks party and a press release. Departments are full of people who do that. But to me, this is much more than that. It has to be something that is delivered and that means something.

**The Chairman:** So whenever it comes out it will be full of information.

**Q73 Baroness Neville-Jones:** Minister, could you tell us how the £170 million figure was arrived at and what it will be spent on?

**Richard Harrington MP:** I would like to ask Fergus to answer that, because I do not want to waffle. He knows the specific answer.

**Fergus Harradence:** As the construction sector, we put in a bid for a sum of money to the industrial strategy challenge fund, a competitive fund run by Innovate UK that is now part of UK Research and Innovation. The original bid was slightly higher than £170 million, but that was the figure arrived at following an internal Innovate UK analysis of the bid and
what it decided to fund, taking account of the fact that it already funds certain activities in this area. It has regular calls for innovation funding that are relevant to the built environment, but this is new and additional funding for the industry on top of what it would have expected to get from within the core budget.

**Baroness Neville-Jones:** So what is it going to be spent on?

**Fergus Harradence:** Seventy million pounds is going to be spent on what we call the core innovation hub, a centre that will take forward the development and commercialisation of digital and off-site manufacturing technologies. Around £30 million will be invested in an active building centre, which essentially will develop technologies that will enable buildings to be energy self-sufficient or ideally energy positive. It is about energy generation and storage technologies for the built environment. The remainder, about £70 million, will be awarded by various competitions and will support R&D projects and demonstration projects.

**Baroness Neville-Jones:** Are the first two that you mentioned new organisations? How will they be composed?

**Fergus Harradence:** No. The core innovation hub is likely to be a consortia of existing organisations, and the active building centre is likely to be established within a university, probably within an existing research group.

**Baroness Neville-Jones:** Is the other one going to be industry?

**Fergus Harradence:** Yes. It was a requirement of the competition that the core innovation hub consortia be led by a research and technology organisation.

**Baroness Neville-Jones:** So there is actually an evolved programme.

**Fergus Harradence:** An evolving programme, I would say. We have planned some of it, but there are further steps to go until we have finally defined it. It will be implemented over a four-year period.

**Baroness Neville-Jones:** I was just going to ask you that.

**Baroness Young of Old Scone:** In addition to the £170 million from government, is money pledged by the sector to match that?

**Fergus Harradence:** Yes. The Innovate UK estimate is that the £170 million from government will leverage around £250 million of matched funding from the industry through its contribution to funding R&D projects, where under state aid rules we can fund a maximum of 50%, or through activities that it chooses to fund in the centres that we will set up.

**Baroness Neville-Jones:** That is an estimate.

**Fergus Harradence:** It is an estimate at this stage.

**Lord Fox:** I am slightly struggling with the phrase “core innovation hub”. Will it work like a catapult, with companies coming in and trying stuff, or will it generate its own stuff? How do you envisage it?
Fergus Harradence: It will essentially work in a similar way to a catapult centre, but it will be a consortia of different institutions with slightly different specialisms, taking account of the fact that there is no single institution in the UK that has all the expertise that we think we will need.

Lord Fox: How will the governance of that work? Will it be through Innovate UK?

Fergus Harradence: The funding will be managed through Innovate UK, and obviously the consortia that win the competition will have various performance metrics against which they will be assessed in delivering the output.

Lord Fox: Assessed by whom?

Fergus Harradence: Quite how they will be governed is for the consortia to decide. The competition is still open and bids are being put in, which we will assess in the next few weeks, so I am afraid I cannot give you any details.

Lord Fox: Is the “we” BEIS? Who is doing the assessment?

Fergus Harradence: It is overseen by Innovate UK.

Richard Harrington MP: There is a panel, which I believe you are involved in.

Fergus Harradence: I personally am one of a number of assessors who will be involved.

Lord Fox: I was trying to work out which of your hats you are wearing. It is the Innovate UK hat in this case.

Richard Harrington MP: There are inside and outside experts on the panel.

Lord Griffiths of Fforestfach: The Chancellor said that five government departments are going to adopt a “presumption in favour” of modern methods of construction, including off-site, next year. When I first read that expression, I felt that it could have been lifted from a script of “Yes Minister”, because it can mean almost anything.

Richard Harrington MP: It probably was.

Lord Griffiths of Fforestfach: I am sure that was not on your mind, as you have a very practical understanding of what it means. Will you spell that out for us? When I worked in No. 10 I found that co-operation between two government departments was difficult, so to get to five, and to add in the Treasury if it is one of them, will be very complex.

Richard Harrington MP: The Treasury is not directly involved in this. Let me explain which departments are. I have not had the pleasure of working in No. 10 as Lord Griffiths and Baroness Morgan have. I cannot speak for other members, but Baroness Neville-Jones has worked in buildings adjacent to No. 10, I know.

Lord Griffiths of Fforestfach: Sounds sinister.
Richard Harrington MP: She should answer that herself. I cannot really comment on that. I take it as I find it as an organisation and as a way of doing it, which I also was inherently cynical about based on my experience in the outside world rather than within government.

They are the Department for Transport, the Department of Health, the Department for Education, the Ministry of Justice and the Ministry of Defence. These are the departments in which there is a mass of government expenditure on buildings. The Treasury is, of course, always there, because it funds everything. It generally regards all the other departments as mere back offices for the Treasury, does it not?

In this case, there is a working group, which includes us as a department and external people. I thought that the presumption in favour did not actually mean very much, but it is a pledge that, from next year, for every built asset that these five department contract there is a presumption in favour of it being made in a factory rather than on the building site in the traditional way. That does not bind them absolutely, because some buildings just would not be suitable for it, but it is possible for many.

Most large supermarkets, for example, and this is nothing to do with public expenditure, are built in factories now. I saw to my amazement in my own constituency of Watford a Morrisons supermarket built in 16 weeks. I observed it, because I was asked to do the footings—you are given a spade which you then put in your office and people ask what it is. Every morning, these huge walls would appear, and it was finished on the day it was supposed to be finished on. I imagine that it is quite possible for buildings such as schools to fit into the process. It is very achievable.

The scepticism I might have is that, as you say, it is the sort of thing that sounds good when you talk about it. I am sure nobody enters into it thinking that they are not going to do it or are going to stop it being done, but in practice there are factors pulling away, such as local planning, where councillors and officers might have a completely different view, or budgetary constraints.

That goes back to the question from the Lord Chairman, which I did not answer, on the lifetime of an asset. We moved on, but perhaps I can answer it in this context. The presumption that everyone has exactly the same type of building made in a factory might be good to get the cost of construction down, but is that better for the lifetime of an asset? Once again, the lifetime of an asset is great in theory, but in practice it might not be, because budgets are to try to get the price down because the Treasury has set a ceiling.

The Green Book for the public sector defines best value over the long term and has done so for many years; it is nothing to do with this Government. That usually means asking: is it worth spending more in the construction phase if you can benefit from that through lower costs of running a building? Of course, all these public buildings are equally as important to the Exchequer one way or the other.

Lord Griffiths of Fforestfach: To what extent do you need to ensure that these five departments have the right resources and skills to do this?
Government – Richard Harrington MP, Minister for Infrastructure and Construction, Department for Business, Energy and Industrial Strategy (BEIS) and Fergus Harradence, Deputy Director, Construction, BEIS – Oral evidence (QQ 71-77)

Are they in any way accountable to you, so that you or other Ministers can tell, say, the Department for Transport, that it has been very lax in the presumption in favour and will have to change things because you are just not happy?

Richard Harrington MP: That will be done through the cross-governmental working group, which is there to monitor it and to make sure that it happens. As far as I am concerned, wearing my construction and more general BEIS hat, and as someone responsible for the implementation of the industrial strategy, I have asked for and will receive reports on a regular basis, I hope. I have asked for those, and a system will be set up when this gets going in a year’s time to monitor it, because sometimes people start with the best intentions but there are always reasons why it cannot be done or cannot be done until the following year.

As has been implied, the Chancellor made a very strong statement about this not long ago in the Budget Statement 2017. The Chancellor is also behind it, maybe for reasons that are not quite to do with improving the construction industry but because it makes a lot of sense financially. Even if it were traditional construction and not off-site construction, it would still make a lot of sense to do it. It is more than in the wind; it is a real policy, and it is my intention to make sure that it is implemented properly. I have said specifically that if any department has a problem we will discuss it openly at the beginning so that it is not said a year later when it has not happened.

Baroness Neville-Jones: Minister, you did not mention DCLG as one of the five departments. Is that right?

Richard Harrington MP: DCLG is not one of them.

Baroness Neville-Jones: I ask, because I wonder how these departments, even if they have the skills, have the power.

We paid a visit to Laing O’Rourke, which is invested very heavily in this. It told us a story that bears on this question. Part of Yorkshire—I do not know which part—commissioned some schools, and these schools were built. Laing O’Rourke invested considerably in the whole business of designing the schools, and after the first delivery it then had a template for more schools at a unit cost that presumably would have been profitable for it.

The next time round, however, Yorkshire reverted to traditional procurement—there was no follow-through. How will you, sitting in London with the central departments, ensure that the message gets through to the bodies that will commission these buildings, whether it is NHS England or local hospitals or schools, so that the good intention of central government is realised?

Baroness Morgan of Huyton: Can I add to that? I was not on the visit, but it is my understanding that the capital for that would come from DfE and not from Yorkshire, so how are we in a situation where capital is coming from DfE and Yorkshire is deciding to do something different with it? You might have to go away and look at that, but it is symptomatic of
Richard Harrington MP: I am afraid I do not know that example, but as Baroness Morgan says, he who pays the piper calls the tune. The Government will have to stipulate that.

Baroness Neville-Jones: And are you really going to do that?

Richard Harrington MP: I am familiar with Laing O'Rourke and have met Ray O'Rourke. It is a big-scale company and they are competent people, but there must have been a reason for Yorkshire to change its mind.

Baroness Neville-Jones: It was not divulged.

Richard Harrington MP: I cannot comment on it, because I do not know. But if it was cheaper and if it was just as good, why would it? I think you and I should declare an interest, Baroness Neville-Jones, as Leodiensians ourselves.

Baroness Neville-Jones: The general point, Minister, is that you are going to use the influence and the power of central government.

Richard Harrington MP: We are going to have to. I am trying in my sectors to continue mentioning it. For example, I have asked for a meeting with Sir Edward Lister, the chairman of Homes England, explaining that, at this point, even though I do not have the direct power to do it, we will be viewing the work of Homes England all over England through the prism of off-site construction, because it is in our industrial strategy and there is a five-department presumption. We have to keep banging away at it.

Baroness Neville-Jones: So presumption means exerting quite a lot of downward pressure.

Richard Harrington MP: I think so. My personal pressure is probably not enough, I have to say, but if it is repeated and repeated by people such as the Chancellor, and if the Treasury starts making this conditional, which it is in its interest to do because of the cost and because it is in all our interests to have an industrial strategy, in the end, that will make authorities such as the one in Yorkshire decide to comply.

It may be that there is no cost difference or it can show that it is not as it appears, and that is why I do not want to criticise Yorkshire without knowing its reasoning. I do not believe that it would be completely illogical and irrational. Without impugning Laing O'Rourke, or any other company for that matter, sometimes companies do see things just from one perspective.

Lord Mair: Minister, in the previous session we heard from Tony Meggs of the Infrastructure and Projects Authority about the presumption in favour. He expressed the view that from 2019 the five departments would be expected to set out in the procurement process that they would want to see at least one off-site manufacture option. What is your comment on that?
Richard Harrington MP: I hope that it would be more than that. That would be part of the presumption in favour, but for the people promoting and managing a project there might be reasons why it is not suitable. That is why we could not make it completely compulsory for all projects to be constructed off-site. The Government are a big procurer, and they cannot do it as directly as perhaps they would have done in different generations, because it was shown for other reasons not to be very efficient, but in the end they can stipulate these matters subject to cases where it is just not appropriate to do so.

Take housing as an example. I can see that a very small development of different units for different use, such as sheltered housing, would not be appropriate. But in many other cases it would be, if it is going to be built on a large scale with exactly the type of modular unit that can be done according to a central design that is much cheaper and more efficient to use.

I have observed quite a lot of it. There is the Building Research Establishment in Garston in my constituency. The BRE has been researching this kind of thing and these different materials for a long time. It is now the time, now that we have different types of computer design and all the other things. We are on the cusp of it, but the Government have to push it by pushing government procurement contracts.

Lord Vallance of Tummel: Can I push you a little further on procurement? In your introductory statement you said that there are two types of benefit from off-site manufacture, one of which is cost and the other is environmental. When you were doing A-level economics I have no doubt that you picked up things about externalities. Of course, the improvements in the environment are very much to do with externalities, one of which was set out when the sector plan was announced but before it was published: to reduce greenhouse gases in the built environment by 50% by 2025. That is quantifiable. Do you think that externalities of that sort should be quantified in government procurement in the same way as costs and, if not, why not?

Richard Harrington MP: First, maybe the reason I did not get the top grade in economics is because I did not understand externalities. This is precisely what government can stipulate in procurement contracts, and government stipulates so many things now in a way that would not have been dreamed about only 10 or 20 years ago. Again, government has to stipulate these things if it is to achieve perfectly proper targets to do with the environment. I would say absolutely yes.

Lord Vallance of Tummel: There are armies of economists who will give you the cost of carbon, so you are saying that the cost of carbon should be included in government procurement of infrastructure of this kind.

Richard Harrington MP: Yes, because the Government have an overall carbon target and this is one way of achieving it. There are armies of economists who will tell you completely the contrary, but Governments have to decide, in the United States as well as here.

Baroness Young of Old Scone: One of our previous witnesses said that
Government – Richard Harrington MP, Minister for Infrastructure and Construction, Department for Business, Energy and Industrial Strategy (BEIS) and Fergus Harradence, Deputy Director, Construction, BEIS – Oral evidence (QQ 71-77)

as yet no performance criteria had been set for the presumption. Is that going to happen, and have you any idea about what they might contain? They could in themselves be quite effective drivers.

Fergus Harradence: There is not a set at the moment, but it is certainly something that we could consider as we develop and work out what the presumption means in practice.

Baroness Young of Old Scone: A simple one of “more off-site construction” is rather bald. There are other things to consider such as capturing externalities.

Fergus Harradence: On off-site construction we would want to capture as comprehensively as possible all the evidence we can about the benefits, whether that is reduced carbon emissions, reduced time taken to complete jobs, reduced error rates and reduced waste produced, taking account of the fact that the construction sector accounts for about 60% of all UK waste, and not least of all the reduced cost of construction. We have done some work on this relating to specific subsectors, and there are good case studies of the benefits of off-site construction in relation to a range of built assets, but we have not done it comprehensively across the board.

The Chairman: Lord Mair, did you have a quick question?

Lord Mair: No.

Q75 Lord Fox: Turning to the construction sector, we have heard countless witnesses tell us that it is fragmented and that co-operation is difficult. In particular, when you move into private sector contracts rather than the ones you have been talking about, it is very difficult to drive the sort of behaviours you describe. How can government involve itself in encouraging this?

We have just heard a couple of questioners talk about the environmental standards, but I would like to throw in here the Hackitt review, which is looking at the sense of an integrated building. We have a very disintegrated industry, and one of the key findings of the Hackitt review is that we need an integrated approach both to the production of the building and to its final sign-off. Is that one way of driving the private sector to integrate? What drivers does government have that it is not currently using and should start to use to create that world?

Fergus Harradence: Ever since the unfortunate fire at Grenfell Tower last year, and during the process of developing the sector deal, we have been taking account of the likely findings of the Hackitt review. The interim report published in December last year identified a number of serious failings in the way the construction sector goes about commissioning and completing jobs and the failure of the people responsible for managing the overall system for ensuring building safety, which in theory is supposed to work but in practice clearly did not work properly.

We have taken account of the recommendations and looked at what the actions we are proposing to undertake through the sector deal can do to
contribute to the wider objective of ensuring building safety in the UK. There are some very obvious areas where the objectives are aligned. The greater use of digital technologies in the design of buildings and the management of the construction phase will make it easier not only to design safe buildings that incorporate safe materials but to ensure that there is better control of the change process within construction.

Lord Fox: You then have a manual for the building afterwards.

Fergus Harradence: Yes, and you will be able to hand over to the ultimate client or building owner a detailed digital model that tells them exactly what is in the building and what has been done to it. If they wish to plan further work and make further improvements in the building, that will similarly be recorded.

So everybody, which in theory includes the emergency services, the local authority and any other relevant regulators, will have access to a comprehensive dataset. If you continue to build buildings this way over time, you build up a very detailed picture of the urban environment and the built assets within it.

Richard Harrington MP: I have seen for myself how fragmented the whole process is. Some of it is to do with the way history has evolved. We have buildings—we are in one—that are from about five different ages effectively in one complex. When I was in the hotel business, you would buy a hotel and no one had any idea what it was built of. Obviously, because of inspections, you would have health and safety reports, fire reports, and different things like that, but it was fragmented and involved catching up from the past.

Now, with the construction sector changing as it is, we have a chance to make sure that in future every owner who buys the land and builds the building, be it a company or government, all the way through its lifespan, has access to the same information. That is so much easier, as Fergus said, because it is digitally based.

Lord Fox: Do you think this will drive off-site manufacturing?

Richard Harrington MP: I think it will, because it is so much easier to control rather than using 20 or 30 different subcontractors, all of which might be doing their job properly but are not paid to look at the big picture at all. It is inevitable and absolutely right that it should.

Q76 Lord Hunt of Chesterton: How are the Government ensuring that the necessary training is available to provide the skills needed for off-site construction and other modern methods of construction? You just made the point about the skills needed for the digital management of buildings.

Apropos of this, one way in which companies can learn, as we heard from the previous witnesses this afternoon, is by taking as an example other buildings that have been put up. Somebody from Sellafield gave the example of borrowing the design of buildings from an adjacent local authority, so not having to go through some formal judging procedure. That seems to me very important.
Richard Harrington MP: It is. The core point is that the skills that the industry needs are changing dramatically. The Government are working with the Construction Industry Training Board and the industry generally to try to analyse what skills are needed for the future. It is very different from mainstream building now. Digital skills are obvious, but it is not just to do with the construction itself; there is design, logistics, site management and so on.

I could pick out so many different sectors of the economy, but take as an example car factories. I have visited Cowley near Oxford twice in my life, once when I was 18 and once a few weeks ago. It is completely different. Most of the people who are building cars there are trained to use some form of computer for what was once a completely manual task. The whole system is based on everything other than physical labour. But building sites have not changed very much at all in that period. The core skills of bricklaying, plumbing and electrics, which are very much divided skills, are still being trained to this day, but that will have to change.

How are the Government going to kick-start that? One way is what we have been talking about: the presumption of building off-site, which clearly involves very different skills. Another way is the successful application of the apprenticeship levy, with which there has been some problems, not in the levy itself, which is generally supported, but in its implementation. There were 100 different standards that were all over the place, but now the Government, with Gerry Berragan and the Institute for Apprenticeships, are looking for standards that will really reflect what the building industry needs in the future. There has to be a vision and things have to change. The car industry is just one example, and the way that cars are now manufactured is fundamentally different. It will change again, but the modular construction requires totally different skills.

The Government can kick-start it in two ways. One way is to work with industry on the skills, which I have explained. The second way comes back to the Government using their money to push these things through. It is for the benefit of everyone. We cannot allow the same situation every time the economy expands. Everything is cyclical. At my age I have seen at least two or three economic cycles, and they always happen one way or another, whatever Governments and Prime Ministers might say—of fund managers, for that matter.

We always have the problem of skills shortages when we go up the economic cycle. I hope we are now in a position to change things so that that will not happen. The skills part of it is critical. Construction, rather than the perception of it being an old-fashioned, traditional industry, will change dramatically. I cannot say that it is going to be as glamorous as iPhones and iPads, but it will be fundamentally different, and future generations will see the benefit of that.

Lord Fox: You brought up the subject of apprenticeships. We heard from the previous panel that one issue currently facing firms is that the length of their contracts is in many cases less than the time it takes to complete an apprenticeship. There are two conclusions from that: one is that you try to produce a modular system of apprenticeships where people can
move to different firms to complete them, and the other is to try to drive a greater degree of certainty within the building industry to enable it to train its own people.

Fundamental to the skills problem is that there is so much uncertainty, because many firms are not investing for the long term, because they do not actually know what the long term is. It is a chicken and egg situation. What are the Government doing to try to get some certainty into this?

**Richard Harrington MP:** You are certainly right in that the current traditional model for short-term construction is based project by project, usually for cash-flow reasons. Even some of the massive building sites are phased, in particular in residential property, for reasons of cash flow. That has to change, and the skills element is part of that.

Not in this life, but when I was David Cameron’s apprenticeship adviser in 2011, which predated the levy, I visited the construction industry apprenticeship centre at King’s Cross. That is not exactly what it is called but that is what it is. Its problem was that contracts were typically for two years and apprenticeships were for three years or more.

At the time, the companies with more substance behind them and more vision included Carillion, which was very good at apprenticeships. At the centre, I met apprentices from all different companies, and Carillion had a vision beyond the two-year contracts. Now, I know what happened and I am certainly not making light of it, but there is no question that the Government have to help the bigger companies in particular with longer-term contracts. Local authorities and housing associations have to take a longer-term vision, otherwise there will always be this skills problem.

I am sure it is the same elsewhere. In another sector completely, I visited Airbus in north Wales where they make the wings for the Airbus planes. But it cannot predict the future beyond the orders that it has, in the same way that a construction company will not be able to predict exactly what it is going to do. But construction companies also have to think more long term. If they are investing a lot of money, as the O’Rourkes are in these massive factories, they have to tell their customers, who are predominantly but not exclusively government, that they can do it at a better price if they are guaranteed four or five years’ work, because that helps with the skills and everything else.

It has to change. It is too old-fashioned to put every little bit out to tender and use different companies. Should the top contractor be the apprenticeship provider, some of which are very small and made up of only five people? Even on big contracts, people are paid by the day or by the square metre. This all has to change, otherwise we will never get to grips with the skills end of it. The Government have to pump-prime this.

**Baroness Neville-Jones:** I want to pursue this for a moment. It has become fairly clear that if you are going to have off-site manufacturing as a predominant element, the business model has to change because the amount of up-front capital that is involved at early stages is much greater than something that involves the traditional, rather slow cash flow—I can wait three or four years as the client before I actually have to fork out anything significant.
Government – Richard Harrington MP, Minister for Infrastructure and Construction, Department for Business, Energy and Industrial Strategy (BEIS) and Fergus Harradence, Deputy Director, Construction, BEIS – Oral evidence (QQ 71-77)

How are you going to turn all this around? What is the Government’s master plan? Can you marshal enough projects that you can guarantee a flow so that the companies themselves have confidence that they will have a business flow? How will you get the thing going in the first instance?

The Chairman: In short, it will require a consistent pipeline of construction projects.

Baroness Neville-Jones: You said that the industry has to change, but it seems to me that the public procurer has to change, too.

Richard Harrington MP: We have the power. A quarter to a third of all construction is government funded one way or the other.

Baroness Neville-Jones: You have the power, but will you use it?

Richard Harrington MP: Why would we not use it, Baroness Neville-Jones?

Baroness Morgan of Huyton: You are showing great conviction, Minister, and you are really clear that it has to change. What we want to understand is: is it definitely going to change?

Richard Harrington MP: Yes, because otherwise off-site construction will not happen. Companies are not going to build what are effectively huge factories completely on spec. Everything is on spec to some extent—we used the Airbus example—but companies take a commercial view based on likely orders. Government spending has to reflect this.

By the way, it is not just government spending. I am sure that the big housebuilders will also have to guarantee 1,000 units in three months, or whatever it is, otherwise the capital expenditure will not happen. The Government have the purchasing power to be able to do that.

Baroness Neville-Jones’s point was: does government intend to use it? Unless this is pushed really hard, it will not happen. That is why, to go back to the five departments, we have to make sure that it does happen. The Treasury sees that. It may see it just for financial reasons, but we see it as something broader than that.

As I said, it will have a fundamental effect. It is almost like the Industrial Revolution happening again, in the same that many industries existed before the Industrial Revolution but were done in people’s homes—for example, weaving and spinning—and then moved to factories. We have learned all those lessons and we have to make sure it changes, unless we want to live in a different type of economy where the Government do everything, which some people might want.

However, we live in a mixed economy, and the only direct power we have is to make sure that the Government use taxpayers’ money for that. For financial and other reasons, it will happen. It has to.

Lord Fox: I want to press the point about cash flow but look at the private sector. Private sector developers have a model whereby money does not go out the door in many cases until money has come in through the door for what they have built. This is asking them to make a
substantial reversal of their cash-flow model. How are you going to persuade them that it is in their interests to do that?

Richard Harrington MP: I disagree with the presumption you are making, Lord Fox.

Lord Fox: Were Lord Borwick here, he would be making that point, and he knows far more than I do about property development.

Richard Harrington MP: He knows far more than I do as well. Builders have a lot of cash flow issues now. If Barratt builds an estate, it is not paid the money until it finishes constructing a house, so it is not such a fundamental change. The difference goes into the cash flow, because at least Barratt pays the money up front and pays all its subcontractors on contract. So it is a change, but not such a major change in financing. Financing is not our problem. These companies have the security for it and the sales. They may have to change their model, but they will have to change their models in many ways.

The Chairman: You said that there is a model, but can the Government help? Let me give an example. As I understand it, in France for instance you buy your apartment and the Government have legislated that at one-third of completion you pay one-third of the price and at half you pay half. The construction industry there always has a cash flow.

Richard Harrington MP: That is for properties that people have constructed for them in the private sector. There are many examples of where that can happen here, in particular when building individual properties, but I agree that it does not happen en masse. It is not a matter for legislation, but the construction industry will have to change its cash-flow model. Take the idea of companies funding a lot of their production by not paying their suppliers for 30, 60, 90 or 120 days or through retentions. All this has to change. That is not the fundamental point in Lord Fox’s question, but cash-flow models do change.

Lord Fox: But there are opportunities, for example, to encourage securitisation, so they could secure it in advance and use that as a cash-flow float. The Government could play a role in encouraging those things.

Richard Harrington MP: They could. I also think that institutions, when they understand this type of construction, will move into it a lot more. We see institutions involved now. For example, Legal & General and others got involved in the construction of what were fairly primitive buy to lets. The institutionalisation of it has significant cash-flow effects, because they do not get the money back for 10 or 20 years. I am not exactly sure what the yields are, but it is lengthy period.

Many of those institutions are now saying that they will move into actual production and become the factory and the supplier. Cash-flow models do change and institutional money will have to come in as an alternative to the fairly primitive forms of funding that are used now, which use client’s money in advance and retentions and other things like that.

Lord Hunt of Chesterton: Do you have financial people planning the future?
Richard Harrington MP: Plenty of them.

Lord Hunt of Chesterton: Are they putting together a coherent policy on this?

Richard Harrington MP: They are. There is more to it than just the financial side, but we have a lot of financial people.

Lord Hunt of Chesterton: Will that be in the document that we are going to get imminently?

Richard Harrington MP: It is in the sector deal, which is broader than just off-site construction, so I cannot promise that, otherwise I will be accused of misleading the Committee, which I have no intention of doing—not if I can help it.

Lord Kakkar: I want to come back to the Treasury’s role in driving forward the five departments. What will be the trigger to actually make something happen and really push this so that procurement by these five departments occurs in the way that you envisage?

Richard Harrington MP: In my opinion, it will be the Treasury saying that this is what is happening here.

Lord Kakkar: What would make the Treasury decide that this is what it has to say?

Richard Harrington MP: If it sees that the policy as laid out in the Chancellor’s Autumn Budget Statement is not happening. We have to make sure that it does happen. As for an absolute trigger of 5%, 10% or 20%, I do not know, because we do not have one. I think it would be wrong in the short term to have one, but this is public and it would be a total failure of policy if it does not happen. I believe that the financial pressures to do it are there as well and, as I discussed before with Baroness Morgan, in the end that overrides everything else.

Baroness Young of Old Scone: Minister, can we focus on the housing sector? The levers that government has in that sector are comparatively small; it is not a big investor in housing development any more. However, we have a real opportunity with the housing targets and the major dash for housing.

Where do you see the leverage coming to influence the speculative private sector builders of low-rise housing in particular, which is where we seem to be least well developed? Is it wrong to say that it is in their interests not to find a way of building out sites quicker, because that means that prices then drop, which is not in their interests in view of the investment that they have already made in land banks?

Richard Harrington MP: If I may, I will first answer the question about the public sector. You made the point that government does not have a direct influence, but actually it does through the funding of housing associations and so on. I know we do not use the terminology that we used to of “direct expenditure”, but it comes back to the fact that it is perfectly reasonable for government to say that, if we are going to fund this project for this housing association, it is done using modular
construction off-site. There is more influence there than might first appear. Government has to use that quite ruthlessly.

On the question of the private sector in effect going slow on this, you are probably right. Management is used to a certain way of doing things. The Government can tell schools all they like that we need more and more apprentices, but the current management—the teachers—will, for perfectly good reasons because it is the way they were brought up and developed, try to say that it is better for children to go to university.

It may be that the current management in the private sector are used to a lifetime of handing out these contracts for the different components of a traditional construction site, and it takes time to change. In the end, if a property developer sees that they can get a better deal for a better product at a lower price, they will do it. They will have every reason and influence to do it, because their building costs have gone up dramatically.

Quite apart from the actual cost, there are big skills shortages on building sites. When you speak to people, the main thing they say is that they cannot get the contractors and the labour. I do not suppose it is the business of this Committee in particular to go into Brexit issues and general migration issues, but putting any principle to one side, the fact is that there is a significant shortage of skilled labour and this will push it. If I were a big developer and I had a choice between paying £150 or £170 per square foot for a basic house in a conventional way, and there is a way of doing the same quality product for two-thirds of that, I am going to choose that. The pressure is more economic than governmental in the private sector.

**Baroness Young of Old Scone:** Is there a government action to help to kick-start that process? You have already made the point that up-front investment in manufacturing facilities could be a blockage for individual housebuilders.

**Richard Harrington MP:** Yes. I do not think it is a government policy in the private sector. If the Government kick-starts this predominantly in the public sector with hospitals and that type of thing and where they can control it—housing associations being a classic example, but there are others—the private sector will follow. At the moment, a typical housing association property is built in exactly the same way as a private sector property. Why should it not be? It is fundamentally the same product, so if one goes the other will go.

The Government are much better kick-starting this where they have direct financial control, albeit through an intermediary delivery organisation such as a housing association. While housing associations are independent in their legal standing, it is quite right that government should apply conditionality to the money that they spend. That is why I am seeing Homes England about it. We have to push this in every way we can. But it is not easy and we cannot command the big housebuilders, “You will build in this way”. They have shareholders and pressures, and I am sure that as they see the costs of modular construction come down they will go for it.

**Lord Mair:** May I ask one question about the role of your department in
standards? A lot of what is being talked about in off-site manufacture would very much be enhanced by more standardisation. Can you comment on that?

**Richard Harrington MP:** Would you like to have a go at that, Fergus?

**Fergus Harradence:** When you say standardisation, do you mean standards in the sense of product and process standards or standard designs?

**Lord Mair:** Probably both.

**Fergus Harradence:** In relation to standardisation, BEIS as a department sponsors the British Standards Institution, so we oversee the framework by which standards are developed in the UK. One of our activities includes a strand of the transforming construction programme to develop new performance standards for buildings that are manufactured off-site and the associated production methodologies that will be used so that people have assurances about the quality of the product they are ultimately going to buy. We see that as part and parcel of having an effective innovation programme that leads to products that will be commercialised and adopted on a large scale.

The standardisation of designs is ultimately a question for the organisation that is commissioning the project or undertaking the developmental work for a client.

**Richard Harrington MP:** I will comment, if I may, on the design element. At the moment, for residential housebuilding it is very much a standard product for cost reasons. Yes, there is design choice A, B, C or D, but really it is the same product—there might be a different gable or type of window or something. That will continue. People, I am sure, will continue to pay a premium price for a premium product, as they do with a suit.

There are clever ways of making things look different using computerised design. They are very good at this in America. Admittedly, they do not have the weather problems we do, but they can go from a piece of land to building a house in the factory usually in 13 weeks. But they look different. People think they have endless choice, but they do not really. It is just the different things that are put on it. I think we will see a lot more of that, which of course helps modular factory-based construction.

Then we get back to the whole question: does everybody want the same? In the past, housebuilders have successfully created the illusion that people are buying different when they are fundamentally buying the same. It will be very much that, albeit built off-site.

**Lord Mair:** But presumably government will want to drive standardisation of the components, because the more that is happening, the more it will incentivise off-site manufacture.

**Richard Harrington MP:** I think the economics will do that. One of the advantages of computer-aided design and production is that there might be more flexibility in the standards and in the choice of different products. But clearly government has to be involved in safety standards and
Lord Fox: There is a different standard on waste. One of you mentioned that on-site building is responsible for a huge amount of waste, which is at the moment almost a subsidy of the process. What are you doing to drive down the waste? Surely a serious financial penalty on waste would drive you further towards the goal of more off-site manufacturing?

Fergus Harradence: There is already the landfill tax, which I would have thought the construction industry—

Lord Fox: Which is clearly not deterring people from wasting a huge amount of what is on site.

Fergus: As with all industries, it is not that the construction sector intentionally wastes this amount of product. The level of waste—

Lord Fox: It is the process. That is exactly why I am asking the question.

Fergus Harradence: It is the intrinsic inefficiency of the process and the fact that people make errors on site; hence the reason why we want to move to digitally designed manufactured buildings—because it enables you to run much more efficient processes and minimise waste.

Lord Fox: At the moment, they can use the inefficient process economically. If it was less economic to be so inefficient, they would perhaps be encouraged to be more efficient.

Lord Vallance of Tummel: It is an externality.

Richard Harrington MP: That is a good point. I must say, I have not considered it. It is a consequence that we have to watch for.

The Chairman: Minister and Mr Harradence, thank you very much indeed. You have been most informative. There is no doubt, Minister, about your commitment to increase the level of off-site construction. Therefore, it makes me feel that our report will be well received by the Government.

Richard Harrington MP: I look forward to receiving it, Lord Chairman. Thank you for your questions.
Executive Summary

1. The Ministry of Justice are committed to supporting the Government drive to transform the construction sector by promoting off site manufacture for construction. The Ministry of Justice (MoJ) gave an early commitment to an MMC (Modern Methods of Construction) approach in early 2016, with the Design and Construction Strategy for the Prison Estate Transformation Programme (PETP) basing the delivery of the new prison estate on this approach. In November 2017, the Ministry were one of the departments named within the Construction Sector Deal, for the UK Industrial Strategy, as adopting a presumption to MMC by 2019.

2. Since 2016, the PETP team has being working with Bryden Wood, initially as Concept Design Team for the new prisons. Bryden Wood are now appointed as Client Design Advisers for delivery of the new prisons from detail design through to project completions.

3. The PETP has progressed to detail design stage for the first two prisons. In February 2018, the MoJ signed a multi-party Pre Partnering Agreement to develop the first two prison projects up to Agreed Maximum Price, in preparation for contract close on each of the prison build projects. The agreement includes Kier and Interserve (the Design and Build contractors for each of the two prisons), Mace (Programme Delivery Partner), WT Partnership (Cost Consultant) and the Ministry of Justice (Client).

4. The PETP approach is to develop Platforms of standard construction components that can be manufactured, in a factory environment, for assembly on site. The component manufacture process could be carried out off site or, in some cases, on site. The evidence within this report relates directly to the experience, to date, of working within this MMC environment.

Perceived advantages of offsite manufacture for construction
What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

5. Manufacturing construction components in a ‘factory environment’ offers opportunities to the Client to:
   - Achieve a consistent quality to production that could result in zero defects at handover thereby improving and easing the transition into operation. Manufacturing uses standard processes and techniques so that learning can be captured and continually refined;
   - Significantly improve health and safety on site, reducing occurrence of death of serious injury to construction workers;
   - Deliver projects quicker and more efficiently;
   - Reduce costs through shorter on-site construction periods.
6. There is a huge opportunity for Government to work together, across departments, to develop a consistent construction client approach. Developing cross government Platforms of Standard Construction Components could:
   - Achieve significant cost savings in terms of unit price per component. Long term Government Infrastructure Pipeline providing confidence in supply chain for quantity of units required. Long term certainty for production lines will achieve efficiency in manufacture and lowest unit price;
   - support the UK Industrial Strategy by helping regional regeneration through developing new supply chain/manufacturing hubs to deliver to government client known needs;
   - inform improved long term UK infrastructure investment planning through higher confidence levels of programme costs and delivery timescales. The use of standardised components will provide a higher level of cost certainty at an early stage that can be used to achieve better return on investment. More efficient UK investment planning will place the government client in the best negotiating position for procurement, attracting highest quality bidders within the market place and achieving optimum outcomes.

7. The main factors that are likely to influence adoption of MMC approach are:
   - The size of the programme. There are greater benefits to be achieved through larger scale and longer-term programmes. For Government clients this means that there is a need to secure early commitment of finance to support the delivery of the whole programme which could be beyond prescribed budget periods. Early certainty of financial commitment gives the level of certainty that the client needs to attract the best bidders and achieve the best outcomes.
   - The maturity of the Client is a key factor in consultant, design and construction contractors and supply chain engaging in MMC. An intelligent client with SMART objectives and a knowledge of the challenges that MMC present will be better able to lead the contractors into the right ways of working;
   - The treatment of risk. MMC currently requires high levels of innovation from all parties. This relies on everyone being able to work in a fully collaborative environment where risk is shared amongst the most appropriate parties. The traditional routes of risk management create a cautious risk appetite amongst contractors which builds in obstacles, particularly to new ways of pricing and programme planning. The easiest route to achieving this is through Project Insurance with the Client holding a larger central risk pot and passing less risk onto the supply chain. New forms of contract could also help to address this challenge.
   - Proof of concept. There are a number of key parties, within the construction sector, that are carefully watching the progress of current MMC projects. It is likely that their current risk profile may prevent them from engaging at the early stages, until there is more confidence in proof of concept. For MMC to be a success we need engagement at a Director level within the Tier 1 UK construction companies. But for MMC to be a success we also need to focus on building new supply chains for
manufacture and not rely, solely, on waiting for the existing supply chain to commit.

*It is often claimed that offsite manufacture can lead to:* • lower costs, faster delivery and increased quality; increased productivity; improved health and safety; greater provision of new, affordable housing. What is the evidence for this?

8. The MoJ are still at fairly early stages of design development for the PETP, but there is already emerging evidence that the on site delivery timescale will be reduced by circa six months in comparison to the most recent, more traditional, prison construction projects. The design team are currently undertaking prototype for the development of standardised construction components. The outputs from this work is beginning to confirm high likelihood to the ability to realise the aims 30% costs savings.

9. The MoJ decision to move to MMC was based on evidence from previous projects such as GlaxoSmithKline ‘Factory in a Box’; Circle Hospital, Reading; Heathrow Terminal 5C Nodes; Heathrow and Gatwick Pier Segregation.

**Potential barriers to wider use of offsite manufacture**

*What are the drawbacks to offsite manufacture for construction? What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?*

10. There is an ageing demographic within the construction sector workforce with 2011 ONS figures showing over 40% of the workforce age 50+ and a predicted decline in workforce by 25% within the next ten years. These figures are without taking into account the impact of Brexit when we know that our current workforce is supplemented, particularly in the south east by high levels of workers from other EEC states. This would suggest that there is less of a need to re-skil the existing workforce and more of a need to generate a new workforce to support MMC.

11. There is evidence to support the argument that MMC can be delivered by low skilled labour. The successful GlaxoSmithKline ‘Factory in a Box’ and the Heathrow / Gatwick ‘Pier Segregation Product’ confirmed this. On PETP, we have been carrying out prototype work using low/un skilled labour within prisons. This prototype work has provided a training and development opportunity for prisoners coming to the end of their sentence, ready for release. The prototype work has proved that unskilled labour can very quickly be trained to manufacture consistent high quality products within a factory environment.

12. Design teams will need to be up-skilled to adopt the new techniques and new approaches that are required to get the maximum benefits out of MMC and ensure that the continuous improvement continues to evolve.

13. Tier 2 and 3 supply chain needs to input to the development of MMC and smaller companies will require up skilling in terms of the digital approach in order to maximise the benefits of their early involvement.
14. The traditional role of Tier 1 construction companies will need to be challenged and re-defined. This may mean a change of approach in terms of risk profile and new forms of contract that make it easier for the companies to fully collaborate. MMC needs to be recognised as a transformational project within organisations and for it to be embedded, new processes will need to be embraced by construction professionals, such as planners and quantity surveyors. PETP can provide an example of this challenge: the design teams developing detail design for each site that informs the build up of cost certainty for each project. The construction companies are sending the information back to the main office where their costing and planning teams are issuing tender information to confirm costs. Initial costs for groundworks were significantly over the estimated budgets; when this was interrogated it was found that the Tier 2 supply chain had taken a traditional, risk averse, approach to foundation design, without waiting for the detail information of the structural design for the new buildings that would have confirmed that there was no need for piling on site; the Tier 2 approach was to over design which covered off their own risk but loaded excessive costs and additional time into the construction contract. One of the main reasons for the Tier 2 approach was the lack of understanding of the MMC approach and their traditional approach to risk.

15. Building the MMC approach requires all parties to recognise that the construction transformation aims need to be pro actively managed to ensure success. Within the project, the transformational aims must be expressly stated, promoted, continually tested and challenged with commitment from all parties, at all levels (Board Director level sponsorship is essential to break down internal barriers).

*Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?*

16. Adopting a standardised approach to construction components ensures a consistent quality finish and technical compliance. The confidence of meeting all statutory requirements, allows the design team to focus their time on adding their expertise to develop the best design outcomes for the building users. The best designed building are those that are designed from the inside out, with the focus on the building user’s needs. MMC allows design expertise to be maximised in the area where it will deliver the biggest impact.

*What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?*

17. R&D is required to provide support for early MMC adopters with regards to successfully managing the transformational challenges, particularly in relation to people and managing change.

18. The cross government MMC working group has already established a forum for promoting change across Departments, sharing best practice and horizon scanning to identify future opportunities for Departments to work in collaboration.
19. More research is needed into procurement and developing new forms of contract that allow for integration of manufacture and supply with construction and on site assembly. Risk profiles need to be considered within this work to identify the best approach to managing risk for all parties, considering project insurance as a route to addressing this issue. These new contracts need to be able to work with capital and alternative financed projects.

20. For Government to lead the way in MMC, as a main construction client, there should be further research on developing cross government construction platforms. Data analysis across main departments would provide a rich data set to define a complete list of platform characteristics. A gap analysis would identify what is already underway and what is needed and further platforms can be developed and tested.

**Government actions**

*(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?*

21. Yes, the construction sector deal does correctly identify the issues but now we can be more definitive about next steps. The proposed core innovation hub to transform UK construction provides an excellent opportunity to further demonstrate the benefits of a construction Platform approach. Rather than building the hub as a traditional construction project, the project itself should:

- Be designed using a more analytical and collaborative approach to optimise building function and ensure comprehensive stakeholder engagement and buy in;
- Be assembled using and refining existing platforms;
- Test new procurement and incentive models;
- Refine digital workflows
- Test the use of sensors and the benefits of ‘smart’ assets;
- Capture data relating to productivity, carbon, supply chain capability etc.

The process of design through delivery and handover should be well documented and published to provide a rich resource for further industry learning and refinement. In this way the proposed hub will make a significant contribution to advancing the sector, even before it is fully operational.

*What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?*

22. Need to consider new forms of contract; new forms of insurance/assurance; better alignment of incentives (outcome focussed) and risk allocation; better use of analysis in developing briefs and problem statements.

*30 April 2018*
Greater London Authority, Willmott Dixon and Legal and General Modular Homes – Oral evidence (QQ 9-16)

Transcript to be found under Legal and General Modular Homes
I am an Associate Professor in the School of Engineering and the Built Environment and head of the Centre for Offsite Construction + Innovative Structures (COCIS) within Edinburgh Napier University's Institute for Sustainable Construction, where I lead on research, innovation and knowledge exchange activities designed to deliver construction technologies for tomorrow's communities within a circular economy.

In addition to my role at ENU I am academic lead of Offsite Solutions Scotland a company formed by 10 industry partners in 2016 with a combined manufacturing output of £170million employing more than 1,000 people. OSS was formed as result of a UK Commission for Employment and Skills funded project ‘Addressing the skills deficiencies in the offsite construction sector’ to encourage an R&D approach to skills and development application in the workplace with follow on funding support from Scottish Enterprise, the Construction Scotland Innovation Centre (CSIC) and the industry members.

The uptake of ‘new’ construction methods has historically been determined by the correct intersection of drivers for change with scalability determined by the economy, given the need for investment. The drivers for change in a modern context I have identified from my research are ‘Sustainability’, ‘Regulatory’, ‘Digitization’, ‘Productivity’, ‘Human Capital’ and ‘Culture’. I have considered these drivers and their influence globally, UK wide and specific to the region of Scotland where the emphasis is timber offsite MMC.

I have excerpted relevant information from a selection of this research in order to demonstrate that the identified drivers are intersecting in a manner that is creating the opportunity for Offsite in general to be a scaleable solution. This research has been compiled from legitimate sources by way of demonstrating an underpinning evidence base and these references are contained at the end.

Note: The full content of this research will be published later this year by Taylor & Francis as a chapter entitled “Core Off-Site Manufacture Industry Drivers” in a seminal text book “Offsite Production and Manufacturing for Innovative, Construction: People, Process and Technology” ISBN: 978-1-138-55071-1 edited by Goulding, J.S., and Pour Rahimian, F.

I trust this information will help demonstrate the opportunity for growth of Offsite construction and facilitate a full response to the questions raised.

1 Introduction
In terms of the economic context the UK is ranked 5th out of the 8 nations in terms of construction output and is set to rise to become the world’s sixth largest and Europe’s largest construction market (McKinsey, 2017, HM Government, 2013; Global Construction Perspectives and Oxford Economics, 2015). The UK is ranked 22nd in the world for population by country with a population of 64.6 million that is expected to increase to 74.3million by 2039 (ONS, 2014). The
population increase will place significant pressures on existing societal infrastructure such as schools, healthcare and particularly housing. It is further understood that this pressure will be exacerbated by changing demographics resulting in a higher proportion of ‘1 and 2 person’ households and assisted living requirements. There are 1.5 million households on the UK housing waiting list, the total number of new homes required to be built is predicted to be 295,000 per year till 2037 plus 15,500 care and retirement buildings by 2035 (TSB, 2013; Smith et al 2016). In response to this a range of investment schemes have been set up by the UK Government including a Home Building Fund (£3bn), Housing Infrastructure Fund (£2.3bn), Affordable Housing Programme (2.9 billion) and Accelerated Construction (£1.7 billion outside of London). In London itself, the Greater London Authority (GLA) ‘Homes for Londoners’ prospectus details plans for its £3.15 billion affordable housing funding deal from central government (Pye Tait, 2017; CLC, 2017). There is also evidence of significant private sector investment in offsite from organization such as CCG OSM (£12M), Laing O’Rourke (£104M – included £22M of government investment) and Legal and General Modular Homes (£55M). The product offering of these organisations tends to have higher levels of technical performance influenced by the necessary levels of investment in capital and corresponding value offering. However, the level offsite construction in the UK is still relatively modest and considered to only represent an estimated 7% of total construction output, equating to £1.5billion per annum (UKCES, 2013). For offsite to scale it requires the correct intersection of the drivers for change to take place, these are identifies as ‘Sustainability’, ‘Regulatory’, ‘Digitisation’, Productivity’, ‘Human Capital’ and ‘Culture’. These drivers are explained below with corresponding evidence demonstrating how offsite can respond.

2 Drivers for Change

2.1 Sustainability

Sustainable development is concerned with ensuring a better quality of life for everyone both now and in the future and must therefore be capable of meeting the needs of the present without compromising the ability of future generations to meet their own needs. It includes three broad components: social, environmental and economic, often referred to as the ‘triple bottom line’. Offsite offers a more sustainable approach to construction. Socially the factory environment improves working conditions and offers a change in “construction culture” by providing a safe, clean place of work with improved job security and flexible shift patterns. This is of particular relevance when considering staff diversification. In the UK for example females account for approximately 13% of the total employment in the construction sector however 27% of “off-site” roles are filled by woman (Construction Skills, 20010). From an environmental perspective “constructing” offsite in a factory corresponds to a more efficient use of materials which can be secured through a qualified supply chain. Offsite has been shown to reduced waste outputs compared with on-site construction with the substitution of tradition methods with offsite systems corresponding to a reduction in waste of between 20 and 40%, with the greater the fabrication the greater the savings (WRAP, 2008). These materials can then be utilised optimally to create components that are assembled on-site to form enhanced levels of building fabric performance. And finally, there are wider economic advantages to Offsite as it can provide opportunities for upskilling a local labour force in order to add value to a localised supply chain for the delivery of a higher quality
product efficiently. According to Krug et al (2013) Offsite construction can offer significant financial benefits through increased speed of construction which brings about reductions in construction programme and consequent reductions in financing costs. There are also significant cash-flow benefits to be had in terms of early completion and consequent early sale/rental income

2.2 Regulatory
In the current context regulations are the primary driver influencing the level of improved performance of building systems. The regulatory requirements are influenced by the overarching international strategies which are geared towards improved levels of sustainable development, economic growth and resource efficiency (UN General Assembly, 2015; COM, 2011 & European Commission, 2014) which the UK Industrial Strategy aligns with (HM Government, 2017). The UK has legally binding targets for a reduction in greenhouse gas emissions by 80% by 2050 (The UK Climate Change Act, 2008) and corresponding strategies to reduce the “performance gap” in terms of less standard deviation, addressing built-as-designed and better assurance towards the fabric performance (Zero Carbon HUB, 2014). Offsite construction is based on the principles of efficiency and quality employing manufacturing techniques in a factory applying a lean philosophy which is conducive to an environment for innovation. Consequently, offsite is often considered to be a “Modern Method of Construction” and therefore as product can evolve more readily to meet the regulatory targets and within the factory environment quality management systems such as ISO9001 can be implemented in order to achieve consistency of approach resulting in improved levels of customer satisfaction.

2.3 Digitisation
Digitisation is regarded as the “Fourth Industrial Revolution” and presents opportunities for innovation and creativity in the built environment with the potential to transform how we think about buildings given they can become increasingly more ‘intelligent’ assets (Ellen Macarthur Foundation, 2016). Building Information Modelling (BIM) moves construction towards increased levels of digitisation and creates a platform for improved levels of project and supply chain communication horizontally and vertically thus facilitating collaboration. Farmer (Farmer, 2016) regards BIM as a critical change agent for the industry and considers it to be completely intertwined with the move to manufacturing led approaches. Offsite is a manufacture-based process and consequently is more aligned to the utilisation of enterprise resource planning (ERPP), computer aided design (CAD) and computer aided manufacture (CAM). BIM facilitates the interoperability and visualisation of these processes with the potential for additional added value via the augmentation of further information such as structure, thermal and environmental performance. Given the more holistic approach to design that BIM can create it presents an opportunity for the value of offsite to be more presentable with attributes such as quality assurance and technological enhancements becoming more easily captured and quantified for customer satisfaction. Tools such as augmented reality and virtual reality (AR/VR) provide examples of this and in theory these tools should also help resolve historic barriers to offsite such as early design freeze as well as facilitate client understanding of capability and mass customisation rather than considering standardisation as a barrier to good design.
2.4 Productivity
National productivity is determined by a combination of physical capital, human capital (skill and knowledge level of the workforce); natural resources and technological knowledge and is connected to the country’s living standards (Mankiw & Taylor, 2010). Undertaking activities in a factory production flow process as opposed to an on-site framework of disjointed activities facilitates the use of lean techniques. The principles of Lean are teamwork, robust communication, and efficient use of resources and elimination of waste. Industrialised building systems therefore have an additional emphasis on improved productivity, quality and safety. Offsite can also be regarded as being more efficient if properly deployed and managed, reducing construction time as a consequence of scheduling activities to take place concurrently rather than sequentially such as systems or modules being manufactured for ‘just-in-time’ delivery upon completion of site infrastructure including foundations and/or services. Offsite therefore has many advantages relative to traditional onsite approaches. The uptake of offsite construction in developed regions internationally such as Australia, New Zealand, USA and the UK has therefore consistently been linked to productivity (Blissmass & Wakefield, 2009; MBI, 2010 Farmer, 2016, Goulding & Arif, 2013). However, building offsite is a change in construction culture towards a process of continuous improvement with enhanced productivity and as a result it requires to be underpinned with research, innovation and training. Skill levels and people development is therefore a key impact factor when considering productivity, moving to a factory will not resolve the issue alone, this change in approach has to be underpinned with adequate skills and leadership (Lavender, 1996; Naoum, 2001, Abdel-Wahab, 2008; Green, 2016).

2.5 Human Capital / Skills
A review of the economic health of the global economic construction sector, The 2016 International Construction Market Survey (Turner & Townsend, 2016) identified the emergence of two distinct types of markets defined as ‘overstretched’ (experiencing capacity constraints and labour shortages) and ‘over-reliant’ (suffering weak GDP growth due to oversupply of commodities and weakening demand). The recommendation made was for organisations in both market types to think differently if they are to deal effectively with the challenges of skills shortages and rising costs of construction. In the UK there are skill shortages, particularly in traditional construction skills, due to school leavers choosing other sectors and a lack of investment resulting in a shortfall in apprenticeships which is being compounded by the demographic of the workforce, 400,00 people are expected to retire over the next 5 to 10 years and there is the potential impact of Brexit given the reliance of migrant workers (Smith et al, 2016, CITB 2013, Farmer, 2016). Offsite construction requires different skills and the development of a more holistic knowledge base with an improved understanding of project management, scheduling and planning requirements. Given that this is the case a new approach to training and skills is needed at all levels providing improved pathways for career progression and enhanced levels of up to date information. The higher levels of capital and technical approval costs for offsite construction requires investment decisions to be more informed and its value proposition to be better and more robustly defined through improved levels of evidence based information. In this respect Offsite construction requires strong business leadership combined with operational management and a technical knowledge in order to address the misconceptions
of the public, clients, lenders and insurers. Addressing this will help challenge the traditional construction business models given offsite has a different cash conversion cycle with more upfront costs which in-turn require different finance arrangements for it to operate at scale. There is also a need for improved levels of guidance and information given offsite is closely associated with manufacturing and draws on principles which seek to achieve improvements in quality and efficiency combined with reductions in waste. The guidance required and flow of information between design, production and assembly is therefore different from traditional construction and requires to be more integrated with a need for more holistic knowledge at all levels.

3 References

3. Construction Leadership Council (2017) Innovation in Building Workstreams – Demand Creation, Investment and Volume Surety,


23. WRAP (2008), Waste minimisation through offsite timber frame construction, Waste Resources and Action Programme


5 May 2018
Hatch has developed a proprietary modular apartment construction system and a lean manufacturing process that produces standard, robust, high quality apartments in a rapid timeframe. The Hatch apartments are delivered through a volumetric system that enhances quality, improves programme through efficient design, manufacture, assembly and installation processes and can deliver reduces costs over a programme of works. Furthermore, the Hatch manufacturing model enables the swift creation of local factories with a minimal financial outlay. These factories create local skilled jobs that enhance Hatch’s overall offering of producing high quality homes, built by the communities who are going to live in them. Hatch is able to offer parties with significant long-term housing demand a local factory if they are able to commit to purchase a minimum number of apartments from the factory over a 3-5 year period. Such commitment ensures the factory is financially self-sustainable over the long term.

What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

In assessing the merits and debits of any process, understanding the outcomes desired is critical. Too often in construction, lowest unit cost prevails, so hence a longer-term view of quality and a whole life asset value assessment are dismissed. Notwithstanding this, applying the right system to the product outcome is key: timber panel systems are well suited to low-rise 2 storey housing where retail sales (B2C) dictate outcomes, while volumetric systems are more suited to apartment buildings where the play is more institutional (B2B). As is generally accepted across all tiers of the industry, there are ‘Givens’ as to the benefits of offsite manufacturing in construction, but specifically for housing:

Speed: Particularly relevant for affordable housing delivery but where it is it is most advantageous is in terms of Build-to-Rent (BTR) and co-living apartment blocks. These mid-rise apartment buildings with regularised units, lend themselves to delivery by volumetric units: On a seven story, 200 unit block, this may afford programme savings of between 4 to 6 months. Any client, retaining this asset, will readily knowledge the difference this can make to the bottom line. The parallel delivery of modules alongside the infrastructure (foundations etc) ensures programme advantages in installation but other benefits emerge in design and commissioning with either side of this period.

Quality: Offsite manufacturing engenders quality improvement at every stage of the process. Early engagement develops design, manufacture and installation details that are robust, that adhere to the regulations from the outset (A factor critically highlighted in the Hackitt Review). Knowing that these details cannot be changed without serious implications to the manufacturing process, enforces collaboration by all parties on these details. These robust details then translate into manufacturing tolerances that can only be produced under the repetitious
environment engendered by manufacturing facility. Interface details with foundation and facades can then be developed that translate from site to site again highlighting how their repetition enables a tightening of quality.

Safety: The very nature of working in the factory does not necessarily guarantee increased safety outputs from the beginning. A manufacturing facility has a different safety environment built around habit, repetition of task and the tidy workspace that can be created. On-site, the working at height, materials falling from height and trip hazards that are the common causes of minor and major injuries are eliminated, or at least vastly reduced within a manufacturing environment.

Indirect benefits: during the town planning process an oft cited concern of the local community is the disruption and danger caused by construction traffic. Offsite manufacturing has generated upwards of 80% reduction in the amount of construction traffic to and from a site. This is just not in relation to the delivery of completed components, as opposed to individual materials, but in relation reduced number of day to day operatives, to the reduction of waste being taken away from site. Furthermore, the deliveries are concentrated into periods where disruption maybe less keenly felt by the community i.e. outside peak hours or over holiday periods.

Drawbacks of offsite manufacturing. The single biggest drawback is the current time and effort required to address the cultural change needed across the industry. Will be the change of approach that will have the most impact will be at the client level. Whilst there is genuinely momentum for change at client level it tends to happen at a glacial pace.

What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

The supply chain is poised and ready to deliver if there is proven demand and understanding from the client side. Collaboration amongst designers, engineers, trade-contractors and material suppliers around digital information, for example, via Building Information Model (BIM) and other applications, are already and will continue to deliver demonstrable efficiencies. However, they are only as good as the brief they are given. The quality of initial client briefs, truly buying into standardisation, belief in the systems and the process that then follow, needs to be significantly enhanced. This understanding can then corral demand to produce economically viable programmes of work that substantiate the investment required.

The economic case for investing in manufacturing facilities should not be taken lightly as the majority of the market does not have the deep pockets of Laing O’Rourke or Legal & General to fall back on. One ill-advised turnkey scheme (taking traditional construction risk) or badly timed expansion has killed many a manufacturers ambitions or even the company. We at hatch. have tried to look at this challenge differently. Regionally aligned bodies (groups of HA’s; LA’s groupings) will be able to progressively standardise their housing requirements. This can then provide a base throughput for a local manufacturing facility, that can then be sited in a relatively readily available, medium-sized, warehouse
(40,000 sq ft, 10m high at eaves) with one caveat around the external storage space required. A minimal capex for equipment (no robotics yet but can be scaled accordingly later on) and appropriate recruitment and training period can produce a viable production entity.

* Note: The investment environment around this area is very positive. If you look at examples like Katerra in California, they have attracted significant VC and institutional investment towards creating a genuine manufacturing change in their construction industry.

**Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

Whilst understanding the overall thrust of the question that standardisation produces boxlike buildings with repetitive and hence monotonous fenestration placement, I would take issue with the term architectural ambition. A good designer responds to a thorough client brief and matches and exceeds expectations from that brief. From the establishment of this brief, it is about early engagement with offsite manufacturers alongside the designers and engineers to help reduce the response that delivers the clients desired outcomes. There is an emerging group of designers and engineers (Bryden Wood; Scott Brownrigg; David Miller Architects; AStudio; 3E Engineers; Elliott Wood Engineers) who understand the offsite manufacturing approach and can assist the process accordingly. Similarly, any designer and engineer well versed in residential design will learn quickly, designers are experts at problem solving and should be rewarded for doing so. They will take the time if it is commercially sensible to do so.

It should be noted that the governing design guidance and rules for residential have a big impact on the degree of influence that off-site manufacturing can make. For example, to get good natural light into the back of an apartment, general rule of thumb dictates a depth of no more than 7 metres. The Nationally described Space Standards (NdSS) dictate that a one bed apartment (50 m²); two bed apartment (70 m²); & a three bed apartment (95 m²) are the minimum required areas. A combination of these ratios dictates an optimum apartment layout, combining good design efficiencies. Calibrating these with the right design for manufacture and assembly (delivery of modules within transport regulations is key) can then create a viable offsite product. But we can go further, for example, increasing the ratios of apartments sizes to 50m²:75m²:100m², instantly produces a replicable product that will optimise DfMA and the subsequent manufacture and installation efficiencies.

With standardised product efficiencies ‘locked in’ and contained in the data model (which can be held in escrow like software source code for resilience), it should enable designers to firstly calibrate the internal space to best meet client and end user aspirations efficiently (apartment height, open plans, orientation) and spend more time on the place making, façade, amenities that uplift a scheme.

**What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?**
As a slight tangent to the question asked it’s not necessarily about research and development but about validation of existing technologies to get the capacity we need. This industry is slow to adopt technologies, irrespective of how proven they are elsewhere in other industries or even in subsectors of this industry – student accommodation and budget hotels are merrily deploying off-site product and processes. This is further evidenced by the majority of construction details employed by the industry that have much in common with those found in Georgian era Construction Patent Books.

It is the validation of systems – the process and the end product – that needs the most attention, to then gain all the benefits of offsite manufacturing. Ensuring the Warranties, Accreditation, Insurance and Council for Mortgage Lenders (CML now UK Finance) Approvals for off-site systems are as understood, and as easily attained as traditional build will insure their adoption by clients. These clients (Housing Associations & Local Authorities, and ultimately the end users they pass their products through to) need surety on the ‘mortgageability’ or retained asset value of any building before committing to the technology that constitutes it.

**What changes could be made to public procurement processes to encourage more sustainable practises in the construction industry and facilitate off-site manufacture?**

There is a range of changes that can be made at the public procurement level to assist the cultural change required and these are extremely well summarised in the section titled ‘Solution 1’ of the IPPR report ‘Building Britain’s Future?’.1

From a more anecdotal point of view, while frameworks, like the LHC consortium, are endeavouring to corral client (Housing Associations and/or local Authorities) demand to best lever delivery efficiencies and economic savings, they struggle to present the opportunities, post the initial byzantine procurement exercise, that SMEs can respond to. The nature of the initial procurement model ultimately favours large organisations that can absorb the high cost and high internal and external resource required to make such a submission. A submission that requires a tome of stated procedures, a substantial trading history, a myriad of commercial positions and risk profiles to be negotiated, and a publication quality submission document to be produced. These are significant barriers to entry for many SME’s, due diligence on an organisations capability is absolutely understood but there needs to be some simplification.

It should be an imperative that offsite manufacturers are only asked to deliver what that are best at, what they are set up for, a manufactured product. This ensures that the service that the framework clients can then purchase, is only asking enterprises to take risk for those elements that they are best positioned to do so, for example:

- Why ask off-site manufacturing organisations to take risk on ground works (as part of a design and build turnkey), when, it is best mitigated by proper client due diligence, full surveys and disclosure with an entity vastly experienced in doing so i.e. a groundworks contractor. All the off-site enterprise does is add a suitably large risk premium to the groundworks trade contractors risk premium and margin it now has to cover.
Delivery of utilities (a consistent programme risk) should be dealt with by the utility companies and the procuring client. The procuring client (housing association and/or local authority) is likely to be a big customer for the utility company and hence able to lever their position accordingly. Any intermediate contracting party on a scheme by scheme basis will have little or no leverage.

A radical step would be linking the planning permission granted with a condition about the deployment of off-site manufacturing. Following the German or New York models of pre-authorised planning for sites, would forewarn developers to the true viability of a site.

The outputs demanded by the clients should also be stiffened and heightened to ensure that the market response for the most appropriate delivery model approach is suitable, i.e. if the outputs are enhanced, the chances of traditional build delivering consistently are reduced:

- Enhanced product tolerances (plus or - millimetres) to ensure the highest safety levels are delivered but importantly how this is guaranteed – stated design tolerances are fine, but how are they checked and validated throughout the process, how is the ‘as-built’ information captured and passed on;
- Programme reliability – reward for delivering to programme – how often are schemes delivered just that little bit, but no less annoyingly, late;
- Whole life costing – moving away from lowest costs wins and rewarding initiatives that produce longer term asset value - 93% of steel used in a building frame can be recycled, compared to 20% for concrete (although a large proportion can be downcycled) or just 13% for timber.
- Performance outcomes that enhance sensible levels of environmental performance, true sustainability. Off-site manufacturing delivers higher quality product, so let us ensure this potential output is designed in for the right reasons. The oft-quoted passive house level of sustainability in its basic form was developed to suit continental Europe climates, i.e. the extremes of hot and cold that are experienced there; we need a UK temperate climate equivalent.
- Post Brexit, thought must also be given to the cost of materials increases that are likely and how this is mitigated. 85% of clay and cement used in UK brick manufacture come from outside the UK. Close to 100% of the Cross Laminated Timber (CLT) used in buildings of any size come from Europe.

5 June 2018

References

1 Dromey J, Morris M and Murphy L (2017) Building Britain’s Future, IPPR.  
http://www.ippr.org/publications.building-britains-future
Heathrow is one of the most experienced infrastructure delivery companies in the UK, having invested more than £11bn over a decade to develop Terminals 2 and 5. It spends up to £1.5 billion annually with over 1,400 suppliers from around the UK.

With expansion there is an opportunity for these roles to grow, and for new innovative suppliers to be identified. Our Procurement Approach outlines at a high level how we will work with our Supply Chain Partners. It describes how Heathrow will engage with the supply chain and business partners to provide Britain with a world class, next generation airport.

Heathrow will be the first major infrastructure project in the UK to pioneer the large-scale use of logistics hubs and revolutionise the construction industry.

This method is better for productivity, better for cost, better for speed of delivery and better for sustainability and safety.

**Heathrow’s Procurement Approach**

Heathrow’s Procurement objective is to engage a supply chain that delivers the world’s best connected, most efficient and sustainable hub airport affordably and on time. There are three distinct procurement phases in the programme – planning and development of the runway and terminals; delivery of the projects; and the operation of new facilities.

Heathrow has developed a contract packaging approach that has broken down the programme of works into deliverable packages. To meet the time, quality, safety, sustainability and cost objectives, we will adopt a robust, fair and transparent approach to sourcing and managing contracts. Where we are not contracting directly, we will ensure the same ethics and values are applied.

To level the procurement playing field, Heathrow will flex our contracting approach to remove hurdles for smaller suppliers and work with 1st tier suppliers to ensure fair payment terms and cash flow are cascaded through the supply chain. We will seek to remove barriers to entry, enabling new and smaller businesses the opportunity to work on this programme either directly with Heathrow, or within the extended supply chain. Where a supplier is not directly procured by Heathrow, we will seek assurances that the supplier is not on less favourable terms than a 1st tier supplier and that the balance of risk and reward is fair for the works being undertaken. To assist businesses across the country to confidently access its supply-chain opportunities, we will advertise 1st and 2nd tier requirements on our website to enable businesses to identify future opportunities directly or indirectly through our supplier partners.

**Logistics hubs**
Heathrow is also eager to encourage a diverse supply chain and embrace innovation within the programme to help achieve new standards of delivery. In April 2017 we invited communities from across Britain to showcase how their area could help build expansion, by hosting one of four UK logistics hubs. The use of Logistics Hubs across the UK will allow for pre-fabrication and off-site manufacturing enabling us to spread the benefits and the legacy of this national piece of infrastructure across the country.

Heathrow will be the first major infrastructure project in the UK to pioneer the large-scale use of logistics hubs, aiming to build as much of the project off-site as possible. Research by WPI Economics demonstrated that integrating an offsite manufacturing supply chain into a major project has the potential to reduce the overall cost of the project by as much as 25%, whilst speeding up delivery by up to 30%.

Heathrow’s portfolio offers a wide range of opportunities for the supply chain ranging from IT equipment, baggage systems, construction and facilities management, not to mention all the component parts that make up these diverse supply chain needs. It recognises that people are the critical component to making a successful supply chain.

Heathrow’s ambition is to grow a thriving supply chain that supports numerous jobs and opportunities for local people and others across the UK. New skills will be needed to build and run the Heathrow of the future. To do this we will champion the creation of new apprenticeships and training opportunities within our supply chain and by doing so enhance economic growth for the region and the UK.

In November 2017 we reduced the 121 proposals received to a longlist of 65. From February to July 2018 Heathrow will be visiting each of these 65 sites across the regions and nations of the UK. Following these site visits, a pre-qualification questionnaire will be launched in Autumn which will inform the shortlist. The shortlisted sites will then be invited to tender in 2019.

Heathrow Chairman, Lord Deighton, launched the nationwide tour of potential Logistics Hubs sites at Leeds Airport in February. As of Easter 2018, Heathrow has successfully completed 16 site visits.

At each site visit, airport representatives meet the businesses applying to become a key part of the expansion supply chain strategy. The Logistics Hubs will have the opportunity to demonstrate strengths in a range of areas, as Britain’s only hub airport seeks out the best businesses to partner with and deliver Heathrow expansion. Bidders will not only need to illustrate engineering prowess, they will also need to demonstrate a skilled and dedicated workforce, capability to collaborate on the nationwide project and good connectivity allowing output to be easily transported to Heathrow.

**The benefits of off site construction**
Off site construction is a catch-all phrase used to describe a range of construction activities that involve bringing together construction processes, components, elements or modules in a factory before installation into their final location. The method is already used successfully in a wide range of countries in a number of settings, but most notably in house building and infrastructure development.

Existing research and practical examples demonstrate some significant advantages over more traditional on-site construction methods. These include:

**Reduced environmental impact:** By reducing traffic flows to and from the construction site, there are significant benefits in terms of congestion and, by implication, pollution in the local area. Recent research based on case studies has suggested that projects using off site construction can deliver a reduction of between 20% and 60% in metric tonnes of CO2 associated with project transport. Substantial benefits in terms of waste are also possible. Traditional methods are associated with 10%-20% raw material wastage, however with more advanced techniques, off site construction can produce the same assets with just half the waste. The energy use associated with the completed assets can also be lower. Estimates suggest these savings could be as high as 25% over life of an asset.

**More reliable delivery:** On-site methods are impacted by weather, and site and access conditions. With off site methods, these factors are controlled within a factory environment, providing greater certainty and allowing improved delivery. A clear example here is Portakabin Group, who delivered nearly 100% performance in delivering off site projects on budget and on time over a 12-year period. The industry average over the same period across all construction projects was 40% for timeliness and 30.7% for budget accuracy.

**Greater efficiency:** Off site construction methods can reduce on-site build time for housing by over 50%. More recent examples have shown that a house can be built in just one day. Industry case studies suggest that homes constructed off site can be built 30% more quickly with 25% lower costs.

**Improved and more consistent quality:** These benefits arise from using a factory environment – facilitating tighter controls and more consistent and standardised processes. As well as the benefits of improved quality, this reduces the need (and associated cost) of re-design and re-work. It is estimated that off site methods are associated with a 50% reduction in the project costs of dealing with “snagging”.

**Improved safety and workforce satisfaction:** An average of 2.2 million working days were lost to work-related injuries and ill health in the construction sector each year between 2013/4 and 2015/16. The costs of workplace injury and work-related illness in the sector is around £1.2 billion a year. Off site construction has the potential to significantly reduce the risk of accidents and ill health through a controlled environment using line techniques and standards.

**Increased support from local residents:** The vast majority of the UK population support the development of critical infrastructure and housing. However, the challenges with gaining support from both residents near
construction sites and planners are apparent in the UK’s long history of slow development. Concerns about the construction process itself are often important in explaining this. For example, responding to qualitative research for a recent report one local authority Director of Planning argued that “…they [local residents] don’t actually object to the new houses... It’s the lorries, the diggers and all that sort of stuff.” In the same report, a London Councillor suggested that: “…people are sick and tired of living on the construction site, because it never ends. There is always something going on: trucks going up and down...”

Off site construction can significantly ease the concerns of local residents. By reducing time, headcount and the range of activities that need to be completed on site compared to traditional on-site methods, it leads to projects that are completed more quickly with less noise, less local air pollution and less traffic disruption.

26 April 2018

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LOGISTICS HUBS
Longlist of potential locations across the UK

Scotland
- Babcock Marine Rosyth Ltd
- Forth Ports Ltd
- Glasgow Prestwick Airport
- Renfrewshire Council
- Scottish Enterprise

North West
- Cammell Laird Shiprepairers and Shipbuilders Ltd
- MIDAS
- Peel Ports Investments Ltd
- Sellafield Ltd

Northern Ireland
- Lisburn & Castlereagh City Council
- MJM Marine Ltd
- Mid and East Antrim Borough Council

West Midlands
- Amalga Ltd
- Belfour Beatty
- Stoke-on-Trent City Council
- Telford & Wrekin Council

Wales
- Welsh Government

South West
- Invest Bristol Bath
- Sedgemoor District Council
- Tarmac Trading Ltd

North East
- Tarmac Trading Ltd
- Tees Valley Combined Authority

Yorkshire and the Humber
- Severfield UK Ltd
- Bishop Auckland Enterprises Ltd
- British Steel
- Doncaster Sheffield Airport Ltd
- Leeds Bradford Airport Ltd
- Sheffield City Region

East Midlands
- Corby Land and Development Ltd
- Leving O'Farrell
- SEGRO PLC
- Prologis UK Ltd
- Tarmac Trading Ltd

East of England
- Opportunity Peterborough
- Peel Ports Investments Ltd

London
- London Borough of Havering
- Wincanton

South East
- Amalga Ltd
- Peel Ports Investments Ltd
Ian Heptinstall, Independent Consultant

Ian Heptinstall, Independent Consultant\textsuperscript{22} - Written evidence (OMC0001)

0. My submission addresses mainly the “Government Actions” questions (7 and 8) in the \textit{Call for Evidence} paper – whether the construction sector deal is addressing all the important issues.

1. I fully support the idea that off-site manufacture should play a greater role in construction, and that it has the potential to improve project performance.

2. However, I believe that this, like many other proposed approaches to improving the performance of construction projects, is not by itself going to make a major improvement.

3. The reason for this is that the lack of off-site manufacturing is not the root cause of poor project performance. The core problem is systemic, and until this is tackled, then potential innovations like increasing the contribution from off-site, will be severely limited in their contribution.

4. Off-site manufacture is often bundled with a range of other innovations and called “modern methods of construction”.

4.1. Other members of this group include established ideas like off-site, integrated digital design tools (such as BIM – Building Information Modelling), and digital project knowledge management and workflow management systems, as well as emerging technologies such as 3-D printing, the “Internet of Things”, blockchain, AI, and drones.

5. The arguments set out in this paper apply not only to off-site manufacture, but also to most of these other ideas. Their use is inhibited by the same root causes.

\textbf{TWO COMMON FALLACIES ABOUT CONSTRUCTION}

6. \textbf{Fallacy 1: Productivity is a core problem}

6.1. Productivity growth is lower in construction that manufacturing, so what?

6.2. Compare these two figures. The one on the left was published in late 2017 by the Infrastructure and Projects Authority and shows labour productivity. The one on the right is my analysis of company profitability, using the same data source (the ONS).

\textsuperscript{22} A graduate in Engineering & Management, I have 15 years project management experience in the chemicals industry, along with 12 years in senior procurement roles, including working as Chief Procurement Officer at a construction contractor. For 8 years I have worked as a management consultant in supply chain, procurement and project management. I am author of "\textit{The Executive Guide to Breakthrough Project Management}".
6.3. So over the past 20 years, despite its ‘high’ productivity growth, manufacturing companies have had below average profitability, and as their productivity growth fell recently, its profitability improved.

6.4. Whilst I agree that labour productivity in construction is too low, I feel that simply looking at ‘copying’ manufacturing as a way to improve it is wrong and may lead to significant unintended consequences. For example, a construction company can improve their productivity by subcontracting more work. The only problem is their profitability falls at the same time!

6.4.1. I believe that the main reason construction projects have relatively poor productivity is due to the distraction of contracting. Far too many people on projects spend their time focused on managing the contracts between the different companies involved, and far too little on designing and building the best project for the client.

6.4.2. Increasing off-site manufacture is not going to help this. It might make things worse, if it simply increases the number of companies involved in the project.

7. **Fallacy 2: The main issue is the lack of application of modern technology and innovation**

7.1. The construction industry has gone backwards in the past century.

7.1.1. In 1931 the Empire State Building opened in New York. The project had no computers, no digitisation, and ‘blueprints’ were blue.

7.1.2. But they managed to build it in 410 days. It opened less than two years after the developer appointed an architect. And in today’s money it cost about $2-3,000/m2 of commercial area.

7.1.3. In New York, the 2014 replacement for the Twin Towers, One World Trade Centre, took 3112 days to build and cost some 5-7 times as much /m2.

7.1.4. In London, The Shard which opened in 2013 tool 1223 days to build, and cost about 3-4 times more per m2 than the Empire State.
7.2. These examples show how modern technology by itself cannot overcome the use of broken management processes.

7.2.1. The Shard used off-site. According to Management Today 80% of the project’s mechanical and electrical services were built off-site, as was the 800-piece, 500 te, glass and steel spire.

7.2.2. Both the Shard and One World Trade Centre used state-of-the-art digital tools and integrated systems.

7.2.3. But despite these “advantages” they got nowhere near the performance levels achieved 80 years earlier, where people worked in ways that maximised project flow.

THE CORE PROBLEM WITH CONSTRUCTION

8. My opinion is that the core issue of construction projects is the fragmented nature of how projects are organised and procured.

8.1. Other observers talk about the ‘fragmented nature of the industry’, but to me this isn’t the key issue. It is fragmentation and misalignment within each project that is the real issue.

8.2. And until we reduce this fragmentation and establish truly collaborative project teams, we stand little chance of exploiting project ‘best practices’ such as those in paragraph 4.

9. And the main driver for this fragmentation is how clients procure their projects.

9.1. Although most clients only interact with a few members of the supply chain, they influence how the whole of the project is procured. This can be either directly through specific contract obligations, or indirectly through performance measures and allowing their supply chain to manage projects in the way they always have done.

10. It seems to me that a misunderstanding of how complex systems work is at the heart of the problem. Most construction projects behave like “complex systems”.

11. And complex systems cannot be managed using the techniques that work for non-complex systems. But that seems to be what we do today on most projects.

12. Simple systems can be managed by breaking the whole down into independent parts and managing each part independently.

12.1. For example, agree a fixed date and budget for each part to complete.

12.2. You then manage the whole by ensuring each part meets their commitment.
12.3. And this approach works very well for simple projects, say arranging an event or publishing a book.

12.4. But it is a very ineffective way to manage construction and infrastructure projects.

13. Complex systems are not simply the ‘sum of the parts’. Their performance is driven by how the parts interact. They are iterative, and they adapt to emerging circumstances.

13.1. You can’t predict with any certainty exactly what will happen during a project. Modern-day planning and project control systems try and fix commitments about the future. Procurement approaches do the same, favouring fixed-price contracts, despite the large number of variables that each of the companies involved in projects are exposed to.

13.2. Managing the parts of a project against firm commitments not only adds significantly to the cost and duration, but it also distracts management’s attention from optimising the overall project performance.

13.3. The two main project practices that work well on simple systems but are damaging in complex systems are (1) procurement and contracting, and (2) planning and controls.

14. Paragraphs 9-12 are based on the science of Systems Theory. The supply chain, manufacturing and distribution industries are currently undergoing a transformation in performance by changing how the overall process is managed in line with systems theory. They have overcome decades of falling performance and frustration. Construction could do the same.

15. I believe the main reason for the low levels of use of off-site manufacture (as well as the ideas in paragraph 4), is this fragmented approach to contracting and sub-contracting on projects. Most of these innovative ideas cross organisational boundaries. Because each part of the project is measured independently, no one company gains sufficient individual benefit to make it worthwhile for them, even though the project overall suffers. Until the rewards of the project team are aligned with the overall project goals, this obstacle will remain in place.

THE ENABLING FOUNDATION

16. If the government wants to improve the performance of construction – both for the nation’s assets, and across the broader economy, it needs to address the core issues described above.

17. My explicit recommendations are:

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23 This is the so-called “Demand Driven” movement, whose roots lie in the same body of knowledge as my recommendations. Within months adopters have improved performance to unheard of levels. Without significant investments.
17.1. To encourage truly collaborative contracting throughout the project supply chain, through the broader adoption of the “Project Alliance” approach. This approach is also known as IPD – Integrated Project Delivery.

17.1.1. Project Alliancing/IPD has been proven to deliver great results when done well. It establishes an integrated collaborative team and overcomes the issue of fragmentation, through aligning the rewards of the project team members.

17.1.2. When done well, projects complete sooner for lower cost, and often exceed outcome expectations.

17.1.3. However, I believe the method is misunderstood, and often implemented in an unnecessarily heavy and bureaucratic way. I guess this is why Government sees it as a method to use only on the most complex and uncertain of projects. I strongly feel it has the potential to be used much more widely. If it was my money, I would have no hesitation in using it as my default approach, down to projects worth a few £million.

17.1.4. This will require the review and rewriting of current contracting guidance, and financial and budgeting practices. Budgets and governance methods that try and force certainty onto inherently uncertain projects, are unintentionally adding to a project’s cost and duration, as well as actually increasing the risk of overshooting commitments.

17.2. By itself a project alliance can deliver significant performance improvements. It aligns the commercial interest of the supply chain and the client, significantly reducing the need (and wasted cost) of managing contracts. However, to really deliver breakthrough improvement, the collaborative team needs to exploit a range of value-enhancing tools and ideas.

17.2.1. These include off-site manufacturing, the ideas in paragraph 4, and a whole host of other methods the industry knows about but has trouble exploiting today.

17.3. There is also another idea, that is not currently on anyone’s horizon that I am aware of. This is a method of scheduling and managing progress on projects that has been proven in many sectors outside of mainstream construction to reduce durations and improve productivity.

17.3.1. The method is called CCPM – Critical Chain Project Management.

17.3.2. Projects managed using CCPM typically are delivered 20-40% faster than those using other methods. And this speed uses less resource and enhances quality.
17.3.3. This could be game-changing – bringing needed projects into use earlier, and allowing more projects for the same budget.

17.3.4. It has been used on projects worth many billions of pounds, in sectors ranging from software development to system implementation, from new product development to manufacturing, and from maintenance and overhaul to construction.

17.3.5. Organisations that use it, and have publicly confirmed these performance claims, include Boeing, the US military, Tata, and the Japanese infrastructure ministry. In 2016 I heard the chairman of Mazda say that CCPM helped to save his company!

17.3.6. It has even proven its success in UK Government-sponsored innovation programmes and UK road-building projects in the past….before being forgotten about!

17.4. CCPM only works in a collaborative project team environment. This explains why its use is so limited in construction – the fragmented, “everyone for themselves” nature of project contracting, is far from collaborative.

17.5. If you move to more collaborative project contracting using a project alliance, then this opens the door, not only for the project to exploit off-site, but also to use CCPM to really make the project flow!

18. Project can be... On-time in less time, on-budget at lower cost, without having to compromise.

5 April 2018
High Value Manufacturing Catapult, Cast, Construction Industry Training Board (CITB) and Mace – Oral evidence (QQ 24-29)

Transcript to be found under Cast
Inquiry into Off-Site Manufacture for Construction

At yesterday’s oral evidence hearing, Lord Hunt asked questions related to gender diversity in the construction industry and then within the High Value Manufacturing Catapult. Giving evidence for the Catapult, Dick Elsy did not have the precise numbers to hand but was confident that we were beginning to draw more and more women into our R&D capability and the proportion of female employees was increasing. He estimated that currently just over 20% of Catapult employees were female. I am pleased to let the Committee know that of the 2152 staff employed across our network at the end of March 595 (27.6%) were women. We continue to work to improve our gender balance and to promote engineering as a career.

2 May 2018
Question 1
**What are the opportunities offered by off-site manufacture for construction?**

- Controlled environment independent of weather conditions provide perfect conditions for a quality job
- No waste on site
- Minimal waste in the factory and reusing most of it
- Better quality control for building materials
- Better supervision of workforce
- Buildings are based on consistent defined standards and details
- Quantity and quality can be achieved at the same time
- Use of innovative materials

**What are the likely drawbacks?**

- Off-site manufacturing needs high investment of capital into factory and initial training of staff
- Know-how of Concept, Detail and Technology need to be developed first

**What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose off-site manufacture?**

- Speed
- Precision
- Certainty
- Consistency
- Quality control

Question 2
**It is often claimed that off-site manufacture can lead to lower cost, faster delivery and increased quality, increased productivity, improved health and safety, greater provision of new, affordable housing. What is the evidence of this?**

- Customer satisfaction
- Like to like comparison with traditional build – higher cost, longer delivery, less quality, less productivity, less health and safety
- Costs can be accurately predicted as there are no on site surprises to drive up cost and increase build time.

Question 3
**What are the drawbacks to off-site manufacture for construction?**

- Access, Logistics and Transportation are more challenging
Question 4
What re-skilling of the construction workforce is required to facilitate change to more off-site manufacture for construction?

- Attitude towards precision needs to be trained

Question 5
Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition?

- Off-site manufacturing is a method of construction but need not hamper the creativity of the architect. The architect may face more challenges and will necessarily have certain restrictions, but in reality every architect must accept the limitations of the building method and the building materials he is choosing.

- Observing the traditional building methods of the housing market for the last twenty years I have not seen much innovation. The very small amount of architectural ambition present in the current housing market can certainly be sustained and even improved upon utilising offsite factory construction techniques. In my view the current underlying issue here is not whether off-site manufacturing will hamper architectural ambition. The main issue is that architectural ambition is not desired or encouraged in most housing developments.

Question 6
What R& D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

- Careful R&D is needed in the area of conceptual design, design of details, choice of materials, logistic and cost analysis. Preplanning is a prerequisite for successful off site manufacturing.

- The R&D team should consist of different disciplines which include architects, structural engineers, craftsmen with experience in construction, logistic and quantity surveyor.

Question 7
Does the construction sector deal correctly identifying the issues faced by the construction industry and the actions that the Government and other stakeholders need to address them? What should it contain / what is missing?

- In my view the construction industry may identify the issues but does not respond enough what could be done. The construction industry as a whole does not embrace change or innovation unless government sets the goals and supports the changes.

Question 8
What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?
• In my view innovative concepts need to be encouraged by government through leading by example. Government needs to motivate and support Councils in undertaking developments on their own. Land owned by the Councils or Government could be developed to their own guidelines promoting innovative off-site manufacturing as a large housing scheme as well as promoting off site manufactured self-build schemes. Councils could host competitions where contracts are awarded to those off-site manufacturers who propose a creative and innovative response to economically and environmentally sustainable developments.

• As an alternative Councils or Government could release land to different developers inviting them to an open market competition. The criteria’s of the competition (amount of off-site manufactured homes, number and size of homes etc.) needs to be set by the Councils.

18 May 2018
IET (Institution of Engineering and Technology) – Written evidence (OMC0071)

This has been compiled with input from various sources on behalf of the Built Environment Panel of The IET.

Perceived advantages of offsite manufacture for construction

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

1.1. The obvious advantages are speed of completion because of little influence from the weather, improved build quality because of the clean and controlled manufacturing environment. Additional opportunities include potential for lower whole life costs and buildings that match their design objectives.

1.2. A serious weakness in traditional housing is the lack of energy efficiency since the Government dispensed with the Codes of Sustainability. Code 4 was the perceived aim for all new housing but currently houses are simply required to meet Building Regulations, resulting in greater energy costs, increased carbon emissions and less disposable income for residents.

1.3. Other benefits are less waste and consequently less materials going to landfill and less local disruption.

1.4. Finally, the requirement for a new workforce will provide many new job opportunities and the commitment to greater number of houses will inevitably see a reduction in cost.

2. It is often claimed that offsite manufacture can lead to:

- lower costs, faster delivery and increased quality;
- increased productivity;
- improved health and safety;
- greater provision of new, affordable housing.

What is the evidence for this?

2.1. Manufacturing environments will inevitably lead a drive to standardisation of components, sub-assemblies and methods have the potential to drive down material costs through economies of scale thereby achieving greater productivity. These claims are evidenced both by comparison with manufacturing industries, where manufacturing principles under discussion have been in place for many decades (e.g. in the automotive sector), and where finished products are assembled from automatically fabricated components without the need for human fitters.
Standardisation also helps simplify assembly techniques and training needs.

2.2. Completing 95% of the house in engineering factory conditions ensures that every house conforms exactly to the design requirements ensuring the quality is standardised unlike the current poor quality of traditional housing. This will place ‘built as designed’ homes in reach of the housing sector.

2.3. Due to the reticence to embrace volumetric/modular housing, the current off-site prices are comparable with traditional construction but without the advantages of volume procurement. Savings of 10-20% could be achieved with the creation of a new supply chain.

2.4. The requirement for much simpler foundations increases the speed of completion and reduces the materials being moved around and shifted from site.

2.5. Engineering factories are infinitely safer than construction sites and with the house simply being delivered to site and connected to the services, minimal time is spent on site.

2.6. The national house builders will not and cannot build any more than they are currently building and volumetrically engineered housing will enable the creation of a new semi-skilled workforce to produce the houses required at an affordable cost in factories located near the places of demand to reduce the carbon footprint. It has been estimated that each 30000 sq ft factory can potentially produce approximately 500 houses/year and with a requirement for 100000 homes/year, it will require 200 new factories and a new workforce of 20000 to meet this demand alongside the increased jobs created by the provision of 100000 steel frames, kitchens, bathrooms, doors, windows, tiles, insulation etc.

2.7. The ‘new factories’ can be collocated with communities where housing is built. This will create opportunities for employment and developing skills in under privileged areas.

Potential barriers to wider use of offsite manufacture

3. What are the drawbacks to offsite manufacture for construction?

3.1. It is essential to define the difference between off site and volumetric housing. Off-Site is a construction process where the house is made in panels in a factory, transported to site, erected with the internal and external finishing and roof being completed on site. Volumetrically engineered housing is 95% completed in the factory, including insulation, windows, doors, kitchen, bathroom, toilets, roof and decorating and delivered to site ready for connecting to the pre-installed services and occupation. For volumetric there are no drawbacks in the manufacturing process save if the house needs be transported, it cannot be more than 5 metres wide due to highways legislation. Manufacturing close to the point of consumption is an important consideration in minimising the logistics overhead.

3.2. Drawbacks include a potential reduction in the ability to make late changes during construction, elevated material/component costs a constraint on design flexibility (perceived by architects) and perhaps by an initial skills insufficiency. Required investment in large manufacturing
plant is an inhibitor, but recent developments have used temporary, smaller-scale ‘pop-up’ factories, mitigating this issue.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

4.1. With the introduction of offsite Manufacturing and on-site Automated Assembly, the need for traditional ‘fitting-centred’ manual building skills will diminish.

4.2. Off-site and volumetric engineered housing will require a new workforce of factory-based operatives. We believe that an apprenticeship programmes in association with further education colleges can produce the necessary workforce.

4.3. However, the demand for professional engineers and technical staff with systems design and integration expertise will increase.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

5.1. The benefits of standardised factory manufacture greatly outweigh the limitations of architectural ambitions.

5.2. Our portfolio of house/apartment/bungalow/homeless units has been created by architects well versed in the housing sector and consists of a variety of types, internal and external finishes.

5.3. The specification of good quality internal components coupled with the benefit of production in an engineering environment will greatly reduce the future maintenance costs.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

6.1. Much research had been undertaken by off-site and volumetric manufacturers for the commercial sector building hotels, hospitals, prisons etc. Architects and planners need to become familiar with the production process, the quality of materials, and the requirement to commit to volume production to reduce costs and be aware that the BOPAS guarantee on volumetric houses is 60 years against the 50 years for traditional housing.

6.2. The R&D needs of the sector may centre more on socio-technical interfaces than pure technology, but they nevertheless span all Technology Readiness Levels. At low (1 – 4) TRLs, better understanding is needed of the drivers and methods for changing corporate cultures (including new business models for build and use), communicating design intent down supply chains and sharing both risk and the benefits of innovation.

6.3. R&D at higher (close to deployment) TRLs, needs to focus on the demonstration of technologies and at-scale applications of off-site manufacture and on-site assembly. Also, the technical and economic factors associated with off-site manufacturing close to the point of consumption should be investigated.

6.4. In use monitoring (e.g. via Internet of Things devices) is also an important theme with the ability to drive down operating costs.
Cybersecurity must be designed in from the start for in-use monitoring and control systems (BMS), and research is needed in this area.

**Government actions**

7. *(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?*

7.1. The construction sector and national house builders are the major stumbling block to success of factory produced housing! They have a current model that works well for them, as new housing numbers are controlled to keep prices high for a product that is far from satisfactory in relation to real value for money. The only way that the Government will deliver an extra 100000 good quality houses/year is to create a completely new supply chain of factory produced volumetrically engineered houses with a newly trained workforce.

8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?**

8.1. The recent debacle with Government procurement practices with Carillion, Serco, Capita, A4E etc has exposed a real weakness in the OJEU process that does not serve the public purse well. The awarding criteria for Government contracts limits the opportunities to large national and multi-national companies, many of whom engage medium sized regional companies to undertake the work as their subcontractors. This automatically adds 30% to the cost of the work as they apply their management fee and profit to the subcontracted cost. It is no secret that the French and German Governments do not approach OJEU procurement with the same rigour as in the U.K. and therefore moves should be made by Government to open up the market to more small/medium sized companies who are currently unable to access the system because of the specified financial criteria.

8.2. There may be no immediate ‘burning platform’ for the construction sector to drive technology shifts or adoption, but this is likely to change given the low margins and high risk endemic in the sector. Drivers for change include all aspects of ‘digitalisation’, importantly the adoption of Building Information Modelling (BIM level 2 is mandatory for government projects) Digital Built Britain, and advances in operational monitoring. (The latter may make new variants of PFI attractive again, as comprehensive digitalised views of operational performance become available.) This highly conservative and craft-centred sector has been generally slow to adopt new technologies, but innovation does diffuse in both directions in the supply chain. It is likely that the deeper involvement of the client, beyond initial specification to improve the likelihood that ‘as built’ matches ‘as designed’ will help. Technologies (e.g. visualisation) that promote this enhanced engagement will be of significant value.
8.3. Government procurement policies seem to be an effective alternative to regulation in achieving target outcomes, although more track record is needed to properly evidence their effectiveness. Additionally, the influence of government procurement policies on creating ‘best practice’ that is subsequently emulated in the private sector might be hoped for, but is not clearly evident. Off-site manufacturing has the potential to reduce capital cost variability, and dynamic monitoring of performance in use can positively impact operation costs, so both might be elements of future government contracts, and could be considered as important procurement levers.

26 April 2018
ilke Homes – Written evidence (OMC0066)

Introduction to ilke Homes
ilke Homes precision engineer, manufacture and install low rise, medium density houses and flats that are fully factory assembled using the latest digital manufacturing solutions. Our homes meet building regulations standards, come with NHBC Buildmark or Building Life Plans warranties and have Council of Mortgage Lenders accreditation. We are working with a range of Housing Associations, Local Authorities and developers across the UK, delivering homes for all forms of sale and rent, with a goal to help solve the UK’s affordable housing shortage.

The company was created from a vision to build quality homes in a better way and has employed over 120 staff in the past 6 months. The executive team are engaged with government departments such as Homes England and the GLA, as well as major housebuilders, so are well placed to provide evidence to the committee.

We define ourselves as a volumetric housing manufacturer, with whole homes being completed within factories and delivered to site as full 3-dimensional models fully finished internally and externally. This is in contrast to other forms of offsite construction which include methods such as 2-dimensional panelised construction, where structures are designed and manufactured in wall and ceiling panels offsite and then joined together onsite.

Perceived advantages of offsite manufacture for construction

What are the opportunities offered by offsite manufacture for construction?

1. **Additional capacity for the UK housebuilding industry** – By moving construction into controlled factory environments where precision engineered components are assembled, an additional set of manufacturing resources can be utilised to increase the production of homes rather than relying on skilled tradespeople.

   This is particularly the case within the housing sector where house types can be standardised while still creating beautiful, personalised homes and focus can be on construction productivity rather than construction management.

   This is achieved by removing limiting factors such as:
   - Limited specialist labour e.g. bricklayers, carpenters – staff within factories can be trained in specific, repeatable assembly tasks for which they can be trained rapidly and with greater quality control.
   - Stoppages caused by inter-dependencies of trades and availability of materials.
   - Limited buying power from smaller projects – larger pipelines and standardised buildings/components mean materials can be purchased on more favourable terms.
   - Weather stopping deliveries and work onsite.
   - Lack of consistency and workmanship by contractors.

2. **Speed and certainty of delivery** – Following from point 1, homes can be built more efficiently and within a controlled environment using best-in-class manufacturing practices. ilke Homes can install up to 6 homes a day from a
single crane; our show homes in London went from planning permission to completion in 7 weeks (3 times faster than traditional construction).

3. **Build cost certainty against rising industry labour and material prices**
   - Purchasing materials in bulk and by hedging prices, offsite manufacturers can ensure set pricing to the industry.
   - Employing our own trained workforce in areas of greater labour availability ensures we are not exposed to rising labour rates and skills shortages seen within construction trades and also supports UK regions with manufacturing legacies.

4. **Minimising defects with precise design and engineered quality**
   - Precision Engineered design and assembly details are implemented by a skilled workforce trained to carry out specific tasks, under manufacturing quality control protocols, meaning there is less chance for defects.
   - Any defects can be identified and remedied during systematic and rigorous checks within manufacturing facilities and prevented from occurring in future homes.

5. **Improved health and safety** standards – The removal of need for scaffolding, construction and movement of heavy materials onsite means there is much less scope for accidents.

6. **Cleaner and quieter sites**
   - Optimised use of materials offsite means there is less wastage.
   - Less vehicle deliveries and tradespeople on site mean less disruption both onsite and to local residents and businesses.

7. **Reduced CO2 emissions** – The combination of factory quality control and use of enhanced materials such as higher specification insulation, mean buildings can achieve better insulation values and in-use performance than traditionally built homes.

8. **Growth of SME housebuilders** – Offsite construction can remove significant risks to housebuilders, which may disproportionately impact SMEs. Providing certainty to SMEs through removal of these risks which include rising material and labour costs, shortages of labour and compliance to increasing regulations, can help drive their activity in the sector. It is also key to note that by using offsite construction and suitable contractual agreements, housebuilders can reduce their working capital requirements, further reducing risks to their business.

9. **World class UK production of homes** – Volumetric construction uses state of the art design and manufacturing technology across the organisation to drive efficiencies and ensure quality of homes. We believe supporting the offsite industry will encourage progress and is important to ensure the UK is seen as a hub for construction innovation.

10. **Expansion of UK based production within adjacent industries** – In order to drive more economies of scale, we are placing larger orders with our suppliers, incentivising them and others in the industry to also think about their productivity – e.g. following a larger pipeline of orders from the
industry, our supplier of brick slips is now more incentivised to bring production to the UK.

11. **Employment opportunities** – Following from above, the expansion of the offsite industry would create employment opportunities within factories, in the wider communities and adjacent industries.

12. **Training** – Factories can be seen as centres for modern construction training and apprenticeships.

**What are the likely drawbacks?**

13. **Individual bespoke house manufacturing, at affordable prices** – Bespoke construction, particularly with small-scale and refurbishment projects, may not initially be more productively completed offsite, so traditional onsite construction may be more suitable here. As previously mentioned, offsite construction should instead be viewed as creating additive capacity to the UK construction market.

**What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

14. The benefits of offsite construction are understood by parties actively pursuing efficiency and innovation, however with low margins and lack of R&D investment, the construction industry on the whole has been slow to adopt offsite construction. As such, education across all parties listed above, particularly in the direct benefits to them, would be the best way to drive adoption of offsite manufacture.

15. As construction is dependent on a multitude of industries including those listed above, collaboration across all disciplines is required.

16. In the short term, incentives may be required to build momentum, particularly as the construction, and property industry more generally, has historically been slow to adapt and innovate.

**Evidence**

17. The select committee would be welcome at our London show homes installed in a single day with the overall construction programme 3 times faster than traditional construction methods. Here the committee can witness the quality of construction and understand how our manufacturing and installation procedure delivers increased productivity, improved health and safety and how we are increasing the provision of new, affordable housing across the UK.

**Potential barriers to wider use of offsite manufacture**

**What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

18. We do not believe traditional construction will be replaced by offsite methods. Instead, offsite construction can be seen largely as an additional capacity in the construction industry.
19. It is key to note that many trades, such as ground workers would still be required in the same or a similar capacity.

20. Where developers and contractors switch to offsite construction instead, workers can be re-trained, leveraging their existing skills and experience. 

*Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?*

21. Many of the UK’s most loved housing is built from standardised designs and pattern books. A focus on standardisation of layouts and use of pattern books in the 18th and 19th century enabled attention and funds to be focused on the main streetscape and facades and the spaces between buildings rather than reworking internal layouts as is often the case today.

*What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?*

22. In order to deliver additional homes in the next 2-5 years, offsite housing schemes need to be designed and put into planning in the next 1-3 years. Government investment in academic R&D projects not directly linked to manufacturing is unlikely to have a near term impact. We believe support for practical, near term R&D support by those looking to refine, develop and scale up their offsite solutions should be a major priority.

**Government actions**

*(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?*

23. Short term support which enables rapid upscaling of offsite construction seems to be missing from the proposed construction sector deal.

*What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?*

24. Proposals which drive speed of construction, quality and as built performance will inherently support offsite construction as well as deliver more and better homes. A major challenge remains the ability for the public sector to work in partnership with offsite housing providers on multiple projects at scale as seems to be the case on large infrastructure projects. The experience of the Education Funding Agency on the procurement of offsite manufactured schools may be of interest to the committee.

**Additional commentary – private sector adoption**

25. Whilst numerous public-sector agencies are taking steps to incorporate offsite construction into their housebuilding strategies, the private sector, particularly SME developers and contractors, have largely been slow to embrace offsite construction due to factors including but not limited to:

- Lack of awareness of its merits.
- Reluctance to or lack of coverage by some insurers and lenders.
- Need for framework agreements and contracts to allow for procurement of buildings and elements constructed offsite e.g. payment terms and
liability clauses reflecting onsite/traditional construction would need to be amended.

26. As private sector housebuilders still provide much of the new housing stock in the UK, in order to see a much needed increase in housebuilding capacity, lower environmental impact of construction and other benefits of offsite construction outlined above, the government must take steps to incentivise the private sector to make use of offsite construction methods.

27. In order to get some momentum from private sector housebuilders, effective incentives may be in the form of financial subsidies, similar to the Green Energy Feed-In-Tariffs which successfully promoted the use of renewables, helped establish a buoyant sector and spread benefits to the wider economy and environment. Grant funding from Homes England and the GLA could be provided on multiple tranches of additional new homes built using offsite construction. The first tranche would have the maximum subsidy per new home and each subsequent tranche’s subsidy would decrease so housebuilders are incentivised to bring offsite schemes further forward in their pipeline. We would work with the relevant agencies to direct housebuilders towards these grants. In particular, we can work with smaller housebuilders who may not otherwise be eligible for or aware of other forms of grants.

28. As well as access to additional funding, preferential access to land would also help drive the adoption of offsite construction. This could work by making bids for publicly owned land favour a need for construction which demonstrates a lower environmental impact and faster delivery. Offsite construction can be suggested as a possible solution to this. It is worth noting that existing initiatives such as the small sites programme by the GLA which makes small site available to developers can add this type of criteria into their programme.

29. As previously mentioned, offsite construction can be seen as adding additional capacity to UK housebuilding. As such, offsite construction provides the opportunity to unlock land held by developers that they do not currently have the capacity to construct on. Financial incentives as suggested above can be provided to help make future schemes more economically viable in the near term, providing additional quality and affordable homes sooner. We note the government has previously indicated a will to help unlock land held by developers, a plan such an initiative may help deliver.

30. Planning permission is another key issue faced by developers which offsite and more specifically, volumetric construction, can help with. Planning departments across the UK are under large workloads, having to deal with an increased number of schemes, often in unique plots attempting to make more dense use of space. By providing a ‘type approval’ of certain volumetric house types offered by a centrally approved panel of suppliers, planners can automatically approve proposed buildings and instead focus on other factors such as local amenities and setting. This would also provide increased certainty, faster turnaround and lower design costs to housebuilders.
The approved panel of suppliers could be made up by volumetric house manufacturers, such as ilke Homes, whose homes comply with building regulations standards, have structural warranties and Council of Mortgage Lenders accreditation.

Authored by:
Bjorn Conway – CEO, ilke Homes
Nigel Banks – Product and Marketing Director, ilke Homes
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26 April 2018
Appendix I: Example ilke Homes project

ilke Homes for Keepmoat Homes, Carr Lodge, Doncaster

2 x semi detached ilke homes flanked by traditionally constructed buildings

Installation of homes
Appendix II: Example ilke Homes house types
Tuesday 5 June 2018

Watch the meeting

Members present: Lord Patel (Chairman); Lord Fox; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Maxton; Baroness Morgan of Huyton; Baroness Neville-Jones; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 9 Heard in Public Questions 64 - 70

Examination of witnesses

Tony Meggs, Ann Bentley and Martin Chown.

Q64  The Chairman: Good afternoon, lady and gentlemen. Thank you very much for coming to help us with this inquiry into off-site construction. Your evidence will be very helpful to us. Before we start it would be helpful if you could introduce yourself and tell us who you are for the record. If any of you would like to make a brief comment—and I mean brief—please feel free to do so.

Tony Meggs: I am the chief executive of the Infrastructure and Projects Authority in government, which reports to the Treasury and to the Cabinet Office. Our job is to improve the way in which projects and infrastructure are delivered in government. We oversee all the Government’s largest infrastructure projects and other types of project. I am very happy to be here.

Ann Bentley: I am global director of Rider Levett Bucknall. We are project managers, cost consultants and building surveyors working both in the UK and internationally. I also sit on the Construction Leadership Council, which provides advice to government on construction matters. From my position on the CLC, I have a particular interest in procurement and productivity.

Martin Chown: Good afternoon. I am the supply chain director at Sellafield, a large, complex nuclear site in the north of the UK. I also sit on the Infrastructure Client Group and I am here to answer any questions you might have on that. We sit together as some of the largest infrastructure providers in the UK to join forces and to collaborate on where we can to make the industry better.

Q65  The Chairman: Thank you very much indeed. I will kick off with the first question.

In virtually all the evidence that we have heard now there has been a great deal of enthusiasm for more projects to be done using off-site construction. But possible barriers have also been identified, and we would like your views on how you think these might be overcome. What
in the business models in the construction sector needs to change? Secondly, companies in the construction sector need to be more collaborative in lots of areas, including in skills development. Thirdly, the cash flow and financing in the sector need to change; in other international construction companies, finances are managed better.

Those are the three key barriers that we have identified and that need to be overcome if we are to have more off-site construction.

Tony Meggs: I am happy to kick things off, if I may. The barriers that you refer to are becoming reasonably well known. Just to supplement that a bit, we have a track record in the industry of working with government to procure for the lowest cost rather than for best value. That has driven a set of behaviours in the industry that are not very collaborative, in that we try to move risk down the value chain.

The second area is aggregation. For this type of technology to take hold we need multiple projects and longer time horizons. Currently, the industry runs largely on the basis of individual projects in which the incremental up-front costs of off-site manufacturing cannot always be justified. I think we need to move to a more collaborative approach where more risk is shared and to an approach within government where we can look at multiple projects over multiple years and aggregate potential demand for off-site construction in a way that is not done at the moment.

The Chairman: How do you bring about more collaboration among companies?

Martin Chown: The Infrastructure Client Group has developed a new model for construction called Project 13. We launched it in early May, although it has been in development for a while, with lots of companies contributing to what it could be.

Essentially, Project 13 is a change to how we can go to market and procure on a more collaborative basis, right from the start of the need for construction. It seeks to establish what is required from the infrastructure and then for us as clients to come up with better models to drive that collaboration within the supply chain. It sets us out very clearly as the owner and sets out what we want from the asset and how we want it to perform over its life cycle. It sets out how the supply chain can be constructed and, as Tony said, how to do that over multiple projects.

The clients around the table of Project 13 come up with models in which suppliers can work on many projects, both large and smaller, and can go from one project to another building on that success. We feel that that enables innovation and productivity and a knowledge to be built in from one project to another. It takes time to be able to do that. The kind of long-term arrangement that we are building through Project 13, and in our own organisations around the table in the Infrastructure Client Group, is key to driving collaboration in the supply chain.

This also takes into the account the third area that you mentioned, cash flow and risk and reward, because it has to be based on payment and profit for performance and outcomes. That is the model advocated as part of Project 13 by the Infrastructure Client Group, and many of the people around the table are driving it forward in their own organisations.
**Ann Bentley:** Going back the first part of your question, there are already very many business models out there and they depend very much on which sector of the market you operate in. The housebuilding model is very different from, say, the commercial development model, which is very different from the infrastructure model. That is quite important to begin with. In some of these models, there are already significant amounts of off-site construction. In fact, in the commercial model something like 80% of all components brought to site already have some level of off-site manufacture to them. That is an important point to make.

From a construction adviser’s point of view, our biggest challenge in promoting off-site construction is the need for competition. Many of the funders of the construction that we work on, whether they are private sector or public, have very high levels of scrutiny for how the contract was let. Did you go out to market? Did you get competitive bids? How is this placed in the marketplace? One of the demands of the off-site model is that you get to the point of freezing the design very early in the process, so you are quite limited in the number of contractors you can go to. We find that a lot of our private sector clients are loath to commit to a single contractor very early in the process and want us to continue with the design development until they can get to the point at which they can go to market.

**Lord Fox:** You alluded to the different reaction in different sectors. Would you say that commercial has more potential for this than homebuilding, and where should we target effort—the public sector or the private sector?

**Ann Bentley:** I would say that it is more value based than necessarily sector based. It is really what Martin was saying. If you have a programme of projects or a single project that is worth in excess of £50 million, you can pretty much specify whatever type of construction you like. It is big enough that somebody could set up the process for it, standardise it or whatever. It could be 50 £1 million projects or one £50 million project. If you are looking at one £1 million project, there is nothing standard about it, so it is very difficult for anybody to advocate—

**Lord Fox:** Is £50 million an illustration or a real figure?

**Ann Bentley:** It is an illustration, but that is the order of magnitude. It is not £10 million. At that magnitude, it is worth the market reacting to the procurement type.

**Martin Chown:** If I could just contribute to that. There is value across many sectors—in fact, all sectors. The approach is different, but I have seen successful off-site manufacturing in student accommodation. Again, there is a repeatability to the schemes. Sometimes the schemes are larger and sometimes they are smaller, but essentially they are the same, converting a disused office building or a new build into quality student accommodation with modular bathrooms and that sort of thing. With my previous employer I was involved in 30 or 40 of these schemes. The benefit does not come in schemes one, two or three but in schemes seven, eight, nine and onwards. That is when you really see the benefit and cost coming back from the off-site manufacture.
For highways and rail infrastructure, parts of the gantries and control systems can be successfully manufactured off-site. All those types of structures, including bridges, can be considered for off-site manufacture.

The sector I am in at the moment is large infrastructure buildings. Interestingly, our classification of a major project is over £50 million. There, we have used off-site manufacture to build large, heavy installations—even 500 tonnes—that were then inserted into a large process building. I have seen different approaches that have been more or less successful over smaller, low-cost builds, right the way up to £700 million-plus projects. The approach and the lead time to benefit are different for each of those projects in each sector, but none of them is immediate.

Lord Griffiths of Fforestfach: Let me just clarify in my own mind your answer to the question about competition. Are you saying that if we were to move to greater use of off-site manufacture and a more collaborative approach with shared risk, there would inevitably be a reduction in competition?

Ann Bentley: No, I am not saying that. I am saying that that is the perception. That is the crux of the issue. Many of the clients we work for believe that the only way we can demonstrate competition is by having a competitive tender on a completed design, if I am honest. I am not saying that that is what all clients believe, but many think that that is how you ensure best value.

I advocate almost the complete opposite. I think you will get better value and still have competition if you go to the market much earlier in the process, because you will get much greater buildability and input from the people who will build it. But the perception is often not like that. We talk about the knowledgeable, educated or competent client, but one-off clients are even more likely to believe that. A client who procures lots of things a lot of the time is clearly an expert client and understands this. One-off clients tend to say that they just want to tender it and see what turns up.

Q66 Lord Renfrew of Kaimsthorn: What actions are needed from the Government, perhaps through the Construction Leadership Council, and from the construction sector to help to increase the use of off-site manufacture? It was disappointing, I think, that the Government did not give the full detail of the sector deal when they made their announcement in the industrial strategy White Paper six months ago. There was a press release that spoke of the objectives of reducing cost, reducing time, reducing greenhouses gases and the trade gap. What do you feel the sector deal should contain to meet these objectives?

Tony Meggs: Talking a little more widely than just the sector deal, I think there are four key necessary and helpful things. One is the need for more research and development, which is part of the sector deal. That is research and development in manufacturing techniques as applied to building. The second, which Ann referred to, is better practices in procurement and a more collaborative approach with much more work together up front. We are pursuing this partly through Project 13 and
through our own government initiative, Transforming Infrastructure Performance.

The third area where we can play a real role is aggregation of demand. As the others have said, if you just have one-off projects it is very difficult to justify the up-front investment of time and money to use really modern methods of construction. If we can aggregate demand, as we can in government by looking across different departments, you can demonstrate the benefits of this approach much better. That is why we have included this so-called presumption in favour in five government departments. That means that they will look first and foremost to using modern off-site construction methods, along with other routes but with a preference for that, provided that it stacks up.

Finally, and down the road, is the development of a library of standardised components. Not to make it sound too much like Lego, but we can see lots of opportunity for developing various platforms that will allow many different types of buildings and things to be constructed from a base number of components. We in government are planning to work on that over time.

Lord Renfrew of Kaimsthorn: Thank you. You mentioned Project 13, about which I have been reading. I am not quite sure of its status. It is clearly very well intentioned—it has almost a piety about it—but who exactly is it directed towards?

Tony Meggs: I will let Martin answer that.

Lord Fox: The high priest.

Martin Chown: Project 13 is directed towards infrastructure clients in the UK. Three hundred people and over 140 organisations contributed to Project 13, including many—

Lord Renfrew of Kaimsthorn: Sorry to interrupt, but why is it called Project 13? The title is striking.

Martin Chown: I am afraid the answer is painstakingly dull. It was the 13th project that we led from the ICG.

Lord Renfrew of Kaimsthorn: Fair enough.

Martin Chown: I was curious myself and I asked the same question. There are four reasons why we developed Project 13 and why it is important for off-site manufacturing and other methods of productivity, and I will cover those briefly, if I may. It provides the scope to drive the efficiency in the supply chain investment, so we add in scope through Project 13 for multiple projects, as I described in an earlier answer. It builds on longer-term relationships. With those longer-term relationships there is investment in advanced manufacturing methods and the products that are required. It has integration at its centre, so we integrate the suppliers and they can compete within it, but not in open competition in the way that Ann described; they are part of the delivery of the outcome. The fourth reason is that there is earlier strategic engagement with the suppliers so that they are there.
One feature that we have found of off-site manufacture and other production methods is that it is not taking what we do on-site and simply moving it off-site; it looks at it right from inception so that things are designed to be manufactured off-site. There is a marginal benefit to safety by moving things off-site, which of course is important, but the best benefits that we can get are through designing things to be made off-site and then building the efficiencies as things arrive on site.

Project 13 launched on 1 May. We have three pilot projects running with it, and we already have the next three. The principles of it are already being embedded in most of the large infrastructure clients. There are 25 large infrastructure clients in the UK already embedding the principles.

Lord Hunt of Chesterton: In this Committee we have been learning about what I call the Griffiths conundrum as to where the Treasury is. It is like Alice in Wonderland: is it on the outside as the funder or is it on the inside trying to move things? In this document here, the Treasury is hardly mentioned, so we do not know what it is doing. How is the central government push happening in this project and in the whole business of introducing these new methods?

Tony Meggs: Can I address that, as somebody who works at least partly for the Treasury? Curiously, we report both to the Treasury and to the Cabinet Office, so in a sense we are helping the Treasury. At the end of the day, the Treasury is clearly interested in value for money. It is also interested in productivity. Therefore, it has a very keen interest in what we are trying to achieve.

We have an initiative, although I hesitate to call it that, in the IPA called Transforming Infrastructure Performance. It has four components. The first is benchmarking to make sure that we are competitive. The second is about integrated development and ensuring that houses, trains and so on are built in a co-ordinated fashion. The third is about better methods of procurement. The fourth is to do with technology, including the use of digital technology—BIM, which you have no doubt heard about—and modern methods of construction. These are the four axes that we are pushing on behalf of central government. We work with lots of departments and with industry so that all that we are doing is lined up with the most advanced current industry thinking.

Within that big programme we have lots of effort under way. Again, that builds on an industry desire to do things differently. For example, we have set up a working group that works across several departments to share best practice on methods of construction and, I hope, to aggregate demand. There is a lot that we can do. We have set up a team within our organisation to help to drive this forward for government, as the biggest client in the country for infrastructure.

Lord Mair: Can I follow up on that? You made a good point earlier about the aggregation of demand, and you mentioned the presumption in favour for the five departments, which the Government have talked about, providing that there is best value for money. I guess that is a very important proviso.

Tony Meggs: It is an important proviso.
Lord Mair: Can you say a bit more about the presumption in favour and tell us what it actually amounts to? We have potentially five government departments. What would the presumption in favour mean in terms of pushing forward this agenda?

Tony Meggs: It is obviously an excellent question. It means that we will work with all those departments, and they will all work together through the working group that I mentioned, early on in the evaluation phase. As you know, with all government projects we require people to develop various options so that the best option can be chosen. In that option selection process we will require the departments that have committed to this to having at least one option that includes the substantial use of off-site manufacture, and I mean modern methods of construction and more advanced approaches.

Our job then, as a practical matter, is to help with that evaluation, by which I mean that where we can see the wider societal benefits of looking at a larger portfolio we will introduce that into the considerations to make sure that the evaluations are done in a forward-looking way.

To clarify that, one project on its own often cannot justify the necessary investment that a group of projects can. By using this presumption and the aggregation of demand across those departments, we will be able to amortise the investments over a larger pool of activity.

Lord Mair: You used the phrase “require the departments” to have at least one option involving off-site manufacture. How would that requirement work in practice?

Tony Meggs: That is yet to be seen. In fairness, all those departments have used various forms of off-site manufacturing already, so this would not be earth-shattering. What will be different on this occasion is that we will be looking for more advanced methods, so not just a few bits of off-site but across the entire manufacturing chain. We will undoubtedly work with those departments to make sure that they have considered the most up-to-date technology approach and that they have all the learning from across the industry and from other departments and places where it has worked. I am clearly not doing a very good job of describing the anatomical details, but it is about collaboration.

The commitment is meaningful. It sends a signal to industry that we are serious. We did not twist the departments’ arms; they made these commitments of their own volition.

Lord Mair: To follow that point, are you saying that they would in effect be held to account if they did not consider off-site manufacture? Would some sort of questions be asked if they did not?

Tony Meggs: All these projects have to get funding approval from the Treasury, and as part of that process the departments are required to have done a thorough evaluation of off-site and modern methods of construction. If they have not, working with our friends and colleagues in the Treasury we will ask them to have another go.

Ann Bentley: I think the key to that question is: where does the wider social value sit? I am pretty sure that anybody with a calculator could make the argument either way, for either off-site or conventional,
depending on what you are actually measuring. If you are absolutely measuring unit cost at the point of supply, traditional construction methods may well come out cheaper.

But if you add in long-term value, quality, local employment, health and safety, and lots of slightly less tangible things—they are not intangible, because they can all be measured, but they are not quite as in-your-face—it becomes a much more complex matrix.

That is the question that I think the Treasury has to be asked. It is not: which is cheaper, A or B? As I said, anyone in the room could make A or B possibly cheaper depending on which factor you come at. It is about which factor is most important.

Lord Kakkar: Just to be clear, are we to understand that the Treasury does not ask any of those questions as part of its enthusiasm for the presumption that there will be off-site manufacture?

Tony Meggs: I would not like to cast any aspersion on the Treasury. I do not think it has been a major theme in the Treasury so far.

Lord Kakkar: But then this presumption we are hearing about is slightly meaningless, is it not?

Tony Meggs: This is new. We have not had any cases through the Treasury since this presumption was introduced.

The Chairman: I think your response has excited quite a lot of Committee members, so I suggest that they ask very brief questions and that we please have very brief answers before we move on.

Baroness Morgan of Huyton: It is okay. My question has been answered.

Lord Vallance of Tummel: This question is just a quickie. The Treasury will understand the concept of externalities, which Ms Bentley talked about. One of the biggest ones in their objectives for the sector is a 50% reduction in greenhouse gas emissions in the built environment by 2025. That is huge. Surely in assessing the procurement of a government deal, that should be quantified and be part of it.

Ann Bentley: My answer as a construction adviser is absolutely yes, it should be. If your question is whether it always is, the answer is not always.

Lord Fox: I started to get agitated as we moved in this direction, because it seems to me that we are looking at the wrong end of the telescope here. We should not be worrying about how we build but about what we build and the quality of what we build. If we were to exert higher standards for on-site waste, construction safety and the safety, quality and environmental performance of the final building, would that not be a better way of driving better building techniques, one of which would be off-site manufacture?

Ann Bentley: It would be an equally good way.

Lord Fox: Equal to what?

Ann Bentley: To factory produced.
Lord Fox: That is what I am saying. If you put higher standards in, you will inevitably drive the industry towards more collaboration. In a sense, I am asking for support or otherwise for a standards-based approach to creating all the other changes that we are discussing.

Ann Bentley: Again, from my perspective both on the CLC and as a construction adviser, absolutely. At the moment, there are examples in both the private and the public sectors of very poor-quality design, construction and procurement. But they are cheap.

Martin Chown: The Infrastructure Client Group and the Institution of Civil Engineers have a role to play. As well as standards and the involvement of the Treasury, which is always welcome in advising us how to proceed in the most cost-effective way, we have a role to drive it forward for ourselves. We have the self-motivation to save the taxpayers money and to deliver the best value that we can.

A recent example is a store that we built in our facility in Cumbria. Previously, we would have designed a store and tried to build it. To build it successfully would have taken time and money. We looked at the industry around us and found that someone else had built an almost identical store; it was a slightly different size but very similar in concept.

We built the same store—they are almost identical, but ours is slightly larger—and we optimised it. We did not specify materials; we just used industry standard direct from the factories. The store came in at about £10 million cheaper and a year early. That is a strong achievement and an example of us using other clients’ work and copying it for the benefit of what we are trying to do.

If the Infrastructure Client Group and the Institution of Civil Engineers can promote that kind of work from the ground up and roll it out through Project 13, we will get a lot of traction. Support for Project 13 and how we want to do things can be client driven, both in the public sector and in the private sector, as well as driven by the Treasury, the Cabinet Office and Tony’s organisation.

Baroness Young of Old Scone: How is presumption going to be measured? It seems to me that the method of measuring the successes of presumption will determine what will be taken into account. Is there clarity about how it will be measured?

Tony Meggs: Quite honestly, I think it is too early in the process to be specific about that. I will measure it in terms of how many projects adopt modern methods of construction. I would not expect it to be universal, but I would expect it to increase over time. We have not set any targets at this stage, because it is too early in what for us is a new initiative in government.

Q67 Lord Hunt of Chesterton: What actions are needed from clients to help to increase the use of off-site manufacture? A couple of weeks ago, we went to a factory that makes off-site equipment and they told us a story that is the opposite of yours. They told us about building all these schools in Yorkshire using off-site methods, but that in the next round of bidding they were not chosen, for reasons that were completely unclear.
One wonders how clients can be educated and informed about the potential benefits of using off-site manufacture. I imagine that the Treasury might want to look at that on a bigger scale. It is a palpable example and it was clearly very disheartening for a company that had made such big investments.

**Martin Chown:** To try to answer your question, I believe that, further to Ann’s point, that project and some others have been re-competed, so they built some knowledge and have been re-competed. Clients could look at their needs over a longer period of time and understand that off-site manufacture requires repeatability and has a long-term nature, and that benefits will not always come in schools one, two or three but definitely will come in schools four, five, six, seven, eight and beyond.

So going to market with a procurement model that is cognisant with what you want to achieve over the longer term and building in scope for where you want to go, then allowing that long-term relationship to build and develop without having to constantly compete or re-compete, as I believe happened in the Yorkshire schools model, is for me the way to go. The clients can understand their requirements, require an off-site manufacturing plan and use the principles of Project 13.

For me, that should come in very early in the day to the market-facing structure. Procurement colleagues, and I sit in that world myself, need to be very careful about what we can achieve over the longer term as opposed to going to market every year or every two years to try to re-compete and save some money.

**Ann Bentley:** I think that the Crown Commercial Service has a really big part to play in this, because a lot of public procurement, not so much on the infrastructure side but more on the residential side and in smaller facilities and education, is done through that service. Historically there were hundreds and hundreds of different frameworks: a framework for police stations, a framework for schools in Lancashire, a framework for this, that and the other. Each one would be subject to serious competition.

The Crown Commercial Service is now trying to combine a lot of these frameworks into much meatier national frameworks. Each framework would then probably have a lot of suppliers on it, because it is not trying to get rid of competition; it is trying, as Tony said, to aggregate the market. Once you know that you are a supplier on that framework and that it is perhaps for five years with a possible extension to seven years, you can start an investment programme, because you know that you are one of the framework suppliers. You might not know exactly which schools or hospitals you are going to build, but you will know that, as you are on the framework, you are in with a good shot of getting a percentage of that work.

In terms of what government supply bodies can do, the work of the Crown Commercial Service is significant. It is broadening and extending the framework, which means that it will be far more attractive to these economies of scale.

**Tony Meggs:** May I just make a couple of points? Over the last few years, the Government have done quite a good job of increasing the
length of these. Highways, for example, used to have an annual plan. Now we have five-year plans, and similarly in rail and so on. That has really opened up the opportunities for longer-term and more collaborative relationships. That is point number one.

The second point goes to part of your question. Part of our job over the next few years is to improve the understanding of the economics here. Right now, as Ann said, if you look at all the evidence, you can come up with any answer you want as to whether it is a good idea or not. We need to build the evidence base and be much clearer not just about the societal benefits but about the economic benefits of taking a long-term manufacturing approach. Fundamentally, it is about improving productivity, but it is going to take quite a long time for those benefits to be clarified.

Baroness Morgan of Huyton: That was my question, which in a sense is about pace. How directive are you being—I am thinking about Mr Meggs really—in, for example, setting out that there should be a move towards value rather than initial capital cost? To what extent is that being driven through the system, or is it a more discursive, working-group approach? It seems to me that time is somewhat of the essence when it comes to driving productivity, and we have not even talked about the domestic housing market and the urgent need to drive productivity there.

Tony Meggs: I have been asked this question several times. In some areas we have taken quite a directive approach: in the use of BIM, for example, which is an enabling technology that we have mandated. Even with making it mandatory, it takes several years for it to spread through the industry. We started that in 2011 or 2012 and it has achieved real momentum now.

In this case, I realise that it feels a bit fluffy, but we are not in a position to mandate this right now. First of all, it is not always the right thing to do and, secondly, the industry capacity does not exist. Thirdly, the right sets of standards are not in place to make it a ubiquitous technology. There is a lot to do over the next few years to improve understanding and research and to set standards. We have a sense of urgency and the industry has a sense of urgency, but it is a large, complex and amorphous industry.

At the end of the day, I think there is a lot of good will here and a desire to move this forward. I would not like to come in with big heavy boots and turn it from something that people want to do into something that people are forced to do—not yet, anyway.

Ann Bentley: To take your point about value, which was at the heart of your question, I would say that the people who are most successful on that are the infrastructure clients. These are the people who have longer-term funding arrangements—

Baroness Morgan of Huyton: So in a sense they are driven to being more able to do it.

Ann Bentley: Yes, because they have longer-term funding arrangements and they are asset owners, so they see the direct benefit of the cost savings. If it is a long-term cost saving rather than a short-term cost
saving, clearly if Highways England or Sellafield realise that spending an extra couple of quid saves them £100 a year for ever, they have the ability to do that. In single projects, that is much more difficult.

**Baroness Morgan of Huyton:** Why cannot that be understood by housing associations, which you could argue also have the long-term relationship?

**Ann Bentley:** This is now opinion.

**Baroness Morgan of Huyton:** That is fine.

**Ann Bentley:** I think that if there was a move to desire housing associations to do that, Homes England would have quite a strong role to play. One of the issues with housing associations is that they still have their own design standards and procurement standards. That is not necessarily a bad thing, because they address local markets, but if you want national economies of scale, you might have to accept that you have to give some of that up.

**Lord Fox:** On a point of clarification, I thought I heard Mr Meggs say that he did not want to force the issue on value assessment, because there is not the capacity in the industry to do it. It seems to me that you do not need off-site manufacture still to be forcing the point that we should be looking at the value rather than at the point cost of a development.

**Tony Meggs:** I am sorry, I may have misspoke or misled you. I meant that we should not at this stage be forcing off-site construction or modern methods of construction.

**Lord Fox:** So the “it” was off-site.

**Tony Meggs:** Absolutely, we should be forcing whole life value considerations.

**Q68 Lord Vallance of Tummel:** Much of the evidence that we have received so far has been about buildings of one kind or another. Be it small or big, it is vertical. Perhaps you can tell us a bit more about the horizontal. Does that offer the same scope for off-site manufacture? Are there different characteristics? Is it easier or more difficult to aggregate schemes of this kind?

**Martin Chown:** There are certainly different challenges in the vertical infrastructure sector. There have been some notable successes in off-site manufacture and standardisation across the Metrolink trams in Manchester, where there were 52 platforms and most of the work and features were standardised across the platforms. At the Canary Wharf Crossrail station, the whole platform was manufactured off-site and dropped down in situ, and Heathrow is looking extensively at where it could do off-site manufacturing.

Driving economic growth in different areas is part of that off-site manufacture. Highways did a lot of work on standardising the gantries that sit across all the motorways. Where there are standard features that could be applied for multiple schemes, there is a very strong case for the off-site manufacture of vertical infrastructure. The cost benefit of that is starting to develop and some of the case studies are quite strong.
Where you are starting to put things into the ground or have more of an interface with the ground geometry, things become more variable and off-site manufacture becomes more difficult. But where features can be established and different sizes of features can be done through modular construction, there is a very strong case for using advanced manufacturing techniques that are both off-site and on-site for the linear infrastructure.

**Lord Vallance of Tummel:** Is the industry structure the same or is it more integrated than perhaps on the vertical side?

**Martin Chown:** Most of the clients that I interface with on the Infrastructure Client Group are very like-minded. Those of us who are building large structures and dealing with highways or rail have looked at each other’s models and seen that we share similarities in our long-term goals. Our thinking, desires, collaboration and incentive models are developing in the same types of ways, which suits the drive for off-site manufacturing.

**Lord Vallance of Tummel:** So there is not the same drive to pass the parcel of risk from one element to the other, is there?

**Martin Chown:** Different risk models have been used, but in Project 13 we advocate risk sharing as opposed to risk transfer. We believe that driving an outcome where both parties are cognisant of the risk and you drive through the project to mitigate and diminish that risk, and there is profit to be had on achieving better outcomes, is the best way.

**Tony Meggs:** I would answer that slightly differently. The industry is quite disaggregated both vertically and horizontally in all sectors, quite frankly. From a government perspective, our historical approach, not universally but a lot of the time, has been to move as much risk as possible down the chain and away from government. There are lots of good reasons for that, such as not wanting to be on the front page of the *Daily Mail*, and so on, but it does not necessarily produce the right outcomes.

It is a substantial cultural shift for government to embrace a more innovative approach where collaboration with the supply chain can produce better outcomes for all, including better commercial outcomes for the suppliers and for the client. That is the basis of Project 13. But it is non-trivial if you are used to living in a world where your job is to get rid of as much risk as possible.

**Lord Vallance of Tummel:** But you do not see any real differences between the horizontal and the vertical.

**Tony Meggs:** I am talking about the social infrastructure sectors versus the economic infrastructure sectors, but not really.

**Ann Bentley:** I see a difference in the way risk is handled. The majority of the large infrastructure clients have a much better acceptance of the concept of risk sharing than many of the commercial clients, and a lot of the commercial clients’ attitude to risk is pushed by their funders. If you are borrowing all the money, clearly the funders will have a very different view of risk and of the return on their investment than if you are building any number of railways and have a longer term over which to distribute
the risk. We certainly see a difference depending on where the money has come from rather than in relation to what is being built.

**Lord Vallance of Tummel:** That is very interesting. Thank you.

**Q69 Baroness Morgan of Huyton:** Can I ask you about skills and workforce? Obviously we know about the shortage of skills even in relation to traditional methods in the construction sector, that it is ageing and that with Brexit it will get more difficult.

Taking that as a starting point, to what extent do you see a need for a completely new set of skills for the new world, and how do you see that being developed? Will it be developed alongside, or can we retrain people? Paint a picture on the skills side, if you will.

**Ann Bentley:** My take on it is that it is about the really significant elements of off-site as opposed to a few percentage elements off-site. There is also a big point about whether it is UK manufactured off-site or overseas manufactured off-site. Going back to my commercial building example, once you are out of the ground, in truth probably 70% or 80% of it is already manufactured off-site but not necessarily in the UK. So there is an issue to do with where the skill base is and what the skill base is.

Certainly the evidence—I am talking about commercial and residential buildings—is that the training needed to get an off-site operative in a manufacturing facility up to a very, very high level of competence takes months, not years, because the very nature of the manufacturing process is that it is repetitive and it has a degree of quality control built into it, so you need very clever people to set it up. But once it is running it is relatively easy to train people over a relatively short period of time.

Clearly there is still a need for site operatives and they will still need general site training, but a lot of the main contractors are now talking about multi-skilled operatives—people who can do many trades on-site rather than just one. That is a retraining programme to some extent. Clearly you will bring new people in, but you will have to retrain some of your existing people.

**Tony Meggs:** I agree entirely with Ann. However, I do not see it as a wholesale “We’ve got to get rid of all of these and do all of that”, because it is a huge industry, and there will still be lots and lots of conventional work and there is a quite a big rate of attrition. So there is tons of opportunity for new people with new skills to come in. Some of them will come from other sectors and have manufacturing and digital skills in particular.

**Lord Hunt of Chesterton:** I used to run the Met Office, and it was interesting that when we had a big project we were told by the Ministry of Defence to use the techniques that we had, and we just used them. There was no looking at all sorts of possibilities. They did it, they did it cheaply, and they howled to have to do it as cheaply as the big department told them to do.

In other words, this is very different from the view of the Treasury, which could be very touchy, very dodgy, about this. Presumably the big
government spending department that deals with Sellafield can get really big projects done in which there is a benefit from each one. Is that not one way in which Whitehall brute force, as it were, can get some big projects done without worrying too much about the finesse of the procedures?

Tony Meggs: I do not think I would describe the Treasury in any way as fluffy or touchy-feely.

Lord Hunt of Chesterton: You should see them.

Tony Meggs: Those are not the words that come to mind. That might be my problem rather than theirs.

Again, the presumption in favour is designed to encourage departments, and they have agreed, to use these methods wherever possible. But to force these methods on every project in a uniform way would not produce the best outcomes. We are in a learning period here, and we will understand over time, as we have with the BIM process, what progress is being made and whether more forceful measures are required.

Lord Vallance of Tummel: We are talking about workforce skills here. What about procurement skills? Do they need to be developed, particularly in the public sector? What about client skills in understanding these different methods? How do we get around that?

Tony Meggs: We have two of the world’s best procurement experts sitting here. Doing procurement in the way we would like it to be done and including off-site manufacturing and other things requires sophisticated players. I think the Government are moving very strongly in that direction. There has been a big programme over the past three or four years to bring in a lot of new procurement capacity and capability into government. So we are moving in the right direction, but we still have a long way to go. Of course, we have people like Martin, a leading procurement expert, procuring on Sellafield—a very complex procurement that he has under way right now.

Lord Fox: For a different reason, I had a meeting with David Lidington, and we were talking through the organisation that comes underneath John Manzoni. We were told that there is an extensive process of procurement training going on. Is this on the curriculum of that training?

Ann Bentley: Could I perhaps answer your question in a slightly different way? Earlier, someone mentioned the industrial strategy and the construction sector deal. One of the key components of the construction sector deal is an element called procuring for value. Someone said it is a shame that it has not been published yet, and I agree with that. It has been written, but it is a real shame that it has not been published, because the answer to some of your questions would come out of that document.

Procuring for value is very much recognised by the Construction Leadership Council, the IPA, the Infrastructure Client Group and pretty much everybody in the industry as being a fundamental tenet of moving this forward. Certainly part of that is that both the advisers and the clients need to be properly trained in it. If they are not, it is just words on
a bit of paper. In different ways, we are all trying to move that forward, and if you have any influence in that area, it would be much appreciated.

**Martin Chown:** Government commercial services are driving forward an extensive reskilling of procurement staff across the whole of government. That is being led from the top, and the whole commerciality of how colleagues in procurement work, whether they are capable of delivering the right outcomes for the department and how they do that is being managed extensively.

It is a large and extensive programme. If people are not of the requisite standards to go forward in that programme, they will not be put into those commercial roles to be able to do it. It is a comprehensive programme with all the right principles behind it to make sure that the Government Commercial Function is a lot stronger across all the departments than it has been in the past. It is being driven very hard.

**Baroness Young of Old Scone:** I was going to talk about R&D, but I want to ask you a prior question. With your insight, why has the sector deal not been published? What flaw is holding it up?

**Ann Bentley:** I do not know. It was written in principle by Christmas. The Carillion failure had an influence, but that was months ago, so I do not know.

**The Chairman:** We will discuss that with the Minister in due course.

Q70 **Baroness Young of Old Scone:** You spoil all my fun, Chairman.

Traditionally the construction sector has invested a hugely small amount, if you will pardon the expression, compared with sectors such as automotive and aerospace. No doubt this will be addressed by the sector deal, I hope, but how can we get more money into R&D, and what areas in the construction sector need more money in R&D?

**Tony Meggs:** I think that the unpublished sector deal seeks to address this. It is a government injection of £170 million—

**Baroness Young of Old Scone:** That is pretty small scale.

**Tony Meggs:** It is pretty small scale, but when combined with the industry contribution it is more than doubling what is currently there. We would waste money if we put in vast amounts. It has to be something that the industry can co-invest in, and it is not rich at the moment, if I can put it that way. One reason why there has been low levels of investment is the very thin margins. It is a substantial increase and it would be wrong to multiply it by 10 over a very short period.

**Baroness Young of Old Scone:** What do you see as the priorities?

**Tony Meggs:** To some extent it is about standards and standardisation, and it is about introducing manufacturing techniques that go all the way from digital models through to components in a factory, as is done in the aerospace and automotive sectors. That is just not commonly done in the UK in the construction sector. Thirdly, there are material developments that could be done. But first and foremost is to enhance the manufacturing process and turn parts of construction into a genuine
manufacturing process rather than just building things off-site. There is quite a difference there.

I think there is an opportunity here to improve the taxonomy. When we talk about off-site construction, we mean many different things. Rather as we have BIM level 1, level 2 and level 3—this is just me musing—we need to develop a clearer taxonomy. Off-site construction is very widely used. At some level, a brick is a piece of off-site construction, and we can mean different things when we talk about it. What I am talking about ultimately is the ability to take three-dimensional electronic designs and turn them into products that can be fitted together in many different ways. I do not know what to call that—perhaps level 5 off-site construction. It would be helpful to introduce some real taxonomy here to clarify it.

**Ann Bentley:** Just to answer your question in a slightly different way, if we have a limited R&D budget we should spend more on the D and less on the R. One issue that the UK construction industry really struggles with is best practice. Again, take Martin’s example of simply going to the market to say, “Where was a similar one built and can we just copy it or use somebody else’s IP?” We are terrible at that. If you go out to the construction sector, you will find examples of absolutely brilliant technology and operations and off-site. Whatever it is, I could find you a brilliant example of it.

However, our ability to share those examples is quite poor. I am not saying that we do not need research. Of course we do, because you have to keep up with the rest of the world. But we need to ensure that the research that we have already done is spread fairly widely across the sector so that other people have access to that good practice and good results.

**Lord Mair:** Just a last point to follow that, where would you say the UK sits in relation to the rest of the world on off-site manufacture?

**Ann Bentley:** It is sector driven, there are no two ways about it. To talk again about the commercial sector, I would say that we are as advanced as anybody. In the high-rise residential sector we are actually quite advanced, and in the low-rise residential sector we are substantially behind Scandinavia, North America and Japan.

**The Chairman:** Thank you very much, all three of you, for helping us. It has been most interesting.
Transcript to be found under Infrastructure and Projects Authority (IPA)
Questions

In answering the questions below please provide practical examples where possible. If relevant, please state how you define off-site manufacture in your response.

Off-site construction is the; design, planning for, fabrication and assembly of any building elements at a location other than their final installed location (the workface).

Building elements may be prefabricated at a different location and transported to site or prefabricated on the construction site (factory on Site) and then transported to the point of installation.

Off-site construction is characterised by a strategy of integrated design, planning and supply chain early selection.

What are the opportunities offered by off-site manufacture for construction?

Potential Product Quality improvements

- Improved detailing due to mock ups and samples being tested in earnest before approval for manufacture.
- Better environment for assemblies leading to improved fit and finish.
- Quality control process can be controlled in detail with systematic testing and commissioning off-site further reducing effort at site (reducing risk of failure at site also)

Potential Reduction in Environmental impact

- Waste reduction through using standard material sizes (designing around standard component sizes)
- Reduced errors and damage leading to less production and waste.
- Reduced travel to site through fewer personnel movements and fewer material deliveries (though operatives do travel to factory environment)
- Greater standardisation leading to more Energy Efficient factories
- Better control of material suppliers – including chain of custody etc.

Rationalised Supply Chains when products have been selected for multiple buildings

- By assembling off-site in volume, seeking buying gains
- Integrating the supply chain early
- Improved buying or warranty support
- Possible impact on the volume of construction SME’s if off-site truly takes off.
Potential Time Benefits (Preconstruction and Off-site)

- Design – parts bin approach, using the same thing every time
- Assembly efficiencies by more productive workforce
- Digital design, extended into the manufacturing process, using the same model to design the fabrication solutions in the factory. (BIM with a level of detail suitable for fab shop use)

Potential Time Benefits (at Site only)

- Better Productivity in the factory – however the planning for installation needs to be considered at the outset. Reference; Interserve prison building solution for off-site cells and M&E risers, substantially reducing site activity and refined with over 6000 cells delivered.
- Shorter site times due to increased factory based work.
- Reduced commissioning on site (some elements are completed in the factory).

Risk Management

- Supplier risks are reduced for individual materials (however risk transfers to the assembler).
- Early quality control and commissioning in the factory reduce risk of failure at site.
- Feedback and quality improvement are an important factor

Social value

- Assembly plants can be created in areas of economic need leading to sustainable employment and training opportunities
- Jobs potentially more attractive than site based opportunities
- Training can be more targeted

Cost Saving

- Better buying of components in volume
- Increased Productivity due to the factory environment (though this is not 100% proven).
- Reduced defects.
- Reduced wages for factory workforce
- Less skilled labour on site
- Less time on site, savings in Preliminary costs and other time related site costs.

Evidence of actual improvements; this would need extensive work to collate and would need multi party input to gain a true picture for a project, i.e when did the client first assess the need for a project?

What are the potential drawbacks to offsite manufacture for construction?
**Time** - The saving of time on site will partially be offset by the additional time to design, assemble and ship to site modules, this does not align with the 50% required overall reduction in time (from beginning to end of new build and refurbished assets) in the Construction Strategy 2025.

Pre-construction time is extended where off-site is the sole delivery method due to a potentially linear critical path (the least risk approach);
- Proof of concept testing (mock-ups and samples) to prove repeatable elements do not have defects built in.
- 100% design for elements to be manufactured (including their integration into the wider building).
- Lead in for the manufacturing period once the design is approved.

**Labour Force and Skills** - The government construction sector deal is focused on creating highly paid construction workers for the future, does this align with a drive for Off-Site, which does not need these highly skilled constructors only assemblers and factory workers (as per the automotive industry) are they deemed to be in the construction industry?

**Client Finances** - Clients have to plan better and commit cash earlier to ensure off-site is delivered in full. Spending profile is front loaded for customers and clients, demanding earlier commitment to constructors and their teams.

**Design Change** - Change is expensive and the freeze point is earlier.

**Quality of product** - Poor Design or Assembly errors will be repeated multiple times, building in defects across an estate or group of buildings.

**Risk** - The same risks that apply on site for quality have not been removed, they have been moved to an earlier stage in the project, you could consider this as an increase in risk not a decrease as the project is potentially not as well understood by all parties.

What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

- Supply chain skills, capacity and capability
- Supply chain resilience
- Cash flow
- Risk apportionment
- Time available to develop solutions including the procurement period.
- Building Type, complexity and suitability for an Off-site assembly
- Client appetite
- Procurement route
- Building Design life
- Individual or corporate knowledge of the availability or value of off-site assemblies
Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

Yes, off-site at module and assembly level does not constrain the architectural ambition of key public buildings, however most need to focus on function as a primary driver to maximise whole life cost benefits.

Most off-site is not focused on Whole Building Solutions only elements within the building such as major services or components and construction elements such as facades, ceilings, doorsets etc.

Architectural ambition can be delivered within a “kit of parts” type approach to standardisation and off-site manufacture but will be much more difficult where a more unique or bespoke approach is adopted to design.

What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

The evidence is not well recorded or analysed to determine the true benefit or otherwise of a 90% plus off-site manufactured building, a focus on detailed performance data for buildings would allow a focus on areas of opportunity.

The use of standard materials, modules and assemblies is slowly becoming more prevalent in the industry as they can offer speed, quality and increased safety in many instances. However current design and pre-construction times do not allow designers and suppliers to maximise the use of this methodology. See DHSC ProCure 22 exemplar framework.

A significant amount of effort needs to be focused on education of the teams responsible for Estate or Capacity Planning, seeking finance, developing briefs and procuring while buildings using off-site or buildings where the potential to have large elements assembled off-site for installation on site.

<table>
<thead>
<tr>
<th>Type</th>
<th>What is needed?</th>
<th>Potential Outcome or Benefit</th>
<th>By Who?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>Improved pre-construction processes to remove a portion of the potential additional design time inherent in off-site design, assembly processes (focused on a whole building solution); Consider a focus on an approach that only allows only a small a portion (circa 10%??) of any design to be bespoke (that can be influenced by any give client).</td>
<td>Benefits in lower costs, reduced exposure to inflationary pressures. Better pipeline capacity. Standard buildings across an estate that allow for easier maintenance regimes</td>
<td>Industry and client Bodies to sponsor BRE or similar?</td>
</tr>
</tbody>
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### Research

| Whole Life Cost Modelling of buildings that have been designed and assembled using an off-site technique. I.e. some methodologies in the construction of the UK prison estate are more effective than others, though we perhaps do not know which is better over a typical lifespan of a UK prison. E.g. - Very lightweight composite wall prison wings at HMP Channings Wood and HMP Erlestoke verses the concrete solutions offered at HMP Cookham Wood. | Zero in on the best techniques that reduce overall cost in use for clients and customers. WLC focus reduces the current industry race to the bottom to win projects. | Relevant Central Government Department and framework partners and suppliers. Investment in UK university to undertake modelling? |

### Develop

| Develop a procurement route (for whole buildings) that meets the additional demands of an off-site approach; namely 100% design completion and approval, the need to have a business case signed off earlier in the process and provision of funds early to allow the securing of factory slots removing excessive lead in times. | Create certainty for suppliers that early efforts will be rewarded. | UK government – Crown Commercial Services or similar with UK major Contractors Group. |

| Better/ more accurate performance criteria for buildings within typical construction sectors, focusing on outcomes required for a buildings whole life. | More standard buildings in any given estate. The best solution |  |

| Skillsets of clients and procurers in the additional constraints an off-site focused building places on projects. | Tenders focused on Off-site from the outset, more visible pipeline for the off-site specialists. |  |

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**What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?**

- Off-site focused projects have a different spending profile that a traditional construction project and client’s need to have funding in place and approved to a different timescale, for example, booking a factory slot for the production of modules needs to be done significantly earlier in the process, this demands early capital commitment from clients and therefore the business case process may need to be re-examined with earlier contractor involvement (See new NHS Proton Beam facility at Manchester for case study of advantages of Early Engagement).

- Procure earlier on performance standards not on designs that cannot easily be converted to the off-site solutions
Use more collaborative procurement routes such as two stage to ensure client aspirations can be accommodated by off-site techniques

Focused on whole building procurements; engagement of the key suppliers early to allow capacity building and prevent delays due to factory space or labour shortages.

○ Procure across programmes of work, placing high level "commitments" to off-site manufacturers for call of by successful contractors

24 April 2018
Question 8:
What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

1. We start with this question, because unless it is correctly answered, all the aspirations for off-site manufacture, both in principle and in terms of its effectiveness, will be of little avail.

2. Despite reports over the years, culminating in Latham and Egan, the structure of the construction industry is still fragmented – between the consultants (with predominantly conceptual skills) and the contractors (with predominantly practical skills).

3. Traditional procurement and contractual processes place a divide between these two sectors, and this divide is the root cause of poor quality, delays, process waste and disputes. Under modern procurement models, consultants and contractors are appointed simultaneously so that they can integrate their conceptual and practical skills in a fully collaborative environment.

4. In an “alliance” of consultants and contractors (with their supply chains) architectural ambition can be realised with the benefits of standardisation and factory manufacture. Furthermore, this can be achieved economically in terms of both time and cost because of the contractors’ and their supply chain’s knowledge of manufacturing and assembly processes.

5. But this knowledge must be transparently shared on a “best for project” basis. The team must be fully collaborative, and all members must have the same motivation, aligned to achieving the client’s success criteria.

6. The same prerequisites apply to Building Information Modelling (“BIM”). It is an ideal tool to obviate the use of specifications that offload risk and eliminate multiple types of drawings (saving waste of time and cost); but it will only deliver its full potential in a fully integrated and collaborative environment.

7. As part of the Government’s Construction Strategy 2011 three new procurement models were endorsed for trial. A representative of the Cabinet Office at the time differentiated the “Integrated Project Insurance” (“IPI”) model from the other two as below:

"Each of the New Models of Construction Procurement was developed by industry and government working together to challenge ourselves on how we can best drive collaboration and release the efficiencies that we all believe are there for the taking. The IPI approach takes things a stage further with its unique insurance arrangement that has its focus on insuring effect, rather than cause. The
potential this has for changing 'normal' commercial behaviours towards creating a truly integrated team can’t be emphasised enough. It is radically different, but then we’re looking for radical improvements to project delivery”.

8. The Select Committee is referred to two published documents via these links:

9. Pertinently to this Evidence, the Foreword to the Prospectus states:

   "The approach offers a game-changing opportunity for the future, and it is ideally suited to modern off-site delivery models which the Autumn Budget 2017 committed central government departments to adopt by 2019”

**Question 2 (part):**
**What is the evidence that offsite manufacture can lead to:**
- lower costs, faster delivery and increased quality?
- increased productivity?

10. The evidence below is taken from the Dudley College Advance II pilot project, which was monitored by Reading University under Innovate UK project 101345, and is offered by James Blood of Metz Architects in relation to Questions 2 and 5

11. We had a prefabricated plant room which meant that these works were delivered in parallel to the onsite works, providing the obvious reduction in time, and then craned in and sited on the roof. Due to the condensed project programme the building on site wasn’t watertight when these works needed to commence, so it meant that they could start when we needed them to, and in an environment much more suitable to the task. Also due to their being carried out in a more controlled environment, the quality was very high, not to mention the opportunities for better recycling of any waste materials.

12. We had brackets for the SIPS (structural insulated panels) prefabricated and installed prior to the panels being delivered which optimised the erection. The SIPS panels themselves were manufactured off-site, allowing us to start manufacturing them in tandem while the steel frame was fabricated and installed - which again had obvious programme benefits. Also, as they were a manufactured item, not constructed on site, this ensured they were produced to tighter tolerances which meant that the thermal and air tightness performance was more robust. This helped someway to close the building performance gap between what was designed and what was delivered which is also a major issue facing the construction
industry, especially in the context of the carbon reduction targets we are signed up to achieve.

**Question 5:**
Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

13. In the opinion of the architects on Advance II (Metz) off-site manufacture enhances architectural ambition, as more can be achieved, and at a higher quality, when constructing things in a more controlled environment like a factory.

**Author:**
Martin Davis, Chairman IPInitiatives and IPI Mentor for the Cabinet Office
James Blood, Technical Director, Metz Architects
on behalf of the Dudley College Advance II alliance

25 April 2018
Kier Construction Ltd – Written evidence (OMC0024)

Context

How do you define off-site manufacture?
1. In the context of this response, we confirm the definition of off-site manufacture (OSM) for construction as the design, planning, manufacture and pre-assembly of construction elements or components in a factory environment prior to installation onsite at their intended, final location.

Perceived Advantages of offsite manufacture for construction

What are the opportunities offered by offsite manufacture for construction?

2. The opportunities offered by offsite manufacture are sufficiently broad as to potentially create a new paradigm. WPI Economics review\(^ {24}\) references productivity, economic, social and environmental benefits, principles reaffirmed by multiple sources (London Assembly\(^ {25}\), McKinsey\(^ {26}\), Farmer Review\(^ {27}\), IPA\(^ {28}\), KPMG\(^ {29}\), etc etc). Through application of OSM, we have achieved:
   - Efficiencies in time and cost at pre-construction and construction phases
   - Enhancements in quality, certainty of delivery and customer satisfaction
   - Reduced waste and minimised SHE risk through controlled product assembly and planned logistics
   - Developed, designed and procured standardised component solutions across frameworks, via multi-contractor collaboration
   - Achieved enhanced customer value both in use & maintenance

3. OSM offers an alternative mindset and therefore extends beyond the direct and immediate performance metrics (such as time, cost, quality, safety) to more holistic principles of integration, collaboration and value proposition. At Kier, OSM is an opportunity to optimise performance, which can deliver value if focussed upon customer need and outcome measures for success.

What are the likely drawbacks?

What factors are likely to influence clients, architects, design engineers, contractors, and the supply chain in deciding whether to choose offsite manufacture.

\(^{24}\) The value of off-site construction to UK productivity and growth: WPI Economics (April 2017)
\(^{25}\) Designed, sealed, delivered. The contribution of offsite manufactured homes to solving London’s housing crisis: London Assembly Planning Committee (August 2017)
\(^{26}\) Reinventing construction through productivity revolution: McKinsey Report (February 2017)
\(^{27}\) The Farmer Review of UK Construction Labour Model, Modernise or Die: CLC (October 2016)
\(^{28}\) Transforming Infrastructure Performance: Infrastructure & Projects Authority (December 2017)
\(^{29}\) Smart Construction, How offsite manufacturing can transform our industry: KPMG (April 2016)
4. It is acknowledged that OSM better suits certain sub-sectors, however factors influencing choice of adoption (or not) within the industry are often borne of convention and habit, as much as considered technical & benefit evaluation.

5. To enable offsite manufacture to be chosen at Developed (RIBA Stage 3) or Technical design (RIBA Stage 4) stages, it is essential that Design for Manufacture and Assembly (DfMA) thinking is embedded at Concept Design (Stage 2). Gaps in knowledge, expertise and a lack of supply chain integration at this juncture are current blockers, with recommendations in response captured at paragraphs 14, 15 & 24.

6. The National Audit Office has previously reported\(^\text{30}\) that “if considered in isolation ... traditional methods of construction remain cheaper in many cases, than modern methods of construction, including off-site manufacture”. Whilst qualitative data suggests that offsite manufactured assets may reduce whole life costs, present day bias too often prevails. Adaption of the choice architecture and application of nudges are required to offset current culture of temporal discounting, a point acknowledge by ‘Procuring for Value’ strategy within Government sector deal.

**It is often claimed offsite manufacture can lead to lower costs, faster delivery, increased quality, productivity, health & safety and greater provision of new affordable housing. What is the evidence for this?**

7. The benefits for offsite construction, relative to traditional methods, have consistently been cited across the industry, reaffirmed by both industry peer review and a breath and regularity of academic research, over past 20 years alone (Chart A refers).

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\(^{30}\) Building more affordable homes: Improving the delivery of affordable housing in areas of high demand: National Audit Office, 2005
8. There is within the mainstream construction industry consensus regarding the benefits relating to time, quality, productivity, people and process, ratified by our own application of off-site solutions, however open source evidence remains largely case study specific with an inconsistent approach in measuring & benchmarking the benefit evaluation.

9. As highlighted by the Construction Industry Council (CIC) “Offsite Housing Review” (dated 2013 – commissioned for Department of Business, Innovation & Skills), recognition of these benefits does not automatically lead to a greater provision of new, affordable housing. The housing building sector has its own set of economic and technical drivers, which remain different to the mainstream. The CIC report identified that house-builders have developed efficient supply chains that can deliver demand at a price point that the off-site industry would find difficult to match.

10. Other advantages such as faster build times and enhanced quality are of less significance to the market. Whilst the Private Rental Sector has altered this profile in part, the Rt Hon Sir Oliver Letwin MP’s letter to Secretary of State for Housing, dated 9th March ’18, references commercial and industrial constraints that may otherwise be solved by off-site construction, but reflects that the limitations are “components of the build-out; but they are not the fundamental rate-setting feature”.

11. Equally, there is distinct lack of evidence to suggest that consumers demand improved levels of quality (inc energy efficiency) that may be derived from OSM; prices of new homes for sale in the main are anchored by the assessed value of adjacent and comparable homes. This point is an opportunity that could be leveraged and is a recommended area of review by the Behavioural Insights Team (or others) – paragraph 21 refers.

**Potential barriers to wider use of offsite manufacture**

What are the drawbacks to offsite manufacture for construction?

12. As referenced within paragraph 4, habit and embedded behaviours are key barriers to the wider adoption of offsite manufacture. This is further compounded by:

   a) **Lack of Industry Self-Awareness** – offsite manufacture for construction is often misinterpreted as exclusively volumetric build, with componentised and manufactured solutions overlooked.

   b) **Skills & Knowledge Gaps** – with limited expertise and experience industry wide in designing for & managing OSM. This is particularly pertinent within design, engineering and project management practices, with the catalyst for offsite manufacture residing at Stage 2 Concept Design. Architectural firms that openly advocate offsite manufacture such as Bryden Wood, HTA Design, Chapman Taylor, remain a minority.

   c) **Supply Chain Maturity & Capacity** – the supply chain with capabilities to manufacture off-site is fragmented with a minority of large scale diversified players (such as LOR, L&G Homes, Saint Gobain) and a broader spectrum of SME’s with capacity limitations. Wider use of offsite manufacture for construction is expected to introduce new markets entrants (with maturity
(risk) and potentially stress capacity of incumbent players, with a residual performance risk.

d) **Pipeline** - the market vulnerabilities are amplified by a sensitivity to fluctuations in pipeline, with a lack of long-term planning, confidence and predictable demand a business and sector challenge.

**What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

13. We endorse the principles outlined within the CITB report “Faster, Smarter, More Efficient: Building Skills for Offsite Construction” in reference to re-skilling and training. As Gold Members of the Offsite Management School, we recognise and support the importance of education to deliver sustainable improvements.

14. Focus should be steered towards Digital Design and education of the professional teams, with equal or greater priority to those within assembly, logistics and operational functions. The delivery strategy is typically a by-product of the design and project strategies (not vice-versa) and therefore ensuring that the design and professional teams adopt a DfMA mindset at Concept Design (Stage 2) is critical.

15. Whilst the spotlight has been turned towards CITB, a joined-up training initiative that engages professional bodies such as the ICE, RICS and RIBA (building upon the latter’s DfMA overlay31), is paramount. Kier have initiated ‘Digital Apprenticeships’ to embed this at a grass-roots level, with competency training of existing staff. Broader support and funding is required to extend this wider.

16. In the same vein that the industry has observed the creation of new roles in the BIM environment (Information Manager, BIM Manager, etc), new roles are expected to develop (DfMA Managers, Assembly Manager, Process Engineer, etc), with industry and professional bodies required to collaborate to provide structure around role definition, competency and accreditation.

**Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

17. Via conventional wisdom, standardised (system delivered) bespoke solutions are an apparent contradiction in terms, however manufactured delivery can be realised without hampering architectural ambition. A review of projects shortlisted for RIBA Sterling Prize award (i.e. architectural excellence) since 2011 demonstrates the use of both traditional and modern methods of construction (inc components and manufactured solutions) – Chart B below refers.

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31 RIBA Plan of Work 2013: Designing for Manufacture and Assembly (September 2016)
18. Burntwood School, winner in 2015, was applauded by the judges for the “technically sophisticated” use of prefabricated modular structures, setting a standard in school design. Projects such as Crossrail Farringdon Station, Sainsbury Wellcome Centre, Kings Cross R7 (all delivered by Kier) or 1000 Museum (by Zaha Hadid) reaffirm that modern digital manufacturing methods can enable greater variation and complexity in components, without traditional increase in labour and costs. OSM has therefore become an enabler for complex geometries, and facilitated, not inhibited architectural ambition.

19. Equally architectural ambition does not preclude standardisation – what justification exists, for variations in structural grid sizing within sectors such as schools, for example?

20. Design rationalisation and optimisation, identifying opportunities to apply standardisation without compromising value, can be applied to small-scale as well as large-scale projects and frameworks. Perceptions of OSM being architecturally constraining may be a symptom, and association of the circumstances of scheme brief. Correlation does not equal causation, however the use of OSM for large scale housing developments, may perpetuate perceptions (an area for recommended review).

What R&D is needed and by who, to realise fully the potential benefits of off-site manufacture?

21. **Psychological / Behavioural Science Review:** Research around OSM has typically been structured around technological and economical solutions. Consideration to psychological, behavioural and cultural factors is potentially the greatest opportunity for review. We would recommend that R&D is conducted by **Behavioural Insights Team** (in collaboration with IPA) to maximise adoption of OSM, with consideration towards the psychology surrounding:

a) **Customer Demand** – the adoption of disruptive marketing could potentially lead consumers to attach higher importance to the benefits offered by OSM solutions than the traditional. Trials within the house sales market to test the capacity to alter consumer behaviour and the potential for OSM solutions to be perceived as a Veblen good (with carbon
performance, architectural merit or construction methodology as potential selection variables) should be explored.

b) **Negative Social Proof** – whilst beneficial in many respects, reviews such as Egan, Latham, Wolstenholme and more recently Farmer, serve to highlight industry frailties and prevalence of negative behaviours, inadvertently providing social acceptance to the status quo. The alternative proposition of promoting best practice and standards through a **Marketing and Messaging Campaign** should be adopted. This should embrace ‘Built Environment’ (not just Construction), with alternative corresponding language set – to address a modernisation agenda.

c) **Status (within Supply Market)** – leveraging principles of relative importance within the supply market via potential peer-to-peer benchmarking and / or best practice sharing (beyond isolated exemplars) through aforementioned ‘Messaging Campaign’ is an area to be explored. The entry of Legal & General within the Client & supply market, for example, has stimulated interest, engagement and confidence in others. Similar principles could be applied to the five government depts that have committed to the presumption of OSM to drive their performance.

d) **Status (with the Consumer)** – Similarly, high profile endorsement of OSM solutions, by an artistic brand (such as V&A for example) could be adopted to amplify themes of enhanced quality product or equally tackle misconceptions, otherwise perpetuated by its application in certain scenarios (paragraph 20 refers).

e) **Certainty** – re-framing the language of OSM as a provider of certainty & enhanced quality in lieu of a model of innovation (and perception of associated risk and uncertainty).

f) **Ikea Effect** – it is suggested that individuals place disproportionately high value on products they have partially created. This cognitive bias should be reviewed in the context of OSM, and ‘Procuring for Value’ focus to ensure that decisions and development of innovative solutions are selected objectively.

22. **Design Procurement Review** – the ambitions of developing platform based designs for Government as part of OSM focus is outlined within Digital Built Britain’s review, ‘Delivery Platforms for Government Assets’\(^\text{32}\). This model holds significant potential to unlock value and derive efficiencies, however it equally holds implications for procurement, management and delivery of design (inc ownership of IP and liabilities) that require independent R&D and policy review.

**Government Actions**

*Does the Construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them?*

\(^{32}\) Delivery Platforms for Government Assets, Bryden Wood (2017)
23. A detailed response is somewhat precluded, given that the White Paper summarises headlines only of the Construction sector deal, with policy also understood to be under review of light of Carillion’s demise.

24. Notwithstanding, the following observations are noted:
   a) **Presumption in favour of Offsite Construction by 2019**: The declaration of five departments engaging upon a presumption in favour of offsite construction is viewed as a positive stride forwards. Clarity around the uptake, priority and timing for other high potential sectors thereafter would be welcomed.
   b) **Interpretation of OSM**: The priorities pertaining to OSM are subject to interpretation. It is probable that the supply market will respond to the declaration of presumption with development of ‘new products’. The establishment of standards, accreditation and education around concepts such as technology readiness levels (learning from Government’s position in other sectors [https://www.gov.uk/government/news/guidance-on-technology-readiness-levels](https://www.gov.uk/government/news/guidance-on-technology-readiness-levels)) is required to anticipate a rise in new solutions.
   c) **Prioritisation of Design**: Clarity is required from the Government in relation to the priority it places upon adoption of Delivery Platforms through design, to avoid a focus bias towards product development.
   d) **Training (Upskilling of Client Base)** – whilst looking outwardly the Government should also consider competency, potential skill gaps and the need for training of its own commissioning teams, recognising their pivotal role in setting leadership, direction and management of OSM adoption.
   e) **Expectation Management** – whilst there is consensus regarding the benefits to be derived from OSM, it is important that the expectations upon speed of benefit return are tempered (learning lessons from industry adoption of BIM). Gartner’s innovation cycle identifies that the peak of ‘inflated expectations’ precedes the ‘slope of enlightenment’; acknowledging that certain initiatives relating to OSM adoption will be innovative / trailblazing the timeline for return on investment should be judged accordingly.

**What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?**

25. We generally endorse the 5 priority interventions identified by the Infrastructure and Projects Authority within Transforming Infrastructure Performance (TIP) report regarding procurement; particularly in respect of standardising and simplifying contracts, with processes structured to support longer-term, collaborative relationships.

26. We would also recommend:
   - Mandated procurement of DfMA Strategy as part of Outline Business Case production – with outputs linked to the evaluation of Optimism Bias within Green Book.
   - Review & re-evaluation of process barriers that otherwise preclude the engagement of Tier 1 & Tier 2 contractors at RIBA Stages 2 & 3 (and in turn inhibit value adding specialist input).
Development of terms to respect equitable risk ownership, recognising the frailties of the supply market, including specialist provision for the integration of off-site manufactured solutions and frameworks across multi-project opportunities.

Review of project level insurance policy to re-aggregate fragmentation & interfaces of legal liabilities that otherwise discourage innovation, shared design and product assembly models.

25 April 2018
Kingspan are a committed innovator and manufacturer in factory-manufactured off-site systems for industrial, commercial and residential building applications. Our capability in this sector in the UK is currently £270 million p.a. of business activity.

Turning to the future, the UK factory/off-site methods of construction is niche and not fully embraced by property sector investors/developers and their design teams thus any “driver” initiative needs a pan-Government/industry approach involving all key stakeholders. Recommend we establish and set-up a group of informed leadership experts to develop a pathway in to the wider application and use of off-site methods. The industrial building sector did this in the 1970’s/80’s with great success and are now world leaders in the application and use of off-site/factory methods.

We would be pleased to support the committee in their work which is now even more essential for the UK construction sector to recover best practice compliance/quality and value post-Grenfell.

**Off-Site Manufacturing Opportunities & Advantages**

1. Certainty of compliance with mandated Building Regulations and Standards.
2. Factory quality ensures 100% ‘right first-time’ specification quality and site build.
3. 45% faster site build compared to conventional construction methods.
4. Accelerated time to market optimises business income stream and quicker return on investment (ROI).
5. ‘Core & Shell’ off-site construction enables earlier internal fit-out and M&E services installation, cutting overall project build, completion and handover programme(s) by up to 25%.
6. Off-site manufactured systems facilitate simpler and rapid site assembly with less reliance on site crew skill level(s).
8. Enhanced site safety due to reduced time on site and working at height.
9. Increases site build productivity by up to 45%.
10. Off-site construction methods reduce total project capital costs by up to 8/10%.

11. Off-site methods provide a high level of sustainability, zero waste, less transportation and lower embodied carbon – suitable for end-of-life recycling and re-use.

| 100% right first-time quality | 45% faster site construction | 25% Reduction in overall project build programme |

**Drawbacks & Barriers**

1. Property investors/ funds, developers and design teams have zero/ low level of awareness and knowledge of the commercial, technical, architectural, productivity and quality benefits of off-site construction.

2. Off-site construction is perceived as modular-boxes with poor and uninspiring architectural expression – this needs addressing by the architectural community and industry.

3. Construction industry resistance to change from traditional methods of construction.

4. Perception that off-site methods have limited durability and life-cycle periods compared with masonry.

5. NHBC resistant to off-site methods and insurance support.

6. Resistance by developers/ investors to commit to the application of using off-site methods at an early project stage: ie. RIBA work plan stage 0-7 [www.ribaplanofwork.com](http://www.ribaplanofwork.com)

7. Developers and contractors prefer elemental type construction methods to allow wide range of ‘value-engineered’ procurement competition.

8. Off-site construction methods require a holistic and integrated project design and construction commitment at the early stage of a project.

9. Off-site construction methods require industry to commit to large scale up front product development, product certification and manufacturing investment. The UK off-site market in 2018 is a niche sector.

10. Most construction/ buildings are bespoke and project specific and do not lend themselves to scale of standardisation. However, the industrial
building’s sector and industry have achieved a very high degree of a
standardised approach, combined with efficient/ productive off-site
methods including rapid site assembly and quality.

11. The Japanese have also a large scale residential off-site sector which
provide totally individually/ bespoke homes.

12 April 2018
Laing O’Rourke would like to thank the committee for taking the time to focus on offsite manufacturing and look at what more can be done to support this step-change in the construction industry. As one of the UK’s leading construction and engineering enterprises, we have both the ambition and, through our offsite component manufacturing facilities in Nottinghamshire and our mechanical and electrical (M&E) manufacturing facilities in Oldbury, have the capacity and capability to deliver high-quality, engineered offsite solutions at volume, across all sectors within the built environment.

**Defining off-site:** At Laing O’Rourke, offsite is best articulated through our proven Design for Manufacture and Assembly (DfMA 70:60:30) approach which enables 70% of a project’s construction to be conducted off site, leading to a 60% improvement in productivity, and a 30% improvement in delivery schedule.

**1.1 Perceived advantages of off-site manufacturing for construction**

Offsite manufacturing offers the opportunity to ‘turbo-charge’ capacity and wider economic productivity in the UK and responds to many demands of the Industrial Strategy.

Improved **sustainability** through accurate, cost and time efficient build delivers high quality projects that are energy efficient and offer whole life benefits to the end user. The sophistication of digital planning allows for a **highly flexible** build process well suited to built-up urban environments. **Productivity** is improved through a more efficient, **high-tech** design and delivery process less reliant on traditional on site construction works, utilising techniques that necessitate diverse, **highly-skilled**, well paid engineers and technicians throughout the UK; and the accuracy and comparative ease of assembly offers a **safer and healthier**, more attractive working environment. The accuracy and quality of the build minimises the risk of additional costs, providing **value for money**; and investors are attracted by the clearer return on investment offered by predictable timescales and greater opportunity for risk and reward sharing.

**1.2 What are the likely drawbacks?**

While the opportunities for offsite are considerable, industry and Government should be cognisant of the barriers or perceived drawbacks.

**Out-dated perceptions** of offsite manufactured products remain within our culture and the term ‘pre-fabrication’ continues to conjure memories of ‘post-war’ high-volume, standardised and low-quality homebuilding. Offsite manufacturing today is driven by precision engineered, quality products delivered more efficiently. A consistent and evidence-based narrative is needed to instil confidence, and the Government can continue to lend support by positioning offsite as a core component of its long-term strategic approach to a more productive nation.
For offsite methods to become the norm and transform the way in which the built environment is delivered, industry needs **confidence and visibility of pipeline**, at a regional and national level. With higher demand and volume visibility, industry will be more encouraged to invest in advanced technology, research and development, skills and training. Government can support surety of pipeline by adapting its procurement methods; adopting an off-site-first approach. Public procurement processes that incentivise smart digitised construction and offsite manufacturing will signal confidence to the market and help to unlock investment. An offsite manufacturing approach will best deliver cost efficiencies and whole-life value through repeatability and volume, and this is discussed in more detail within our response to question eight.

### 2. Evidence of benefits

Offsite manufacture brings benefits across all sectors. While there is a growing bank of available evidence, industry and Government should work together to agree consistent data collection parameters, thus continuing to build confidence in the approach. The following three short case studies provide evidence of various, and inter-linked benefits.

**Box 1: Crossrail**

As part of the Crossrail programme, Laing O’Rourke has delivered Tottenham Court Road and Liverpool Street. While both stations had similar scope, the similarly sized 450 metre platforms were built using very different methods, the former relying on traditional in-situ and latter applying DfMA solutions, where 460 precast concrete elements were manufactured at Explore Industrial Park, in a controlled factory environment.

The offsite approach delivered an 11-week programme saving with a reduction in people required to work in an underground environment, with an associated elimination and mitigation of occupational health risk. The comparison of the two approaches offer evidence of **faster delivery, improved health and safety** and ultimately, **increased productivity**.

- **41-week construction period at Tottenham Court Road versus 30-week construction period at Liverpool Street.**
- **57 skilled operatives required to deliver the in-situ installation at Tottenham Court Road versus seven people on site, and 27 people in the factory to deliver Liverpool Street.**

**Box 2: Two Fifty One, London**

The 41-storey tower is one of the tallest residential buildings in London. Through early engagement, a DfMA approach was employed from the outset allowing 70 per cent of the main tower to be built offsite; taking only 70 weeks to build from the ground floor to level 40.

At peak delivery, a new floor was completed every six days; using traditional methods a floor would be delivered every nine days. The façade of the building maximises DfMA, with 1,000 manufactured concrete panels with windows and doors pre-installed before being fitted to the building.
The process has delivered a quicker construction programme, with greater consistency and quality and a safer working environment.

**Box 3: Road and Rail Bridges - Stafford Area Improvement Programme (SAIP)**

Network Rail partnered with Laing O’Rourke, Atkins and VolkerRail to form the Staffordshire Alliance to deliver a vital programme to increase the speed and frequency of trains on the UK rail network linking London, the Midlands and the North West and Scotland. The Alliance, was underpinned by collaboration between the partners from the outset. Five of the 10 bridges used DfMA methods, with a bridge taking just a week to deliver. The overall SAIP was delivered 12 months early, within budget, with a 40% labour reduction and a 40% programme reduction, providing savings to the taxpayer. On the basis of this success, the approach was adopted for the East West Rail Programme, with the Alliance involved earlier in the project process.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

Architectural ambition need not be hampered through standardisation. A good design approach will look to minimise as much as possible the non value-adding variation through appropriate standardisation; for example structural grid sizes or column dimensions in a range. In car manufacture, customer choice is offered through a wide range of configurable options and price-points but the use of common fixings, standardises the assembly process. Similar techniques can be applied to construction. A façade system can have a common set of fixings and dimensions, but offer different options in terms of facing materials or even facing geometry and relief. Laing O’Rourke already deploys some of these approaches, for example, in the Glass Reinforced Concrete tunnel lining panels for Crossrail Tunnels, where the design was re-engineered to support common fixing arrangements to support better installation processes. Laing O’Rourke’s DfMA 70:60:30 approach was also used successfully at British Land’s Clarges development in Mayfair, a collection of some of the city’s most sought-after ‘super-prime’ apartments – without compromising architectural individuality or the quality of finish.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

The three areas of focus for R&D as set out in the construction sector deal of Digital, Manufacturing and Performance, is aligned and constant with Laing O’Rourke’s priority areas. The i3P roadmap provides an initial industry level view on the main elements within these areas, as well as enabling aspects such as business models, culture and procurement processes that should also be addressed.

For innovation to be adopted and for R&D investment to deliver the desired returns in productivity, profitability and sustainability, it is critical to address the route to market. The industry must become more systematic in progressively identifying requirements, demonstrating, and gathering evidence to support
wider uptake and deployment. Procurement processes need to incentivise and reward the development and adoption of new methods.

Laing O’Rourke has found Innovate UK funding an important mechanism to support the innovation process, enabling collaboration more widely than possible without external support, and this should be further supported through the Industrial Strategy Challenge Fund. The roles of Catapults and Universities is welcome in supporting this, but particularly in this sector the real challenge is adoption and deployment of new technology and practices within the challenging construction environment. This innovation needs to be industry-led, and continued support to industrial companies large and small is needed to help encourage uptake and learning of the R&D and deployment processes. Links between future workload, innovation and skills capacity building needs to be further improved.

7. Government actions. Does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

We welcome the sector deal and have been active in supporting it during its formation, and are hopeful that it will support the change we would like to see in the industry. Critical will be to support industry in enabling it to engage with uptake, and deploy new technologies and methods, particularly through public procurement policies as outlined below in response to question eight.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

Continuity of workload is a significant factor for the construction supply chain. Where future workload can be made more visible and also more contractually secure, but still tied to performance, this enables the supply chain to anticipate a return on investment in capacity, skills and innovation, including facilities for offsite manufacturing. The November 2017 budget (4.52) stated that Government will use its purchasing power to drive adoption of modern methods of construction including offsite manufacturing. This is an encouraging move that we strongly welcome and support, but better procurement approaches need to be more consistently adopted, across all departments and this will require a change in current practice, culture and behaviours starting with client organisations.

To support this approach we recommend more collaborative forms of procurement based on longer term strategic relationships. Having contracts structured to enable multiple sequential delivery over a period of time enables visibility of continuity of resource and the ability to invest in and benefit from progressive learning and innovation. Although current procurement has used frameworks, in practice this has not consistently resulted in the intended outcomes due to the nature of the base contracts and fragmentation of workload; with each successful partner incurring excessive costs of bidding, oftentimes with little or no commitment and resulting in insufficient workload to be viable. Our preference is to adopt procurement more aligned to collaborative
Laing O’Rourke – Written evidence (OMC0055)

Alliance methods, whereby project participants are properly enabled and incentivised to deliver better project outcomes. One example is the Stafford Area Improvement Programme, as evidenced in question 2 above.

The Construction Leadership Council Innovation in Buildings “Demand Surety” working group has published a position paper recommending longer term strategic relationships and has commissioned King’s College London Centre for Construction Law to develop a model contract for such relationships, based on the Framework Alliance Contract. In related work, Ann Bentley, is leading a Construction Leadership Council workstream on “Procuring for Value”; the ICE’s Project13: From Transactions to Enterprises; and the IPA’s “Procure for Growth” strategy set out in “Transforming Infrastructure Performance” are all seeking to support this objective. Laing O’Rourke is working with private sector partners to develop longer term strategic relationships and agreements to support enhanced delivery and project outcomes.

26 April 2018
Laing O’Rourke, Severfield and NG Bailey – Oral evidence (QQ 41-49)

Tuesday 8 May 2018

Watch the meeting

Members present: Lord Mair (Chairman); Lord Borwick; Lord Fox; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Maxton; Baroness Morgan of Huyton; Baroness Neville-Jones; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 6 Heard in Public Questions 41 - 49

Examination of witnesses

Dr Sarah Williamson, Martin Kelly and David Hurcomb.

Q41  The Chairman: Welcome. Thank you very much for bearing with us and I apologise for the delay. As you will probably have noted, there was a Division in the House, so we had to stop the proceedings of the previous session in order to vote. Unfortunately, it looks as though it will happen again. Nevertheless, I feel that we should make a start, because there are many things that we are interested to hear from you.

I will begin by asking each of you to introduce yourselves, and if you wish to make an opening statement, please feel free to do so.

Dr Sarah Williamson: Good afternoon. I am the technical director of Laing O’Rourke and I have been with the company for the past six years. For the past three years I have been working predominantly on the Hinkley Point C project at Somerset as part of the bi-Laing O’Rourke joint venture with Bouygues Travaux Publics.

Martin Kelly: Good afternoon. I am the strategy director of the Severfield group. Severfield is a structural steelwork provider. Structural steelwork is one of the longer-standing proponents in the off-site environment. We have been working in a factory environment and delivering work to sites since the 1970s.

David Hurcomb: Good afternoon. I am the chief executive of the NG Bailey Group, which operates in the mechanical and electrical installation and maintenance space. We are a family-owned company that has been going for nearly 100 years. We started getting into off-site assembly manufacture about 17 years ago. I am a real champion of it and I would like to see lots more of it, so I am delighted to speak to the Committee today.

Q42  The Chairman: Thank you. Before I ask the first question, I should declare an interest in that I have an association with Laing O’Rourke, which is very closely connected to my university. I am also a consultant to Laing O’Rourke, although I have very little to do with off-site manufacture. My work with Laing O’Rourke is more to do with
underground construction and tunnelling. I thought I should make that clear.

We have heard a lot about the advantages of off-site manufacturing. What are the barriers to the wider uptake of off-site manufacture?

**David Hurcomb:** I think it is about an understanding in the design community of how to design for manufacture. Most designers will have been trained many years ago in traditional methods, so they do not do not have the knowledge and expertise in how to design for manufacture. The commercial reality is that it is of no real interest for them to do that if their clients are not seeking it. So it is usually the contractors and the companies that physically install and build these buildings that get the most benefit in programme certainty and so on.

So there is a commercial reality here, along with a question of knowledge and skills. We are still very fragmented between design and construct, and unless you have design and construct in the same envelope, it is really hard to influence the client.

**Martin Kelly:** I agree. There is also something fundamental about the nature of the construction industry. It is a very large and fragmented industry, and the knowledge base in it is equally fragmented. There is a circularity—

**The Chairman:** I am so sorry, but already we are being interrupted. There is a Division in the House and we will have to stop the session. If you can be patient, we will resume in about 15 minutes.

*The Committee suspended for a Division in the House.*

**The Chairman:** We are now in a position to resume. Mr Kelly, if you can remember where you were, please continue.

**Martin Kelly:** I was following on from what David said.

There are three main areas where there are barriers. We have talked about one: design. There are challenges to off-site methods being specified from a design perspective. There is a challenge for the industry generally in that it is fragmented and the players are often quite small and not always suited to adopting off-site methods.

There is also an issue with the contractual structure of the industry in that it tends to be in silos. Similar trades do not work together as effectively as they could. There is a circularity in all that, which is that we cannot demand that designers design off-site solutions, because they will turn to the industry and point out that off-site solutions are not fully available, and so it goes on. That is the real challenge for the industry: how do we break the circularity of an adoption that has not fully taken place?

**Dr Sarah Williamson:** I agree with much of what David and Martin have said. In many instances, the barriers are more about perception and thus potentially more about cost. Rather than talking about the benefits of consistency of product, reliability of programme and a reduced reliance on traditional construction skills, what comes across is an increased up-front cost and perhaps in many areas a perception about quality. People have in their minds the prefabrication of the 1960s and 1970s post the Second
World War, which is not at all like the componentised offering of off-site construction that we see today. There is that perception.

On organisations that are providing modular or off-site offerings, there is difficulty in seeing a pipeline. Significant investment is required in order to develop componentised solutions, whether in structure, MEP services or whatever it might be. Without the visibility and the demand, it will take something to push such investment forward.

There are other components in this such as the regulatory influence. I know that my own organisation has had some success with private clients who can see the benefits of certainty in programme. For example, a residential developer will want to know when they will be getting their rental income, so they will be quick to see the benefit of having a componentised solution. We have started to bring a lot of things into this, and componentisation lends itself to being more what we call digital engineering. We get to the point where we have real security of programme and assembly sequence, and an enlightened client will see the benefit of that because within a short space of time they will have a realised programme that is producing income for them.

In other areas, it is more difficult to get that traction. Speaking from my recent experience in the regulatory environment, there is a massive drive towards safety, which clearly there should be, but with the slight twist that could move towards componentisation and modularisation, which would give an industry that traditionally has struggled with cost and programme the opportunity to achieve reliability.

I am sorry if that answer is rather long, but there are a number of intertwined barriers to the uptake of off-site manufacturing componentisation.

Q43

Baroness Young of Old Scone: Perhaps I may turn the question the other way around. Is there a silver bullet, a big breakthrough, or a leader out there who could break this cycle and make it happen? At the moment, it is going round and round with a small amount of incremental change, but it sounds as though that could take a very long time.

Martin Kelly: My view is that there needs to be a client who starts that circle. It is not for the supply chain to offer, it is for the client side to demand. There are a number of ways in which we can think about the circle. One is that certainly the public sector is a client, and if it chose to do so it could be more prescriptive about what levels of off-site are required in public procurement projects. Similarly, it could incentivise private developers to take a more off-site approach, in which case again you would see a top-down drive for pushing their designers to specify off-site, which would of course have the recurring reaction of the supply chain providing the right solutions.

Baroness Young of Old Scone: What sort of incentives would you see that comprising? How would you incentivise the private developers?

Martin Kelly: You are perhaps looking at tax incentives in the form of an extensive of R&D-type tax credits that would drive a different level of behaviour. An example is how effective it was for the construction industry when public sector projects insisted on adopting BIM. That has
worked its way through and now it is not just public sector projects that adopt BIM because it is actually a good thing to do.

A huge number of private sector projects have now adopted BIM. The kick-start that came from the public sector requirement gave everyone enough time, understanding and financial incentive to say, “We’re prepared to develop our understanding of BIM”. I think we could get something similar in off-site.

**Dr Sarah Williamson:** I support that. There is a huge opportunity for the Government to use their buying power in public projects. There is also something in planning and development. We have two ends of the scale. We have done lots of modularisation in off-site for highways projects and HS2. We have examples of Crossrail projects where the benefits have been clear to see.

At the other end of the scale, there is a huge opportunity in the housing market, but it seems to stick doggedly to its guns and building with bricks. However, there are requirements for developers to build affordable housing, so why not drive a bit of innovative thinking into that part of the market and ask them to consider off-site quality of design and other criteria than are currently required?

**Lord Hunt of Chesterton:** Could wholesale companies not exist that would make all kinds of beams and other elements, so that small builders could continue to operate but they could get these significant components? My impression is that that happens on the continent. In France, for example, you can have lots of houses, all of which contain similar components but they are designed differently. There must be a company or organisation that is producing all those components. Are there companies in Britain doing the wholesale construction and marketing of building components?

**David Hurcomb:** Not at the moment, because the UK is very much about control of the land. Once you have the land, you have the key resource and you will then want to sell your design, which is manufactured to a cost that will allow a return to be made.

There is no wholesale provider of the bigger components. Obviously roof trusses and so forth are very standardised, but not the actual layouts of properties.

**Lord Hunt of Chesterton:** Do you not think that it will happen in the future?

**Martin Kelly:** There is the potential for it. To some degree, elements of it have already happened in things like structural insulated panels and roof trusses that are pre-manufactured. You can get elements of pre-manufacture. Perhaps one of the challenges is that you will have a single trade such as roofing—roof trusses is a single trade—and we tend to be specialists in our own area.

Let us take the example of my company, which prefabricates steel. We limit ourselves to prefabricating steel. We could not move into the MEP space or the concrete space, because steel is all we know. One of the challenges is that most of these components require an understanding of
potentially working with other trades or specialists, and we have not encouraged that in the UK.

**Lord Hunt of Chesterton:** It is clearly different, is it not, in some of the other European countries?

**Dr Sarah Williamson:** In Sweden, for example, 85% of properties use off-site prefabrication, so there is a massive opportunity in the UK.

**Lord Griffiths of Fforestfach:** I thank you for the evidence you have given so far. What interests me in this session and in the previous session with people who are intimately involved in the industry is that one example after another has been quoted, including HS2, Highways England, BAA and GlaxoSmithKline.

First, on a scale of zero to 100, how much construction at present is actually done in this modular way in the UK? Secondly, if I were working for a company and the CEO told me to look after the construction of a new building, there would be dozens of examples of modular construction. I must ask, therefore, why this is not already happening.

**David Hurcomb:** It goes back to what I said earlier about the commercial reality of the way the industry works. If you want a building, you will appoint a team of professionals that is probably led by the architect and the designers who will want to design in the traditional way. The more hours they spend designing, the more revenue they make, whereas if they create a plug in and play, modularised and componentised system, I would think it likely that their fee income would decline quite substantially. They would be putting a series of components together to achieve an output specification. There is quite a lot of commercial tension in this.

**Lord Griffiths of Fforestfach:** Are you not looking for a Walmart or an Amazon to come along and say, “We’ll take the initiative”? Going back to Baroness Young’s question, if you had a leader, a disruptor, in the industry, that would change things.

**David Hurcomb:** Yes. It is most likely to come from overseas and perhaps from China, which is looking at some very serious technology, including the 3D printing of concrete structures. It has actually built a 20-storey office block. We will see that silver bullet of an organisation in the UK, but because of the fragmented nature of the commercial relationships it is very difficult, although it might happen.

Another thing that is driving the conversation today is that a chronic skills shortage is looming, and obviously we know that with Brexit that might get a whole lot worse over the next 18 months or so.

**The Chairman:** We will come to the question of skills later.

**David Hurcomb:** Going back to the reason for using off-site, if I was a client I would be thinking about security of resource to build my project. I would be thinking, “These guys use off-site and they do not need a lot of resource”. I would be talking to the contractors who are utilising these techniques.

**Lord Fox:** We have talked about clients and different sectors quite a lot,
and there seems to be a distinct difference between the commercial sector and the residential sector.

Dr Williamson, you have just said almost in exasperation that they are still building with bricks. I wonder if that is because the buyers of houses want them to be built of bricks. What market research has gone into what people want? If I was buying a new house, I would not buy one built using a technology that had only been around for five years, because history has proved that in many residential situations it has tended not to be as good as it promised.

How can you convince not only the housebuilders but the people who will be buying the houses that perhaps they do not want to go for a brick-built house? What would convince me as the buyer of a house?

**Dr Sarah Williamson:** That is a very interesting question. I go back to the first point I made about one of the barriers, which is perception of the quality. You will think straightaway about a property that you may have seen as a child that was not of the best quality or you will think about places like Ronan Point.

There is another side to this, which is the risk factor for investors. As a self-builder, for example, you would struggle to get a mortgage. It is not a technical question that I can give an answer to, but a huge amount of work is now available that demonstrates that if you go for a componentised approach, the materials are understood. Going back to the 1960s, we did not really understand how in-situ products were going to perform and we made some fairly significant errors with reinforced concrete and salt.

**Lord Fox:** That is what I was thinking of.

**Dr Sarah Williamson:** If you lay out two plans—a brick-built house and a prefabricated, highly engineered product—while you cannot account for personal taste you could have something that is going to be a really nice use of space, is energy-efficient and sustainable. That is the kind of discussion we need, along with an understanding that this is not just about bolting together panels, these are highly engineered products.

**Lord Fox:** We have talked in other evidence sessions about using big public sector housing projects along the lines of Ebbsfleet to kick-start this technology. Is there a danger that it will be looked on as second-class housing because of the stigma of prefabs and so on? I do not have the data on this, but people seem to like brick-built buildings. Is there a danger that in using the public sector to kick-start this development, it might stigmatise it at the same time?

**Dr Sarah Williamson:** I suppose there is a risk, but if it is understood it can be mitigated. With some of the new prefabricated houses, if someone likes brick-built they can have brick cladding on the outside, which would also have been prepared in a factory in the warm.

**Martin Kelly:** We talk about housing and residential, and there is a part of us that will always focus on the two and three-storey green-belt estate that is being built by a housing developer, but actually there is a significant amount of development of inner-city, urban housing for the
private rented model. Most of the residential in London falls into that category because of the density required: it needs to be towers. We should look at some of the new off-site solutions that are being driven in that market. It is certainly present in the PRS market.

**Lord Fox:** I was not expressing a personal view.

**Martin Kelly:** No, but there is demonstrable quality in that market and a traction that goes beyond the familiarity of bricks and mortar.

**Q46 Lord Borwick:** Could we talk about the business models in the construction industry? How would the cash flow change if you were to go for off-site manufacture? Presumably Dr Williamson can talk about this with some knowledge, if not with some caution, given her own experience in Laing O’Rourke. Is the cash flow better or worse when using factory components?

**Dr Sarah Williamson:** The models need to be significantly different. Laing O’Rourke has invested in a number of manufacturing facilities. There is the precast concrete facility in Steetley along with an MEP facility and another advanced manufacturing facility that is in the planning stage. The investment is being made, but for that model to work there has to be a demand for the products that come from the factories.

In effect, we have to generate the market that keeps the factories busy. That is where the industry needs to get to; in addition to that push, the balance needs to be tipped so that it becomes more of a pull.

**Lord Borwick:** Okay. You have made your investment and you have to wait and see whether you get a return, but how would the cash flow alter for the construction company that had not made that investment?

**David Hurcomb:** In the short term, you have a factory to buy and fit out and a workforce to train, which is quite expensive. I would say that you would have a number of years of investment. It is all about the continuity of the demand side.

**Lord Borwick:** What if you did not actually build the factory yourselves, but rather you purchased it?

**David Hurcomb:** You could rent a factory, which would smooth out the cash flow.

When it comes to getting paid versus traditional, to be honest, once you get going it is pretty neutral. I am assuming that you guys are paid by certain stage payments in the construction cycle.

**Dr Sarah Williamson:** Indeed, but the key is being able to envisage the demand that will support the investment.

**Martin Kelly:** The point is valid. You move from looking simply at profit motives to looking at returns on capital employed. The capital employed includes all the working capital that you might have to outlay through the process, because if you take complete ownership of a process from the sourcing of raw materials through to the design, on to the fabrication and to the ultimate assembly and erection, that will give you a higher level of capital employed than you would have in the traditional construction model.
Baroness Morgan of Huyton: Perhaps I may move on to skills, which we also talked about with the previous witnesses. Mr Kelly has alluded to the fact that there is already a skills shortage that we think will get worse because of leaving the EU and an ageing skills base anyway. Our previous witnesses suggested that you could almost run this in parallel in the sense that the skills base will decline, but you should be developing a new skill set at the same time. Do you agree? What range of new skills is needed and what are the opportunities for filling the current skills gap with a new approach to off-site?

Dr Sarah Williamson: We have already started on that. On skills, a number of assembly apprenticeships have been started and this is a massive opportunity. The current key skills for civil engineering are concreting, reinforcement, fixing, carpentry and, on the domestic side, bricklaying. If we could let them go and not force people to work in those environments, that would be a positive thing.

The skills we are looking at now vary. From an engineering perspective, we are looking for people who understand data. We talk about BIM, but there is a lot more to it. It is not just about models and pictures. You need to understand data engineering and data science. We have people in civil engineering and even in the construction engineering teams who are data analysts and programmers who can work with the APIs.

Lord Hunt of Chesterton: What is an API?

Dr Sarah Williamson: I am sorry. We have people who can modify programs to suit our particular needs, so we need people who are very software literate. We have people whose job it is to sit inside the office and do the construction sequencing before we go to site, so the engineering is starting to look a lot different.

When we get to what used to be construction, we are now talking about manufacture. Today we have been talking about what we do in an actual manufacturing facility producing components that come off the assembly line, but even on a normal construction site we will off-line as much as we can and we will create components in a controlled environment. It is much more like manufacturing and you need fewer people on the construction site doing the assembly.

Baroness Morgan of Huyton: What level are the apprenticeships that you have just talked about? Are people coming to you at 18 or 16?

Dr Sarah Williamson: I would say at 16. We can get a lot out of people who have just left school.

Baroness Morgan of Huyton: And would you develop them in all of these data areas?

Dr Sarah Williamson: Yes.

Martin Kelly: Some of the traditional construction skills that we have on site will transfer directly into an off-site environment, but what might change is the element of mobility. London, for example, is a core site for construction activities, but it would not be a core site for off-site manufacturing. That is likely to be done in different places. Our facilities are in the Midlands and in the north, but in effect we all work in London.
When you are talking about moving people from a construction site in London, even those with transferable skills may not be quite so available, given the geography.

**Lord Fox:** The world that Dr Williamson has just described is alluring, but when I walk past building sites in London I still see people up to their ankles in mud plaiting rebar on-site in order to create reinforced concrete structures. How much of what you have described is real and actually happening in scale, and how much of it is still aspirational?

**Dr Sarah Williamson:** I do not know the figures for the reality versus the aspiration. Take our London projects as an example. In the document that Laing O’Rourke submitted, we talk about one of our high-rise projects, Two Fifty One, which was fully componentised, but that was a landmark project for us.

**Lord Fox:** Is that the reinforced concrete component as well?

**Dr Sarah Williamson:** It is the reinforced concrete, the MEP and the cladding. The components came from various places around the country and they were assembled on a very tight London site. As much as possible we get rid of things like reinforcement fixing and the wet trades. The in-situ concrete, plastering and finishes are all done off-site. It is not the world now, but it is the world that we want to live in.

**Lord Fox:** It is the world to come rather than the world we currently have.

**Dr Sarah Williamson:** Exactly. May I add to Martin’s point about the geography? It is not just that these components come from different places, they are actually made by different people, or they have the potential to be. This is a massive opportunity to tap into the diversity agenda once you start building things in a factory and thus away from the traditional construction site.

**Lord Hunt of Chesterton:** While the others were voting in the Division—I always get to the vote late—I was going to ask you some questions. You told me that the Hinkley Point nuclear power station will eventually have 10,000 people working on that site. How many of them will be apprentices?

**Dr Sarah Williamson:** I did not research that figure, but I could provide it. Both EDF and the contractors on the site have made significant investments into apprenticeships. We are working closely with Bridgwater & Taunton College and the University of Exeter, because they are running those apprenticeships for us.

**Lord Hunt of Chesterton:** So you will be instrumental in producing a very large number of apprentices.

**Dr Sarah Williamson:** Yes. We are about to start a digital engineering apprenticeship, which involves something like BIM.

**Lord Hunt of Chesterton:** Will big projects like this be one of the ways in which we engage people in generating many more apprenticeships?
**Dr Sarah Williamson:** I believe so. I also believe that people go away from projects like Hinkley with a clear idea of how they want to work on future projects.

**Lord Hunt of Chesterton:** That is very interesting.

Q48 **Baroness Neville-Jones:** In the previous session we heard that quite a lot of integrated team building is desirable and necessary if a project is going to be successful, which rather suggests that over time you get consolidation of these teams because they will have become accustomed to working with each other.

We also heard that the advent of off-site manufacturing would provide a great opportunity for the expansion of the skills base in the factories around the country, and in effect we would be able to create greater variety and to take advantage of it. I could not entirely reconcile these two bits of evidence, because it rather suggests that there will be a great deal more ad hocery in who you choose to work with. Where do you think this is going?

**Martin Kelly:** You have picked up on a key point. I introduced my company as a structural steel provider and we are in a bit of a silo, but we have seen a real opportunity. Our organisations are two that you would not normally see working side by side. In a factory environment we have built the canopies for London Bridge, which are a combination of structural steel, a cladded roof and the MEP services required for the lighting. The material is craned in overnight and it is a matter of plug in and play.

That is a perfect example of what we are talking about, although it is unusual. It is unusual for us to have MEP, structural steel and cladding in the same building and working alongside one another as three separate organisations. But that is what needs to happen, and it needs to happen more widely than only two or three times. It needs to be on a much wider scale.

**Baroness Neville-Jones:** You say that it needs to happen. What kind of structure of the industry would be likely to provide that greater likelihood?

**David Hurcomb:** First, it will be as you said earlier: it will be outsiders, probably from the Far East and China, who will have developed a product that they can sell. It will be quick and safe and it will meet all the requirements of the users. I think it will go down certain product lines such as office blocks and maybe residential. That is the only way it can happen. They have worked out how to build quickly and safely in a way that meets the required building standards. That is quite likely to happen, and it will use robotics on site to do the actual building. If you go on to YouTube you can see quite a bit of R&D taking place around the world using robotics to build houses.

**Baroness Neville-Jones:** Can those techniques not be reshored?

**David Hurcomb:** We are still in the research phase rather than the development phase at the moment, but it is not unreasonable to think that in 20 years’ time an awful lot of tasks will be done by robots.
Baroness Neville-Jones: Yes, but why should the UK be such a laggard? Why does it have to come via the Chinese or the Indians?

Martin Kelly: There are a few self-help options, but they require us as the industry and everyone around it.

Baroness Neville-Jones: And the client?

Martin Kelly: Yes, they are driven by the client, but we need to focus on collaborative working. I understand where David is coming from, because that is quite a big ask from where we are, but we can focus on collaborative working. A couple of contracting models are available that do that, but in practice we find that it kind of goes against the grain. The hardest bit to break is the mindset.

Lord Vallance of Tummel: I have two quick questions. If it were to come from China, do you envisage big volumetric stuff being shipped in from China, or would the manufacturing element be done here?

David Hurcomb: No. Obviously the aggregate and all the heavy stuff would arrive locally, but that is not the brains. The brains is in how all that is assembled into the finished product. The techniques would come from there.

Lord Hunt of Chesterton: Sorry, you say the techniques would come from China.

David Hurcomb: Yes.

Q49 Lord Vallance of Tummel: I have another point that is not entirely related. Earlier you were talking about the trade skills, but what about the other end of the skills? What about the marketing and commercial skills? To a simple onlooker like me, you have a product that looks to be cheaper, better and offers value for money, so there ought to be additional returns to the consumer. All right, there are some technical difficulties in getting there, but surely a part of all this is actually marketing the stuff. Once you have invested in plant and you have all that capital, which is now a sunk cost, how do you sell this stuff commercially to residential or other contractors?

David Hurcomb: The problem is that there is no one party in the industry that is responsible for selling the consumer the product because it is so fragmented. The client chooses a multidisciplinary team of consultants and trade contractors, so none of us is selling that sort of product. If we could have it, it would be easy to sell its benefits of speed, quality, price and so on. We are just part of the very fragmented process that comes together to build buildings in the UK.

Dr Sarah Williamson: A fully off-sited solution will not necessarily be the cheapest option. The client will be buying something else; they will be buying quality, certainty of programme and reliability in the whole-life cost.

Lord Vallance of Tummel: Value for money is a valid point.

Baroness Neville-Jones: What about performance if you produce something that works using less energy and less of this and that?
Dr Sarah Williamson: Indeed. It is about moving away from that initial capital cost to more whole-life thinking.

Lord Griffiths of Fforestfach: I am still struggling as to why this thing is not happening more quickly. The area that I know best is finance and banking. Back in the 1980s, the City of London was in a whole lot of separate silos—discount houses, commercial banks, merchant banks, many kinds of asset management companies, jobbers, brokers and so on. Today, the whole thing has come together in one. It seems to me that what held it back was regulation.

Given that there are silos, and given that you have Grenfell Tower and so on, you have to be very concerned about regulation. In the end, for a steel structurer to go into something to do with roofing, there is a risk element in trying to put it together. Secondly, in the end it was the advent of foreign competition that changed the City. In this industry, regulation is important in relation to something that is a barrier or at least something that slows down the process of integration.

Martin Kelly: It is fair to say that that does not exist currently. You are right: the reason for every silo is that it takes 20 or 30 years to be a specialist in these areas and to understand every aspect of the regulations. Moving out of that comfort zone into somebody else’s sphere of expertise is hard for one organisation to do. Collaboration is the right way to do it, because trying to learn 20 or 30 years of experience is ineffective. As I say, there are not as many examples of true collaboration in the construction industry as you would imagine.

Dr Sarah Williamson: For this to work, you do not have to learn everyone else’s specialism. What would make a real difference is a change in the procurement practices, with a fairer or a different sharing of risk and with practices that encourage a long-term alliancing between industry partners that have the different required skills. That is not how construction tends to be procured now.

Martin Kelly: All the component parts are there. It just requires that mindset and capability to bring them all together.

Lord Griffiths of Fforestfach: With the City of London, it was also the inflow of capital from American institutions that enabled that to happen.

Lord Vallance of Tummel: On procurement practices, are these self-imposed or are they the function of regulation?

David Hurcomb: The industry has always been very competitive. Therefore, the continual benchmarking of costs is the thing. For the Government, yes, there are rules and regulations that absolutely insist that there are three prices for the job, if you like, but frameworks in the past have been successful in driving innovation. I am thinking way back in the mists of time to the Decent Homes programme, with which I was involved. We were let seven-year contracts to upgrade the social housing. Surprise, surprise, we worked with the same people—the integrated project team that you spoke about earlier—and we got incredibly good. We drove innovation, because that was in our interests.

Where you have seen innovation in this industry, it is through large government programmes—housing or whatever—because the supply
chain gets good at doing stuff and you start to see that benefit. The problem is that as these programmes come to an end, some of that innovation gets lost. That is the shame. Government needs to trust the industry a bit more to give itself innovation targets in return for longer-term certainty frameworks to allow you to make that investment and to reap the rewards of spending a longer time as a partner.

**Lord Vallance of Tummel:** I can understand that, but leaving aside government procurement and just looking at the private market, what I am after is whether the regulations on procurement in that market are constraining things or whether these procurement issues ought to be dealt with by the private sector itself. Perhaps that is not happening because of the silo structure.

**Martin Kelly:** In my view, it is not driven by regulation, it is driven by the commercial environment in which we work. The supply chain could be 40 different trades, of which there are three to four competitive tenders for every package before you start getting to component parts. There are multiple layers of procurement. They can be done at different times and in different ways. Tier 1 might have a cost-plus type of arrangement with the ultimate client, but below him he may have five different major subcontractors all on fixed price, who below them have 15 different subcontractors procured in a different way and at different times. We talk about trying to have MEP, concrete and steel talk to one another, but often we are not even appointed at the same time.

**The Chairman:** I am sorry to interrupt, but we have run out of time. We have a few more questions. If you are willing, perhaps we could put those to you in writing to give you the chance to respond to them. At this juncture, we have to draw proceedings to a close. Again, I am sorry for the disruption that we had earlier due to a Division. Thank you very much indeed for coming and for giving such interesting and useful evidence.
Thank you for opportunity to provide supplementary written evidence. Laing O’Rourke has already formally submitted written evidence, so I have concentrated on those areas that we did not previously respond to, or where we feel that elaboration will prove useful. Threaded throughout our response is a call for cross-industry collaboration.

**Can you explain your Company’s approach to Offsite, to help the Committee understand the range of what you do? A few examples would be helpful, together with an understanding of the benefits.**

**Defining off-site:** At Laing O’Rourke, offsite is best articulated through our proven Design for Manufacture and Assembly (DfMA 70:60:30) approach which enables 70% of a project’s construction to be conducted off site, leading to a 60% improvement in productivity, and a 30% improvement in delivery schedule.

We aim to engage as early as possible in a design, maximising the opportunity to manufacture building façades, frame, mechanical and electrical components off site. Offsite offers a variety of solutions, ranging from individual components, sub assembly, to fully manufactured volumetric approaches, e.g;

- Components: columns, floor slabs, beams
- Sub assembly: complete mechanical and electrical plant-rooms, service risers, bathroom pods, integrated façade and window panels
- Volumetric elements: LOR housing solution includes segments of completed building manufactured offsite

Our written evidence response to question 2, contains specific project examples in boxes, 1,2 and 3.

**How do you see offsite solutions developing in the future for your own business and for the construction and house building sectors as a whole?**

Offsite manufacture will drive modernisation in the construction industry. Construction today is characterised by low margins with one-off projects delivered using non-systematic processes in an on-site production environment. The on-site production environment is complex and continuously changing, with many processes and participants. Without the processes and decision-making tools required to manage this environment it is too easy to lose control – resulting in the overruns often encountered in construction project delivery.

The industry of the future will derive value from processes that integrate design, manufacture, assembly and installation resulting in the delivery of projects which meets clients’ requirements through the configuration of standard components rather than the repeated development of bespoke solutions. The complex construction process will be managed by a combination of reduction in the number of activities required on the construction site – i.e. componentisation.
allowing the amount of work done in a controlled factory environment to be maximised, supporting organised assembly on site of a minimum number of components.

Current business models and practices in construction are fragmented and tend to be based on lowest cost. The industry in general does not have the processes or systems required to successfully manage the complex supply and production relationships involved in delivery of one-off projects; resulting in waste, low productivity, poor quality design and construction.

To drive the increases in efficiency and productivity required by the industry will demand a focus on structured and integrated processes and manufactured product. Supplementing the message we articulated in our initial written submission, justification for the investment in manufacturing facilities will be based on confidence and visibility of pipeline; in the consistent returns based on efficient production and assembly of standard components at realistic volumes. The belief that these volumes will be achieved being a key underpinning of the investment.

Digital technology and data will be significant enablers to the change allowing detailed design, planning and visualisation of products and projects. Additionally, the ability to analyse in real time, key production and delivery metric will allow monitoring of process performance and timely decision making. Examples of this range from: the rapid configuration of bespoke solutions from sets of standard products, virtual assembly to confirm construction sequence and programme, to the ability to automatically track progress, productivity and quality.

At Laing O’Rourke, we continue enhancing our capability with investment in people, products and processes to support delivery, certainty and productivity. Offsite solutions are for us “business as usual” and we are seeing the benefits of continuous learning. Through our plans for precision manufactured homes, we are looking forward to making a further step change in our delivery capability.

As we outlined in response to questions regarding procurement, the “presumption in favour of offsite” in the November 2017 budget (4.52) stated that Government will use its purchasing power to drive adoption of modern methods of construction including offsite manufacturing. This will help build momentum, although it is important that this policy is followed through and implemented correctly.

**Do you have any suggested recommendations the Committee could make that would help increase the momentum of offsite solutions in the construction industry?**

In Laing O’Rourke’s written evidence, we responded to question 8 around public procurement processes. This response gives recommendations that would increase the momentum of offsite solutions.

Supplementary thoughts include:
- Demonstrate an assessment of offsite manufacture, whole life costing and design/performance in residential development through planning policy, or in Homes England funding requirements.
• Public sector client organisations should aggregate demand and stipulate a common set of requirements, linked to longer term strategic alliance procurement arrangements. Such a model would unlock and enable investment and allow successive projects to benefit from continuous learning.
• Government should offer an offsite manufacturing finance scheme to provide commercial loans or loan guarantee to those seeking to invest in offsite manufacturing capability. This signal of confidence will help unlock further private finance.
• Industry should continue to lead, in collaboration with Government, CITB and education and training providers a review of skills required to support transformation of industry vs traditional construction skills.

How can companies in the construction sector be encouraged to collaborate and work together to facilitate the wider use of off-site manufacture?

The right incentive structures need to be put in place to encourage collaboration. The three key considerations are:

• The link to and visibility of future workload and volumes to enable longer term collaboration and investment.
• Collaborative alliance contracts, providing the correct commercial model for investment and return.
• Shared objectives to progressively improve performance, and collectively share risk and reward appropriately.

With these elements in place, the wider industry and its supply chain will respond to market need and demand. The imperative will be in place and the natural motivation to collaborate will be improved.

As public and private sector clients witness and recognise the benefits derived from changing modes of engagement; those of consistency, certainty of delivery; and opportunity to progressively improve efficiency, they too will feel more compelled to collaborate.

As momentum gathers, industry, educational establishments and Government must continue to work together through recognised, co-ordinated bodies who have authority to drive change, such as the Construction Leadership Council. A coherent, consistent and strong industry voice will lead the charge in collaboration where change is evident.

In each of the above, is there a difference between the different sectors of residential, building and infrastructure markets?

While residential, building and infrastructure markets, share many common aspects, they also have specific varying considerations.

These are summarised in terms of:
### Key Factors

<table>
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<tr>
<th>Nature of client organisation, extent of stakeholders</th>
<th>Residential</th>
<th>Building</th>
<th>Infrastructure</th>
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<tr>
<td>Varies from private sale, rental and housing associations.</td>
<td>Either repeat private developer; Government multiple clients, or single project clients.</td>
<td>Regulated industry and Government clients with multiple external stakeholder influences.</td>
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| Nature of structures / components and performance requirements | Common base typologies but need to address planning and site context. Suits forms of volumetric, and is the focus of volumetric development. | More varied but can be manufactured and standardised at component level and subassembly e.g column, floorplates, façades and mechanical risers. | Although high variation in site context, a high degree of structure/component or sub-assembly level potential repeatability e.g. bridge structures or reinforcement cages. |

| Timing / length of projects | Usually multiple phases of development in larger development areas. | Can be relatively stand alone as individual sites but can form part of wider national programmes e.g schools. | Major projects have relatively long lead in. Usually large programmes of work at national level. |

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**What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture and to evidence those benefits? How can the sector be encouraged to play a greater role in R&D?**

Please refer to our response in the written evidence to question 6. To supplement this more specifically, to investigate and support the case for offsite manufacture research is required in a number of areas:

1. Components and assemblies:
   - Element and assembly behaviour, particularly joints
   - Manufacture methods
   - Assembly methods
2. Data/digital engineering and technology
   Data engineering and analysis – requirements for data specifications to support entire project lifecycle
   Design and data for:
     - Manufacture
Materials ordering and management
Progress tracking
Field applications
Setting out
Quality records
Waste management

3. Logistics
Optimisation of componentisation, assembly methods and sequence

4. Business models
Client driven - Procurement models required to support shift in delivery model and culture change
Supplier driven – Investigation of benefits/feasibility of investment in radical change of delivery model to drive market change

5. Skills
Investigation of levels and nature of skills required to deliver industry transformation, role of educators – schools/universities accrediting bodies in recognising and providing these skills without compromising fundamentals.

24 May 2018
Offsite construction/manufacturing can be one of the most tangible ways of radically reducing project time.

The end to end project time accounts for close to 80% of the project cost and over 90% of the project risk. Therefore, off site if focused on compressing time offers an enormous opportunity for reducing project cost and risk.

To realise and optimize use of off site to compress time two key factors should be considered:

1. The use of offsite should be very specifically focused:
   - The best way to look at off site manufacturing/construction is to think of it as just a method or technique amongst many other production improvement techniques.
   - The underlying principle of offsite that can deliver radical time reduction is, as well known in other industries, parallel processing.
   - In a project environment the benefits of parallel processing to compress time can only be realised if whatever is considered for offsite is on the critical path.
   - Non critical path activities built off site may provide limited cost reduction. Ie through possible reduction in site scaffolding which may also have positive safety implications. These benefits however have to be balanced against the safety and cost of the substantially extra craneage time on site.
   - If very large chunks of the build on the critical path are taken off site then the on site project time is just shifted to the factory. The production time in a factory and the predictability of on time completion will then depend on the quality of the factory production system.

2. The use of offsite should be amalgamated with all the other modern methods of management and production in to one system whilst focusing on compressing time.
   - Such a system is the only way to achieve the 2025 governments target and the productivity improvement.
   - The current reality is that the use of off site increases year on year but 70%-80% of projects still continue to run late and over budget. This is partly due to the fact that offsite as with other methods is utilized in isolation and mixed with the current broken construction processes and as the result the benefits are lost.

**Productivity benefits:**
Improving productivity in construction is very complex and requires many considerations. Currently on projects the operatives on average are working only 30% of the time. Ie fixing or assembling. This could be the same in a factory.
Improving the productivity of individuals on site, in a factory or in a design office will mean that projects will take twice as long and productivity of the project will go down.

There is an erroneous assumption that productivity is always higher in a factory than outside on a project and all factories have consistently high levels of productivity.

It is very possible for productivity to go down when building offsite. Apparently a study has shown offsite to be less productive in some circumstances that on site.

Many of offsite factories can be described as construction sites in a shed. They use the same inefficient processes with the same fragmented sub-contractors used on projects.

Offsite units do at times arrive on site late, incomplete and of poor quality requiring manufactures gangs to complete or make good the work on the construction site. This can take longer than on site build by sub-contractors coordinated by the main contractor.

The overall impact of weather on off site productivity would need research.

**Impact of weather and climate on productivity**
A factory environment can provide protection against wet and cold weather.

Weather conditions can however work against modular offsite units as the loading, unloading and assembly means substantially longer cranage lifting periods which can frequently be winded off.

It is possible that more time is lost due to wind than rain and low temperatures through out the year.

**Safety Advantages**
Is it safer to use the same processes in a shed? In some cases the use of modular is likely to mean less or no site scaffolding but on the flip side it means much longer periods of lifting during assembly on site.

**Standardization**
Standardization should be treated as a separate production technique that can help compress time.

The main benefit of standardization is design time saving.

Other industries have moved to mass customization but in construction we are still thinking Henry Ford. Any colour as long as it’s black.

Some offsite manufacturers are promoting standardization mainly due to the limitation of their factory production processes to customize.

The greatest benefit of standardization would come from standardizing the project delivery system/process rather than the product ie what we build.
Government Policy and Recommendation:
Off site or parallel processing is only one of many techniques that collectively can radically improve project performance. Most often each technique is used in isolation and hence delivers zero project improvement. Most of the benefits will be sub-optimized and with little or no impact on the project time or cost.

Any policy to be set to improve productivity should be directed to utilizing a standardized system of project delivery focused on compressing project time. Such a system must utilize as a minimum the collective benefits of all the latest management, production and motivational techniques used by other industries, sports etc.

The system as a minimum must utilize principles such as One Piece Continuous Flow, Critical Chain, scientific work prioritization, Short feedback and learning loops, horizontal accountability, BIM etc.

In terms of offsite such a system must be able to demonstrate that it has considered at the project opportunities for utilizing any form of off site in order to compress time.

25 April 2018
Legal and General Modular Homes – Written evidence (OMC0062)

Letter from Rosie Toogood, CEO

Thank you for your invitation to appear before the Committee to explain the work my team has been doing to deliver high quality, beautifully designed and affordable homes. We have so far invested more than £50m in our new manufacturing site in Sherburn, North Yorkshire. My team’s current focus is creating homes that can address the crisis in social and affordable housing. Without subsidy, we are proud to be proactively investing in the regions of the UK.

Established in 1836, Legal & General is one of the UK’s leading financial services groups and a major global investor with a number of growing businesses in the US. Around fifteen million people worldwide rely on us to help them save for the future and to protect their families and their homes. We have made a commitment to investing in UK infrastructure, including urban regeneration, housing (including the private rental sector), clean energy, care homes and hospitals and we have already made over £14 billion of these direct investments.

Legal & General is determined to disrupt the supply side of the housing market so that generation-rent can have the opportunity their parents had; so that people in need of social housing can access it and so that older people can choose the right kind of housing for them.

Legal & General’s housing strategy will deliver a supply-side boost across all types and tenures. We are creating ‘build-to-rent’, properties all over the country including sites in Walthamstow and Salford. We are also committed to building a new generation of student housing; our sites include Imperial College, University of the Arts London, Southampton University and Greenwich University, Aberystwyth University and Newcastle University.

We are, in addition, creating new urban communities. For example, Cardiff “Central Square”: is one of the largest regeneration sites of its type to be announced within the UK and will ultimately transform a tired and underutilized 12 acre site to provide over 1.4m sq ft of prime mixed use space and a total Gross Development Value of £450m.

Finally, L&G is also investing in later living. For example, we have forward funded and purchased five high quality care homes in Suffolk with Care UK for £31m and completed the acquisition of 13 care homes let to Methodist Homes, a leading care home provider, for a total of just over £70m.

Social and affordable housing is hard-wired into our housing strategy: we are working hard to increase the number of homes in this sector by providing funding and modular homes. In terms of funding Legal & General is originating and underwriting loans for the social housing sector. For example, we have offered a £50m, 40 year loan to Chorley
Community Housing Ltd (CCH) to fund a pipeline of 814 new homes over the next three years in the North West of England.

Creating modern, quality and good-value Modular Homes for social and affordable need is a key part of our overall strategy. At the heart of the business is the 550,000 sq.ft. modular factory in Leeds (the largest in Europe). The Sherburn site will industrialise volume housing supply with a focus on affordable and social housing.

We are currently moving into the production phase of our work in Sherburn. Over the few months we will see the first two, three and four-bedroom houses become available and in the medium term we hope to be able to deliver mid and high-rise homes.

We are pleased to contribute to the Committee’s important inquiry; please find below our response to the inquiry. We would be delighted to host any of the Committee members or staff at our site in Sherburn, Yorkshire.

26 April 2018

Legal and General Consultation Response:

Modular Housing offers a great opportunity to address the social housing crisis

Our vision at L&G Modular Homes is straightforward and ambitious; we are focused on: “Making the Housing Market Fairer for All.” As a group L&G is investing billions of pounds in all types and all tenures of home. Modular homes of the highest quality and standards are a key part of achieving our vision. Our initial focus is on providing social and affordable housing of the highest quality; best modern-design and great value.

1.1 L&G Modular Homes has invested more than £50m to create a design and manufacturing eco-system capable of building affordable homes at scale and pace. Our combination of technology, skilled staff and great materials means that quality is built in and time spent on site reduced. Our industrialisation approach adopts standardised and lean manufacturing techniques that ensure scalability and productivity.

Advantages of offsite manufacture

2.1 UK Construction productivity has barely improved since 1997. Offsite manufacture can, at scale, deliver significant benefits to developers and the residents. Offsite manufacture and assembly is significantly faster than traditional construction techniques. A L&G modular house can go from module delivery to ‘ready for occupancy’ in circa 10 weeks.

2.2 A further key issue in the delivery of new housing units is the time lag between planning permission being granted and homes being built. To date more than 33% of all housing permissions given since 2010 are yet to be built. This is
a major constraint that can be unlocked by adopting offsite solutions and enabling ‘new players’ to invest in capacity and innovative solutions.

2.3 Offsite techniques rely far less on the existing traditional skilled trades and artisan techniques of the building industry. Whilst the UK construction industry requires more than 46,000 additional skilled trades people per annum against a trend that is shrinking & ageing, offsite manufacture will create a new generation of multi-skilled employees who can work in an innovative ‘modern manufacturing’ environment based on a digital platform.

2.5 L&G Modular Homes also offer considerable benefits to their occupants. Our manufacturing system adopts a ‘fabric first’ approach that optimises building fabric efficiency and has the potential to significantly reduce running costs to heat and cool homes.

**Barriers to early adoption of off-site**

3.1 The offsite industry has largely been fragmented; populated by small and medium sized businesses. Many of these businesses may not have the financial strength that clients and developers would require within their supply chain to make a significant shift towards off-site methods of construction.

3.2 Until recently the sector has simply not had the scale to deliver the kind of volume needed to address the housing crisis. We are addressing this at our Sherburn site which will be capable of producing 3,500 homes per year.

**Government & Sector Actions**

Modular housing provides a great opportunity to add modern, affordable and high-quality supply into the housing market. At L&G we are determined that the modular homes market supplies its customers with the best in design; quality; value and finish.

We are proud that our manufacturing site, and the brand-new technologies and skills within it, have been delivered without a subsidy. Disrupting the existing market to this extent is a real responsibility and our investment, more than £50m so far, testifies to the strength of our commitment.

Our initial focus is on delivering great affordable housing; achieving this naturally means working alongside public housing providers. We have suggested below a set of recommendations we believe will help to establish the modular housing market:

**7.1: Pipeline.** To achieve efficiency and yield it is important to have a smooth and aggregated demand. Public & private sector clients that wish to adopt off-site solutions should work towards creating validated long-term demand pipeline visibility. Then off-site manufacturers can invest in capacity with confidence and make their manufacturing assets viable.

**7.2: Smart Contracts.** We need industry forms of contract that establish a new set of rules and disciplines commensurate with the requirements for off-site
project solutions that will allow mass production to serve well the design, procurement, construction and operation of our future housing supply.

**7.3: Design Codes of Practice.** All key stakeholders involved in delivering our future housing stock should support the development of a manufacturing housing design code of practice; re-working traditional design practice in a way that will animate alternative solutions from the off-site supply chain. Developing a code that recognises the key considerations of a DfMA (Design for Manufacture & Assembly) approach would allow the market to respond in new and innovative ways.

**7.4: Digital connections.** Public & private sector client leadership in establishing a collaborative digital platform for delivery will also support the accelerated adoption of off-site solutions. If client, designer, constructor and manufacturer can be SMART connected, then collaboration will thrive and the adoption of a production manufacturing led approach will be enhanced. Building on the DfMA overlay to RIBA Plan of Works should be considered.

**7.5: Skills.** The need for new skills and a multi-skilled workforce must be recognised throughout our industry and suitably accommodated. The CITB should consider new courses and apprentice programmes that focus on manufacture, assembly and logistics. We believe that this will help to attract talent and diversity to the industry.

As well as the work the sector itself can do we also believe that there is a crucial role for local and central government to play in delivering a bigger and better modular housing market.

**8.1: Public Sector Procurement.** The Government should introduce funding streams and procurement policies that will further stimulate earlier adoption of off-site technology. Funding streams that ‘stick to the asset’ and can be accessed through the supply chain should be promoted and embedded in public sector procurement.

**8.2: Long-term Strategic Relationships.** In terms of the construction sector deal, we would encourage further development of the key principles set out the ‘Construction Leadership Council- Innovation in Buildings Workstream’ paper (Kings College London -September 2017), a model form for building long term strategic relationships using FAC-1.

**8.3: Innovation Hub.** We would support the CLC’s recommendation to establish a more innovative industry through the creation of an Innovation Hub. Such an organisation can be focussed on the residential sector (similar in principle to the Manufacturing Technology Centre in Anstey and the AMRC (Advanced Manufacturing Research Centre) in Sheffield). With this focus an Innovation Hub would have the potential to accelerate our capability to establish a digitally-enabled modular construction environment that embraces high volume production platforms (standard designs and components manufactured off-site/near-site and assembled on-site). Such a hub could also support the development of evidence-based cost/benefit analysis, as well as support future skills & training development. R&D in our sector is traditionally diversified and dislocated. The Innovation Hub would make R&D Innovation shared and
collaborative with a strong leadership focus (similar to what the aerospace and automotive industries have already achieved), a centre of excellence & collaboration.

8.4: Collaboration first. Currently, business models within the sector seek to minimise risk, are adversarial and based around projects. We need more than longer term and more co-operative collaborations.

26 April 2018
Legal and General Modular Homes, Greater London Authority and Willmott Dixon – Oral evidence (QQ 9-16)

Tuesday 24 April 2018

Watch the meeting

Members present: Lord Patel (Chairman); Lord Borwick; Lord Fox; Lord Griffiths of Fforestfach; Lord Kakkar; Lord Hunt of Chesterton; Lord Mair; Lord Maxton; Baroness Morgan of Huyton; Baroness Neville-Jones; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 2 Heard in Public Questions 9 - 16

Examination of witnesses

Rosie Toogood, Jamie Ratcliff and Tim Carey.

Q9 The Chairman: Thank you very much, lady and gentlemen, for coming and helping us with this inquiry. Before we start, please introduce yourselves from my left so that we get you on the record. If you have anything brief to say to start with about yourself, please do so.

Tim Carey: I am national product director for Willmott Dixon. We are a privately owned main contractor with a turnover of about £1.5 billion a year. I chair our national team looking at innovation off-site. I am also a member of Buildoffsite.

Rosie Toogood: I am chief executive officer of Legal & General Modular Homes. I joined the business about 10 months ago, having spent a 25-year career in Rolls-Royce aerospace, leading engine development programmes, supply chain management and manufacturing businesses. At Legal & General Modular Homes, we have invested over £50 million in designing, manufacturing and assembling modular homes. We are just at the point of going through the final stages of pre-production and about to go into production. We aim to address the social and affordable housing market initially and the later living products following that.

Jamie Ratcliff: I am assistant director of housing for the Greater London Authority. I am responsible for a budget of about £5 billion, mainly to invest into affordable housing. I am a passionate advocate of innovation in the construction industry. I was on the advisory panel for the Farmer review of the UK construction labour model, and in a personal capacity also wrote a piece for Policy Exchange called “Mass-delivery of Manufactured Homes for Rent”.

The Chairman: Thank you. In exploring the advantages and disadvantages of off-site manufacturing, what is it that makes people go for off-site construction? What are the key advantages they see? On the other side of the coin, what is it that puts them off? What are the disadvantages?

Rosie Toogood: Speed is a clear advantage in terms of ability to deliver in shorter timescales. The quality of the products that are delivered is a really important advantage, as well as certainty and more predictability of
cost. In terms of disadvantages—and I have heard some of the previous panel discussion—it is not easy. There is no silver bullet and it takes a lot of diligence and dedication to get a model that works.

**Tim Carey:** I agree with the advantages. The biggest advantage is the fact there is not enough capacity out there any more to deliver projects, especially housing, using traditional methods of construction. We are almost past the point of no return. We have seen off-site manufacturing go in cycles and it has always reverted back every time we have gone through an economic down cycle. The circumstances are such that we now need to be there for good.

One disadvantage is capacity. Sometimes the market perception of off-site is something which it is not, so while there are a number of larger suppliers and manufacturers, such as Rosie’s company, the majority of off-site manufacturing is still very much a cottage industry. It is still very much men and women in sheds building stuff traditionally, just not at the coalface. A lot of the off-site manufacturers want to scale up and want to invest but they need certainty. We can discuss that later.

**Jamie Ratcliffe:** I agree with Tim’s point that there is not an option from a housing point of view. If we are serious about building the homes this country needs, we are not going to do it through traditional construction. There is still going to be lots of traditional construction, but we need to add to it in new ways of precision manufacturing many more homes in factories. I stress the point about speed being a benefit. That particularly appeals to build-to-rent providers. Everyone in London who is delivering build-to-rent—professional, large-scale rented homes—is looking at ways they can speed up construction through precision manufacturing of homes. To them every extra week they can shave off the construction timeline is an extra week in rent. That driver is not necessarily there for for-sale developers but it absolutely is for build to rent. That is working well.

Picking up on Rosie’s point around costs, that is going to be particularly relevant in relation to small sites. In London, through the London Plan, we are aiming to see a significantly higher proportion of homes delivered on small sites, which can be very expensive to deliver through traditional construction; you have the same overheads on those sites, whereas if you can have a repeatable design that you can drag and drop to lots of locations, you can deliver it much more cost effectively. There is also a macro-benefit in terms of economic policy. London is where most housing growth is needed, but it is also under a lot of economic pressure. Wages are expensive here; you can build homes in places where there are fewer jobs and deliver an economic benefit to those places while delivering homes where they are needed most. At a countrywide level that is really important.

There are two challenges, one of which is fundamental to the way the construction industry works—it is really bad at partnerships and collaboration. People do not trust each other and to make this work you need that trust relationship and to work together at an early stage. You need to commit to it and depend on your partners and work through the problems. For whatever reason, culturally, lots of people in construction find that very difficult.
You will also hear a lot of discussion around innovative technologies not being tried and tested and there being problems with them, I just do not buy that. Mostly we are not talking about fantastical things such as aerogel. It is tried and tested ways of building homes broadly three different ways: timber frame, which has been around for thousands of years; steel-framed buildings, which have been around for 150 years; and concrete-framed buildings, which have been around for 125 years. They are not massively innovative things, but we need to be doing much more of them.

**Lord Fox:** We heard from the previous evidence that somehow the development side and the business side may be what have held back the rapid adoption of this technology. In the L&G decision to gain control of the means of production, if you like, I can understand wanting to invest in houses as being a revenue stream that sits in parallel with its business, but what was the decision-making process that went on when you were sat round the table saying, “We are not just going to build houses; we are going to build a factory that builds houses”? How did you come by that decision?

**Rosie Toogood:** There were two main driving factors. Legal & General is passionate about investing in schemes which deliver socially and economically beneficial outcomes.

**Lord Fox:** You could have done that through traditional manufacturing.

**Rosie Toogood:** Correct, and we are doing so. We have a number of traditional housebuilders within the Legal & General capital portfolio, but we saw a growing gap in capacity availability in the industry and a growing gap in terms of the skills and competencies required to do it. The concept that we are developing at the factory is all about manufacturing homes: not building in a shed, as Tim said, but truly getting to the point where we are designing, manufacturing and assembling homes, creating new skills and new capacity for the industry.

**Lord Fox:** You are doing real vertical integration.

**Rosie Toogood:** That is right.

**Lord Hunt of Chesterton:** I was very interested in what you said. A few months ago in this Committee we had people talking to us about fusion and fission. Legal & General, for example, is investing in one of the most advanced areas of modular fusion energy, and so on. It seems of a piece that you are very advanced. My question is about going from that awfulness. Last week in the *Times* there was a report of visiting a building site. I will not name the name but you can read last week’s *Times*. Houses were being completed with just plasterboard and people’s feet, not surprisingly, went through. Is mass production or modular production going to avoid the kinds of errors or problems that you have with ad hoc methods—as it were traditional methods? Presumably, that is one of the reasons for using more advanced techniques. You have a situation such as was reported last week of a very major company putting up buildings, which people have put all their savings in, and it failed. Many of them fail. Will the use of off-site manufacture help avoid that kind of terrible situation?
Legal and General Modular Homes, Greater London Authority and Willmott Dixon – Oral evidence (QQ 9-16)

**Tim Carey:** Absolutely, it should do. Any other industry would not choose to construct something in the way that we do in construction. We would not build an aeroplane on the runway, would we? Undertaking the research and development to design the product in the right way to make it suitable for design, manufacture and assembly creates fewer interfaces than there would be traditionally. In effect, we should be able to produce the same product and deskill the circumstances to deliver that product as well. There is also much greater control in a factory environment than there would be necessarily out on the site.

**Lord Fox:** Did it take a relatively new entrant in the development market to introduce this rapidly? We have two examples of a long-standing developer and a relatively new developer. Is the advantage of being a new developer that you can bring new techniques in and it is harder for an established developer, or is that a spurious argument?

**Rosie Toogood:** I cannot speak for Tim, and he can follow me, but Legal & General has a very positive, disruptive mind-set and a very determined goal here. That has allowed me the freedom to assemble a great team in Sherburn-in-Elmet from a number of different industries. We have people from the automotive industry, aerospace, electronics, construction and design consultancy. We are melding those skills together and bringing the best of the best from those industries to bring new thinking and new ways of doing things. We want to truly understand the customer requirements and take them into the design. It is about really and truly getting underneath the design and designing to a level of detail that is not commonly seen in construction. We want to expand that into a bill of materials and bill of process, as the automakers and aerospace makers and other standardised industries would, and drive the level of process standardisation, consistency and repeatability that has been proven over a number of years to drive up quality. That is the journey that we are on. We have invested heavily to do so. It is not an easy journey, but we are a long way down the track and right at the cusp of getting into production and starting to serve in volume the UK market.

**Lord Vallance of Tummel:** Two of you mentioned in particular affordable housing, which is quite intriguing, because one can argue that there is no affordable housing market at the moment. Housing has become less and less affordable as time has gone on. You mentioned in passing the word “disruptive”. Are we on the edge of a disruptive technology for the building industry for houses? Is this a step change where you could enter it in a very different way, ignoring much of what is going on in the traditional market and change the whole thing?

**Rosie Toogood:** That is certainly what we are about. I used the word disruptive deliberately. We believe we are tackling the market in a very different way and tackling designing and manufacturing in a very different way. That would allow us to scale up the factory rapidly and build in volume.

**Lord Vallance of Tummel:** Is there anything in public policy terms which is holding back that disruptive edge?

**Jamie Ratcliff:** First, the affordable housing situation is not quite as negative as you paint it there. We are starting to see things change. In
the last financial year we started the highest number of affordable housing starts in London since devolution of affordable housing funding to the Mayor.

**Lord Vallance of Tummel:** This is of interest to the Committee. Could you define the price of an affordable house with a couple of bedrooms?

**Jamie Ratcliff:** The affordable housing that we are funding is one of three types. A low-rent product, which is based on council rents, is about £150 a week for a two-bedroomed home. Secondly, a London living rent product, which is based on a third of local incomes, on a London-wide average—it varies from place to place—is about £1,000 a month for a two-bedroomed property.

**Lord Vallance of Tummel:** You are talking about the rental market. What about the price to buy?

**Jamie Ratcliff:** The third one is affordable home ownership, which is primarily part buy/part low-rent shared ownership. The price of that varies from place to place and you buy a share in it and pay a low rent. The average household income of people buying those is about £40,000, which is pretty much the same as the average household income across London as a whole, so ordinary Londoners are buying those homes.

Coming back to your point on public policy, it is quite significant in terms of the way that housing associations, and perhaps, to an extent, local authorities react to off-site precision manufacturing—they had the experience of being told to do it before. In the 1960s, under the subsidy regime, councils were highly incentivised to build homes in precast concrete panels. In the past, the Housing Corporation made housing associations use modern methods of construction, and English Partnerships, through procuring partners on land, made people use certain techniques. That meant they were doing it for compliance reasons rather than being bought into it, and some of the problems that some of them experienced make them negatively disposed to doing this. It only works when we see organisations fully buy into it and see the benefits. The benefits are around quality and speed. The arguments of speed that apply to build-to-rent should apply equally to affordable housing, where you will get more income in at an earlier stage, and some of our partners are definitely seeing that.

Swan Housing Association has set up its own factory in Basildon using cross-laminated timber and a number of our other large partners are committing significant parts of their pipeline to precision manufacturing homes. They are doing it because they see the business drivers for themselves and not because they are being told to.

**Lord Vallance of Tummel:** Is off-site manufacturing more helpful for high-rise buildings than others? Presumably, the answer is yes because the price of land is more than the price of the building itself. Looking at the affordable sector, is there some link between the size of the building you want to build and the use of the technology?

**Rosie Toogood:** I would argue that, with good design, modular housing can address all markets and all tenures.

**Lord Vallance of Tummel:** I can see that, but from a London point of
view, where land comes at a great premium and the value of the land is much higher than the value of the buildings, are you looking to having affordable housing in high rise, or a mixture, or what?

Jamie Ratcliff: We have taken off the brakes on density in terms of the London Plan and we are trying to optimise the density in every location, whether that is on very small sites, very large sites, mid-rise like mansion blocks or tall buildings in appropriate locations. There is a mix of everything. Most of these technologies top out at perhaps 20 or 25 storeys, although there are a couple of 30-storey plus steel-framed buildings in Croydon. One is student accommodation and one is for Pocket homes, which delivers an innovative affordable home ownership product. They can get quite tall. It could work very well on small sites where you could have something that is very replicable and could be delivered at very low cost. We have been talking to a couple of manufacturers which can deliver homes at what look like fantastically low costs—three or four-storey townhouses or small blocks of flats for infill sites around London.

Tim Carey: It is about scale of opportunity as much as scale of building. Most of the technologies can go up to the relevant heights, as my colleagues have said. One of the barriers at the moment is that there are too many design standards. I know it is often preached, but there is a lack of harmonisation of design standards, particularly in the affordable sector. Like anything with manufacturing, the more you can make of the one thing the better.

Lord Fox: Whose standards are these?

Tim Carey: Registered providers, London standards. There is a whole spectrum of spatial standards, and that puts lots of different flavours on what an internal layout should look like. To achieve scale and efficiency, it makes it more difficult than it would otherwise be. If we could solve that problem, we could really get volume.

Q11 Lord Hunt of Chesterton: What changes could be made to the public procurement processes, in particular for public sector housing, so we can have more sustainable and economic housing? To add to that, a point which we discussed with the previous panel is whether we can have highly intelligent customers who will help us to improve the procurement process. There needs to be more training if all these different organisations are buying housing. You have a specialist branch in the GLA, but all sorts of people are involved in making these decisions about housing and sometimes they are rather amateurish.

Rosie Toogood: In any major change you always have the early adopters who are the enlightened advocates of that change, who will move first and prove out the concept. We are working with a number of councils, local enterprise partnerships and housing associations which fit in that mould. I know Jamie, through his work in the GLA, is also encouraging that. I think we will start to see groups of councils and local enterprise partnerships coming together.

One thing that would really help is a long-term pipeline of demand. We touched on the fact earlier that keeping the flow in a factory is really important in terms of driving efficiency, quality and improvement. It is
really important to have long-term aggregated demand pipelines in the industry. Collaboration and changing the way in which contracts are let fits with a long-term aggregation of demand so that you are not contracting scheme by scheme; you are working in long-term partnerships with some of the major housing providers. Those sorts of things would really help modular to take off. Promoting innovation and skills through technology centres, much like the Manufacturing Technology Centre in Coventry and the Advanced Manufacturing Research Centre in Sheffield, can provide a real benefit to the industry.

**Lord Hunt of Chesterton:** In Germany, I believe many insurance companies are quite involved in investment. Is what you are doing with Legal & General similar to what is being done in other countries in Europe or is it very new?

**Rosie Toogood:** I cannot comment directly on that.

**Lord Fox:** Mr Carey, you mentioned the standards issue: who could drive the standards together? The second point on aggregating demand is whether we wait for the councils, local authorities and housing associations to do this naturally or could the Government do something to bring these things together and create aggregated demand? In London there is a big aggregated demand almost naturally, but outside of London in smaller authorities what could central government do in both cases to drive standards together and to aggregate demand?

**Tim Carey:** On the first part—and I have to confess I am not an expert on the various groups that can be established—I would suggest some kind of specialist group/task force that was charged with working with various interested parties to aggregate their thoughts and deliver a standardised suite of harmonised design standards. Similar things have been done in the medium to longer-term past. If we leave the industry bodies and registered providers to themselves, trying to get an agreement without an external influence would be very difficult. I think it needs an independent body to do that for them or to work with them.

**Jamie Ratcliff:** I am pleased to say that we have just procured some work with some partners—manufacturers, a large housing association, a build-to-rent provider—and commissioned Cast consultancy and Bryden Wood to come up with the beginnings of a standardisation guide, which would address Tim’s point. But that is coming from two perspectives, one of which is on the client side of how you can have a more standardised layout which can be more replicable and built at a higher quality, and secondly on the manufacturer side of there being too many small manufacturers which have a bespoke product that no one else can do. That creates a lack of resilience in the supply chain. If only one quite small company can do something and it goes wrong, that is a big problem. We need to look at standardised fixings and at different technologies that can fit together if something goes wrong.

**Lord Fox:** If you are able to give us a few details, I think that would be quite useful.

**Jamie Ratcliff:** I can certainly send a link to the outline of it and it will be progressing fairly soon with some more announcements.
Rosie Toogood: We are working with Jamie on that project with Cast. We are one of the sponsors of that activity because we feel that that standardisation drive is really important.

On the subject of aggregating demand, we are also doing work with local enterprise partnerships and bringing groups of councils and housing associations together through the various industry and trade bodies to try to create a like-minded group of early adopters who will work with us on developing the modular products. Anything that can come from government to help encourage that positively and in favour of modular would be welcome.

The Chairman: We will get evidence from the people you have mentioned in due course, but can I move on to Lord Borwick?

Q12 Lord Borwick: The planning system is so often most of the critical path of a new development. How could the planning system be changed to encourage the use of off-site construction and make it all happen quicker?

Jamie Ratcliff: The current planning system is agnostic about how homes are built. Through the development of the draft London Plan we looked at it in quite a lot of detail. One thing we explored was whether you could give some kind of height reward to people who were doing standardised homes, on the basis that you might not get as many homes if you had a standardised block of things that fit together and you might need to go a bit higher. That did not work for two reasons: we have ripped up the density standards and said that the optimum density should go everywhere, so it is about trying to get as much as possible, and because the technologies top out at a certain level, it might not be that useful to give somebody a height reward. Within the current planning system, I think it is quite difficult.

In 2015, I spent some time in California and they have a very different planning system from us, but their system of accreditation, which is somewhere in between our planning approvals and building control, was carried out in factories, some of them in the Far East or a long way from California, and was able to give certainty and predictability through their equivalent to the planning system by doing that. It feels as though we should be more open to some innovation in that space.

Lord Borwick: As far as Legal & General is concerned, what changes would you suggest, not to keep it agnostic but to bias the system in favour of off-site construction?

Rosie Toogood: I think the work that we are doing on standardisation will help. We find that by working with the early adopters with a positive mindset we are able to get through the issues that we need to get through and deliver.

Q13 Lord Fox: The Government’s industrial strategy has involved a number of different sector deals and it was announced in November that there is going to be a construction sector deal. The details are still emerging, so now is your chance to try to feed in what the construction sector deal should focus on to deliver the promise that we are hearing for off-site construction.
Jamie Ratcliff: Announcing new pots of funding is not necessarily the most helpful thing because some of the previous pots of funding that have been announced have not been deployed.

Lord Fox: The intimation is around pots of funding for new construction methods and things such as that, so there is an element of that.

Jamie Ratcliff: For example, we have been talking to government for well over 18 months about London’s share of the accelerated construction fund and, while I have been told progress has been made, there is no confirmation of the money we are going to get, so we can get on and do something. We have said that we would like very much to use that money to drive much more precision manufacturing of homes and it is caught somewhere in the machinery of government. If more pots are announced and they take just as long—

Lord Fox: Point made.

Lord Hunt of Chesterton: Can you explain why there is this reservation about introducing higher standards? You are saying you want a higher standard of construction which this off-site method will deliver. Are you saying there is some problem in government about that?

Jamie Ratcliff: In deploying the funding, in London we do not have an automatic share of pots that are announced. We have to negotiate on a case-by-case basis and sometimes it takes a very long time for us to get our share and be able to do something with it. The accelerated construction fund is definitely one of the slower ones, in my experience.

Baroness Neville-Jones: And funding is competitive.

Lord Fox: Are there any other thoughts?

Rosie Toogood: We need a new mindset in the industry and a new approach. I would like to see more collaboration, more long-term contracts, fewer adversarial contracts, more interdependence, less power within the relationships down the supply chain and longer pipelines of secure demand, so we can plan, resource, invest and improve the products, and more investment in innovation and skills. We are building capacity in the industry, bringing in people, multiskilling them and making them able to do a number of different tasks, rather than giving them just one skill or trade, and those things are key. We are also developing new skills and trades, so there is more advanced understanding around architecture and design, and design for manufacture and investment in that space, and more investment around the logistics and manufacturing flows and manufacturing engineering. Investment in innovation and skills in those spaces would be really helpful.

Tim Carey: I agree with all that. With the research and development in technologies there is an ongoing demand for it. The more we push higher standards of construction—higher thermal performance, higher efficiencies of everything else as well—that will, in effect, force us to use more methods of construction as the traditional ways of constructing houses can no longer meet those requirements. There is a useful lever there that some kind of incentivisation for higher levels of thermal performance would be a big thing.
Lord Fox: Environmental frameworks?

Tim Carey: Frameworks is a big thing as well; we need to acknowledge that as a main contractor there is a disparity between the requirements that I need to fulfil for my customers in terms of providing three quotations for a particular trade and my desire to partner and provide a meaningful pipeline to an off-site supplier. That goes back to trust and evidence.

The key thing for me in all this is that effectively we are asking a customer or an end user to make a different decision—to elect to support the use of off-site rather than something that they know and may think is a better option. We do not collect enough output data on projects. We are working with BSRIA on this to try to collect data, because if we are asking someone to make an informed decision, they need to be informed. We need some kind of lever that we can put in place whereby we can capture outturn data from projects so that we can prove that where we use off-site, we have the benefits of fewer defects, more time certainty, lower costs, repeatability and so on.

Lord Mair: This seems to be a marketing issue. Is it a marketing issue that Legal & General is addressing?

Rosie Toogood: I think it is a change curve. As I said earlier, you get early adopters who absolutely get the modular benefits, who are passionate about that and who we are working with. As we gain momentum in that space, I think the market will move.

Tim Carey: We need to bridge the adoption gap and data again. Sorry to reinforce it, but data will help us to get over that. We need to be more explicit about marketing. We still talk in the industry about a “World in Action” report that happened in 1983 backing timber-frame and that was years and years ago. We need to reinforce the positive messages about off-site and the outturn impacts that it can have as well.

Lord Vallance of Tummel: In a way it is not so much construction as manufacturing and assembly. That is the slip gain.

Tim Carey: Absolutely.

Q14 Lord Hunt of Chesterton: This carries on from the previous discussion. What reskilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction? A point we have not discussed very much is the fact that where you put your houses makes a difference. In some areas that I know of in the UK, valleys in Devon and other places, it is much more difficult to put up houses. Is the use of off-site methods going to be appropriate just for nice level areas where you build them, or are we going to be able to use these new techniques in many areas of Britain where people live that are quite demanding, with complicated floods and slopes and so on? Will the new technologies be available for those areas as well?

Jamie Ratcliff: I do not know much about Devon, but if I take the first part of your question, if we had a reskilling challenge, that would be a nice problem to have. We have the opposite which is a dramatically reducing construction workforce. The Farmer review found that due to the
age profile of the workforce, huge numbers are retiring and not being replaced and there was what he called a “burning platform”. That was before the referendum on leaving the European Union. In London, according to official statistics, half the workforce is from overseas, and we think the figure could be much higher. There is a massive challenge with the uncertainty of what is going to happen when we leave the European Union, and what that means for our construction workforce. Whatever is left, we are likely to need to keep building in traditional ways. We are looking at building in factories as being more productive and needing fewer workers per home that is built. We hope it will attract many more new people into the industry, who will be attracted to working in different places.

For me, one of the key benefits of moving more homes to being precision manufactured in factories is that you can attract a more diverse range of workforce. Currently, only 12% of the construction workforce in the UK are women, so we are ignoring half the population who could have a safe and dry fixed place of work, where they can have split shifts, it will be more flexible and there can be more oversight. That should be appealing to women and we should be able to get a greater gender balance in the workforce, which is one of the things we need to do.

Q15 Lord Mair: Can I ask about the issue of off-site manufacture potentially hampering architectural ambition? There is a perception that somehow having standardisation of components means standardisation of the end product and the prevention of architectural interest. What are your views about that?

Jamie Ratcliff: I do not buy it at all. I was booed out of the AA School of Architecture a few months ago when I talked about standardisation and having standard elevation and fenestration treatments. I was in their building in Bloomsbury Square which is entirely standard and in one of the most beautiful parts of London. I think some of that is overstated. The other thing that is overstated is, according to the numbers that my team pulled out for me, there are just over a million terraced homes in London. Pretty much all of those are of a standard design—it is two-up, two-down, with an outrigger at the back—and there is a huge amount of variety you can have within that standard design. Many more have been converted into flats so it is probably more like 1.2 million in terms of that standard building that can be converted.

What we are starting to see—I mentioned the Swan factory earlier—through manufacturing and having standardisation is mass customisation. You see it in car manufacture, which Rosie might want to say something about, as she knows much more about it than me. Swan, through their initial site in Basildon, is offering consumers 288,000 options in terms of things that they can vary. It is very easy for them to offer those options because they are just swapping out different components within the factory. You can have variety and flexibility, but you are not sacrificing how beautiful the building looks. You can finish them externally in what you want and have a range of different interesting things happening.

Rosie Toogood: In many other industries, standardisation is seen as an enabler, a building block for the added extras and the flair. Our intention
is to create the standard building blocks in terms of the modular design and be very sympathetic to the needs of the individual housing association, council and local enterprise partnership in terms of creating a different street scene and different orientation of the housing, different fascias and roofing to create nice places to live. That is how we intend to work with our clients.

**Lord Renfrew of Kaimsthorn:** So there is a role for the architect still in implementing design locally?

**Rosie Toogood:** And creating great places to live—absolutely.

**Lord Fox:** We are conflating two things here: off-site construction and standardisation. Are you saying that standardisation, which has all the benefits you have just described, is impossible to do with on-site construction? Or do you have to have the off-site delivery to deliver the full benefit of standardisation? Is there an agenda that says that we should standardise on-site construction as well?

**Tim Carey:** I think it is both. There are definitely benefits to standardising on-site construction as well.

**Lord Fox:** But it has not happened.

**Tim Carey:** It may not have happened in a widespread fashion. There are pockets of good practice where it does and we do not have to keep reinventing the wheel.

**Lord Fox:** I am suggesting that off-site delivery forces standardisation whereas with on-site delivery it kind of drips in.

**Lord Hunt of Chesterton:** You have just said there are hundreds of thousands of permutations you can make.

**Lord Fox:** But it is still standard.

**Tim Carey:** The thing about a mass customisation platform-based approach is you get the benefits of both. Off-site will drive the standardisation, because, inevitably, if you are going to design a system from the ground up, you are going to design it with standardisation of components in mind. There will always be a role for an architect. Designing standard components does not mean that you do not need an architect to assemble those in an elegant, beautiful manner. It just means that you spend your time on the elements that matter to the end users and the surrounding vernacular rather than worry about how you build a wall or a ceiling time and time again.

**Jamie Ratcliff:** I think it is about discipline. Standardisation would absolutely deliver a range of benefits through traditional construction, but because there is no massive cost which is immediately apparent of tweaking something or doing something a bit differently, people do. We have been involved in a site with about 700 homes where there are 368 different property layouts. I do not think an architect who has been employed to make a toilet go in a slightly different place or a corridor look a bit different is utilising his or her skills particularly well, whereas getting something right and replicating it would have delivered lots of benefits. In a traditional construction, you probably do not get all the benefits of the
quality, the oversight and the precision that you get from building homes in factories, but you can go quite a long way through standardisation.

**Lord Mair:** To follow up this point, Mr Ratcliff, of the three of you, you are a client: would you be giving preference to off-site manufacture in your design briefs to your architects? In the business of producing houses would you see that as a preference now?

**Jamie Ratcliff:** We do not directly procure any homes ourselves. We mainly fund third parties such as housing associations or councils, which would be building homes themselves. The point I have made before is the client has to adopt it. I would not want to put rules in our grant that made people go in a certain way, but, certainly, we have been trying to create a strategic environment where it makes sense for them to push people to deliver homes at speed, at scale which drives you towards these types of things.

**Lord Mair:** Do you think that those organisations that are clients are beginning to get the message about the advantages of off-site manufacture or do you think there is still a long way to go?

**Jamie Ratcliff:** By nature I am an optimist, but it does feels like we are at a point where we are going to see much more precision manufacturing. The build-to-rent sector is driving that but lots of forward-looking housing associations very much want to do it at scale as well. Some of those with large sites have signed up to ambitious build programmes that need to deliver at pace, because they have committed to that pace they are therefore committed to looking at delivery in a different way.

**Q16 Lord Renfrew of Kaimsthorn:** I was very struck by the point made earlier about harmonisation of design standards standing in the way of off-site construction in some cases, or resistance to harmonisation of design standards, I suppose. That really surprised me, because I have been trying to understand what has impeded a more rapid adoption of off-site manufacture. That was the strongest argument that I heard and I see that could be an impediment to plans being adopted. Is that a fair comment?

**Tim Carey:** You have made the point and I would think that is an entirely fair comment. I see that as one of the biggest barriers, because, at the end of the day, you can still do it, but it will not be as efficient as it could be. I would agree.

**Jamie Ratcliff:** It is a question of how much of that variation is conscious and value-adding to activity. Certainly my hypothesis is that very little is. It is people tweaking things because they can, for example a designer who is asked to produce a new staircase makes up a new staircase each time.

**Lord Hunt of Chesterton:** I asked this before: what about energy? An extraordinarily important part of the buildings is the energy. In the public sector programmes you are doing, are you ensuring more uniformity of the energy systems in the houses or can people choose different heaters, refrigerators and other devices? Will that be an area where you can have regularisation and more efficiency?
Rosie Toogood: We believe the way in which we are designing and precision manufacturing these homes makes them more airtight and delivers homes of a higher quality and use of the fabric-first approach allows us to deliver homes which are more energy-efficient in the long term. That is driving up standards in the industry across the board. In terms of adopting new energy systems, the factory-manufactured environment allows us to look at innovations in the way in which energy is captured and stored to be able to take homes off grid and deliver new energy solutions.

Lord Hunt of Chesterton: As I understand what you are saying, it still means that you will do all this insulation, but people in different houses in a big block will use their own different energy devices, whereas in Germany there seems to be much greater standardisation of the energy supply in their public housing. Is that important?

Jamie Ratcliff: I am not an expert, but I can certainly get somebody to write with a bit more information on our policies in relation to decentralised energy and how that is supplied. We have adapted the approach in the latest draft of the London Plan and in the right places, with the right demand for energy, we are certainly promoting it a lot. If it is helpful, I can get some more information and provide that.

Lord Hunt of Chesterton: In New York it is well known that you have centralised heating which makes an extraordinary contribution to efficiency. We do not do that in England but rely on a neighbour’s heat or whatever it is.

The Chairman: No comment on that. I think our time is probably up. You have helped us a lot. May I thank all three of you for taking time out to come and help us.
Prepared by:

**Dr Chris Goodier** PhD MCIOB FICT FHEA, Director, Centre for Innovative and Collaborative Construction Engineering and **Prof Alistair Gibb** PhD BSc CEng MICE MCIOB, Professor of Construction Engineering Management

### Perceived advantages of offsite manufacture for construction

1. The potential advantages of offsite are well researched and widely available, and Loughborough University has led much of the academic research in this area, see books: Lawson et al 2014, Goodier & Pan 2010, and Gibb 1999; papers: Goodier and Gibb, 2007 (amongst others); and website [https://offsite.lboro.ac.uk/](https://offsite.lboro.ac.uk/). Tables 1 and 2 in the Appendix provide a useful summary.

2. Claimed advantages include: decreased time, less waste and environmental impact, and less H&S risks. Reduced cost is sometimes expressed, but a perceived offsite cost premium often exists. Costs are also dependent on the supplier, location, design, and number of units/dwellings, amongst other factors.

3. The future housing market however, neatly matches the widely-accepted attributes of offsite as there is: a diminishing pool of skilled tradesmen; a required increase in build standards; a need to reduce accidents, and; a marked increase in housebuilding output.

4. The main advantage is speed of deployment. Often the choice of approach (e.g. volumetric or non-volumetric) is determined by the function of the specific unit and the overall project requirements, location, and number required. Table 3 (Appendix) provides a useful comparison of potential benefits and drawbacks of volumetric and non-volumetric construction.

### Potential barriers to wider use of offsite manufacture

5. Similarly to the advantages, the potential or perceived disadvantages of offsite are well researched and widely available, much of it by Loughborough University, for example Tables 4 and 5 in the Appendix.

6. Despite these potential disadvantages, recent decades have seen increasing interest in adopting offsite technologies for housebuilding. However, for the offsite market to continue to develop, the negative connotations need to be overcome and more transparent information provided to decision makers, particularly cost comparisons with traditional methods.

7. Anecdotal evidence suggests that the house-building industry is receptive to the use of offsite construction solutions where it is in their commercial interests to do so. However, there is often a reluctance to consider the adoption of offsite, and many remain sceptical given past failings and bad publicity. For some, there is a reluctance to embrace offsite, so housebuilders have often instead endeavoured to improve their traditional methods instead.

8. An increased adoption of offsite would require a cultural change among both those housebuilders who have always used traditional methods, and consumers, who often prefer masonry houses due to negative offsite experiences or perceptions, some of it from as far back as post WWII.

9. Despite an increasing awareness of using more balanced criteria, technology selection in house building is still largely cost driven (Pan et al, 2012).
Additional criteria including time, process, quality, and procurement is often interpreted in financial terms, either implicitly or explicitly. Sustainability, H&S, and regulatory and statutory acceptance criteria are regarded by housebuilders as important but compulsory, hence offering little trade-off in the decision equation. A lack of strategic thinking regarding incorporating innovative sustainable technologies into organizational strategy is also commonplace (Pan et al, 2012).

**Housebuilding production strategies and the disadvantage of offsite**

10. Most of new UK housing is currently delivered by the private sector using predominantly traditional, site-based, construction methods. Private housebuilding firms production strategies are a direct response to their operational environment, and the adoption of offsite would arguably alter the way that they deliver their developments. Hence, there is a clear need to understand the relationship between house building firm’s production strategies and their construction methods (Lang et al, 2016). Increased offsite approaches therefore, will potentially alter the way that house-building firms manage their production processes, reducing their control, and crucially, restricting the very flexibility on which their own business model (and hence success and profits) relies.

11. Traditional construction methods allow a flexible (house) production approach - production speed can be adjusted at both the unit level (how quickly each house is constructed) and the site development level (how many houses are under construction on one site). Furthermore, as the basic materials (mainly brick and block) and the construction process (mainly bricklayers) used are not plot/site/house type specific, and can be easily moved around the site from unit to unit, as well as to other sites, housebuilders are able to purchase materials and labour without committing to the exact timing or location, or even the actual design, of their houses.

12. The increased adoption of offsite methods would therefore potentially reduce housebuilders' flexibility to respond to changes in the housing market, both locally and nationally (Lang et al, 2016). The longer lead-times associated with offsite methods (i.e. the early design freeze and the offsite manufacturing stage) requires the housebuilder (usually) to commit to a production schedule significantly in advance of actual unit sales. When market conditions deteriorate (which they always will at some point, and which housebuilding firms are acutely aware of and sensitive to), or do not grow as anticipated, offsite housebuilders may find it difficult to reduce unit output and thus expenditure. The risk of committing to production early is a concern for housebuilders looking to adopt offsite – there is a risk that they will no longer have full control of production, and hence financial outlay, on site.

13. The requirement for flexibility during housing production therefore, is a response to the frequently uncertain market conditions. Therefore, if the operational environment was more predictable (i.e. guaranteed sales and price in specific locations), the need for flexibility in production would diminish.

26 April 2018

**Relevant Loughborough University references**

Other work referenced here


### Appendix – Data Tables

**Table 1. Advantages of offsite (Goodier and Gibb, 2007)**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Time**  | ▪ Less time on-site – speed of construction  
▪ Speed of delivery of product  
▪ Less time spent on commissioning  
▪ Guaranteed delivery, more certainty over the program, reduced management time |
| **Cost**  | ▪ Lower cost  
▪ Lower preliminary costs  
▪ Increased certainty, less risk  
▪ Increases added value  
▪ Lower overheads, less on-site damage, less wastage |
| **Quality** | ▪ Higher quality on-site and from factory  
▪ Product tried and tested in factory  
▪ Greater consistency- more reproducible  
▪ More control over quality, consistent standards |
| **Productivity** | ▪ Includes less snagging  
▪ More successful at interfaces  
▪ Less site disruption  
▪ Reducing the use of wet trades  
▪ Removing difficult operation off-site  
▪ Products work first time  
▪ Work continues on-site independent of off-site production |
| **People** | ▪ Fewer people on-site  
▪ People know how to use products  
▪ Lack of skilled labor  
▪ Production off-site is independent of local labor issues |
| **Process** | ▪ Program driven centrally  
▪ Simplifies construction process  
▪ Allow systems to be measured |
Table 2. Advantages of offsite

<table>
<thead>
<tr>
<th>Source</th>
<th>Increased quality</th>
<th>Decreased time</th>
<th>Less health and safety risks</th>
<th>Reduced cost</th>
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<td></td>
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<tr>
<td>Goodier and Gibb (2007) *</td>
<td>✓</td>
<td>✓</td>
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<td>Lu and Liska (2008) *</td>
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<td>✓</td>
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<td>Jenkins and McLachlan (2010)</td>
<td>✓</td>
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<td>Elnaas et al. (2014)</td>
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<td>Gibb (1999)</td>
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* indicates authors reporting on the wider construction sector rather than specifically housebuilding.

Table 3. Comparison of potential benefits and drawbacks of volumetric and non-volumetric construction (Gibb, 1999)

<table>
<thead>
<tr>
<th>Volumetric</th>
<th>Non-volumetric</th>
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<tbody>
<tr>
<td>Benefits</td>
<td></td>
</tr>
<tr>
<td>• Minimal assembly required on site</td>
<td>• Ability to customize product to customer specifications</td>
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<tr>
<td>• Speed of deployment</td>
<td>• Easier to ship or transport</td>
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<tr>
<td>Drawbacks</td>
<td></td>
</tr>
<tr>
<td>• Less flexible to customer demands</td>
<td>• Requires more assembly on site</td>
</tr>
<tr>
<td>• More difficult to transport larger, volumetric modules</td>
<td></td>
</tr>
<tr>
<td>Typical use cases</td>
<td></td>
</tr>
<tr>
<td>• Toilets / washrooms</td>
<td>• Structural frames</td>
</tr>
<tr>
<td>• Kitchens</td>
<td>• Exterior cladding</td>
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<tr>
<td>• Elevators</td>
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Table 4. Disadvantages of offsite (Goodier and Gibb, 2007)

<table>
<thead>
<tr>
<th>Disadvantage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Time</td>
<td>Longer lead-in times</td>
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<tr>
<td>Cost</td>
<td>May be more expensive</td>
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<tr>
<td></td>
<td>Obtaining finance may be a challenge</td>
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<td></td>
<td>Competition, with potential lack of market demand</td>
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<td>Quality</td>
<td>Few standards available</td>
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<td>Restrictive regulations</td>
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<td>General negative image of prefabricated buildings</td>
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<tr>
<td>Productivity</td>
<td>Increased risk</td>
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<td></td>
<td>May not be a locally-available option</td>
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<td>Technical limitations</td>
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<td>People</td>
<td>Client resistance</td>
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<td>Lack of personal experience of use</td>
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<td>Insufficient worker skills</td>
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<td>Process</td>
<td>Lack of readily-available guidance and information</td>
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<td></td>
<td>Lack of manufacturing capacity</td>
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Table 5. Disadvantages of offsite

<table>
<thead>
<tr>
<th>Source</th>
<th>Perceived cost</th>
<th>Transport constraints</th>
<th>Stakeholder</th>
<th>Longer lead-in times</th>
<th>Lack of flexibility</th>
<th>Slower planning</th>
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* indicates authors reporting on the wider construction sector rather than specifically housebuilding.
Low Carbon Construction – Written evidence (OMC0038)

1.0 It is our firm belief that off-site construction provides part of the solution to the affordable housing crisis, but it can be completely resolved with a further level of innovation - the widespread introduction of offsite/onsite construction – a solution that provides even greater efficiency, productivity and environmental advantages.

1.1 Offsite/onsite combines the concept of bringing together construction processes and components into one place for construction/assembly with the creation of bespoke ‘factories’ at each development site, that are removed at the completion of each build, making way for amenity space and/or car parking. This process removes the need for transportation of building modules from distant factories therefore reducing the environmental impact, significantly saving time and money, increasing efficiency and productivity and what is more offering local employment opportunities at each site.

1.2 The LCC method of Modular SIPS Offsite/Onsite construction is unique in the world. Our method relies on the remote production of 1200 x 2400 175mm SIP Panels - manufactured in Liverpool by our Supply Partners, Hemsec. The high quality affordable home interior and exterior components, supplied by our dedicated supply chain partners, are then fitted seamlessly in our ‘production line’ within a factory controlled environment with our methodical fit out teams working at low level. Totally completed ground floor sections are rolled out to their closely located foundation, followed by first floor and roof sections when the services are linked.

1.3 Once combined with structural timbers these form large ‘Modular Sections’ of a building which can then be 100% completely fitted out externally and internally within the temporary assembly factory without ever having to use road transport to be installed on the plot.

Opportunities offered by offsite construction

2.0 This innovative method of construction offers a large amount of opportunities, predominantly:

- Providing an efficient means to construct a mix of housing of different sizes, types and tenures to meet local needs, creating a balanced housing market within developments.
- Provides value for money and the best use of public resources where such funds have been made available in high value land areas.
- Well-designed properties of a high quality, creating strong and inclusive communities living in safe and affordable homes.
- A long term sustainable solution, protecting the affordable home status within high land value areas (if combined with our proposed covenant to ensure affordability in perpetuity).
- Protects and enhances the environment.
- Maintains and extends the health and prosperity of tenants and purchasers through the latest fire safety innovations, the latest technology in air quality control equipment and low energy costs enabled by the standard
fitting of Solar PV and Battery Storage resulting in free electricity for the home occupier - making an affordable home also truly affordable to live in.

Factors likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to chose offsite manufacture?

3.0 The LCC strategy to provide affordable housing is supported by the pre-agreed and extensive network of a 58-strong company supply chain, including providers of flooring, kitchens, bathrooms and environmentally innovative solar technologies. Due to the ‘production line’ style of construction this provides a guarantee of high quality components in each and every home, giving the architects, design engineers and contractors the opportunity to develop housing styles that meet the needs of the community. In addition:

- The homes are equally affordable to heat and light. This enables the provision of affordable housing for those on lower incomes and those who otherwise could not obtain housing easily.
- It guarantees a safe, affordable and healthy place to live by ensuring that occupiers are protected from fire, have low energy costs, and enjoy good health by installing the latest technology in air quality control equipment within their home.
- It creates strong and inclusive communities, making developments secure with estate wide CCTV coverage to discourage crime and encourage social responsibility towards neighbours.

How can offsite manufacture lead to:

Lower costs, faster delivery & increased quality

4.0 Offsite/onsite assembly factories allow LCC to deliver at least 250 homes per factory, per annum on each and every site they commence (with the option for multiple factories per site) and the method removes all the volume and delivery barriers faced by modular offsite builders and traditional construction methods to date.

4.1 Consequently, we are uniquely able, with the support of our supply partners and professional team members, to actually physically deliver on the Government ambition of 225,000 homes over this Parliament, as we are only limited in volume of homes that can be produced by virtue of land availability and planning approvals.

Increased productivity

5.0 Traditional construction methods would typically result in the construction of approximately 2 houses per week, however traditional methods can be impacted by many external factors such as the weather, which can bring about extensive delays. With offsite/onsite construction it is possible to guarantee the production of five houses per week, per factory, empowering planning teams to guarantee both time and budgets of their programmes and ensure that they do not over run.

Improved health & safety

6.0 Offsite/onsite properties constructed by LCC improve the health and wellbeing of residents through a number of innovations including the inclusion of the following technologies as standard in every home:
• Fire Suppression Water Mist system in every home
• Fire Retardant Underlay under all carpets
• Solar PV and Battery Storage which means FREE electricity for the home occupier - making an affordable home also truly affordable to live in.
• No Gas – so no servicing costs or breakdowns.
• Individual room Thermostatic Heating Control

Greater provision of new, affordable housing.
7.0 As already mentioned, the unique Offsite/Onsite SIP Volumetric Factory delivery method, which LCC has pioneered, is capable of delivering anything up to 50 homes per week (per development site) and therefore capable of increasing housing supply in very substantial numbers, subject only to suitable site availability.

Barriers to offsite manufacture for construction
8.0 For the government to achieve their target of providing over 45,000 new affordable homes per annum across all sectors seems, to us, to be unrealistic under the current methodology, even with the investment they propose. We see, on a weekly basis, construction firms abusing the viability loophole and reducing their commitment to affordable housing on the sites they have been commissioned to develop and offsite construction will not address this problem. Instead of allowing developers to continue with reduced levels of affordability provision they should be compelled to release land to Offsite/Onsite manufacturers who are able to deliver on that provision of 100% affordable home developments. Communities cannot and must not suffer because of the economic realities of current build methods when a viable alternative is already available with LCC.

8.1 If targets are to be met, then the availability of land will be a key component. Increasing the land supply for the use of offsite/onsite construction to deliver affordable housing, including the use of existing, redundant council and Government owned land, would of course help, but there will still need to be ‘fast’ planning decisions at the LPA level.

What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?
9.0 Offsite/onsite will use less skilled personnel as you do not need some of the skill sets for wet trades, such as bricklaying or plastering. Fundamental to ensuring the provision of high quality homes is securing high standard partners in the supply chain. This enables the installation of, not just standard fittings, but state of the art elements all available within the affordable price bracket including:
• Very Low Maintenance Exterior Finishes.
• Triple Glazed Argon Filled A Rated Windows.
• ThermaSkirt Heating, with every room individually controlled by thermostat.
• Magic Thermodynamic Box Solar Assisted Water Heating.
• Electric Car Charging Point.
• LED Downlights throughout.
• Personal choice of Kitchen Units and Worktops from Howdens Joinery Co.
• Personal choice of Wall Tiles from Topps Tiles.
• Personal choice of Flooring from Karndean and Cormar Carpets
• Personal choice of Bathrooms from VictoriaPlum.

**Can the benefits of standardisation & factory manufacture be realised without hampering architectural ambition?**

10.0 From 2012 through to 2016 LCC has successfully delivered ever larger and more complex types of bespoke residential and commercial buildings, which has allowed us to prove concept of both design and delivery of our unique build system. During these formative years LCC has been able to pioneer many new building techniques to achieve a thoroughly tested model for the expedient delivery of bulk housing stock. This provides the reassurance to any architects with ambitions for innovation that the method is agile and enables unique construction as well as harnessing the value in quantities of similarly efficient designs.

**What R&D is needed, by whom to realise fully the potential benefits?**

11.0 Due to extensive R&D innovation we are already able to use our unique Offsite/Onsite method of Volumetric SIPs Construction which allows us to install a ‘temporary’ Volumetric SIP Assembly Factory actually on the development site and then remove it at the end of the development cycle once all the Homes are delivered.

11.1 LCC has pioneered many innovations already and continues its R&D with a passion. A few of our pioneering ‘firsts’ to show our commitment to industry innovation include:

- First to use SIPs as a standard floor structure.
- First to use SIPs as a standard flat roof structure.
- First to use SIPs as a standard ‘dormer’ roof window structure.
- First to manufacture and deliver a 100% SIPs Modular building Offsite.
- First to use only BBA (British Board of Agrément) and CE marked accredited SIPs in Modular/Volumetric form.
- First to design/implement the LCC Offsite/Onsite method of construction.
- First to be able to 100% finish a Modular SIPs building within a factory environment.
- First to use Polyurea (‘Prokol’) to water and air seal all Homes as standard.
- First to specify MVHR in every home as standard.
- First to specify Solar PV (with battery storage) on every home as standard.
- First to specify individual room Thermostatic Heating Control as standard.
- First to specify a Fire Suppression Water Mist system in every home as standard.
- First to specify Fire Retardant Underlay under all carpets as standard.

26 April 2018
Low Carbon Journey – Written evidence (OMC0005)

Author: Tom Jarman, Director

I am submitting in a personal capacity although I work for a large Local Authority and have long experience within a medium size (c.25,000) social landlord. I am also a member of the Construction Leadership Council (CLC) Innovation in Buildings workstream and BIM Regions NE committee.

In this response I define off-site manufacture (OSM) as the production of buildings, or significant parts of buildings that are constructed as a complete system, in a factory. I am assuming that the building and/or components are designed using a digital model and are produced from this model. In this sense it is more similar to what the CLC defines as ‘smart’ construction; factory production from a digital model. The third element of smart construction is whole life costing, which emphasises OSM as a value proposition.

Perceived advantages of offsite manufacture for construction

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

1.1 Opportunities:

a) The ability to produce buildings in a controlled and safe environment meaning higher quality production output in a good working environment. This is important in terms of addressing the performance gap within traditional construction as well as attracting people to the industry;

b) It is also a more productive way of building, meaning there is a better opportunity to deliver housing numbers in a way that recognises the reality of less labour due to demography and Brexit; and

c) It is a route to better value buildings (but not necessarily cheaper). Value can be defined in this context as product quality, ability to design and model performance including fabric, ventilation and climate risk, and including elements within the factory process that would be difficult or more expensive to install on a site due to traditional manual processes;

d) ‘Information as a deliverable’; with most housing procurement the finished product is the deliverable part of the contract and although there is an information handover stage this is generally a less successful element in the process. Because OSM buildings are designed and constructed based on a digital model, the information relevant to the client can be handed over in a structured way during the construction process and on completion. This information is critical to cost-effective long term operational management. While this is less relevant to some client groups than others, information as
an output alongside the product offers real opportunities for long-term asset managers/owners to check the delivered product conforms to design, make sound investment decisions, operate safe buildings, maintain them appropriately, react to information requests quickly and offer a high quality and effective customer journey. Traditionally-constructed buildings can offer this to some extent but the potential to embed the relationship between information, build quality, long-term performance and quality of service to the occupant is embedded in OSM (with some caveats regarding manufacturer and client capability in virtual construction).

e) ‘2050-ready’ buildings. Although 2050 is over 30 years away, we have very little lead-in time for the scale of the challenge ahead. Buildings that meet the coming energy and climate challenges need to be different to the bulk of production today. They will need to be digitally enabled, accommodate renewable and stored energy, integrate with electric vehicles and be zero (or very nearly zero) carbon. They will need to be designed and built with in a way that understands and mitigates risk, and allows them to cope with climate events such as overheating or 1:100 year weather events, including recovery from such events. They will need to support biodiversity and green infrastructure. The fact is that a supply chain that designs and models buildings virtually and constructs them in a factory is much more likely to enable this outcome, which I refer to as 2050-ready.

1.2 Drawbacks generally derive from the requirement to think in terms of DFMA (Design for Manufacture and Assembly) rather than traditional specification. Most of the housing construction and client chain are not familiar with this. There are practical drawbacks in terms of finance and working capital requirements. Client perception is an issue. Finally traditional construction is a risk management tool for volume retail builders within the context described by the Farmer Review (Modernise or Die, 2017).

1.3 Your list of influencers in qu.1 will ultimately be driven by the client, and in the case of a weak or ill-informed client they may seek to influence them one way or another dependent on familiarity with and experience of OSM. Client pull for OSM is extremely important, but it won’t fit all client requirements (eg retail builders have very different requirements to the build-to-rent developers), so it is a case of identifying clients where there is alignment. Many of those will be influenced primarily by cost, so this starts to become a circular argument; OSM is a value proposition, so clients who are cost-driven (even where there is an alignment of interests) and/or don’t think DFMA are unlikely to pull OSM through, so unless they have a design and construction team that can articulate the advantages and are confident about proceeding with OSM, or OSM is the solution to a specific problem, then reliance on traditional construction will predominate.

**Potential barriers to wider use of offsite manufacture**

3. What are the drawbacks to offsite manufacture for construction?

3.1 I’m going to answer a slightly different question, because this question captures one of the issues with OSM that effectively forms a barrier to adoption. OSM is an operational response to your construction requirements
– so as a client you need to (1) understand what quality and performance you want over what period of time, and (2) have enough internal competence to assess whether the industry response is of good quality, what the risks are for you as a client, and how you and your supply chain are going to understand and mitigate risk and successfully implement and manage the solution.

3.2 So there are drawbacks which could be listed as a set of bullet points, but to understand what change may look like and what the implications are we need to focus on a different strategic question, namely how we move as a client group procuring outcomes. Any industry response will have a balance of advantages and drawbacks; my worry is that as a client group we are not sophisticated enough to drive productivity and innovation, because we keep asking questions like question 3.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

4.1 I can see 3 areas worth considering;

a) There is a real opportunity to link more closely with the digital design, modelling and 3D output to support the final quality of the delivered building. This involves an uplift in skills (and culture) throughout the construction chain, including clients, to realise the benefits that can be collaboratively drawn through;

b) Higher performing buildings are riskier buildings, so much greater attention needs to be paid to competence regarding risk assessment. In my view, this is a core client role and we are far too reliant on Building Regulations to deliver these outcomes on our behalf. This works at the moment – just – because most housing is based on traditional construction with a considerable performance gap (this explains further). This is a very risky strategy if OSM (or any low carbon buildings) are deployed at scale, so this is an area where the supply chain and clients need to be much more skilled;

c) Site implementation. This is less of an issue with OSM than traditional construction, in the sense that most completion is carried out in the factory. But someone with a drill on site can do a huge amount of damage that may affect both the health of the occupant and the fabric of the building over the long term. So there is a need for all workers engaged in OSM production to better understand building physics, ie the consequences of poor working practice. There is a lot of crossover here with deep retrofit where similar principles apply; get implementation of a good design wrong and there can be very serious consequences. This presents an opportunity to create a workforce that has a skill set that can be used more widely than just OSM to meet some of the carbon challenges we are facing as a nation.

5. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

5.1 Again, this comes down to the client understanding (1) what they want from a building and (2) DFMA. A good understanding of DFMA means they should
be able to engage in a productive and informed discussion with their supply chain about what is fundamental to the structure and outcomes, and what falls into DF...X, with X being the elements that can be negotiated, tweaked, etc. So the answer to the questions is ‘It depends...’ – but it can’t be properly answered until clients start focussing on what outcomes they want their capital expenditure to achieve and build a level of competence that allows them to manage the responses effectively.

**Government actions**

8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?**

8.1 I think this is more of a question of culture than direct issues with procurement. The key changes needed are to move towards an outcome focus, and build client competence. To some extent this isn’t even about OSM. As a nation at some point in the near future we are going to have to push towards better quality newbuild and a deep retrofit programme for existing stock otherwise we will never meet our climate commitments in 2050. I am not aware of anything fundamental in public procurement that prevents organisations from working more collaboratively, focussing on outcomes and building internal competence. Northumbrian Water have a very refreshing approach to this; “A great organisation has a great supply chain”. I would be interested to see what other responses to this question emerge, but there is a huge amount that public organisations can do to draw through OSM as a value proposition. Lowest capital cost procurement to minimum regulatory standards is the opposite of this, but there isn’t anything I’m aware of in public procurement that obliges the bulk of the public sector to take this approach.

8.2 Secondly, from a procurement point of view Homes England is a key influencer within the social housing sector. This sector is critical to building a successful, innovative, dynamic and productive OSM industry due to the scale of it’s procurement and the fact that it manages assets over the long term. Homes England needs to be an exemplar in terms of outcome based procurement, and separating out the operational decision regarding OSM from the strategic one regarding quality and performance.

*15 April 2018*

**Additional information which may be of use to the Committee;**

In the introduction to this submission I stated that OSM is a value proposition. In some areas of the country such as London and the South East the economics of housing means that in financial terms it can compete with traditional construction to minimum regulatory standards (I call this Building Regs at lowest cost (BRLC)). Generally however, it struggles to compete with BRLC. This is an enormous missed opportunity, especially as BRLC is quite a poor proposition over the long term. Whilst not all organisations need to take a long-term view, some
that should tend not to. This is why the CLC work on Procuring for Performance is so critical. But it is also dependent on a different client culture. Many clients tend to be waiting until the OSM industry has an offer that competes in initial capital cost terms with ‘business as usual’. This is unlikely to happen, meaning that as a nation we are missing the opportunities outlined in 1.1. My graphic below may be useful, and to me emphasises why Homes England has such a critical role as an influencer, grant distributor, as an exemplar in its own procurement practice and as a real source of challenge to the housing sector.
Mace – Written evidence (OMC0025)

Perceived advantages of offsite manufacture for construction

1. The opportunities offered by offsite manufacture for construction

The primary opportunity is to improve productivity, which will support wage growth and increase profitability within the industry. Research by Mace shows that if we’d just kept up with manufacturing since the mid-1990’s – construction could be delivering more than £100bn of additional economic growth in the UK, and providing more than £40bn in additional tax revenues to the Exchequer.

That would be enough to pay off the predicted 2018 budget deficit, add 3% to our GDP and increase construction productivity from £25.50 an hour per worker to £38 per hour per worker.

In its current state, construction performance is poor, and has been for too long. More than 50% of the labour used on projects could be saved by eliminating delays and achieving best practice task productivity – BSRIA study in 1997. Up to 15% of materials delivered to sites ends up in skips – WRAP report 2007. Defects and errors in traditional projects adds up to 20% to their final costs – Get It Right Initiative, 2017.

We need to change. Offsite construction will enable significant benefit. We have direct experience of delivering cost efficiencies, faster speed to market, improved quality and with better sustainable performance through the use of offsite construction methods.

The opportunity is potentially broader than that. Clear focus and commitment from the Government, at scale, will unlock the opportunity for rebalancing construction activity across the UK, moving emphasis from London into regional manufacturing heartlands as we shift supply chains. A manufactured construction industry could allow UK companies to research, develop and build new products, for use both in the UK, and internationally, boosting export revenues.

Collectively the industry, be it clients, architects, engineers, contractors or the supply chain, recognise the need to change. We are still influenced by institutional challenges, such as funding models that demand tried and tested solutions and impose challenging risk transfer mechanisms, together with the risk of failure vs the limited balance sheet capacity of the industry. We need to recognise the initial higher capital expenditure costs of offsite construction, and the need to allow appropriate time for R&D, and prototyping when developing schemes that include high levels of MMC.

2. Evidence of the benefit of offsite construction

We see it as a safer, and better way of delivering construction. At Mace we have been driving an offsite construction agenda since building the London
Eye on the Southbank in 1999. On this project, off-site modular sub-assemblies, including the steel rims, and passenger capsules, allowed us to meet an immovable programme deadline for our client on a world stage at the eve of the millennium.

Following the 9/11 terrorist attack in NYC, new DTLR regulation set out that airports had to segregate arriving and departing passengers. At Gatwick and Heathrow between 2002-03 we led projects such as the Gatwick Passenger Pier Product, where we were able to improve programme, quality, safety and reduce capital cost by 28%, using modular solutions to install passenger corridors on existing piers.

We have championed an offsite agenda since, helping us to deliver iconic projects such as The Shard, where offsite assembly of key components improved programme, quality and safety, and allowed us to deliver elements such as the plantrooms and mechanical systems with a maximum of 80 operatives on site, vs a traditional expectation of 320.

Most recently, in 2017 at our N08 project at the Olympic Park, Stratford, where we’ve been able to prefabricate 98% of the building structure and primary services for 2 x residential towers, and deliver the towers 30% faster, without impacting the original design intent or performance of the product.

We have included project profiles for each as an annex to this document.

We have a proven track record in delivering offsite manufactured products that improve delivery times by 20-30%, and increase quality exponentially. It also drives productivity. As an example, we are currently delivering two x residential projects in Central London at a similar stage of the build programme. One, built traditionally, has a productivity rate of £36 output per hour, vs one built using a number of offsite construction techniques is at £61 output per hour.

Generally, offsite construction is cost neutral, as the money saved on site labour and logistics is spent in early design validation and prototyping. Our strategy has evolved from volumetric modular solutions to a platform strategy based upon sub-system and pre-assembled elements. If we can realise a manufactured construction industry, more akin to automotive, where common, standardised elements are used repeatably across many different products, we will be able to drive cost efficiencies over time.

**Potential barriers to wider use of offsite manufacture**

3. **The drawbacks to offsite manufacture for construction**

There are still barriers preventing a broader acceptance of offsite construction. Within the industry, there is a general lack of understanding of manufacturing, in its truest sense. Current industry-standard process, such as the RIBA plan of works, does not accommodate a manufactured construction solution. To meet the scale of the challenge set out in the Construction Sector Deal, we should recognise that there are a multitude of unproven techniques.
for manufacturing construction. Our industry has a significant element of learning and R&D to go through.

Government should be wary of its role in creating demand, and not following it through. The Green Deal, announced 2012 and eventually scrapped in 2015, signalled a pipeline of work that the construction sector ramped up for, and never materialised, resulting in several high-profile company closures.

The success of factory production is predicated on maintaining consistent volume, and the impact of a change in Government strategy could result in similar negative outcomes.

The other potential drawback may be Government creating its own capacity challenges. The current presumption for offsite, as best evidenced in the ESFA component schools programme, demonstrates how being overtly-specific on the specification of solutions ie. volumetric can create challenges in your own ability to deliver the number of schools required – as highlighted in the current lack of supply chain capacity.

Drawbacks such as design compromise, performance quality and lifecycle need to be addressed through appropriate building standards and codes. We are an intelligent enough industry now to specify the right quality of product, that is tested and prototyped appropriately, and there is an important role to be played out by organisations such as the BRE regards assurance.

4. The re-skilling required to facilitate the change

Re-skilling of the workforce is a primary concern. The UK construction industry currently employs 2.4 million people (ONS Data, 21 Feb 2018). And CITB forecasts an additional 150K+ jobs to be created to match the growth in the sector to 2022.

The industry must face up to this challenge at a time when up to 25% of the workforce is expected to reach retirement age in the next decade (Farmer Report), and Brexit is having a significant impact on our ability to attract labour – recent research at Mace demonstrates that 60% of our on-site labour force in London are non-UK nationals.

Offsite construction will help to address these challenges, in part.

The skills mix of the construction labour force will inevitably move away from the traditional bricklayers, plasterers and labourers and towards a ‘newer generation’ or ‘Industry 4.0 ready’ construction workforce. Recent economic analysis by Mace estimated that, under a ‘fast change’ scenario towards Industry 4.0, up to 600,000 construction jobs could be affected over the next 20 years.

5. Realising the benefit without hampering architectural ambition

Yes. A successful response from the industry should work on two levels, and does not involve a compromise.
The first requirement is the modular or volumetric construction; a standardised construction product that can be delivered efficiently, at volume, where design intent is perhaps not as important as more basic requirements such as capacity and speed.

The second requirement is for a more factory-manufactured product with standard components, but an ability to maintain architectural design ambition, and exacting standards in quality. At Mace, we are developing a platform and system-based approach to construction, which still allows us to meet architectural ambition and design intent, but structurally follows a consistent platform-based approach. We’re developing this solution, made up of a series of systems, sub-systems and components that can be standardised and implemented as plug and play across many product types. Those components can vary from large, heavy items such as staircases, to more repeatable elements such as chillers or fixtures and fittings.

The way to do this more broadly across industry will to be engage architects and designers in the agenda. And to remember the impact of the built environment on the health and wellbeing of those that use or live and work in them.

6. **The R&D required, and by whom**

We recognise a need for R&D throughout all levels of the industry. Of primary importance to enable the Government ambition of offsite construction is to build a supply chain of the breadth and depth required to meet future demand. We see a move towards offsite construction as having significant benefit for the UK economy, fuelling a growth in manufacturing and production across all regions of the UK (ideally creating centres of excellence). As an example, currently we ship prefabricated bathroom pods from across Europe (Germany, Spain, Poland) to install in UK projects.

But the most important factor to unlock offsite manufacture in construction is a change in behaviours and mindset. In that respect, we see the establishment of a ‘centre of excellence’ as proposed in the Construction Sector Deal, as a positive step forward, borrowing on how the automotive industry has enabled collaboration, from their leadership council and down into the supply chain.

**Government actions**

7. **How the construction sector deal works for industry**

Broadly yes. Many of the issues identified and actions to be taken are correct. At top-level, focusing on how we manufacture buildings, how we design & manage buildings, and how we power buildings should address the areas needed to transform our industry. But more needs to be done to ensure that this message is clear, and well-communicated, to the totality of the supply chain, with simple means and measures of how they can engage and benefit from the investment.
We might challenge if the funding is enough. The UK construction industry is 8 x that of the automotive sector. Our impact on the economy, and society, is significant. Yet in a £4.7bn Govt. investment in R&D over the next 4 years, only £170m is ear-marked for construction. By contrast, your automotive sector deal states £725m of investment in Industrial Strategy Challenge Fund programmes. Government has a £600bn infrastructure pipeline, but with £170m allocated, is investing less than 0.03% in R&D. We all recognise the positive step, and welcome the investment, but when you step back and consider the real size and scale of the challenge for our industry, and the opportunity if we are to transform it.

We believe the ‘Transforming Infrastructure Performance’ report by the Infrastructure Projects Authority is an important accompaniment to the outlined sector deal, particularly in the motion of ‘alignment and integration’ of Govt. departments – ensuring that projects and programmes are planned in an integrated way, looking across sectors and tiers of government so that they are designed from the outset to support priority economic, social and environmental objectives, such as increased offsite construction. To be successful, this needs to be conducted with an integrated supply chain, adopting forward-thinking procurement approaches, as outlined in the soon to be released Project 13 framework guidance from the Institute of Civil Engineers.

8. Potential changes to procurement practices

Procurement is a key area to address to enable the change. The current mechanism for ‘risk transfer’ into the supply chain from clients is stifling collaboration and innovation. And the result of high bidding costs and investment costs to secure projects and programmes results in a lack of investment in product development and prototyping.

It will be important for Government Departments to procure on more than lowest price. The announcement in the recent Industrial Strategy about introducing a balanced scorecard approach to measure construction projects is welcome. A scorecard that tracks elements such as spend with SMEs, payment practices, productivity and use of MMC can be used to drive the right behaviour and practices that will promote productivity improvements.

Furthermore the Government should consider increasing R&D tax credits for construction from 12% to 20% to encourage R&D investment.

Procurement methods such as competitive dialogue should be considered when procuring MMC solutions. This will enable participants to explain and discuss proposals in greater detail and enable organisations such as Innovate UK to participate in the process to consider and evaluate proposals.

14 May 2018
Annex 1

London Eye

Project: London Eye
Client: British Airways

The London Eye is the tallest cantilevered observation wheel in the world and one of the most complex engineering projects in modern history.

The wheel was constructed to a demanding and complex schedule where we co-ordinated multiple work packages and developed unique and innovative offsite construction solutions to create significant savings in time and cost.

Gatwick Pier Product

Project: Gatwick Pier Product
Client: Gatwick Airports Ltd
Dates: 2002-2003

Gatwick Airport had to segregate the flow of inbound and outbound passengers, through the airport. The works involved the pre-assembly of 400 metres of corridor, seven vertical segregation cones and associated, high level horizontal connectors. These generic products were delivered to the head of stands complete and installed above and adjacent to the existing pier.

We delivered fastly, safely, and reduced the capital cost by 11% on the first iteration, and a further 17% on the second.
The Shard

Project: The Shard
Client: Sellar Properties
Dates: 2010-2012

Rising up on London’s skyline, the Shard is the tallest building in Western Europe. But the 'vertical city' at the heart of the landmark development, has broken more records than just height – construction also saw a number of engineering innovations.

Offsite construction enabled a number of productivity improvements, including elements such as the MEP plantrooms and mechanical systems, which were delivered by a maximum of 80 operatives on site, vs a traditional expectation of 320.

N08 East Village

Project: N08
Client: Qatari Diar Delancey
Dates: 2014-2017

Part of the ongoing transformation of the former Olympic site in Stratford, N08 includes the construction of two 28 and 30 storey towers containing 481 residential units for private rent, in addition to 1,514 m² of retail space and 1,473 m² of leisure.

A factory environment, built on the top of each core, has enabled the prefabrication of 96% of the projects structure and services, improving efficiency of the tower construction by 30%.
Mace, High Value Manufacturing Catapult, Cast and Construction Industry Training Board (CITB) – Oral evidence (QQ 24-29)

Transcript to be found under Cast
Executive Summary

The construction industry faces significant challenges – low productivity, poor performance in consistent delivery on time and on budget, a growing shortage of key skills, and a lack of management information/data transparency relating to issues such as life cycle costing and project performance. We believe these issues can be addressed with wider adoption of offsite construction technology. Whilst there is tremendous potential for offsite to address these challenges, there are several barriers to change:

- There is a clear lack of visibility of pipeline projects which makes it very difficult for offsite manufacturers such as The McAvoy Group to make investment and expansion decisions. Greater collaboration and transparency across the public sector would contribute significantly to investment. Education has embraced this to a degree via the Education & Skills Funding Agency and its modular frameworks, but much greater collaboration and earlier engagement are needed.

- Procurement frameworks should be established which use offsite as a credible alternative to site-based construction.

- The use of offsite construction should be encouraged and particularly where repeatable design is the dominant factor. This should be reflected in public sector tenders.

- One client-related aspect which is impacting on the use of offsite, is the fear of insolvency and the effect that would have on completing a project using a specialist offsite solution. The issue of financial instability relates directly to the need for a sustainable pipeline of work, investment and strategic planning for both offsite specialists and the industry.

In our view, the best way to mitigate this risk is to grow the industry to a level where methodologies are common place and the market is mature. A commonality of process and standards, and more interaction and collaborative working across the offsite sector would allow specialists to better serve their customers.

Introduction - The McAvoy Group

The McAvoy Group is an independent, family-owned business and an established principal contractor and offsite manufacturer. The Group has been providing bespoke offsite solutions and interim modular buildings for more than 40 years. It has a strong track record in the education, healthcare, commercial and infrastructure sectors.

The Group has two purpose-built manufacturing centres spanning more than 120,000sqft. McAvoy is leading the industry in its award-winning application of Building Information Modelling (BIM) and virtual reality to optimise efficiency and
enhance stakeholder collaboration from design to manufacture and site installation. It was the first offsite specialist to be accredited to BIM Level 2.

Following extensive product development, McAvoy has plans to diversify into the residential sector – affordable housing, build-to-rent, emergency housing and student accommodation. These plans will include investment in a new factory to expand production capacity to meet demand.

As a company, McAvoy is extremely keen to engage with Government to help inform the process. We are happy to organise site and factory visits and to encourage collaboration at every level, including across the offsite sector.

1. What are the opportunities offered by offsite manufacture for construction?

There are significant opportunities for wider use of offsite construction to help address issues such as the shortage of new housing and the severe shortfall in primary and secondary education provision.

1.1 Cost reductions both in project construction and maintenance can be achieved over the lifetime of building through:
   o Clear efficiencies inherent in taking a ‘component’ approach and moving construction offsite into a controlled factory environment
   o Increased standardisation to reduce time and cost whilst integrating innovative design
   o Better quality resulting from factory production methods and robust quality control processes
   o Easier maintenance of assets with the utilisation of standardised components.

1.2 Less risk - Offsite offers greater certainty of delivery on time, on budget and to the required quality standard, reducing risk for the client/public sector.

1.3 Faster delivery - Offsite delivers significant programme savings and efficiencies. Shorter programmes result in earlier delivery of client services, revenue generation, and improved return on investment – and help to address issues such as the shortage of school places, hospital waiting times and the urgent need for affordable and temporary housing.

1.4 Less impact on the environment - Precision manufacture of buildings in a factory reduces carbon emissions and energy usage. There are fewer vehicle movements to site, improved thermal performance, and significantly less material waste compared to site-based construction. Steel-framed modular structures are also inherently recyclable when a building reaches the end of its life.

1.5 Improved site safety - The approach creates a safer working environment for operatives by maximising work offsite.

1.6 More efficient use of skilled labour - Offsite offers a new, modern approach to construction that can attract, retain and inspire a new generation of workers who are increasingly disillusioned and disenfranchised with traditional
construction and all of the inherent problems the wider industry is facing.

2. **What are the likely drawbacks?**

2.1 **Perception issues** - There is a clear lack of knowledge about the quality of buildings manufactured offsite, whole life cost performance, technical ability, and new offsite innovations. These are restricting the use of offsite manufacture and can change if procurement models, professional bodies and Government actively reflect the benefits and drive its use in public sector construction.

2.2 **Suitability for volumetric construction** - There has to be an acceptance that a modular solution may not suitable for every project. There are physical restrictions in its use from a design perspective but the true potential and flexibility of offsite for many projects, particularly those with repeatable design, are not yet widely accepted.

2.3 **Design considerations** - In any project, the site conditions have to be considered and may mitigate against certain types of offsite construction. Modular units are limited in size to facilitate transport and handling on site. However, these considerations are often easily overcome with good design and logistics planning.

2.4 **Early engagement** - If a building is designed for offsite from the outset, the benefits can be maximised.

2.5 **The need for standardisation** - Offsite is not well suited to bespoke buildings – the more elements of a building that can be standardised, the greater the cost and programme savings.

3. **What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

- The availability of strong evidence and benchmarking for the true cost of project delivery and asset use, including finance, whole life costing etc.
- Confidence in the offsite process and in the offsite specialist’s ability to deliver
- Willingness to accept a degree of standardisation in design
- Industry recognition for market-leading design and innovation
- The opportunity to integrate digital design with offsite solutions.

4. **Evidence of the benefits of offsite:**

4.1 The offsite sector is not a mature sector, so it is very challenging to provide data transparency and evidence of the benefits. This is a point the industry needs to address.

4.2 **Faster delivery/increased productivity** – An example is the £20m Lynch Hill Enterprise Academy in Slough. McAvoy delivered this 1,140-place campus 17 weeks ahead of programme and after only 53 weeks on site. This allowed the school to benefit from earlier occupation and reduced the overall
programme by around six months. This project is a fantastic endorsement of what offsite can achieve. For more information see - https://www.mcavoygroup.com/newcasestudies/lynchhill/

4.3 **Added value/less disruption/reduced programme/reduced cost** – A challenging sloping and highly restricted site at West Hill School was developed to link the original special needs school and an existing modular building with a new classroom block. The offsite solution was then adapted to accommodate an additional storey for a teacher training centre – a more cost-effective solution than the separate freestanding building originally envisaged.

The building was manufactured offsite by McAvoy and was ready for occupation on time and after less than eight months on site. Both buildings either side of the new facility remained fully operational throughout. The project made extensive use of BIM and virtual reality which facilitated early decision making with stakeholders and helped to engineer an offsite solution which addressed the complexities of the site. For more detail see https://www.mcavoygroup.com/newcasestudies/westhill/.

5. **What re-skilling of the construction workforce is required to facilitate change?**

5.1 Offsite manufacture facilitates a multi-skilled workforce. For example, M&E disciplines are integrated into the manufacturing process. This cross-skilling helps to address the skills shortages facing the construction industry.

5.2 Offsite construction is far less reliant on subcontracted labour than site-based construction. This means there are greater opportunities for training, development and retention of the workforce.

5.3 Offsite production facilities and the growth in digital construction technology associated with offsite solutions are ideal opportunities to facilitate skills growth through modern apprenticeships.

6. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

6.1 More efficient design processes – The ability to design using a suite of standardised components allows design time to be freed up for more focus on innovation and adding value. Landmark buildings or schemes to reflect existing architecture can still be achieved with good design and early engagement of the offsite specialist.

6.2 Digital technology – There is tremendous synergy between offsite manufacture and digital construction technology, such as BIM and virtual reality. These techniques facilitate the development of outstanding buildings with limited, if any, compromise on architectural design.

Teachers and healthcare professionals for example, are not trained to read 2D construction drawings. If we use data rich, fully detailed 3D BIM models and virtual reality walkthroughs, we can communicate a building design much more effectively, and present design options for discussion in a far better way.
6.3 **Greater use of hybrid buildings** - With advanced engineering and a greater range of module sizes and configurations, links between the offsite elements and other construction methods are seamless, accurate and integrated. The site-based elements can still utilise offsite techniques with manufactured components such as structural steel insulated panel systems and offsite M&E, further minimising work on site.

6.4 **Design for manufacture ethos** – This requires earlier decision making and can be facilitated by the new digital technologies which makes the design process more efficient. More accurate design decisions minimise the risk of projects running late and over budget – still too common in the wider construction industry.

7. **What R&D is needed, and by whom, to realise fully the benefits of offsite?**

7.1 There should be more focus on R&D for both offsite components and materials to enhance performance, supported by an efficient testing and certification process. This will facilitate greater use of offsite construction and will remove some of the barriers to change.

7.2 There needs to be greater clarity in the use of composite systems and their integration with other building elements. This will raise awareness with designers, give clients further peace of mind and support better supply chain integration.

7.3 Offsite specialists should be incentivised to invest in R&D, for example through a challenge fund or grant funding, so a longer-term approach can be taken. R&D should be recognised as an inherent and critical part of offsite to maximise the potential of the sector and its positive impact on the wider construction industry. There should also be provision of Government incentives for part of the offsite factory set-up cost.

7.4 Consideration should be given to support multi-skilled training programmes for offsite to improve productivity, and accreditation for R&D in construction as opposed to lateral entry to this as a career.

7.5 A system for benchmarking data for performance and cost should be established for both project delivery and the project life cycle that has industry acceptance and recognition.

8. **What changes could be made to public procurement processes?**

8.1 **Greater leadership through public sector procurement** – We need other central Government departments to follow the lead of the Department for Education in the modular frameworks it has established. We urge the Government Construction Board Strategy to reinforce the message about prioritising offsite on all public sector projects where deemed to be value for money and that it closely monitors implementation. This also applies to local authority procurement.
8.2 *There should be clear, realistic visibility of the pipeline of public sector work.* This would allow offsite specialists such as McAvoy to plan growth in a strategic way rather than a reactive approach. This would support the required investment in innovation, low carbon technologies, digital construction technology, business planning and finance. It would also allow companies to apply a more structured approach to growth and to attract and retain talent.

8.3 *Frameworks should be actively encouraged* for offsite to facilitate take-up and to keep tendering costs to sustainable levels. Offsite manufacturers tend to be smaller than the mid- to large contractors and cannot carry large one-off tendering costs repeatedly. Clients should also be made aware of the true benefits that can be realised under those frameworks.

8.4 *Greater use of whole life costing* – The whole life cost of assets should be a key consideration earlier in procurement and should feature in strategic decisions about contracts.

8.5 *Increased cross-sector collaboration* – The sharing of experience in the use of offsite and component building across different sectors (housing, transport, education, healthcare etc) should be actively encouraged and promoted by Government. This could be achieved through widening the scope of some frameworks. Greater endorsement is definitely needed to promote the use of offsite in sectors that are not currently embracing the approach and its benefits.

8.6 *The procurement evaluation process and weightings should more accurately reflect the desired outcomes and public sector priorities* – build safely, deliver on time and on budget, and with less impact on the environment.

26 April 2018
This paper responds to The House of Lords Science and Technology Committee’s call for evidence on the subject of ‘Off-site Manufacture for Construction’. We understand the Committee’s inquiry will consider the potential benefits of off-site manufacture for construction and any drawbacks or obstacles to its wider use.

This response sets out what MOBIE is, and does, and gives an early indication of what could be envisaged for a new national MOBIE Centre for offsite site manufacturing (OSM) skills, R+D, Vocational Training and Retraining as well as vital Social Mobility programmes.

1.0 What is MOBIE?
Architect George Clarke founded MOBIE in 2017 as an educational charity to promote innovation in the design and delivery of homes. The charity’s purpose is to attract and inspire future creators of the Built Environment through exciting new technical and vocational courses and schools outreach. OSM plays a vital role in this endeavour.

1.1 Why is MOBIE needed?
The housing sector in the UK is in crisis, there is an urgent need to develop and grow the skills needed to create, produce and deliver large numbers of high quality, well designed (and affordable) homes in the UK.

1.2 What does MOBIE do?
MOBIE recognises that education is an essential part of the solution to the housing crisis. We have addressed this by establishing the UK’s first vocational training courses with an emphasis on the skills required by the OSM sector. MOBIE ‘Advanced Home Futures’ Courses provided a unique educational pathway from schools to Further Education (FE) and Higher Education (HE) courses. Ensuring that learning can be accessed and delivered at the levels that students want and the construction industry needs.

The courses launched by MOBIE are a new type of education, design and construction model that thinks differently. Our courses combine R&D, training, re-training, innovation, manufacturing and works in partnership with schools, FE and HE providers, local, regional and national government and industry.

In parallel to the educational initiatives, the MOBIE team bring together a breadth of experience in the design and delivery of OSM homes. From the initiation of pioneering modular housing schemes, procurement understanding, architectural design through to site delivery. Our real world experience in the industry alongside our commitment to R+D continually inform the charity’s educational strategy.

2.0 Advantages of offsite manufacture for construction
MOBIE’s aspirations are clear, we want to inspire new generations to choose careers designing and making innovative homes. Investment and growth of OSM is pivotal to our aims for these reasons:
2.1 A new image for construction
A generation of talented young people are turning their back on careers in the construction industry because house building simply doesn’t inspire them. Building sites are seen as unappealing workplaces, where the labour is hard and at the mercy of the elements.

Moving production from the construction site inside to a factory environment can change this perception. It’s an opportunity to create aspirational workplaces with an emphasis on digitalised construction and safer, more inclusive working environments. We need to promote a new forward thinking image for home building and provide places where young people aspire to embrace their future careers.

2.2 Bridging the skills gap
It’s no secret that the construction industry skills gap is projected to widen in the foreseeable future. OSM offers the opportunity for more controlled methods of working over traditional construction, providing improved efficiency and productivity.

With continued investment in R+D, the way we design buildings can adapt for manufacture and assembly, reducing the reliance on specialist tools, equipment and processes. Much like an automotive factory, members of the production team could work across all stages of the production line, avoiding the reliance on the isolated trades of traditional construction. OSM is an opportunity for a broader, more collaborative form of vocational training, which if implemented correctly could go some way to addressing the forecast shortfall in skills.

3.0 Potential barriers to wider use of offsite manufacture
MOBIE has encountered a number of specific barriers in the process of designing and implementing our new ‘Advanced Home Futures’ courses:

3.1 The apprenticeship levy
The Apprenticeship Levy is a mandatory scheme for larger companies to pay for the training of their apprentices. Nationwide, there is a lot of enthusiasm from industry to enrol apprentices on MOBIE HNC, HND and degree courses. However, there is currently no approved standard suitable for OSM or innovative digital design training courses. This means that companies effectively have to pay twice in order to provide this training, as the lack of approved standard obstructs the ability to draw down from the levy.

A specific approved standard for OSM and digital design training courses is needed to engage and incentivise employers. Its’ critical that employers can draw funds from the levy for the wider training needed in OSM construction.

It’s also worth noting, that the size of the companies that need most support from the levy might be too small to pay into the levy fund. There could be an opportunity to encourage agile small / medium sized companies and embrace the ‘Innovators Dilemma’ rather than fear it. Perhaps this should be the group that should be the focus of more support and marketing.

3.2 Acknowledge of new roles and new skills needed
New roles need to be recognised and people need to be trained or re-trained to perform them. For example, the commercial roles in OSM do not equate to the role of a traditional QS. Those from other industries cannot easily step into these roles as construction knowledge is essential. The New headline roles for OSM:

- Designers (can be architects but so far usually architectural technologists)
- Cost Managers
- Production Managers
- Motivated Shop Floor Team

Educational courses are needed to train new generations for these roles as traditional construction training is woefully outdated for these purposes. We need a workforce skilled with BIM and Digital skills, there is also a need to train Educators to deliver these new digital skills.

MOBIE is currently addressing this with ‘Advanced Home Futures’ HNC and HND courses (either full or part time) and MSc. MOBIE is designing a BSc sandwich degree as a progression from the HNC/D which allows specialisation into one or more of the new headline Digital Design, OSM roles.

4.0 The need for a national centre
There is both a need and an opportunity to create a National MOBIE Centre of Home-Making, capturing the very best of innovative thinking, new methodologies, processes and data in the home creation market. This National Centre should operate as the hub for a number of satellite operations – in education, training and re-training – around the country.

The UK needs a Centre which captures and coheres the very latest innovative thinking in modern methods of home-making, which brings together like-minded organisations and individuals to create, make and refine and learn, and which acts not just as a developer of thinking but also as an implementer of these ideas.

It should be THE go-to place for all that is best in home-making in the UK and will, over time, become an increasingly important International reference point. A centre that will bring together, and work in partnership with, like-minded and motivated organisations, from Government, Authorities and private enterprise.

A flexible space which will be capable of hosting education, training, work space, will be an innovation centre, will set standards and be a practical space for creating and testing new methodologies, components and processes. It should be the main place for industry to come to share and publish research about HOME design, making and innovation.

4.1 Why mobile?
MOBIE is the only non-aligned organisation committed to improving the home-building capabilities of the UK. It has already demonstrated that it is a ‘ThinkDo’ organisation, recognising that demonstrating progress is the best way to engage future generations.

Because we are non-aligned we can bring together a wide spread of relevant bodies, from Government, through Education and private enterprise.
4.2 The national centre for home-making
This is an opportunity to create a landmark establishment, a place of innovation, creativity and, most importantly, inspiration. It will be open to all, but in particular to schools and children who can imagine how they can play a part in creating better solutions in the future. We are developing the full scope and scale of the National Centre in conjunction with the key partners over the next twelve months but it is envisaged that it should include:

- MOBI EDUCATION - A range of further/higher education courses, run independently or in association with a local Universities

- MOBIE RETRAINING - A MOBIE OSM / Accelerated Construction Retraining Facility. A department dedicated to vocational retraining of a broad spectrum of manufacturing and production line skills for the OSM industry. Not training bricklayers and plasterers but retraining for a new way of making homes.

- MOBIE LAB - We envisage a R+D team (professionals and PHD students) acting as the link between education and industry. Our ‘MOBIE home R+D’ would be linked to organisations such as BRE and MTC. Our work would be national (working in partnership with our regional hubs) but also international, bringing information from all over the world back to the UK to promote the MOBIE knowledge economy. Vitally MOBIE LAB will also be developing prototype homes, at the cutting edge of home design, which will go on to be designed and developed as Model Villages nationwide.

- MOBIE OUTREACH - Through all of our ‘home’ initiatives the social mobility team would work with regional and national departments to raise the aspirations and ambitions of young people.

- MOBIE KIDS - An inspirational play space for young children to come to MOBIE and be inspired into home design and making. This is the world of drawing, Minecraft, sketchup, Revit, junior BIM and 3D printing. This would be the base for all MOBIE school education programmes where we have a core team of staff that promote links with schools in the region.

Submitted by George Clarke and John Mathers

27 April 2018
Mott MacDonald – Written evidence (OMC0069)

Mott MacDonald is a global engineering, management and development consultancy firm focused on guiding our clients through many of the planet’s most intricate challenges. We employ over 16,000 people, delivering high-profile projects in transportation, water, the built environment, energy, and development sectors in partnership with governments, contractors, as well as asset owners and maintainers. Many projects include off-site manufacturing. It is in this context that we respond to this inquiry.

1. Opportunities and influences

1.1 Off-site manufacture for construction represents a key step in the industrialisation of the industry. It offers the potential of increased productivity, but this can only be fully achieved when supported by wider changes across the delivery process. Off-site manufacture enables optimisation of performance, tolerance and efficiency. This can lead to improved productivity, reliability and sustainability by reducing waste, creating environments for quality control and reducing health and safety hazards. Key opportunities offered by greater adoption of off-site manufacture for construction include:

1.1.1 Improved certainty: early resolution of all aspects of design is essential, increasing collaboration between parties, which improves programme certainty. Certainty in the quality of the end product is improved via greater quality control under factory conditions, better processes, standardisation and the ability to rehearse assembly physically and digitally.

1.1.2 Reduced time on site reduces disruption to the public and to operations. Reducing the size of the site workforce and the time on site also improves safety (as a lot of work can be moved from site to factory conditions), reducing exposure to variable conditions and unfamiliar tasks.

1.1.3 Better use of skills by making use of skills in multiple locations – not just at the site but also around the manufacturing facilities. Factory-based manufacture may be seen by workers as being better than site work.

1.1.4 Greater sustainability through improved design, more efficient use of materials and reduced waste. Thinking beyond Design for Manufacture and Assembly (DfMA), we can imagine Design for Excellence (DfX), which would also include design for safety, security, operation, maintenance, reduction, reuse and recycling. This approach would move towards the circular economy, in which waste becomes resource.

1.2 Where disruption to the public, to operations or to construction schedules is important, we have used off-site manufacture for construction as a key mitigation. The disruption to a school caused by construction activities on site can be reduced from a school year to half a term using off-site methods. Elements of water treatment works can be replaced or upgraded quickly and efficiently.

33 https://www.mottmac.com/views/dfma---the-key-to-a-more-efficient-industry
34 https://www.mottmac.com/views/bim-advances-sustainability
reliably to minimise the impact on operations. Tram renewals can use off-site-manufactured track sections to minimise disruption to existing highways.

1.3 Mott MacDonald’s experience with different sectors and geographies is that off-site manufacture is often driven by necessity, where the site logistics are such that elements or modules cannot be constructed in situ. Singapore and Hong Kong have long used off-site manufacture to address a lack of space on site.

1.4 Digital and process maturity is required to help unlock the broader benefits of off-site manufacture. A main strand of this is end-to-end digital delivery, without which off-site manufacture is often more challenging due to slower, less reliable information and fragmentation of the project team. Key elements include: the use of building information modelling (BIM), common data environments, digital component catalogues; supply chain integration, allowing optimal use of expertise and skills during the design and planning process; and the ability to rehearse digitally to ensure optimised right-first-time delivery.

1.5 Design for off-site manufacture requires a change in mindset; a different approach and more collaboration across the supply chain, objectively answering whether an organisation really is best placed to complete certain tasks. Procurement needs to move from a traditional, transactional, risk-averse approach to recognise that value (not price) is all important, and instead taking a portfolio approach and focusing on behaviours and holistic benefits. Logistics are critical to successful project execution, including optimising sequencing to make the best use of space, resources and skills. Manufacturing depends on timely availability of appropriate facilities, maturity of processes and experience, costs and economies of scale. Transport options and accessibility are key considerations, as well as sustainability implications of long-distance transport.

2. Evidence for benefits

2.1 Through Mott MacDonald’s involvement in the delivery of projects across the globe, we have been integral to delivering significant benefits using off-site manufacture for construction.

2.2 We have enabled 10-20% reductions in raw materials using off-site manufactured elements (for example, thinner, higher performing wall panels) at Davyhulme wastewater treatment works, while saving three months on project delivery. By adopting a fully digital approach to delivering the Ordsall Chord viaduct in Manchester, we reduced the project programme by 20% and costs by 15%, while eliminating site queries and associated costs and delays. By designing plant rooms for off-site manufacture, we enabled a 60% saving in fit out time at Heathrow Terminal 2. Our work with Yorkshire Water employed off-site manufacture for of a spillway, reducing site activities meeting tight programme requirements.

https://www.mottmac.com/views/shift-from-output-to-outcomes
https://www.mottmac.com/article/38101/ordsall-chord-uk
2.3 We have seen continuous improvement in the levels of efficiency and innovation through the UK Priority Schools Building Programme (PSBP)\(^{37}\), leading to dramatic reductions in duration and disruption, while increasing the quality (with substantially less snagging) and reducing the cost. Structural connections at the new stations on London’s Northern Line Extension were designed for off-site manufacture to ensure the highest levels of quality due to its unusual complexity with added benefits of reduced construction time and integration of mechanical and electrical services, saving further time.

2.4 We saw a 20-week reduction in programme at the Royal Victoria Hospital\(^{38}\), where 55% of the project was manufactured off-site and was delivered with a team that was 25% smaller with zero accidents. Through DfMA, we optimised available site access and on-site space at Wimbledon Substation enabling concurrent (though unrelated) construction activities reducing a necessary cable rack installation from two weeks to two days and the overall programme from 16 months to 8.

2.5 The HSE is beginning research the health and safety benefits of off-site manufacture. Off-site manufacture results in less exposure to recurring and site-based hazards in variable conditions. Factories offer the ability to control the environment and hazards to which people are exposed, which marks a drastic improvement over current construction sites (although they can still be dangerous).

3. Drawbacks

3.1 Off-site manufacture for construction is not a panacea. With the wrong understanding, it can be highly limiting, and provides a temptation to seek the best solution that can be manufactured off-site, rather than the best solution being to manufacture off-site. Without care, standardisation can potentially stifle innovation and lead to a loss of skill and regression of knowledge. Other drawbacks fall into four main areas: cost, access, quality and flexibility.

3.2 Cost is not always reduced with off-site manufacture: multiple layers of manufacturers lead to cost on cost; if production rates or scales are insufficient, manufacture may be more expensive; there are risks of inadequate levels of competition to drive innovation, optimisation and cost reduction, and potential to be tied to a single supplier; there may not be sufficient or appropriate manufacturing capability within the UK, which may lead to work being undertaken offshore (for example nuclear module construction). Transitioning from traditional to more off-site manufacture may be expensive.

3.3 Access requirements are a constraint to successful off-site manufacture. In cases such as underground infrastructure, rural areas with narrow roads or pedestrianised areas of cities, sufficient access may not be possible. Additional pressures will be placed on existing transport infrastructure by increasing levels of time-sensitive heavy vehicles, raising questions about maintaining the network. If elements are fabricated far from site, sustainability savings are

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37 https://www.mottmac.com/article/37874/new-school-standards
38 https://www.mottmac.com/article/3379/royal-victoria-building-uk
reduced due to energy consumption during transportation. Off-site manufacture results in more transport, lifting and cranage, which can be hazardous.

3.4 Successful off-site manufacture relies on high quality – if the solution is not right first time, it can be more expensive to make good on site. Quality control must avoid systemic errors from mass-producing defective or out of tolerance components, and the quality of supply chain processes may make projects slower or more complex.

3.5 Reduced flexibility can also be a drawback: there is less scope to change or adapt designs during a project; the economies of scale needed to make standardisation economical may not be available with variable asset management approaches (as we have seen across water companies). This reduced flexibility can make off-site manufacturing more suitable for new build, rather than existing assets. It may be harder to comply with prescriptive requirements with off-site manufactured elements and there can be less flexibility in the configuration (floor plate size or number of storeys) achievable using off-site manufacture.

4. Re-skilling

4.1 Large parts of the sector already adopt off-site manufacture at component-level – from facades to tunnel lining segments – and at a volumetric level – residential, hotels, schools, prisons, hospitals and student accommodation. But to truly unlock opportunities, off-site manufacturing cannot be considered in isolation. The transition to more off-site manufacture requires a cultural shift: steps must be taken to encourage and incentivise collaboration across the value chain. This requires a more open approach, objectively deciding which organisation has the best people and skills for each task, and improving abilities to discuss and articulate value.

4.2 In addition, the end-to-end delivery process needs to be improved and this must include digital transformation. This provides the technological base to shift from the current transactional approach to an enterprise approach, improving collaboration and focusing value on the assets being created (see also the Institution of Civil Engineers’ Project 13). The processes of design and planning need to adjust to do more, earlier in the project - freezing design before manufacture, having already rehearsed and optimised digital construction.

4.3 Skilled tradespeople will need reskilling to move from processes of building to processes of assembling and integrating, entailing training in the use of new equipment and materials. Technical professionals must adapt designs to reflect new interfaces and processes. This will include embedding optimisation and logistics focus throughout design life such as designing for reconfiguration and adaptation. This process can be enhanced through the development of standard design libraries.

4.4 Professionals and project managers are integral to embedding a culture that moves away from the transactional to that of the enterprise. To do this, they must work to enhance supply chain workflows, which in turn will improve the programme delivery. The adoption of digitised procurement can also help streamline programme management and facilitate improved supply chain
relationships. Clients and asset owners are key to the transition, and they must fully support and incentivise the use of off-site construction methods to realise the full benefits across the supply chain. This will include rebalancing risk apportioning, which has conventionally been to the detriment of subcontractors, and incentivising performance and alignment improvements at project-outcome level and nurturing long term collaborative relationships.

5. Architectural ambition

5.1 Standardisation and off-site manufacture do not necessarily limit architectural ambition or represent a new era of boring design. Indeed, the opposite could be true: off-site manufacture offers new opportunities. Historically, architecture, engineering and materials have been linked – the availability and properties of stone enabled the vaulted arches synonymous with gothic and renaissance architecture. More recently, precast concrete panels supported the emergence of Brutalist architecture and the later filigree reinforced concrete facades used in striking designs across Northern Europe.

5.2 Many landmark projects already include some standardisation - bridges, facades, or sports stadia - where the design seeks to modularise and standardise as much as possible, while realising the architectural vision. Off-site manufacture may encourage designs that can be readily assembled and mass produced; it also creates opportunities for new and innovative architectural styles informed by engineering efficiency.

5.3 Industrialisation leads to greater presence and distribution of designers and creative input. Those parts of the supply chain involved in off-site manufacture will increasingly include creative designers (akin to product designers), imbedding architectural ambition and aesthetics throughout. The exact outputs of standardisation are yet to be defined, and architects have extensive scope to influence engineering design to incorporate architectural creativity to encompass the needs of the human user. Thus, any transition towards standardisation must be predicated on interdisciplinary thinking and a culture of integrated intelligence.

6. Research and Development (R&D)

6.1 Greater use of off-site manufacture will drive innovation, however, the surety and scale of work needs to be sufficient to incentivise the supply chain to undertake the associated research, development and implementation across all areas. At an industry level, the mechanisms introduced through i3P can have a significant impact, encouraging a new culture of collaborative relationships in innovation within the industry.

6.2 Our work with Project 13 has highlighted the importance of R&D focusing on digital transformation. Further integration of BIM will facilitate standardised design processes and enhance understanding of element interdependencies to mitigate clashes and improve constructability. 3D printing could present a significant opportunity for both off-site and onsite construction. Blockchain technologies can run parallel to these advancements as a means of establishing a “single source of truth” to monitor project progress (from concept to digital to physical) and to link this to value and payment.
6.3 High-level studies of the construction sector should be undertaken to understand how off-site manufacture will impact the various stakeholders throughout the supply chain. A key development will be the implementation of change management strategies that address automation and other new ways of working. The training and engagement of skilled tradespeople is fundamental to realising the full benefits of off-site manufacturing, necessitating an in depth understanding of how these stakeholders can be engaged and incentivised.

6.4 We have seen in Hong Kong\(^39\) that building regulations can impede the use of off-site manufacturing, as compliance with prescriptive requirements (rather than being about performance or outcome) can make the approach uneconomical. Developments in design codes and building regulations are needed to recognise the nuances of off-site manufacture to improve processes and approvals for faster delivery.

6.5 To enable necessary R&D, organisations need to move towards a portfolio approach (from the current project approach): moving away from the current 'race to the bottom' cycle of low margins and underinvestment in R&D; shifting from continuous reinvention to continuous improvement. The loop needs to be closed between designer and re-purposer.

7. Construction Sector Deal

7.1 The Construction Sector Deal has been broadly welcomed by the industry, as well as by i3P members. It is aligned with the technology roadmaps developed by i3P members, and the focus on industry-led innovation and a drive towards improved productivity are key issues to address. The current business models across the industry lead to increased focus on day-to-day business with limited resources allocated to forward thinking and changes in approach such as those required to capitalise on off-site manufacture. Government is making funds available for this, although clear measures on target outcomes are still needed.

8. Procurement and Policy

8.1 Procurement processes need to increase the focus on best value, not lowest quoted price. This does not necessarily need bespoke or new forms of contract; we have successfully delivered projects where off-site manufacture was key using both NEC3 contracts and existing frameworks. The key change is a move to value-based outcomes and incentivising collaboration and sharing of skills, knowledge and resources for the good of the project. Portfolios, such as frameworks, can help by providing the economies of scale necessary.

8.2 Early identification and targeting of off-site manufacture is critical to its success (if it is added too late, it becomes more expensive) and consideration of project requirements or referenced standards is needed to avoid inadvertently precluding certain forms of construction. This allows timely selection of project structure, for example introducing an “integrator” role to bring together the various disciplines needed to deliver a successful project.

8.3 Appropriate incentivisation for inclusion, adoption and innovation are needed. These may include a move towards project insurances, rather than relying solely on organisational insurance, to incentivise more collaborative behaviours rather than protection of insurance.

26 April 2018
Mott MacDonald and PCSG (Professional Construction Strategies Group) Ltd – Oral evidence (QQ 17-23)

Transcript to be found under PCSG (Professional Construction Strategies Group) Ltd
NG Bailey, Laing O’Rourke and Severfield – Oral evidence (QQ 41-49)

Transcript to be found under Laing O’Rourke
NG Bailey – Supplementary written evidence (OMC0086)

Question 1
Can you explain your Company’s approach to Offsite, to help the Committee understand the range of what you do? A few examples would be helpful, together with an understanding of the benefits.

At NG Bailey, we design, manufacture and deliver off-site building services solutions, primarily relating to mechanical, electrical and plumbing (MEP).

We have been pioneering the use of offsite for nearly two decades, having set up our specialist manufacturing facility in Bradford, West Yorkshire, in 2006 at a cost of £5m.

Our ‘design for manufacture’ approach presents a realistic, affordable, efficient and environmentally-friendly alternative to labour-intensive and time-consuming on-site production and assembly, or where there are specific challenges related to being on site. For example, our offsite manufacturing solutions can help in secure environments, where there are often lengthy and prohibitive security clearance issues, or where an on-site build would impact on sensitive operations – such as at airports or rail stations.

One example of this is our work at London Bridge Station where, in order to minimise disruption to the day-to-day operations at the station, the large and technically-demanding plant room was fully manufactured at our offsite facility.

At Heathrow’s Terminal 5, offsite was used to construct 12 nodes connecting the departure lounges to the aircraft. Each of the nodes was 10m high and 15m long and weighed 90 tonnes. In addition to the manufacturing challenges, we also had to carefully plan the logistics of getting the nodes to the airport. This included a trial run to ensure the convoys could clear all the motorway bridges. Once at Heathrow, it took the NG Bailey team less than a week to erect the 12 nodes, compared to a traditional build that would have seen us on site for up to six months.

At both London Bridge and Heathrow, our offsite manufacturing expertise realised significant savings in terms of time, labour and waste, as well as the huge cost savings made by minimising disruption and downtime at two major UK transport hubs.

In financial terms, our clients have verified cost savings of up to 35 per cent through the use of offsite, with time-saving benefits of 90 per cent being typical on a project. That can create more financial benefits for clients by enabling them to begin operations much sooner than with a traditional build.
For NG Bailey, safety is first and foremost, and offsite has significant safety benefits. Typically, we see a 40 per cent reduction in overall on-site labour requirements, and this has a positive impact on safety. On the redevelopment of Birmingham New Street Station, for example, offsite manufacture had a significant contribution to more than one million project hours without a single reportable accident.

We believe other benefits of offsite include:

- Improved quality control and traceability
- Reduced waste and impact on the environment (what gets designed gets manufactured)
- Increased productivity

We always seek to maximise the use of offsite on every project we undertake and do this at the outset of every project. Offsite is easily incorporated into a building when the building is designed with offsite manufacture in mind but it’s more difficult to ‘retrofit’ into a pre-designed scheme.

There is also a belief that offsite manufacture has the potential to alleviate the industry’s wider skills shortage through the creation of new job roles that are considered more attractive to the emerging workforce, and generally improving their skills and role flexibility.
Question 2
How do you see offsite solutions developing in the future for your own business and for the construction and house building sectors as a whole?

We can only see offsite solutions becoming even more widely used, particularly as the application of Building Information Modelling (BIM) and digital engineering become standard across the construction industry.

We expect to see greater use of standardised solutions and products, rather than everything being bespoke to each project. We currently have standard processes, not standard products.

The use of technology in our facility will inevitably increase, allowing us to invest in more equipment to undertake what are currently manual tasks.

We also need to find a way of being more flexible and adaptable to how we serve our projects, which cover the whole of the UK. We are currently looking at a ‘Hub & Spoke’ model with the overall aim of reducing our transportation costs. This would allow the manufacture of sub-assemblies in a central location with the assembly of our final products at locations situated in closer proximity to our projects.

Although it is not within our range of operations, we expect to see a significant increase in the number of modular homes being produced. The volume of new homes required, the high levels of standardisation and an ageing and declining workforce across the building industry all lend themselves to greater use of offsite manufacture.
When it comes to housebuilding, modern materials make designing homes more flexible – as well as being more energy-efficient and cheaper to run – while still allowing buyers to tailor certain elements to suit their individual needs.

Offsite solutions allow us as a company to maximise the use of technology and to ensure we continue to add value and influence not only to our customers but the end consumer as well.

The Government’s Industrial Strategy highlighted the UK’s poor productivity – offsite is one way we can address this. We believe politicians, policymakers, industry bodies and companies across the construction sector need to continue working together to drive that change.

**Question 3**

*Do you have any suggested recommendations the Committee could make that would help increase the momentum of offsite solutions in the construction industry?*

The construction industry has been accused of being slow to adapt and to update legislation is often seen by industry as a barrier to change, but we believe it can actually help drive improvements in our industry. There is a view that the industry only accepts and incorporates changes when change is forced upon it, such as with the introduction of BIM Level 2 requirements on all public sector projects.

Procurement is another important area requiring change. Ours is an industry where the initial build price is generally considered to be the most important consideration. Driving alternative and more collaborative procurement routes that enforce designers to “design for manufacture” by engaging specialist suppliers much earlier in the process is required.

Instead of looking at the lowest capital cost – which can come with the biggest risks – changing behaviours among clients and contractors, and encouraging greater collaboration and a more balanced sharing of risk, will naturally allow risk mitigation strategies such as offsite solutions to the forefront.

In addition, if clients such as the government were to commit to longer term relationships and integrated teams, we believe this would create an environment and mindset that would drive continuous improvement, progressively leading to greater efficiencies and reduced cost.
We would also recommend greater tax breaks for research and development, as this would allow for a more collaborative approach to determining designs and solutions. Instead of having a prescribed design to price from, specialist suppliers would be able to work with the contractor to improve performance and maximise benefits. It will also allow for more innovation and creativity.

**Question 4**

*How can companies in the construction sector be encouraged to collaborate and work together to facilitate the wider use of off-site manufacture?*

As we’ve outlined above, we feel collaboration is a key issue to be addressed.

One way to tackle this would be through creating frameworks of integrated teams, which will require clients and contractors to change their procurement behaviours. We believe this will help create a less commercially-aggressive environment and reduce ‘protectionist’ behaviours.

A building is a bespoke product and needs to be treated as such and not like a commodity that is being purchased off the shelf, therefore encouraging clients and designers to be clearer about the performance output of their buildings and allow industry specialists to propose innovative solutions, rather than the client being prescriptive about what, who and how, and then simply finding the cheapest price for it.

Integration and interface management is an important component of the construction process. Currently procurement is undertaken in a linear fashion, with orders placed one at a time in the order they are required on site. To maximise the benefits of offsite, often two or three differing contractors need to be working together, much earlier, to make the most of the opportunity, otherwise work and materials can be unnecessarily duplicated.

Clients rigidly enforcing the adoption and standardisation of BIM models, software, standards and definitions should also facilitate greater collaboration between clients and contractors.

**Question 5**

*In each of the above, is there a difference between the different sectors of residential, building and infrastructure markets.*

Each of these sectors are very different by nature.

In residential construction there are high levels of repeatability that are much less apparent in commercial construction and infrastructure. This naturally lends itself to greater use of innovative, cost-saving solutions, such as offsite, but the extremely fragmented nature of the residential supply chain means these benefits are not being fully exploited currently.

Within the infrastructure market, on the other hand, the scale of those projects means we tend to see more ‘target price’ form of contracts. This can often result in better margins for the contractors, which facilitates a more productive, collaborative working environment. These contractors are also more open to
innovative solutions such as offsite, that mitigate risk on high profile projects where safety, quality and time are treated just as important as cost.

**Question 6**

*What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture and to evidence those benefits? How can the sector be encouraged to play a greater role in R&D?*

We believe all parties across the construction industry need to innovate and invest in R&D. In order to do that, the supply chain needs to have visibility of the opportunities pipeline and to operate in a less volatile business environment.

R&D in software applications is particularly important, in order to improve collaboration techniques and working. Greater development of an open platform approach (such as across Apple and Android systems) would allow the industry to have a more standardised approach to how software is configured and used.

Benefits could also be realised through the provision of funding for R&D related systems and software to smaller contractors and SMEs within the supply chain and also by increasing or incentivising R&D practices through greater tax credits for all parties across the industry.

25 May 2018
NHBC – Written evidence (OMC0021)

1. Introduction

1.1. As an independent, non-profit distributing company, NHBC plays an important role in the UK housing sector, helping builders to deliver quality new homes and supporting the industry with our Standards\(^\text{40}\) that cover 80% of all new homes. We also provide 10-year Buildmark insurance cover for about 1.5 million UK homeowners. NHBC supports new approaches that will help deliver high quality new homes, and works closely with the industry to help ensure that new products and systems are thoroughly researched and tested.

1.2. NHBC welcomes the opportunity to contribute its research and technical expertise to the House of Lords Science & Technology Committee’s inquiry. As the Committee points out, off-site construction describes a range of construction types and, whilst it is not a new idea, the level of technology now available means it is much more viable as a modern method of construction (MMC). This submission will focus specifically the various types of off-site built housing, which can be described as:

- volumetric construction - three-dimensional units which are fully fitted off-site;
- pods - such as bathroom or kitchen pods used in conjunction with another construction method;
- panelised systems - panels with timber or light steel framing, structural insulated panels or cross-laminated timber;
- sub-assemblies and components - larger components incorporated into new homes, such as roof and floor cassettes, prefabricated chimneys, porches and dormers, and I-beams\(^\text{41}\).

2. Opportunities and advantages

Housing supply

2.1. NHBC’s annual registration figures show that more than 160,000 new homes were registered to be built in 2017\(^\text{42}\). This is positive, representing an increase of 6% on 2016 and the highest new home figures for a decade. However, more needs to be done to boost housing supply in order to meet demand. A key benefit of off-site construction is therefore the potential to boost supply, as highlighted by the 2016

\(^{40}\) For more information, see NHBC 2018 NHBC Standards
\(^{41}\) NHBC Foundation, NF70 - Modern methods of construction: views from the industry, 2 June 2016
\(^{42}\) NHBC press release, UK new home registrations up 6% in 2017, reports NHBC, 25 January 2018
Farmer Review “Modernise or Die”\textsuperscript{43}. It stated that, if technical and quality standards are met, pre-manufactured construction systems could improve the speed of housing delivery.

2.2. NHBC Foundation research similarly identified the perceived ability to build more quickly as one of the key attractions driving the use of off-site and modern methods of construction\textsuperscript{44}. The research found that while house builders reported faster construction is being realised in practice, housing associations were less convinced (they did, however, believe that a weathertight envelope was achieved quicker with the use of modern methods of construction)\textsuperscript{45}.

2.3. On take up, the NHBC Foundation research found that the majority of the organisations it surveyed (98\%) had made use of, or considered at least one form of, MMC in the last three years\textsuperscript{46}. Other key findings include:

- Sub-assemblies and components were the most widely-adopted form of MMC (e.g. door sets, timber I-beams, prefabricated chimneys and prefabricated dormers). Panelised systems (e.g. timber and steel frame) were second most popular;
- Only limited use was being made of volumetric construction (large modules fully fitted out on-site) and pods (room-sized modules normally bathrooms or kitchens) with 6\% and 7\% of organisations having used these methods respectively one or more times in 2015. Use tends to be concentrated in apartment buildings in London and the South East\textsuperscript{47}.

\textit{Quality control}

2.4. Since 2008, approximately 30\% of homes with NHBC’s 10-year Buildmark warranty\textsuperscript{48} have been built with forms of construction other than ‘conventional’ masonry. In the past year, NHBC has assessed and accepted over 50 off-site manufacturing systems and components and has another 30 in the pipeline. In particular, NHBC is seeing an increase in the use of MMC in developments for Build to Rent and for housing associations – especially in high rise residential blocks.

2.5. The Farmer Review highlighted the potential for factory manufactured components to improve productivity in house building and the quality of finish in new homes. To continue to support the industry in delivering high quality off-site built housing, NHBC launched an online

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\textsuperscript{43} Construction Leadership Council, \textit{The Farmer Review of the UK Construction Labour Model: Modernise or Die}, 17 October 2016
\textsuperscript{44} NHBC Foundation, \textit{NF70 - Modern methods of construction: views from the industry}, 2 June 2016
\textsuperscript{45} ibid
\textsuperscript{46} ibid
\textsuperscript{47} ibid
\textsuperscript{48} For more information see: \textit{How NHBC’s Buildmark works - a quick overview}
\end{flushleft}
resource centre – the MMC Hub\(^{49}\) – providing developers, contractors, and manufacturers with details of systems already accepted following NHBC’s rigorous review.

2.6. It should be noted that most “modern methods of construction” are using conventional components of building structure (such as timber or steel), and the innovation is that they are assembled off-site. As such, NHBC does not differentiate in the performance required of homes built by MMC or conventional construction. NHBC’s technical review of MMC systems is aimed at ensuring that all new homes (regardless of construction method) meet homeowners’ reasonable expectations. Our review is based on a desktop review of the system design, visits to the manufacturing facility as well as participation in site trials. This process gives us confidence that homes will satisfy the NHBC Standards and be of acceptable quality. An overview of NHBC’s quality assurance approach includes:

- Early engagement at design reviews to identify potential risks;
- Requiring components to meet NHBC Standards to be designed for a 60-year life and comply with other recognised material performance standards;
- Review of production controls and method of transportation and installation with detailing to deliver a finished home that meets NHBC Standards;
- Assessment of the whole finished home (i.e. not just the components of the home).

Skills and career perception

2.7. The Farmer review highlights the current dependence of the construction sector on on-site labour\(^{50}\). House building in particular remains an industry that is typically traditional in its method of building, and current skills shortages are exacerbated by an ageing workforce. NHBC Foundation research found consensus amongst organisations surveyed that MMC would have a role to play, not just in improving the quality of construction, but also in helping to overcome current skills shortages\(^{51}\).

2.8. However, more needs to be done to address the industry’s poor image (i.e. the perception of poor job security, working conditions and health and safety issues)\(^{52}\). NHBC Foundation research comparing 14-24 year olds’ interest in careers found this was the case especially for girls and young women, who chose building and construction as the sector of

\(^{49}\) For more information see: NHBC MMC Hub

\(^{50}\) Construction Leadership Council, *The Farmer Review of the UK Construction Labour Model: Modernise or Die*, 17 October 2016

\(^{51}\) NHBC Foundation, *NF70 - Modern methods of construction: views from the industry*, 2 June 2016

lowest interest\textsuperscript{53}. The research found a general lack of information on professional house building careers, and a reliance on parental guidance (which would typically have a limited understanding of house building).

2.9. More must therefore be done to counter the poor image of a career in house building, and promote the range of exciting career prospects in technical, managerial and business improvement roles. Greater use in off-site construction by house builders will demand new digital skills for roles such as BIM technicians as well as changing the image of a construction worker to be a specialist working in a comfortable, controlled environment. Doing more to promote the awareness of such roles in schools and colleges, for example through closer partnerships with employers, could be an opportunity to attract younger, more diverse entrants into the industry.

3. Barriers and limitations

Confidence and investment

3.1. As recognised by the Government’s 2017 housing white paper, ‘\textit{Fixing our broken housing market}\textsuperscript{54}, confidence is required among mortgage lenders, insurers and warranty providers over the use and performance of the different forms of MMC. NHBC is currently working closely with both policymakers (as a member of the Government’s working group) and lenders to further develop how MMC is assessed from product concept, through factory production, transportation and incorporation into the completed home.

3.2. The NHBC Foundation has found that the majority of organisations surveyed consider themselves to be ‘late adopters’ or ‘followers’ of volumetric construction, pod and panelised forms of MMC, watching the success of others before making the decision to move away from conventional construction\textsuperscript{55}. The research found that only 10% of house builders considered themselves to be ‘market leaders’, leading innovation\textsuperscript{56}. The commitment from companies such as Legal & General has started to make a positive impact in off-site built housing, but more investment of that scale would be required to improve confidence and significantly boost housing supply.

3.3. NHBC’s experience would suggest that insufficient investment in product development and testing of off-site systems, together with misunderstandings as to what will be required in order to secure necessary insurance, warranty and finance, may cause issues with

\textsuperscript{53} NHBC Foundation, \textit{NF61 - A career of choice: Attracting talented young people into house building}, 9 March 2015

\textsuperscript{54} Ministry of Housing, Communities & Local Government, \textit{Fixing our broken housing market}, 7 February 2017

\textsuperscript{55} NHBC Foundation, \textit{NF70 - Modern methods of construction: views from the industry}, 2 June 2016

\textsuperscript{56} ibid
bringing such products to market. Factors contributing to the lack of investment include a lack of certainty in demand, a lack of economies of scale, and a drive to be competitive on price. Therefore greater investment in product development and systems, together with clarity around the ‘approvals’ process, would help to ensure that new emerging systems are introduced for the long-term benefit of the UK housing stock and are readily accepted by home builders, insurance providers, mortgage providers and the public.

4. Conclusion

4.1. This submission focuses on the key advantages of off-site built housing in boosting housing supply of the right quality. A rigorous review process, from proof of concept right through to integration into complete homes, is particularly important for addressing limitations in confidence and long-term investment in the market. Consideration should also be given to lessons learned from past failures and the time it will take for industry to adjust to and re-skill the workforce as new products and systems enter the market.

4.2. NHBC is continuing its work with all relevant parties to embrace innovation and ensure that new emerging systems are introduced for the long-term benefit of the UK housing stock. Research by the NHBC Foundation, undertaken by Cast Consultancy, is due to be published shortly and will provide further findings on housing developer activity within the off-site sector. NHBC looks forward to providing the Committee with this detail in due course.

25 April 2018
Offsite Solutions – Written evidence (OMC0039)

Executive Summary
Government documents and policy widely promote the use and benefits of full modular construction, but consideration needs to be given to partial-modular solutions. This is where elements of a building’s construction, such as bathrooms, kitchens and utility rooms, can be moved offsite into a factory and the units inserted into almost any building structure. This approach to offsite addresses all the issues the wider industry is facing – skills shortages, low productivity, quality issues, poor record of delivery on time and budget. However, because pods are smaller than full volumetric modules, factories can be smaller and therefore require less investment and the businesses are more agile and flexible. The role of partial-modular solutions, such as bathroom pods, should most definitely be reflected in the Government’s strategy and policy planning for increased use of offsite as it is already a highly successful, high growth sector of the industry.

Introduction – Offsite Solutions
Offsite Solutions is the leading and longest established bathroom pod manufacturer in the UK, supplying over 10,000 pod units every year to major main contractors and developers. In the next 12 months we will manufacture our 100,000th pod. Awarded Manufacturer of the Year at the Made in South West Awards, we manufacture the UK’s largest range of bathroom pods to suit different building types and applications – from high-end apartments and hotels to student accommodation, affordable housing, build-to-rent, care homes and hospitals. www.offsitesolutions.com

1. What are the opportunities offered by offsite manufacture for construction?
Some of the most significant benefits include:

1.1 Significantly reduce construction time
1.2 Improved cost certainty - less susceptibility to cost inflation during construction
1.3 Improved programme certainty
1.4 Enhanced quality with manufacture in a controlled factory environment
1.5 Improved health and safety on site
1.6 Significant environmental benefits – less waste and fewer vehicle movements to and from site
1.7 Reduced requirement for skilled trades on site and less reliance on subcontracted labour
1.8 Reduced material damage and theft on site
1.9 Reduced defects and snagging, and improved after-sales support.

2. What are the likely drawbacks?
Some of the most significant considerations include:

2.1 Earlier engagement – Decision making at an earlier stage is critical and resource should be allocated to this.
2.2 Buildings should be designed to be full or part modular from the earliest stage as it is difficult and inefficient to change part way through the process.
2.3 Some traditional funding models do not align themselves well with the modular building process as some costs will be incurred at an earlier stage.

2.4 The irregular and unpredictable sequencing of large construction projects means they often do not align themselves well with the manufacturing process which operates most efficiently with smooth and consistent throughput.

2.5 Points 2.3 and 2.4 above, along with the recession and the construction sector’s notoriously long payment terms, have caused some financial instability in the offsite supply chain. This has led to historic negative experiences for some main contractors and a reluctance to adopt new offsite technologies.

2.6 Larger modular units are difficult to store and transport.

2.7 Offsite can generate greater efficiency with the use of standardisation and repetition. This could lead to uniformity of appearance, lack of architectural variety and/or difficulty of incorporation within the local vernacular.

2.8 Employment is moved from site to the factory location – but this also has the advantage of spreading economic growth throughout the UK rather than concentrating employment in London and the South East where there is a higher level of development activity.

2.9 A part-modular solution such as bathroom, kitchen and utility pods, allows much greater flexibility with all the benefits of offsite construction but these units can be installed in any type of construction, to any timeframe and can be aligned with funding.

2.10 Where modular construction is used for the entire building, the system can be inflexible and difficult to accommodate change of use, for example from residential to commercial if local needs change.

2.11 Main contractors are typically resistant to full modular as much of the budget, decision-making process and control is moved to the offsite specialist.

3. What factors are likely to influence whether to choose offsite manufacture?

3.1 Cost

3.1.1 Ultimately most construction projects are driven by cost. Historically offsite construction has not been proven to be cheaper than site-based methods on a direct-only cost basis.

3.1.2 The part-modular solutions sub-sector in the UK is now more mature with several bathroom pod manufacturers having been established for more than 10 years and growing at a significant rate. As a result, most main contractors are now well experienced in the use of bathroom pods or other part-modular structures for major construction projects.

3.1.3 Once these part-modular structures have been used on a scheme and the construction team have experienced the direct, indirect and incidental benefits, they are typically very reluctant to revert to traditional in-situ methods. As evidence of this, we received this comment from a developer recently:

"Bathroom pods were recommended to us for use in the conversion of a commercial building into high quality student accommodation. Having involved the pod team from the earliest stage, pods then defined every aspect of this project, which was a critical factor in its success. As a result, the factory-built bathrooms generated significant time savings which were
very beneficial as the project is for student living and so the completion date is absolutely critical. After such a positive experience of bathroom pods, we will never go back to traditionally-built bathrooms.” \textit{Chris Eke, Development Director, Charter Land}

3.1.4 The traditional main contractor procurement models do not currently give sufficient credit to the indirect and incidental advantages and cost savings when pricing new construction projects. These advantages include faster return on investment and simplified procurement and management by reducing bathroom construction and quality control from up to 7 different trades, to a single supplier.

3.1.5 We are now reaching an inflection point where lack of availability of certain trades on site and the resulting wage inflation is forcing main contractors to look more seriously at offsite manufacture to help address the shortage of skilled labour and allow projects to be delivered on time and on budget.

3.2 Quality

3.2.1 Historically in the UK there is a perception that ‘prefab’ means low quality, temporary structures. This is less so in other countries where prefabrication is a more mainstream method of construction.

3.2.2 The advancement of materials and production methods means that quality and longevity concerns are no longer legitimate and that factory-built modules are now manufactured to much more rigorous standards than is achievable on site.

3.2.3 The perception of lower quality ‘prefab’ products is something which is perpetuated by the UK media and is often based on heavily outdated views which may reinforce the preconceptions of some key decision makers.

3.2.4 A gradual re-education of key influencers, particularly those of a more traditional and more established mindset is now occurring, often with part-modular structures, such as bathroom pods, on a project and the resulting positive experience.

3.2.5 The use of 3D digital technology, the increasing uptake of BIM, and influence of trade bodies such as BuildOffsite are all invaluable means of raising quality standards across the sector. These factors create consistency and educate key decision makers. However ultimately this re-education will come via first-hand experience - which Government has a role to stimulate.

3.3 Programme

3.3.1 The current lack of availability of skilled trades for site-based construction is causing programmes to be extended. The result is main contractors can complete fewer projects in any given timeframe, potentially affecting revenue and profitability and lowering the productivity of UK construction.

3.3.2 Developers want to complete projects as quickly as possible to achieve a faster return on investment, minimise the cost of development finance, and meet critical fixed completion dates, for example in student accommodation for the start of the new academic year.

3.3.3 Full or part-modular structures will provide much greater programme certainty and allow developers and contractors to complete more projects more quickly with less reliance on site-based trades and subcontracted labour.
4. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

4.1 The internal elements of most buildings can be designed for offsite factory manufacture with no detrimental effect on functionality and external or internal appearance.

4.2 Full modular buildings are better suited to regular-sized building plots where the footprint can be repeated.

4.3 Part-modular buildings can fit on any site and are not restricted by shape or regularity.

4.4 Although economies of scale and manufacturing efficiencies are improved by repeat designs and limited variation, these variations can be handled in a factory environment just as cars manufactured on a production line can be different whilst sharing common components and platforms.

5. What R&D is needed to fully realise the potential benefits of offsite manufacture?

5.1 Product development is very often driven by client demand – and client demand is often driven by the need to solve a problem. The current issues of skills shortages, wage inflation, low productivity and the industry’s poor track record of delivery on time and budget are causing main contractors and developers to look more closely at modern methods of construction and offsite manufacture.

5.2 Main contractors are inherently traditional and largely averse to change. With this in mind, products and solutions which bear some resemblance to traditional construction methods are those which are most likely to gain traction the soonest.

5.3 High-tech solutions may in theory be more progressive and game changing, however delivering these in sufficient volumes through the established channels will prove not only challenging but time consuming and capital intensive.

5.4 The UK has a reasonable base of established, stable and proven modular and offsite manufacturers. These companies are well placed to increase capacity and to develop new products and solutions to meet customer requirements. These specialists will have little interest in developing new innovative solutions if there is no immediate commercial demand or benefit for that product or service.

5.5 Government grant funding towards capital expenditure would allow these companies to increase capacity at a faster rate to help meet the growing demand in both public and private sectors.

5.6 R&D tax breaks would encourage offsite manufacturers to allocate resources to more progressive and long-term product and service developments, particularly those where there may not be immediate commercial demand.

5.7 Grant funding and R&D tax breaks would allow the offsite industry to accelerate at a much faster rate than it would otherwise. This should result in reduced construction costs, higher productivity and increased delivery of new housing.

6. What changes could be made to public procurement processes to facilitate offsite manufacture?

6.1 General Payment Terms
6.1.1 The construction industry is renowned for very protracted payment terms, which are prohibitive for smaller offsite manufacturers looking for growth. Larger projects require more materials to be purchased at an early stage but payment for these materials – even in public sector projects – is only forthcoming once the materials have been incorporated into the final product, sent to site and signed off. Payment terms can be as long as 60 days.

6.1.2 These protracted payment terms cause significant negative cash flow which severely restricts the growth of many offsite manufacturers without readily available credit.

6.2 Retentions
6.2.1 The cash flow situation for many suppliers and subcontractors in the construction sector is exacerbated by retentions and the unreasonable holding back of monies.

6.3 Project-specific Special Purpose Vehicles (SPVs)
6.3.1 Increasingly, project-specific SPVs are being used by developers and main contractors as a means of ring fencing projects to prevent cross contamination if a project fails. These project-specific SPVs are typically new companies with no credit rating. This often means that credit insurance companies are unwilling to provide cover to suppliers and subcontractors so if a project fails, the supply chain is very exposed to serious financial issues.

6.3.2 If Government could address these challenges on all public construction projects this would help significantly and facilitate the growth of the offsite sector.

6.3.3 The introduction of legislation to address these financial challenges would assist all construction projects, both public and private.

6.3.4 The Government could introduce a requirement in the procurement of public sector projects, that a certain proportion of schemes should use modern methods of construction, such as offsite manufacturing.

26 April 2018
Perceived advantages of offsite manufacture for construction

1.0 What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

1.1.1 In the general debate off-site is all too often considered in its most simplistic and holistic form and typically refers to volumetric or modular build solutions. These are primarily completed mini buildings (or specific completed pods such as plant rooms, ticket offices and bathrooms). Transported in their entirety and placed in position but typically associated with unimaginative or uninspiring living, working and educational environments. Off-site is the consequence of improving standardisation in approach to the design and build process. Consequently in addition to the above typically constrained solutions there is a whole spectrum of possible solutions using varying degrees of off-site/onsite manufacture.

1.1.2 Some wider alternatives adopt standardised kits of pre-manufactured and accredited components assembled on site (E.g. Component parts construction adopted for the Swiss railway station programme) that can often bring a drawback that they typically use pre-defined module/component sizes that can potentially inhibit the full optimisation of the available land.

1.1.3 Ultimately progressing to off-site manufacture opportunities that are able to capitalise on all the potential benefits of standardisation techniques outlined above and integrate those benefits into large format panelised solutions (for example SIP’s) adopting a project specific balance using a flexible mix of off-site manufacture with onsite assembly. This approach crucially enables those additional end user benefits possible using highly adaptable design for manufacture techniques to create inspiring living spaces and adaptable and complementary aesthetic finishes.

1.2 The benefits and drawbacks of offsite are therefore complex and need to consider the vast range of options outlined briefly above. There are two overarching issues that will significantly impact the value and quality considerations with offsite.

1.2.1 The need for surety of quality, approval and accreditation for off-site pre-manufactured components, products and composite systems irrespective of the degree of final assembly in factory or at the final location.

1.2.2 The project specific criteria that predominantly influences the most effective and efficient mix of onsite and offsite assembly. These criteria will include the particular constraints related to the site location, access arrangements and required timescales and programme considerations.

1.3 Opportunities
1.3.1 In our experience off-site is proven to shorten the duration of projects physically on site. Reducing both duration and the proportion of activities undertaken physically on site it automatically follows that potential disruption to the immediate community and local infrastructure reduces as a consequence. Removing the seasonal risks of inclement weather, local travel disruption and congestion in getting resources, plant and labour to and from site. Utilising factory controlled environments provides all parties increase cost and time certainty and in addition can remove significant on site hazards such as those associated with working at height.

1.3.2 A further benefit with off-site is in creating wider local economic growth away from London and the main congested conurbations. Noting that onsite construction resources do in themselves place large additional demand on the already limited availability of affordable accommodation within those conurbations.

2. It is often claimed that offsite manufacture can lead to:

- lower costs, faster delivery and increased quality;
- increased productivity;
- improved health and safety;
- greater provision of new, affordable housing.

What is the evidence for this?

2.1.1 Reigate Primary School (Completed 14 weeks early)

2.1.1.1 The main building structure took just 5 weeks to complete and the school was completed 14 weeks early by achieving the best combination between offsite and onsite assembly using a bespoke structural i-SIP System.

2.1.2 Kidwells Housing Estate (Offsite responding to specific site constraints)

2.2.2.1 One Housing Group needed to replace 84 homes and add a further 120 apartments. The new homes for existing tenants had to be built without them moving off site during construction. Minimising onsite disruption was important and several noise restrictions were imposed. An energy-efficient, convenient and cost-effective, offsite manufactured infill system was adopted for the concrete framed structures.

2.1.3 Heath Mount School (Off-site solution to harmonise with Grade 1 listed buildings).

2.1.3.1 The prestigious Heath Mount School required a new seven classroom teaching block and performing arts auditorium. Site access was restricted, designs needed to complement the existing Grade 1 listed buildings but make a statement of modern design, and disruption had to be minimal as the construction took place during term times.

2.1.4 Whitham Railway Station (A watertight ticket office in one week)
2.1.4.1 The new booking hall structure was created within one week, compared to the 8 weeks required for traditional techniques and the station superstructure was completed within a 3 week programme to reduce impact on railway commuters using the station.

Potential barriers to wider use of offsite manufacture

3. What are the drawbacks to offsite manufacture for construction?

3.1 In many cases off-site solutions are not as established and/or commonly understood methods for potential end use investors and mortgage providers. If the enormous potential economic value of off-site is to be realised for the UK economy a joined up industry approach is needed with underwriting specialists and government representatives to help demystify and remove the potential uncertainties around perceived risk.

3.2 There is an enormous degree of flexibility in the range and extent of components, products and composites systems used in offsite solutions. This increases the complexity for Architects, Structural Engineers and Consultants when creating specifications and subsequently in their due diligence approvals of the many bespoke offsite solutions being put forward. This fragmented approach further impacts on those organisations seeking and providing adequate and economical PI insurances. Therefore greater standardisation in designs and pre-designed system approvals will make it easier for all parties to provide assurances to the customers and end users of the buildings constructed.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

4.1 Re-skilling required can be considered for both the technical and management workforce and the skilled trades and operative’s workforce.

4.2 The technical personnel will need greater integration skills at a higher level in technical planning and development of the solutions. Increasing numbers of people with the specialist skills will be required to operate manufacturing facilities. Currently the largest off-site housing factory in the UK is capable of circa 3000 units per annum, an insignificant output compared to the number of new homes required to meet growing demand and subsequently create many more affordable homes.

4.3 For skilled trades and operatives, depending on the mix of off-site and onsite assembly the skills are wholly transferable. A plumber for example can work in a factory producing completed bathroom pods or onsite using traditional plumbing techniques. The opportunity also exists for multi-skill trades to carry our multiple specific tasks in offsite assembly.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

5.1 There is a case that can be made that off-site restricts the potential for creativity in design for Architects. This is certainly the case in boxy volumetric offsite. However, by adopting a complementary mix of onsite and off-site
elements using a bespoke design and manufacture large panel SIPS option contemporary and aesthetically creative spaces and finishes are easily and cost effectively achievable over traditional construction. This enables the efficiencies of a standardised process with the bespoke and unique product.

5.2 In terms of creative design off-site requires a significant change in mindset to customary design practice. Architectural and structural designs have to be completed and signed off much earlier in the project development process. Once the design is fixed the off-site element makes it far more difficult to change during the project implementation and delivery phases. There is still substantial opportunity for creative design it simply needs to be done at the outset and not drip fed and continually amended through the building phase.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

6.1 The disparate and wide range of potential off-site components, products and composite solutions will make it essential for greater interoperability between products to be possible. This will be driven through the greater need for standardisation in design approaches. Investigating how greater automation can play its part also warrants industry and specialist investment.

6.2 Given the fragmentation of the off-site manufacture industry and the fragmentation of the investment into research and development to date, it is vitally important to capture industry best practice, as in reality this has not yet been established.

6.3 The intellectual property for off-site falls in its entirety within individual specialist off-site suppliers and organisations. A wider industry and government approach is necessary to drive regulation and increase collective industry learning following the lead shown in the IT and aviation industries.

Government actions

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

7.1 We have no specific issues above those identified in the construction sector deal to add at this point.

7.2 We would emphasise that off-site has a key role to play in meeting the construction sector deal objectives in reducing capital and whole life costs, reducing the end to end duration of the project lifecycle and driving down greenhouse gas emissions.

7.3 However, it is essential that off-site is not seen as an all or nothing solution. The most important consideration is identifying the most appropriate and cost effective balance between off-site and onsite assembly activities. In doing so capitalising on standardise processes that create bespoke products and
spaces using pre-approved designs that provide the essential assurances and confidence of outturn quality and product resilience for all stakeholders.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

8.1 Certainty and transparency in the flow of work is essential for all aspects of the construction and engineering industry. However, it becomes even more critical for off-site manufacture due to the extremely high initial investment in factory/manufacturing space, specialist plant and equipment, automation controls and design integration and the relatively high levels of raw material stocks required.

8.2 A further concern is that traditional standard forms of contract do not protect the main contractor where a large proportion of the contract sum is placed with a single service provider (as is the case for off-site). This presents a significant risk with any specialist off-site supplier who may not be able to deliver and for which there may not easily procured alternative.

Submitted of behalf of Osborne Group Holdings Limited owner of Innovaré Systems

25 April 2018
Dr Mark Bew: Good afternoon. I chair a company called PCSG Ltd and we are in the space of digital engineering to the built environment. I chaired the government and industry BIM Task Group between 2011 and 2016 and I continue to be on the board of the Digital Built Britain programme, which has carried on from there. I spent most of my career in construction, either as a contractor or a designer. I was on the board of Costain and Scott Wilson, and I am an engineer by training.

Mark Enzer: I am the chief technical officer at Mott MacDonald where I am responsible for professional and technical excellence, which I drive generally through our internal professional networks. I have an interest in build off-site and DfMA, as a number of years back I worked in Anglian Water for seven years and introduced what they call product-based delivery, which in effect is a predecessor of DfMA—design for manufacture and assembly.

Q18 The Chairman: I will start with the first question. What leads a client to decide whether the project they have, whatever that is, might be suitable for off-site construction, and who are the clients?

Dr Mark Bew: From my point of view, there are a number of considerations that you would want to look at when it comes to off-site construction. Clearly, a repeat asset lends itself to an off-site componentised approach. Schools, hospitals, prisons, residential properties and some infrastructure where there are repeat components lend themselves to that scenario.
The challenges are that people immediately want to have variations. At what level do you standardise those components? In some industries the componentisation happens at a very low level, and we sometimes end up with platform-type approaches, such as in the automotive industry, where we have lots of different components built into standard platforms and then into lots of different products. That level of maturity does not yet exist in the construction sector, and building that is key. That is one reason why we have not yet seen many clients take that on board.

The other challenge for a lot of clients is that their day job is not building things, it is running a business. A supplier choosing a DfMA route or a traditional route is not their problem, and we need to find a way of encouraging it to be their problem and to become part of their selection criteria.

Mark Enzer: I have just a couple of things to add to that. If a client is looking at an individual project, or one project at a time, there might be some project-specific needs that would drive the decision to go with DfMA—design for manufacture and assembly—and off-site manufacture. A classic example would be if the site is particularly constrained and there is real advantage to spending a short amount of time on the site. Delivering components that are effectively ready-made reduces disruption to the public and can work in a constrained site. That might be a driver for a specific project choosing off-site manufacture.

It is also important to note that many clients do not just have individual projects that they want to deliver but have programmes of projects that are sometimes quite similar. In that case, standardisation is a driver of an approach where they design once and build many times, which drives a much more productive way of delivering.

I just wanted to extend the question beyond individual projects to programmes of many projects.

The Chairman: At what stage does a client, whether you are talking about architects, design contractors or others, decide that a project is suitable for off-site manufacture?

Dr Mark Bew: Always as early as possible. One challenge is finding a design team that is capable of designing for manufacture. If you go to a traditional architect or engineer, you are likely to get a traditional result. By far the bulk of the industry is currently configured to deliver traditionally. We see some parts of the market starting to understand the benefits of design for manufacture in quality and cost and speed to site. That is encouraging, but it is a very small capacity. It is quite interesting that we are starting to see an emerging capability, but there is very low capacity, and incentivisation and creating awareness among clients that these opportunities are available are key parts of any intervention in the future.

Mark Enzer: Building on what Mark said about the decision being taken as early as possible being better, off-site manufacture will always fit somewhere in a delivery process, which might begin with something such as strategy and move into planning, outline design and detailed design, and then the construction, operation and maintenance.
The later the decision is taken in that delivery process to do off-site manufacture, the more it will probably cost and the less benefit will accrue. It is very important to design the end-to-end delivery process around off-site manufacture rather than just bolting it on as an afterthought. Certainly, if most of the rest of the delivery process has been traditional, a design has already been produced and a contractor has bid against that particular design, going for off-site manufacture is unlikely to deliver the kind of productivity and cost savings that one would hope for, whereas if the end-to-end delivery process has been designed with DFMA in mind, the productivity benefits can come.

The Chairman: If you want to increase the number of buildings being manufactured off-site, whether they are prisons, schools or hospitals, who is the key person you have to educate or influence?

Dr Mark Bew: The key is to create capacity in the market. Currently, anyone who opens a factory to build components carries all the risk of building those components, and if the market does not take up the opportunity to procure those components due to all the factors that we have just described, they fail.

The costs of a factory and labour mean that overheads overtake takings. Finding ways of maintaining the market for those components so that we can get the volumes up to pay for the overheads and invest back into new components is the key. A whole variety of people along the value chain need to be aware of this intervention. Clearly, the client needs to be encouraged primarily. Then the specifiers, designers, engineers and the commercial teams who are in the chain of decisions down through this process need to be aware of the benefits, and supportive of them, to the point where an order is placed in that factory with a DFMA design that goes to site.

Baroness Young of Old Scone: I was really taken with the Mott MacDonald evidence, but it appeared to me to hint at the fact that there is no great evidence base as yet of the benefits of off-site manufacture. There are a lot of theoretical benefits and downsides, but do we have a really substantial evidence base yet? If not, what should be done about that?

Mark Enzer: We do not have a substantial evidence base, but we have enough of one to be quite convinced that design for manufacture and assembly off-site can deliver genuine savings. To get a more substantial evidence base, we need to do more of it. We have seen evidence in the water industry, transport, energy, so in most of the major sectors of economic infrastructure, to convince us that there is some genuine benefit in going down this route.

Baroness Young of Old Scone: Is there some process that we need, because presumably people are not going to jump unless they see the evidence that persuades them?

Mark Enzer: Evidence is part of it, and an element of leadership is needed, which in many ways goes back to the previous question: who needs to change to bring about industry change? Leadership is required throughout the value chain. At one end, there needs to be leadership in client organisations to commit to what is quite a big change. As I
explained, the whole delivery process needs to change, not just the construction part of it, and that takes real leadership in a client organisation.

But that is not enough. There needs to be change in the procurement departments, because generally procurement departments have grown up believing that the route to value is the lowest price against a particular specification, whereas DfMA points to value that comes from lower whole-life cost and better outcomes for customers. Procurement has to change, and that is a big change.

As Mark indicated, the supply chain itself also needs to change. If we join that up through the whole value chain, a lot of change and a lot of leadership is needed, and that is tough.

**Dr Mark Bew:** Part of the challenge is the fact that the current value chain is incentivised to spend against man-hours rather than outcomes, so it is incentivised in reverse to reduce the costs and to standardise. We need to look at the incentivisation and contractual relationships all the way through the supply chain to ensure that everyone is focused on the same outcomes.

At that point, we can start to create a new market, in effect. There is a bit of a challenge here where we have the traditional market and a DfMA outcomes-based market and the journey in the middle between one and the other. We need to be in one or the other for it to work properly. Otherwise, we will never create a market for enough components to get the unit price down.

**Lord Vallance of Tummel:** I know nothing about this market, but from what you are saying there appears to be a case for vertical integration of the supply chain? Does anybody do the lot?

**Dr Mark Bew:** Some are getting closer, but very few do the lot. If you go back to when I started in the mid-1980s, a lot of tier 1s had the lot. They had all the sub-contractors, project managers and designers. Trafalgar House, Tarmac, Laing O’Rourke and those sorts of organisations were vertically integrated.

The challenge with that is that you end up with lots of layers of overheads and profit in each part of the organisation, which adds up to a non-competitive position because clients have got into the habit of taking the lowest cost of each package within the project, adding them up and saying that is the cost of the project rather than looking at the project in the round. Effectively, that is what happened when we moved from traditional contracting to design-and-build contracting in the late 1980s/early 1990s.

**Lord Vallance of Tummel:** Are you are saying that it is more expensive to have something that is vertically integrated, or is it a failure of marketing?

**Dr Mark Bew:** There is a big difference between the tender cost and the outturn, and you need to look at both numbers. They are not the same number, and pricing costs are not the same numbers either. Once you unpack those, you see that vertical integration gives you a lower cost at the end.
Mark Enzer: Just this morning, across at the Institution of Civil Engineers, there was the launch of Project 13, which in many ways speaks exactly to your question. That is a movement within the infrastructure industry to transform the industry into something that is more vertically integrated; not necessarily vertically integrated by one organisation being vertically integrated but by many organisations coming together in an enterprise to be more integrated. At the heart of that is the role of the integrator—that is exactly what they call it—whose job it is to pull things together. That delivers precisely what you were getting at.

Baroness Morgan of Huyton: I was fascinated by what you said about moving to whole-life valuation, but how on earth do we make that happen? It is not just about lots of little bits of evidence, is it? It is quite a transformational way of doing procurement and management of huge projects. What should we suggest is the way forward to demonstrate how we need this significant shift?

Dr Mark Bew: There are a number of steps in a journey, not just one. As Mark said, an industry that is 10% of GDP is going to take some moving. It is a big issue. To go to the end game a little more and step back, the three numbers that we are interested in are the capital cost of the asset, the operational cost of the asset and the cost of delivering services through that asset, whatever it may be.

If we look at the ratios, at the moment there is roughly £90 billion of capex in the UK—40% is public and the rest private; £122 billion to £125 billion on services and £400 billion to £500 billion on delivering services—the cost of doctors, nurses, train drivers and so on.

If we can make our assets more efficient and deliver more with the resources that are delivering the services, ultimately we can put more money back into the capex, which starts to create a virtuous circle. To do that—and the Green Book investment process allows us to do that—we need good-quality evidence. We do not have that at the moment. We also have a very long timescale for the life of an asset, so we need to gather that data over a long time.

Clearly, as we start to gather better-quality data with measurements and things like sensors, we will have better insights as to how assets perform and consumers consume those assets. That is some way off but that will give us the evidence to do exactly what you have just described: to self-learn from how we do it.

Baroness Morgan of Huyton: Is that built into the system now? Are people starting to gather that?

Dr Mark Bew: We are slowly edging that way, yes. We have started that journey.

Baroness Morgan of Huyton: Who is “we” in that situation?

Dr Mark Bew: Certainly when it comes to public procurement we are starting to procure data with assets. It is not perfect, but it is the first step in that process. It will start to improve as time goes on. We are seeing the 5G and sensor standards start to become more common, so it will be easier to gather that data.
In the short term, in order to create some steps we have to do some things in the next five and 10 years. We should look at how we can encourage and incentivise the use of standard components and greater skills in design teams to be able to configure those components. That is something that we can do now, and we should look at incentives for enabling that.

Q19 Lord Borwick: In the first question we asked about the advantages of the system, but you carefully, and helpfully, answered on both the advantages and the disadvantages, which is a much more balanced answer.

Can I ask more about some of the drawbacks of this process? Are there any financial drawbacks both on cash flow and on other aspects of it? Can you talk a little more about the trend towards making everything the same: identical houses, identical blocks, which is fine for prisons but may not be what customers want in a housing development?

Dr Mark Bew: Some are less bespoke than others, that is for sure. Let me answer the second question first. A great thing about the UK is we have fantastically diverse architecture. We still have good architects in this country and we must not lose that; it creates us and our identity. For the sake of the quality of life of our citizens, we must not get to a cookie-cutter world where everything looks the same. That would be absolutely catastrophic. We see some nations that are heading in that direction. Poor-quality architecture has an impact on social outcomes and mental health and those sorts of things. We know from work that Mind and Shelter have done that the quality of residential accommodation has a big impact on mental health. Mental health is one of the biggest bills in the NHS budget, so we do not want to go down that route. I do not sign up to cookie cutters or standard architecture. We need diversity in our architecture and it needs to work for us.

There is absolutely no reason why standard components cannot also lead us to high-quality architecture. If we look at the automotive industry, standard components make up lots of different vehicles. If you look at a BMW 3 series, the underlying chassis and assembly for that is a 2 series, a 3 series, a Mini and something else, so four cars with all those components. I think you can get 3 million combinations in a 3 series. There is no excuse for going down the route of completely consistent architecture. I would absolutely agree with that.

On the disadvantages around finances, you mentioned cash flow, and I alluded to the same thing. There is a very different cash flow profile to opening a factory, buying materials, buying labour and having stock sitting in a yard. All the tier 1 contractors’ balance sheets are geared to not doing that and to letting someone else do it. They need to change and there needs to be a different model for the design of their balance sheets and their operating models.

We have seen some organisations start that journey. Laing, for example, has factories as well as contracting elements. The big challenge, if you can afford and fund the investment around the factory and the labour and materials, is to keep utilisation up, otherwise you run out of cash. That is
PCSG (Professional Construction Strategies Group) Ltd and Mott MacDonald – Oral evidence (QQ 17-23)

a fact of life. We have to be able to create a market where we can not only keep the capacity matched with the demand but we can get enough capacity through the machinery to invest in new product in the future, because the first ones we design will not be good enough and we will need to iterate them over time.

The incentives that we should be offering and the leadership from government, as Mark said, should be around enabling that market to exist. We should not tell them how to do it; they know how to do it. We should create a market for them to be able to thrive.

**Mark Enzer:** Can I add to a few of those points, not so much on the financial side but regarding other potential drawbacks? Some people would suggest that manufacturing can stifle innovation. I am not quite sure why that should be the case, because manufacturing does not seem to stifle innovation in the automotive or aerospace industries, but people certainly mention it.

There is also potentially an initial cost, because there is a lack of manufacturing capacity to do all the things that we might want to do, and that might require some attention to address it. There is a potential concern about being tied to one particular supplier rather than having a lot of choice in the supply chain. That is a potential drawback.

There are another couple of drawbacks, which are in effect the other side of a benefit coin. I would point out that those are to do with quality and adaptability. On the quality side, to make design for manufacture and assembly work, there needs to be much higher quality, which you can get in a factory. Some might say that it is too tough to aim for higher quality or that it is easier to bodge a job, so why even try for quality in the first place? I do not subscribe to that argument, but it is an argument that is made.

There is also the question of the ability to change things later on. In this country we have been used to being able to change things when we are on-site. There has been enough flexibility to redesign while we are building it. That luxury, if you can call it that, goes away with design for manufacture and assembly. I would say it is a good thing to design it properly first and assemble it on-site, but we lose flexibility, and some would say that that is a disadvantage.

**Lord Borwick:** You mentioned the automotive industry. In 1900 you bought the chassis and had a coach builder build the body on it. Henry Ford came along with this brilliant idea of doing it all in the factory. It was only when he invested the money to make the factory that automotive engineering took great steps forward and cars became better and cheaper proportionately. Is that a valid comparison?

**Dr Mark Bew:** There is a saying—I am sure it is attributed to Henry Ford—and it goes back to the client conversation we had earlier, “If I’d asked the client, he would have asked for a faster horse”. There is some of that in here. A catalyst such as Henry Ford or digitisation—there are a number of them that we could identify—is the key. We know that fundamentally it is the right answer. We need to catalyse it now. He is a
really good example of that. The client is always right, but sometimes he needs to be helped to understand what is right.

**Mark Enzer:** It is quite interesting that manufacturing in the automotive industry has gone through another few revolutions since then. We could point to lessons learned and driven by Toyota in automotive manufacturing. There are other manufacturing analogues such as shipbuilding and aerospace. Maybe the good news in all this is that all those analogues exist and we can learn from what they have already been through. It is quite odd in a way that construction should be coming to this party quite so late. A lot of the lessons are already very well learned.

**Lord Vallance of Tummel:** If you take the analogy of shipbuilding, or whatever, is a reason why things did not change very quickly the vested interests of the various trades and professions? Are there strong vested interests here? I would have thought architects, for example, would not do too well out of this, because there would be fewer of them around. Construction firms might not do too well out of it either. From experience I know that if you change things on-site it costs you an arm and a leg, and that is probably where the construction firms make a lot of their money. Are we up against vested interests in the professions and the trades?

**Dr Mark Bew:** Absolutely. That is exactly the point I made earlier. We have a new world and we have where we are now. We have to unpick where we are now. This combination of old and new, which is where we find ourselves at the moment, is the worst of all worlds. You have the costs of the new world and the disbenefits of the old. The leadership point we are making is that we have to make a step and do something different. The emerging strategies for manufacturing, digitisation, productisation and those sorts of things are where we have to be heading now. We have to work out the right intervention to move us from here to there, otherwise we will be left with those vested interests.

The challenge, though, is that we have existing demand and capacity, and we have to keep going while we create this new machine in flight and transfer to it. We cannot stop building schools, hospitals and roads, so how do we make that transition? So far we have been trying to fix the old model with the building information modelling and digitisation programme and the existing interventions in manufacturing. We now need to work out how we get to the new model, otherwise we will stay where we are.

**Q20 Lord Hunt of Chesterton:** How can building information modelling and other digital technologies be used in conjunction with off-site manufacture? Does this facilitate or necessitate? In our previous discussions, I at least, and I think many of us, have been thinking of rather large buildings—large schools, hospitals and off-site modelling—but there is an enormous amount of building in Britain by quite small builders who could be more progressive. Is it like going to the supermarket rather than manufacturing it yourself? Is there a trend towards the use off-site manufacturing where lots of contractors could go and get modelling and building help and so on? We are thinking of a big contractor with his own big factory, but could wholesale off-site manufacture in some senses be something that lots of smaller building businesses could make use of?
Dr Mark Bew: There are two important issues there. One is the digitisation of the sector to help manufacturing and the other is capacity growth and components. Certainly, when contractors have built factories and started to generate products, the competition is unwilling to go to them because they are the competition and they want to avoid them and go somewhere else. As a contractor, growing a market outside your own market is very challenging, which is why most of the tier 1s came out of that market in the 1980s and 1990s. Having stand-alone businesses that make these components is a likely area, because you become expert in those components rather than a jack-of-all-trades. That is happening in other sectors.

Lord Hunt of Chesterton: Is that happening?

Dr Mark Bew: It comes and goes, unfortunately, because we end up with this cyclical financial market that we described earlier. The first thing that happens in a downturn is that the factories run out of work, the overheads become unaffordable and they are shut down. We have been through that loop lots of times already, and we try to avoid that.

One way to look at that is to start consolidating spend from many builders into a fewer number of manufacturers. That is what we see in the automotive industry. There is only one Bosch and one Dunlop. Dunlop make all the tyres and Bosch make all the injectors and what have you. That sort of thing needs to happen for the market to grow. That is where the digitisation process comes in. If those components are available digitally and can be found digitally, we can start to create an online market. The most famous online aggregators are systems such as Amazon and eBay where you type in concrete, plank, column, stairs, pump, or whatever it may be, and there is a whole array of components that you can procure and drag off and put into your design, and away you go. Those kinds of procurement aggregators are likely to be part of the equation when it comes to growing this market. Whether the Government should intervene in that aggregation strategy or not is a decision that needs to be made.

Mark Enzer: Building information modelling—BIM—is a huge enabler of design for manufacture and assembly. As we go forward, it will almost become a necessary enabler of it. It is very difficult to imagine an efficient approach to off-site manufacture that does not use information modelling. We should see that as a great opportunity and not just in the building and assembly part of it, because information ends up being the golden thread that joins up the overall delivery process, and any loss of information in that delivery process is a loss of value.

We can see the same kinds of information being very relevant in the logistics, which is a key part of design for manufacture and assembly and a key enabler for its success. It is not just about the delivery. It gets into the operation, the maintenance and use of the assets, and, again, information ends up being a golden thread that runs through all that. I would see BIM as being a key enabler to start with, but it is just the beginning of something that is of even more value when we recognise the information that sits behind it.

Lord Maxton: Does what you are proposing necessarily mean changes in
planning laws? I think that is at the heart of a lot of this. Planning is of course a local government function, not a national government function, whereas in other countries it tends to be a national government function. Do we need changes in the planning laws?

**Dr Mark Bew:** There are a number of touch points into here. Whether it is a direct touch point is a different question. We lack and are in need of high-quality data in the planning process. Digitisation of data on mapping, floods, demographics, people flows, and other data available for the planning process is a key enabler in gaining transparency in planning and those sorts of things.

Do we need it to encourage DfMA? Possibly, but it is not one of the first places I would start, unless there was a specific need, as Mark says, for things such as logistics. If there are particularly sensitive places, you could you look at the part of the planning process for deliveries through small villages and those sorts of things, but it is probably a peripheral issue rather than a direct issue.

**The Chairman:** Mr Enzer, do you have any comment?

**Mark Enzer:** Not on planning.

**Q21 Lord Mair:** Can I come back to the barriers to the wider use of BIM? In the context of R&D and evidence, what ought to be done to make BIM much more widely adopted? What are the R&D priorities?

**Mark Enzer:** When it comes to building information modelling—Mark is really the expert in this, because he defined it all—we are at different stages for different levels of BIM. If we look at the entry level, level 2 BIM, for design and build, would enable the design for manufacture and assembly that we just talked about. Its adoption in infrastructure is quite well advanced now, and we are getting the benefit from that. There is further for it to go and the strategy is to drive the wider adoption of it, but I do not think it specifically needs R&D. In many ways, that has already happened for that level of BIM.

However, as we look forward to more value in greater integration of information across the whole of the delivery process, including the operation, maintenance and use, which I referred to earlier, that needs R&D because that is making use of information in ways that we have not done before. I would say that the answer really depends on which aspect of BIM we are looking at.

**Lord Hunt of Chesterton:** If we look at the City of London, and the amazing number of buildings that have been built, can we identify the BIM used for each of these? Was off-the-shelf BIM used by the structural engineers and the architects? They have all been successful, as it were.

**Dr Mark Bew:** If you look around the City of London now at the Walkie-Talkie, the Cheesegrater, the Gherkin, a few famous ones, all those were BIM-enabled or digitally enabled projects where the design was done digitally on a computer.

**Lord Hunt of Chesterton:** Did they have to invent a BIM system for those buildings or were they standard ones that were already available?
Dr Mark Bew: The building information modelling tool creates an environment in which to create designs and geometry. If you look at the Gherkin, a series of floor plates was designed and a shape and information can be attached to each of those components within the building. The glass cladding or floor plates would have had some information on manufacturing, weight, stress, maintenance, cost, time and those sorts of things. In effect, you should think of building information modelling as a database of drawings and information that describes the design of that building.

The Chairman: You have to do that whether construction is off-site or not.

Dr Mark Bew: Absolutely, yes.

The Chairman: It is a tool.

Lord Hunt of Chesterton: Was this UK software or imported software?

Dr Mark Bew: Unfortunately, not dissimilarly to other markets, we have invented a lot of these things and they have gone to America to be capitalised. The two biggest vendors in the market—Autodesk and Bentley—are both US-based businesses. We have lots of organisations in the UK that are very innovative in new functionalities, but they often get bought and sold very early in their life and taken to the States to be grown. We see lots of acquisitions going on in the sector at the moment. Two UK-originating companies have been sold for just over £1 billion in the last three or four months. It is a very active market.

Lord Mair: Can I come back to the evidence that you both mentioned a number of times and the role of BIM in providing the evidence, particularly in terms of performance of infrastructure assets? You talked about operation, maintenance and use. Presumably, there is a huge opportunity to combine BIM, which is a digitisation of the building or infrastructure, with data that will come from using advanced sensing technologies and so on. Could you say a little more about that, because that would add an awful lot more to BIM when you have the evidence about how infrastructure is in fact performing?

Dr Mark Bew: I will give a really short synopsis of 2011 to now. Back in 2011, the Government and industry came up with a digitisation strategy that was basically rolling out building information modelling into the sector. We took an approach where we had a series of steps or levels. The level 2 intervention that we made was a very small step to take a very big industry along a journey. That step was about engaging suppliers, clients and the standards authorities in a relationship that enabled us to start to create an environment that used data and BIM information to deliver assets. We worked with the core government departments, particularly the MoJ and highways and environment, to become a data-procuring client. We worked with the supply chain to be able to grow capacity within their environments and we helped BSI create a series of standards that could be included in contracts.

That was completed in 2013, and we started to roll out some pilot projects and we did some measurements. When we intervened in the market in 2011-12, we were at the bottom of the market, we were post
crash, we had lots of contractors that were very hungry at that point and we had the austerity challenge of “more for less”. We proved that we could deliver assets more cheaply at a capex level, and more importantly we created an awareness in the industry that digital was a useful thing in starting to deliver a more efficient industry. It was a very low-level conversation, but it was the first one.

We now have an opportunity to have a few thousand people in the debate rather than a few tens of people to do exactly what you described on the next step. How can we take this dataset and enhance it, not only with better quality of design and manufacturing information but in its in-service performance, with the sensors and other things that we know about? We can start to ask: “What was my brief? What did I set out to deliver? What did I design? What did I build? And what is operating?” Those three datasets give us the opportunity to feed back and start to learn. Having learning assets will put us in a very different place in a few years’ time, and that is exactly the journey that we anticipate going on.

Mark Enzer: There is enormous potential value down the route of your question when we look at the value of information through the whole life of the asset, not just in the delivery of the new asset. I do not want in any way to denigrate the delivery of new assets. We have a lot of massive assets to deliver, which is important, and increasing the productivity of construction would be very beneficial for us as a nation. The delivery of new assets is clearly a very important issue, and I am sure that off-site manufacture has a part to play.

However, if we look at the wider picture of the performance of the assets in use, where we already have 99.5% of the assets that we need this year, we are only building a very small proportion of that, and the performance of the assets in use is clearly of massive importance. Being able to look at and manage the information through the whole life of the asset—this picks up on Baroness Morgan’s earlier question on whole-life valuation—is clearly a route to even greater value. BIM makes a connection through all this.

One further point to make on this is that when we look at the performance of infrastructure assets through their whole life we can see the performance of infrastructure as a system, which is really about mathematics and the percentage of the theoretical capacity that we are using. However, we also see infrastructure as a service, which is a very different thing when we look at it through the eyes of the ultimate customer and what the outcomes are for them.

When we talk about the performance of infrastructure, we should be talking about both those things: performance as a system and performance as a service, because they are both incredibly important. If we increase the performance of infrastructure, that is likely to have an even bigger effect on national productivity than increasing the productivity of construction alone.

Lord Mair: I have one further question. Presumably, everything you have both been saying applies equally, whether it is off-site manufacture or not, but the ability in the factory to be able to put in various sensors in the same way as in an automotive factory sensors are placed in the car.
component applies even more readily to off-site manufacture, arguably, than to conventional construction. Is that right?

**Dr Mark Bew:** I think it does, because the smarts that we put into the components can be used in manufacturing, delivery and operation as well. The benefit will come from that whole-life use of the smarts within the component, because if we can get the performance data of the components back into the front of the process and start to optimise the components, we will see even more improvement. We understand very little about how these assets perform, either physically or from a consumer point of view, and the more data that we can gather on that and the more analytics that we can do, the more we can learn.

**Mark Enzer:** It is important to see off-site manufacture as part of a number of different related things that together will deliver greater productivity. It is not off-site manufacture by itself. What you say about off-site manufacture being a really good opportunity to get sensors built into the units is exactly right. It is what those sensors are used for in the rest of the life of the asset that will yield even more value. If we see off-site manufacture as part of a suite of measures that we can drive within delivery of new assets to increase productivity, and as part of a bigger picture of infrastructure performance, off-site manufacture has its rightful place. If we see it as the whole of the picture, we will be looking at too small a thing.

**Lord Kakkar:** Before I turn to the question of overcoming barriers to the adoption of building information modelling, I want to return to something that was said a moment ago about the value of this continuum of data from design through to manufacture, through to construction, and then through to performance and back again. Have business models been developed to capitalise on the value of that information in terms of its application to the domestic market informing infrastructure, construction, building management and so on, in other parts of the world?

**Dr Mark Bew:** There are lots of fragmented ideas, but nothing has been brought together. A lot of these datasets exist, but they are poorly understood and accessed. You mentioned one on building performance. The building management system datasets are very comprehensive but almost impenetrable, because the standards around them have made them so.

The lack of skills in the operational parts of the supply chain means that there are not enough people who can interpret that data in order to start to make use of it. A lot of people are hiding behind IP, copyright and those sorts of things. The ability to share this information has been a real challenge. As we move into a new contractual model, we need to ensure that the rights over that data enable it to be collaborated in and shared, obviously within the constraints of contracts and security and those sorts of issues, which we clearly have to manage.

We are not seeing any other nation doing massively better than us at the moment. It is probably the reverse: a lot of other nations have taken the UK standards model and replicated them. We see that Australia and Singapore and even the States are using similar standards to us. The standards that we wrote as part of the first part of the programme are in
the process of being promoted to ISOs, so it is a great UK story for that part of the market.

We see other sectors starting to do exactly what we were describing. In aerospace, Rolls-Royce is now selling hours of thrust rather than engines. Engines used to be very expensive and unreliable, so they had to be maintained. You had a big capex bill and a big opex bill. Now, because you are paying for the outcome, these two bills have become very small because all the flaws have been designed out of the engines and have become some of the most reliable machinery that we know. It has been the commercial model that has driven that engineering input into the product to drive those flaws out. The time between servicing is enormous compared with what it was 10, 15 or 20 years ago. We see evidence in other sectors and other applications where it has worked well.

**Lord Kakkar:** Does that mean that you could eventually have an infrastructure project or a major building project with all this kind of data monitoring and you would pay for the performance of the building or the asset rather than, principally, the capital cost of constructing it?

**Dr Mark Bew:** I do not think that is impossible at all. Stranger things have happened. We should be heading towards those kinds of ideas and opportunities, because it will drive better behaviour. If we can drive more value out of our capex and opex pound and deliver better outcomes to citizens, that is exactly where we should be heading.

There are some good examples. In High Speed 2 we are looking at how we can use these three datasets to predict faults at least six weeks before they happen. An aspiration for that infrastructure is that any fault will be detected well before it becomes an operational issue. Those are the kinds of aspirations that we are driving for now. Whether that turns into, as you describe, a new contracting model for outcomes, I do not know. I know that Sellafield is looking at outcome-based contracting for its contracts, because it has a very long investment in its assets—2,000 years potentially for some of them. Those kinds of scenarios are starting to emerge.

**Lord Kakkar:** On the broader question of adoption of this type of building modelling system, if I understood you correctly, the principal software technology asset is now owned overseas and has to be purchased by UK participants. Is that correct?

**Dr Mark Bew:** Yes.

**Lord Kakkar:** How can the Government, and the sector more generally, ensure proper access? Do all participants in a project need to have access to the same system?

**Dr Mark Bew:** There are a number of components to this. There is the system that you use to create and hold the information. It is an application equivalent to Word on your PC. There is some data that drops out the bottom that you share and someone else uses, maybe another copy of Word, to look at the design. The applications that you use come and go; they will get updated every year.

The key thing, the IP and the value, is in the data that sits underneath. Absolutely, we are looking at creating open standards for the data. We
want to create a market around better-quality applications so that Word becomes Word 2020 in a few years’ time and improves its functionality. What we are really interested in is the quality, the reliability and the security of the underlying data so that we can reuse it for other purposes. That is where the R&D question comes in. How do we drive the quality of this data up? We know what data we need and we already have it, but how do we massively improve the quality and start to join it up with other pieces of data to make sense out of it?

**Lord Hunt of Chesterton:** The data must be evolving. In the City, the Gherkin will be a big source of new data, will it not?

**Dr Mark Bew:** Absolutely. The data that you start with at briefing is very thin, and when you hand it over to operations it is very thick. It also grows in fidelity. That is all part of the management process. We have started the journey of understanding that sequence of events. We have a set of very basic standards for sharing that data, but it needs to be developed and improved. The next generation will be how we do that.

**Lord Hunt of Chesterton:** You talk about outcome costing. It used to be called some other word when a person puts up a hospital and charges the Government per hour, but the whole process, particularly for public sector buildings, has had a pretty negative press. Why are you so positive about it in light of that?

**Dr Mark Bew:** The interesting thing about the method that you describe—PF1 and PF2—is there was no feedback loop. It was a linear journey, so we learned nothing from it other than we had a very large bill at the end. We have to feed that data back into the front. We missed a vital component. There is masses to be learned from those projects. It was not all good, but some of that learning needs to be fed back in.

**Lord Hunt of Chesterton:** I notice you do not use the phrase “PFI”. That is a no-no now. I understand that “output costing” is a better phrase.

**Mark Enzer:** May I add to both these points, which I think are connected? We need to look further when we are talking about the outcomes to consider what outcomes we want from infrastructure, and not just from a particular project. We could look to reducing reoffending rates or to improving educational outcomes. If those are the outcomes we want, maybe those are the outcomes that should be rewarded. It has nothing to do with whether you build a prison, a hospital or a road. If the outcomes are what are wanted and the outcomes are what are rewarded, that can open up all sorts of more interesting solutions, which are not necessarily about just building more.

There are many cases where we do not have enough space to build more, so we need to think more cleverly and therefore we should come up with cyber-physical solutions and digital solutions that release more capacity without having to build things. It is important for us to have a whole-life view, because there is a danger that the kinds of sensors that Lord Mair talks about are seen as a cost rather than a value, whereas what they are doing is releasing more capacity and should be seen as a value.
Coming back to your point on the value chain, it is entirely possible for us to see a new value chain that goes from data to outcomes, and built on the basis of better-quality data we can make better sense of that data, which will give us better insights, which means that we can make better decisions and get better outcomes.

There is a direct connection between data and outcomes. What would make sense, with that view of value chain, is to reward the adding of value to information rather than the time spent doing it. We now have a number of cases where the amount of time we spend doing something like design does not make it worth getting paid for by the hour. The most recent example used to take 15 days and now takes four and a half seconds.

We do not want to get paid on an hours-based model for that, but it equates to productivity. That is exactly the kind of productivity we want. The message for me coming out of that is that we must change the business models. It is not a case of just looking at other business models. It is an absolute necessity that we change the business models to release that kind of value.

Q23 **Lord Renfrew of Kaimsthorn:** I should first declare my personal interests. I am a fellow of the British Academy and an honorary fellow of the Royal Society of Edinburgh. Currently, BIM is used for commercial buildings and infrastructure and perhaps not quite so much for housebuilding. Could you say more about the benefits it could have in the housebuilding sector?

**Dr Mark Bew:** It is used in housebuilding, but less so, for sure. We see organisations such as the L&Q Group and Laing O’Rourke using it routinely. They have big transformation programmes to enable that, because they have seen the benefits. All these sectors are on a slightly different curve of adoption and on a slightly different timescale. The application is very similar. It is an asset with components and data that can be managed in the same way.

The volume of housing certainly lends itself to using a component-based manufacture approach, and I think we will see it accelerate massively in the future. The challenge with that is going to be ensuring the capacity in factories, as we said earlier, to enable that to be sustained and potentially in the way we distribute and encourage designers and suppliers to use the data in a standard common way. If we end up fragmenting that market through the interventions we make, we will lose the opportunity.

**Lord Renfrew of Kaimsthorn:** It is potentially very sensitive to downturns in the market, is it not? You have quite a long chain of sequence from the factory to the finished house, and if there is a downturn in the market there is a big investment that is rather hanging fire. Is that a problem that one faces?

**Dr Mark Bew:** That is a problem across the manufacturing sector. You have a very high sunk cost in factories, materials and equipment. Anything we can do through the intervention that we design here to increase the demand, either for the domestic or the international market, the better. We need to focus on that, because this is a commercial
conundrum that we are unlocking here. We know how to do this stuff. The teams and the experience is in the UK. It is scaling that capacity.

**Lord Renfrew of Kaimsthorn:** I have a very specific question in trying to think through volumetric construction for houses. Obviously, one wants as large a unit as possible to be manufactured and brought on-site. Does the 5-metre limitation on what you can transport by road prevent a difficulty when we are talking about house construction?

**Dr Mark Bew:** Logistics is a really interesting constraint. If we look at inner city London, one of the biggest constraints on building in London is access underneath the hoist to deliver the components. The bigger we can make those components when they are delivered and the fewer lorries we need to come into London, the better—environmentally, congestion-wise and all the things that go with that—it will be.

We mentioned earlier that we have components, big assemblies and buildings. The strategy for that is always going to be linked to a set of constraints that are managed in the design. If you have a constrained site or constrained access, you are going to have to build a smaller assembly, but clearly you want to make it as big as you sensibly can.

**Lord Hunt of Chesterton:** You made a slightly cryptic remark about other countries having ticky-tacky houses that are all the same and so on. I do not know whether you are referring to France, but some of these countries are building them at three times the rate we are, and people are quite content with that. As I understand it, those countries have a lot of centres where they can get parts, or they design parts which they keep using year after year, and they have a much higher volume of construction. Presumably part of the limitation of introducing these off-site methods is the financial side in the UK compared with some other countries where there seems to be a longer, more continuous run. Is that improving?

**Dr Mark Bew:** For sure, France has a bigger demand than the UK. It is a bigger country with more people, so there is more opportunity to grow their market. They are also much more used to having outcome-based methodologies in France.

The particular example of the quality of architecture that I had in mind was Scandinavia, because you see lots of buildings that look very similar, and in China they all look identical, because they are. What the impact of that might be on future generations we will have to wait and see. We know already from the work done by the mental health people in that sector that there is a correlation between poor-quality or small poorly designed residential accommodation and mental health.

We do not want to save a few pounds here and grow a massive bill over here by making the wrong decision. We do not want to view this as a big experiment. We want to get this right. There are lots of components in the question that you just asked, and we need to understand each very clearly. There is a danger that we solve one problem and create another one that is much worse.

**Lord Hunt of Chesterton:** In principle, the Government or the Treasury could decide that it is important to have a continuum of building. That
does not seem to be very high on the Treasury’s list of priorities. It goes up and down.

Dr Mark Bew: Cyclical funding is a challenge. We have seen improvements over the last few years with departments such as highways getting five-year deals rather than one-year deals, which enables them to build long-term projects such as the smart motorways project, for instance, which has been enabled through that strategy. Because the Government have such a low input into the residential market, that is more difficult. Homes England is more of a land-property organisation now and has a small fund of around about 15%, so it provides a smaller lever for government to intervene in that particular market. If you look at prisons and schools, there is a much bigger lever. We are the client for a much bigger number of products and we can start to insist on a standard set of products and designs. It depends on which department you look at, its agenda and its funding arrangements.

Lord Hunt of Chesterton: Dr Bew and Mr Enzer, we are coming to the end of the session. You said something about the BIM software having to be imported. What is the percentage of the cost of a building if you have to buy that software from overseas?

Dr Mark Bew: I mentioned earlier the analogy between the software, tools and labour that you use to deliver it. The cost of the labour, the architect, is much higher than the cost of the software itself. For some SMEs, there is a little bit of a barrier, but not much. Over the last five years, the push back has not been the cost of the software but the cost of training, and, particularly on the part of the manufacturers and SMEs, nervousness that the Government will not stay committed to this direction of travel. These guys can do this. They have the capacity to do it, but they need a medium to long-term commitment so that all their efforts are not wasted, because that would be catastrophic to them.

The Chairman: What percentage of the schools that are built in England, let us say, would use off-site construction?

Dr Mark Bew: I would not know about schools.

The Chairman: Take any example that you know.

Dr Mark Bew: I know of several off-site schools, and there are more now than there were. It is a growing number.

The Chairman: Mr Enzer, do you know?

Mark Enzer: I do not know what the percentage is, but it is a low percentage.

The Chairman: Thank you both very much indeed. It has been an interesting session and we thank you both for coming to give us evidence.
Place Venture Management Limited – Written evidence (OMC0003)

- More than double build rates
- Exceed environmental targets
- Provide affordable housing
- Eliminate fuel poverty
- Reduce consumer costs by up to 67%

KEY POINTS

Based on established Off-site Manufacture techniques, building 1 million new homes with associated employment space can achieve the following:

- At least double build rates. (For example, 10,000 homes development with associated employment space can be completed within 5 years.)
- Meet or exceed Government targets for greenhouse gas reduction. (Zero hydrocarbon generated CO₂.)
- Meet or exceed Government targets for affordable housing within the scope of modelling.
- Eliminate fuel poverty and fully address energy security within the scope of Off-site Manufacture new build.
- Reduce the total cost of living by up to 67%. (For example, on a twenty year horizon £46tn is reduced to £15tn.)

This can be achieved using selected technologies, business processes and structures already proven at scale elsewhere in the world.

Moving from traditional build methods to off-site manufacture on a like-for-like basis alone is unlikely to offer the construction industry or home buyers significant benefit compared to a holistic approach that integrates off-site build with common utilities and transport infrastructure and low-energy designs.

SOURCES OF VALUE

Numeric economic modelling conducted by Place Venture Management with selected councils and utility companies identifies the following key enablers:

1. **High Energy Efficiency Off-Site Manufactured Building**... reduces energy and water consumption by a factor of 10. A new-build house in the UK is on average 10 times less energy efficient than the current best-in-class technology can provide.

2. **Restructuring the Sector’s Workforce**... creating high value jobs and alleviating constraints on build rates due to the current skills shortage.

3. **Local Combined Heat and Power Generation with District Heating Systems**... reduces energy costs, environmental impact, and dependency on stressed national generation and grid capacity.
4. **Energy recovery and Water optimisation**... recovers energy from waste water and reduces water usage by installing simple technologies while new properties are being built.

5. **A common utilities tunnel network**... means that most utilities can be maintained and new ones introduced without the cost and inconvenience of repeatedly digging up the road.

6. **Smart grid technology**... automatically optimises energy and water usage across communities. Energy costs and environmental impact are reduced as well as reducing the capital and running cost of power grids and water processing.

7. **Unified Communications and IT**... required to maximise the value of infrastructure for end users and minimise the cost of end user engagement.

8. **Reduce Administrative Overhead**... for industry business development, project monitoring, regulation, legal service and public sector planning.

**About the Evidence Base**

Over the past 3 years Place Venture Management (PVM) and its associated companies worked with a group of Councils and major utility suppliers and developers to understand an innovative model for new build homes and associated employment space based on off-site manufacturing techniques. Requiring a strong evidential base and clear financial justification, PVM researched best-in-class approaches throughout the world and developed a numeric economic modelling capability.

**Worked Example – 10,000 Home Garden Town with Associated Employment Space**

The table below outlines the costs and economic returns of a typical development based on off-site manufacture.
Notes:

Total Capital Expense: Total capital expense covers all off-site build, utilities plant and infrastructure (energy, water, waste and communications). This cannot be broken into specific lines without significantly increasing overall costs. This approach to holistic funding and build-out is a key success factor identified by PVM’s economic model. It enables a composite of suppliers to provide higher quality residential and commercial space beyond current UK market norms (i.e. higher levels of ‘comfort’ at lower cost with higher economic margins).

One-Off Revenues: These are principally sale of housing stock and commercial space. The One-Off revenues to Council is the current UK New Homes Bonus, paid to the Council directly.

Annuity Revenues: This is principally returns from rental income from retained housing and commercial property, energy, water, waste services, and communications. The Annuity Revenues To Council is the current UK Council and business tax. The investment case assumes a twenty-year horizon for annuity returns starting in the first year of capital investment. However, returns are likely to accrue over a forty-year period before further significant capital renewal is required. Both periods are shown.

Margins: This is the composite returns derived from all sources including water, waste services, communications and sales and rental of residential and commercial property.

11 April 2018
1. Introduction

ProCure22 (P22) is a Department of Health & Social Care (DHSC) £4bn/4 year national framework for the delivery of public sector healthcare buildings. The Principle Supply Chain Partners (PSCPs) are:

- IHP (VINCI/Sir Robert McAlpine)
- Interserve
- Kier
- BAM
- Graham
- Galliford Try

This submission is on behalf of P22 (the 6 PSCPs & DHSC). For ease of reference we have included your questions/numbering (in black) and added our response in blue.

How we define OSM:
The production of assemblies using standard or bespoke materials/components in a controlled off site environment to produce assemblies that are then delivered to and installed on site.

Examples of terminology and what this applies too:

<table>
<thead>
<tr>
<th>PRE- ASSEMBLY - Length of Services Run/Riser</th>
<th>PRE-FABRICATION – SIPS panels, Bathroom Pods</th>
<th>MODULARISATION – Volumetric room/building unit</th>
</tr>
</thead>
</table>

2. Perceived advantages of offsite manufacture for construction

2.1. What are the opportunities offered by offsite manufacture for construction?

Improved quality control arising from:
- Controlled environment
- Operatives/supervisors trained and familiar with their activity
- Repeated use of the same materials/components
- Prompt/ongoing improvement from lessons learnt
- Reduced on-site damage

Potential for reduced costs arising from:
- Higher operative productivity
- More efficient use of labour (more in fixed place of work and less on variable sites)
ProCure22 – Written evidence (OMC0017)

- Lower cost materials/components arising from bulk/repeat buying
- Less material/component waste
- Less defects/on site remedial work
- Less post completion building downtime
- Easier replacement/refresh of assemblies
- Improved logistics/transport efficiency

Construction time savings arising from:
- Assemblies can be manufactured off site whilst preceding on site activities are carried out and then installed in short time periods
- Rapid installation of assemblies on site with engineered/co-ordinated connections
- Less on-site activities improving health & safety
- Just in time delivery to point of installation reducing multiple handling

2.2. What are the likely [potential] drawbacks?

Design has to be complete and finalised at an earlier stage and prior to construction starting (some projects/Clients have internal design finalised after the structure starts). This can extend overall design and construction periods and/or reduce Client flexibility.

Changes during construction (that may be required) can be more difficult/expensive.

Low repeatability/standardisation in building design means OSM assemblies end up being largely bespoke and this reduces the benefit of OSM. This restricts ability for OSM sector to invest/tool-up for OSM and this can result in OSM being more expensive.

Some OSM solutions (and volumetric in particular) could reduce future flexibility/adaptability of the building.

2.3. What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

In general, the design of buildings that are going to optimise OSM need to consider this from concept through to detailed design stage and all need to have an understanding of what design facilitates added value OSM.

Clients:
- Sometimes perceive OSM as prefabrication (prefabs) as less robust (bouncy floors in modular buildings) with shorter lifespan.
- May want flexibility to change things as design/construction progresses, or after completion, to meet their evolving operational requirements.
- Often feel they are unique and need a building (and its assemblies) specifically designed for them.
- May require repeat/standard buildings that are ideally suited to being produced by putting together OSM assemblies.
- May require rapid delivery of building space that can be achieved with standard volumetric/flat pack buildings (NHS winter bed pressures are an example).
- Restricted site access and need to minimise disruption may require short on-site period that OSM can deliver.
Architects/design engineers:
- Sometimes may feel OSM requires standardisation that reduces their scope for unique/award winning designs.
- May not design with OSM in mind from the outset and this reduces OSM opportunities.
- Sometimes fully embrace a “design for manufacture” approach that utilises available OSM solutions and facilitates new ones.

Contractors:
- Can be more confident in traditional construction methods and understand the materials, processes and resources required to deliver.
- This can be reflected in the pricing (including risk factors).
- Sometimes look to maximise OSM options to reduce reliance on on-site resources (that may be difficult to find in some locations) and improve quality.

Supply Chain:
- OSM enables production line approach (increased efficiency/quality).
- Efficient use of labour and materials/components (less waste).
- Specialised plant and equipment all in one place.
- Improved logistics for goods in and out.
- Requires reliable/consistent demand to “tool-up” and invest and this requires Clients and Designers to adopt repeatable OSM assemblies.

2.4. It is often claimed that offsite manufacture can lead to:
- lower costs, faster delivery and increased quality;
- increased productivity;
- improved health and safety;
- greater provision of new, affordable housing.

What is the evidence for this?

There is evidence for this in pockets in the construction industry. This includes assemblies such as bathroom pods, SIP panels and building services cassettes.

These, and other OSM assemblies, have been widely utilised where they have sufficient volume on a project or programme of projects.

This demonstrates that where the design facilitates OSM and the volume of repeatable assemblies exist then these claims can be realised.

3. Potential barriers to wider use of offsite manufacture

3.1. What are the drawbacks to offsite manufacture for construction?

Please see 2.2 above

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

The skills for OSM of building assemblies exist within the construction workforce and can also draw on the workforce from the manufacturing industry.
Training would be more focused on the assembly being produced and the equipment/automation to be used. This could be more detailed but less frequent than toolbox/site specific training required on site.

The handling of larger OSM assemblies on site needs to be accommodated in the design, construction and mechanical handling processes that will require some focused training.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

Yes because:
- Large elements of a building have negligible architectural impact and there are award winning buildings that have utilised OSM.
- If particular OSM assemblies became standard architects would have the skill/flair to incorporate them into a building (after all a brick is a OSM assembly!)

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

We feel this needs a bringing together of Architects, Engineers, Contractors, the OSM sector and material/component suppliers to identify OSM assemblies that add value to the delivery of a building.

These standard (entry level) assemblies would then be jointly developed and made part of the OSM sectors offering.

Architects, Engineers and Contractors would need to commit to utilising these OSM assemblies in design and construction. This would generate the volume required to refine and invest in manufacturing processes to drive down cost and assure quality through continuous improvement.

OSM sector and material/component suppliers need to be encouraged to be more collaborative so they can plan for and develop OSM solutions that are needed.

Government actions

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

Include in Construction Sector Deal:
- Coming to market at the right time with accurate brief and funding solutions.
- Facilitating sustainable contract terms and conditions.
- Facilitate effective collaboration from Client groups and across the whole supply chain.
8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?**

- More accurate/robust Project pipeline forecasts to facilitate confidence in investment.
- Recognition that price competition alone does not necessarily deliver innovation.
- Enabling focus on, and investment in, whole life cost of building (as opposed to just initial capital cost).
- Facilitate good quality Client brief/requirements and sign off process for design and construction at the outset (reducing need for change during the process).
- Quicker investment decision making and only progress project where they will continue into construction (robust business case approvals procedures).
- Encourage acceptance of standard/repeatable solutions (as opposed to organisations who do the same thing needing something different) so OSM becomes the norm (not the exception).
- Greater reliance on standard components/materials as well as repeatable rooms – need to address use of these in respect of refurbishment not just new build.
- Enable more effective collaboration and repeat use of successful teams/supply chains.

9. **What ProCure22 have been doing encourage OSM**

In response to the Government Construction Strategy and the NHS Efficiency & Productivity Agenda the 6 PSCPs and DHSC set up a collaborative Efficiency and Productivity Programme (EPP) to reduce the capital cost of healthcare buildings whilst improving healthcare outcomes.

This ongoing EPP objectives have focused on:
- Repeatable healthcare room design
- Standard components and assemblies (for OSM)
- Post Occupation Evaluation (POE) providing continuous improvement
- Design Appraisal to determine and deliver requirements

These programme objectives were presented to the NHS and the then Government Construction Advisor, Peter Hansford, and we received the following feedback:
- 95% said they would support a move to standard designs
- 81% said they would embed standardisation in their requirements at an early stage

With this endorsement, we have gone through the following evidence based process:
- Evidence/data gathering and review
- Stakeholder participation – Clients, Designers, Supply Cain and staff/patient groups (Royal Colleges / MH Fight Club)
- Mock ups and testing
- National roll-out and communication
POE and continuous improvement
Provided improved both patient outcomes and cost reduction

This evidence based collaborative process has delivered:
- 24 HBN compliant repeatable arrangements with Level 2 BIM files
  - 4 Bed Multi-Bed Bays
  - Single Bedrooms
  - Consult/Exam Rooms
  - MH Bedrooms
  - ED Treatment Rooms
- Culture change (Designer/NHS acceptance of repeatability)
- PC and iPad based App providing a virtual showroom to earlier approvals
- Cost savings c4-11% against HPCG benchmarks with GSC savings of 14.1%
- National industry awards for Integration and Collaborative Working, Service User Experience, Production Design Innovation and Supply Chain Excellence

Standardisation within these repeatable room arrangements include efficient standard Asymmetric Bed Bay and Ensuit Assembly utilised in all repeatable room layouts. These facilitate OSM.
Having designed this standardisation into the repeatable rooms we have developed Standard Component agreements with suppliers for the key components within the rooms. These agreements are focused on quality, life cycle, warranties and maximum pricing irrespective of quantity.

The next step that we have now embarked upon is to work with the OSM suppliers to develop bathroom/service wall and clinical washbasin assemblies for OSM across the P22 Framework.

In view of the work we have done and our interest in getting the best from OSM we would welcome the opportunity to contribute to SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY work on off-site manufacture for construction.

We recognise there is a challenge for the UK construction industry.
This paper is submitted on behalf of P22 by: Alan Kondys FRICS, Health Sector Director – VINCI Construction UK, Framework Director – IHP

24 April 2018
**Ramboll UK – Written evidence (OMC0057)**

Submitted by: Gediminas Jakutavicius

Written by: Gavin White (Director, Ramboll UK) and Andrew Mather (Principal Structural Engineer, Ramboll UK), Gediminas Jakutavicius (Structural Engineer, Ramboll UK)

**Perceived advantages of off-site manufacture for construction**

1. What are the opportunities offered by off-site manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose off-site manufacture?

**Opportunities**

- With the overall improvement and cost reduction of factory automatization and robotics, off-site manufacturing is becoming increasingly viable in other traditionally low-tech industries.
- Improvement in the overall construction quality due to better quality assurance procedures within controlled factory environment.
- Off-site manufacturing for construction suits digitalisation trend particularly well. Use of digital tools to design, coordinate and build projects would realistically help to improve quality and efficiency.
- Off-site manufacturing for construction is particularly suitable for constrained site locations, e.g. small sites in densely populated urban areas. This suits another global megatrend worldwide urbanisation.
- Off-site construction has potential to allow for mass customisation, which would heavily improve its attractiveness in the market.
- Improved safety through appropriate construction sequencing and H&S coordination (4D planning in BIM). Also, certain construction activities that are harmful to health and environment could be adopted off-site in a substantially safer manner.
- Potential to improve sustainability through reduced waste and high rates of recycling in off-site manufacturing facility. Also, an accurate carbon accounting process could be achieved as most of project information is stored within the manufacturer for production purposes (e.g. full BIM 3D model with full product specifications).

**Drawbacks**

- Currently, off-site manufacturing for construction is realistically suitable only to a fraction of the construction projects. For more bespoke construction projects (driven by the client), traditional construction techniques are usually more suitable, but should still aim to maximise the levels of off-site manufacturing. For example, highly advanced Japanese prefabricated housing industry independently delivers approximately 15% share of homes annually (this does not account for projects that are delivered with a partial use of off-site manufacturing). This number is comparable to the total annual output of UK’s housing market (Johnson, 2007).
Supply chain needs to be set-up and developed to provide cost effective and reliable production. This is often limited by the economical viability of investing into large manufacturing facilities required to achieve economy of scale.

Costs and carbon emissions associated with the transportation if there are no off-site manufacturing facilities nearby (e.g. volumetric steel).

Factors

- Off-site construction supply chain cost competitiveness is usually limited to a small number of construction segments (affordable housing, residential student accommodation, healthcare and hotels). To realistically compete with traditional construction industry, economy of scale is required to be achieved through substantial investment in facilities and R&D.
- In UK, off-site manufacturing is often understood as poor-quality alternative to traditional construction. This can be partly related to the poor public opinion of prefabricated houses during the post-second World War housing shortage.
- Industry wide knowledge/experience in designing and building off-site projects is limited to specialist contractors.
- Construction legislation (building standards) has been developed for traditional construction methods, which off-site manufacturing is still required to comply with. This requires substantial investment into R&D, often by the client.
- Off-site construction projects usually involve different emphasis and time in the programme for the design development. This means that most of the design work and coordination between different parties involved is required to be completed before manufacturing takes place. This is very different from the traditional construction projects and might not suit traditional contracts, procurement routes and funding estimates.

2. It is often claimed that off-site manufacture can lead to:
   - lower costs, faster delivery and increased quality;
   - increased productivity;
   - improved health and safety;
   - greater provision of new, affordable housing.

What is the evidence for this?

There are major advantages available to those that can capitalise on off-site construction and digital design. A well programmed and developed off-site construction solution in the residential market has the potential to be 20% less than traditional methods, with fully fitted out modular volumetric construction times as much as 40% less. Shorter time on site, which is tremendously costly part of the industry, should in turn have a significant impact on cost and cashflow if the solution is put to work correctly.

The examples below show data from real projects with estimated comparisons for more traditional techniques, as well as aggregated data for a wider perspective.

Project specific example - Dalston Works, London.
- More apartments were built as Cross Laminated Timber (CLT) solution was lighter and could still sit above Crossrail 2 (lower cost/value).
- On site construction crew of only 5 people required to erect the structural frame (productivity).
- In-built edge protection on panels with all structural connections accessible from the inside. One face had cladding and insulation pre-installed too (health and safety).
- All windows & doors fit since manufacturing tolerances of panels are millimetre specific (increased quality).

**Dalston Works, London**
Comparison of 10 storey mixed used CLT frame with traditional concrete and steel frame:

<table>
<thead>
<tr>
<th></th>
<th>CLT</th>
<th>Concrete</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average site team</td>
<td>5</td>
<td>15+</td>
<td>10+</td>
</tr>
<tr>
<td>Material volume</td>
<td>4030 m³</td>
<td>2630 m³</td>
<td>1550m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>concrete, 64m³</td>
</tr>
<tr>
<td>Weight of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>superstructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(frame only):</td>
<td>1900 tonnes</td>
<td>6600 tonnes</td>
<td>4400 tonnes</td>
</tr>
<tr>
<td>Number of units:</td>
<td>121 (+20 future</td>
<td>106</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>extension)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embodied Carbon:</td>
<td>850 tCO₂e</td>
<td>2200 tCO₂e</td>
<td>1400 tCO₂e</td>
</tr>
<tr>
<td>Carbon sink for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sequestration</td>
<td>-2500 tCO₂e</td>
<td>0 tCO₂e</td>
<td>0 tCO₂e</td>
</tr>
<tr>
<td>Estimated Programme:</td>
<td>29 weeks</td>
<td>35 weeks</td>
<td>32 weeks</td>
</tr>
</tbody>
</table>

*All figures approximate and for comparison purposes only*

**Project specific example – Crescent Point, Plymouth.**
- Rapid construction programme on site (faster delivery on site).
- On site construction crew of only 9 people required to erect the structural frame (productivity).
- All modules were fitted out and finished to a high standard (increased quality).

**Crescent Point, Plymouth**
Comparison of 13 storey student residential modular frame with traditional concrete cores:

<table>
<thead>
<tr>
<th></th>
<th>Modular</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average site team</td>
<td>9</td>
<td>15+</td>
</tr>
<tr>
<td>Material volume</td>
<td>360 modules</td>
<td>2210m³</td>
</tr>
<tr>
<td>Weight of</td>
<td>3200 tonnes</td>
<td>5300 tonnes</td>
</tr>
<tr>
<td>superstructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(frame only):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of units:</td>
<td>349</td>
<td>349</td>
</tr>
<tr>
<td>Embodied Carbon:</td>
<td>1200 tCO₂e</td>
<td>1800 tCO₂e</td>
</tr>
<tr>
<td>Carbon sink for</td>
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<td>0 tCO₂e</td>
</tr>
<tr>
<td>sequestration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Programme:</td>
<td>9 weeks + 9 weeks</td>
<td>29 weeks</td>
</tr>
<tr>
<td></td>
<td>core construction</td>
<td></td>
</tr>
</tbody>
</table>

*All figures approximate and for comparison purposes only*
General comments on Infrastructure
- On infrastructure projects, change to off-site manufactured bridge abutments can be cost neutral, but significant programme savings will be realised (faster delivery).
- Reduction in labour resource on site, particularly if used across many structures.

Potential barriers to wider use of off-site manufacture
3. What are the drawbacks to off-site manufacture for construction?

Whilst Off-site Construction is a neat term which seems to have won in the buzzword battle between DfMA, prefab, MMC and others, it can mean many things depending on the client. It can encompass Cross Laminated Timber panels to unitised façade systems, fully finished ‘bed made’ volumetric steel modules to MEP riser units. There is a huge variation and range in off-site construction and understanding the benefits for a project can be challenging. Indeed, the benefits are normally only realised through a carefully co-ordinated and detailed holistic view.

- Costing
  Pricing off-site construction methods needs a different and more iterative approach than traditional build methods. Typically, there is no easily accessible data on the rates for an off-site approach for early stage cost plans. If you do have rates from a few suppliers, they are often not directly comparable due to the different offerings of each manufacturer. More importantly, the cost benefits of off-site methods are not about material costs alone. Savings also come from shorter construction times and reduced follow on trades, therefore requiring a detailed knowledge of the impact of each off-site method on the overall programme. This means that cost plans need to iterate much more often and quickly, with close collaboration from the rest of the project team. If not, then the risks of misleading information or missed opportunities abound.

- Design & Procurement
  The design process for off-site construction is also very different to a traditional build process. If clients were to tender on RIBA Stage 4 information with little input from an off-site consultant or contractor, they would almost certainly have locked in design decisions which make off-site construction methods costlier and less efficient. Consequently, off-site suppliers often get involved early in the design process, with the RIBA Plan of Work 2013: Designing for Manufacture and Assembly being a helpful guide. This ensures the design is in accordance with the manufacturing criteria and helps develop the cost plan in more detail. However, there is a risk of involving a single off-site supplier too early since clients could lock in their construction method and miss out on potential value from alternatives. A detailed knowledge of both the breadth of off-site suppliers and their capabilities is required to correctly advise clients on the right technical details as well as the right procurement route. This is something which is typically in short supply since suppliers are focused on their product alone, and consultants often lack the required breadth and depth of knowledge.
4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

- Due to ongoing digitalisation of various industries (construction included), the design, testing and fabrication has become a very fluid process. However, in construction, substantial proportion of designers and the supply chain still tend to work in 2D format. Therefore, sufficient investment should be made to re-skill construction workforce to adopt digital tools and methodologies available, e.g. Building Information Modelling (BIM).
- Understandably, most designers tend to have much stronger design skills in traditional construction. To facilitate more off-site manufacture for construction, architects, engineers and other members of the design team need to have a strong understanding of off-site manufacturing methods, techniques, materials and its current limitations. However, this is currently limited to a small number of specialists and innovators.
- Off-site manufacturing and traditional construction have very different design & construction programmes. Therefore, project procurement and people involved in this process would require adopting a change in paradigm (e.g. contract types, procurement route, project programme).

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

- Architectural community should embrace off-site manufacturing for construction whenever possible and learn to design using different approach. For example, a lot of residential schemes are purposely designed to hide the fact that off-site manufacturing has been employed and tends to mimic the appearance traditional buildings.
- With sufficient investment into R&D and development of centralised standard details/product catalogue list, mass customisation could be achieved. This would allow architects to actively engage with various products and solutions that can be provided by the off-site manufacture for construction. Currently, industry is very segmental.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

Other countries that successfully adopted off-site manufacturing within their construction industry (e.g. Japan and Sweden), concentrated on investing heavily in R&D and used housing shortage to boost their off-site manufacturing for construction:

- In Sweden prefabricated housing production was initially driven and developed due to governmental subsidized housing loans (between 1965 and 1975 more than 100,000 units were produced annually (Nord, 2008)).
- In Japan, production of Prefabricated Housing Manufacturer (PHM) was initially driven by the process of replenishing the housing stock damage during World War II and over-capacity in light-gauge steel production due to The Korean War (Johnson, 2007).
- In Japan, large regional or national suppliers have developed sophisticated factory-based systems (Johnson, 2007) that required years of intensive R&D (earthquake design, design for manufacturing, typical details and testing, product catalogues and the development of various supply chain standards).
- R&D of typical construction details that off-site fabrication for construction would utilise. The development of centralised standard details/product catalogue list would improve knowledge sharing and adoption of best practices and mass customisation.
- Further R&D in the use of robotics to assemble or even print buildings on site.

**Government actions**

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

- Further incentives for public sector to invest into R&D associated with the off-site manufacturing for construction.
- Investment into government or public initiatives dedicated to re-skilling of the existing construction workforce.
- Investment and emphasis on off-site fabrication for construction within educational system (e.g. Universities, Colleges).
- Further provision of long-term subsidized government funding/loans for the delivery of affordable housing that is built using off-site fabrication for construction.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

Set a clear requirement to achieve quantifiable sustainability targets (e.g. limits to wastage, embodied carbon and similar).

- Off-site manufacturing manages their wastage much more carefully and have usually procedures in place to estimate their recycling and wastage credentials.
- Carbon accounting (based on agreed methodologies and inventories) could be used as one of the factors when considering the procurement of a certain type of project. Taking Open Academy as an example (a 9500m2 new build school in Norwich), three separate solutions where developed and compared:
  - concrete frame,
  - steel beam and precast concrete frame
  - timber panelised frame

These options were compared during the scheme design phase. The timber solution was shown to have 660t of embodied CO2 (discounting sequestration), which was approximately one-third of that of the other alternatives. Such project specific embodied CO2 figures are always presented in an open and transparent manner that allow the client and design team to make an informed decision for the final building.
26 April 2018

REFERENCES


Rider Levett Bucknall, Infrastructure Client Group and Infrastructure and Projects Authority (IPA) – Oral evidence (QQ 64-70)

Transcript to be found under Infrastructure and Projects Authority (IPA)
Tuesday 8 May 2018

Watch the meeting

Members present: Lord Mair (Chairman); Lord Borwick; Lord Fox; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Maxton; Baroness Morgan of Huyton; Baroness Neville-Jones; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 5 Heard in Public Questions 30 - 40

Examination of witnesses

Andrew Morris, Partner, Jane Richards and Jaimie Johnston.

Q30 The Chairman: Good afternoon and welcome to this session. I am afraid that the Chair of the Committee, Lord Patel, is unwell, so I am deputising for him today. Perhaps we could start by having you introduce yourselves, and if at the same time you would like to make an opening statement, you are welcome to do so.

Andrew Morris: I am an architect and the senior commercial partner at Rogers Stirk Harbour and Partners, a firm of international architects. I have been with the firm for the past 37 years. I also chair the management boards of the practice and generally look after the day-to-day business to make sure that we keep afloat. I have worked mainly in the UK on a number of notable buildings that you would probably recognise. They include Lloyd’s of London in the City, the Welsh Assembly building, the 02 Arena—not the latest iteration but for the 2000 celebrations—terminal 5, and a number of residential projects for clients for both the high-end residential and low-cost sectors. We have also just completed a new whisky distillery in Scotland for Macallan.

Jane Richards: I am a chartered structural engineer and I head up the structural engineering division of WSP, which is a large professional consultancy for engineering services. Like Andrew, my experience is quite general in building structures but also specific in modular. My involvement with modular and off-site design goes back some 15 years and includes the development of a volumetric modular system for the Unite Group, which provides student accommodation. We took a product that was suitable for a production line facility through its design development and out into manufacture. When that product was completed in 2007 it was used by the Unite Group on all its projects.

That goes right through to the present day with, for example, some projects that I am involved in now in modular and off-site. Again, they include a volumetric off-site product for the Berkeley Group, a large residential developer in the UK. That product will deliver homes that go from three storeys to 20 storeys. We also work for contractors with an
interest in off-site construction, including Laing O’Rourke and the Mace Group. That is where I have experience in modular and off-site.

**Jaimie Johnston:** I am from Bryden Wood, which is an integrated design and operations consultancy. We have all the design disciplines, including architects and mechanical, electrical and structural engineers. Increasingly, we also have a team of data analysts and mathematicians who do early-stage problem statements and writing briefs.

Bryden Wood was set up 23 years ago and I was its first employee. We were set up to look specifically at how we could import learning and best practice from other sectors, notably manufacturing, into construction to get the benefits of better quality, fewer people, better cost certainty and so on.

My career has been involved in looking at those issues in a number of major projects. I worked on terminal 5 at Heathrow and the Olympic athletes’ village. We are currently working on the Ministry of Justice prison estate transformation. We also have a particular interest in building information modelling and digital workflows.

In our minds, the digital and the physical are increasingly interlinked. I was part of the BIM task group when level 2 was implemented from 2012, and I continue to work with departments such as the Ministry of Justice by first getting them up to speed with BIM and then using that to drive better efficiency in design and ultimately in delivery. My career has been spent trying to understand how we can import this best practice into construction.

**Q31 The Chairman:** Thank you. I would like to ask the first question. We have heard from a number of previous witnesses about the various advantages and benefits of off-site manufacture. Can you tell us a bit more about what you would view as the drawbacks and barriers to off-site manufacture?

**Jaimie Johnston:** The biggest barrier is the current fragmentation of the market at every stage of the process from design through to delivery. What we are seeing in the design space is very deep but quite narrow specialisms emerging within the design disciplines, which means that you do not necessarily have a controlling mind with a complete view of every aspect of the design.

Once we get to procurement, an awful lot of work can be put into a fabulously co-ordinated and integrated design, which then gets pulled apart into multiple individual packages that are sent out to the individual trades to price their bit of it. We are seeing increasingly that people have a very narrow view of the overall problem and potentially quite a short-term interest in the project, because they are there only for their bit of the design or procurement.

All that fragmentation creates gaps and provides opportunities for the client’s vision and requirements to be diluted, and because there is no holistic view that ties together the design requirements, the design and the means of manufacture, we are starting to lose opportunities. What manufacturing can do well is capture the voice of the customer, which becomes the thing that is persistent and drives everything. Construction
is very fragmented and no one has a holistic view, which makes it very hard to get the level of integration that you need to drive a manufactured outcome properly.

**Jane Richards:** I mentioned my experience with the Unite Group. When it came to the 2008-10 downturn in the industry, having invested hugely in a factory, a production line and a commitment to building in that way, suddenly the funds were not available for more development. A three shift per day pattern at the factory went down to zero and the factory had to be shut for six months. When the group took stock of that, it decided that it was not sustainable into the future, so it took the unfortunate decision to close the factory and put it into administration, and all that investment went.

I think the industry has matured, and as Jamie has said, there are a number of different aspects to it now. While I am always mindful of that, I am surprised at how much investment is being made by individual companies into off-site at the moment, so it is clearly of enormous benefit to businesses.

At the same time, if we cannot enable them to have a secure pipeline and a better understanding of how their commissions are going to come in, that is a big drawback. Let us look at the people who are investing, such as the Berkeley Group and Laing O'Rourke, which has just signed a development agreement with Stanhope and has secured a pipeline of 10,000 units a year. Unless those strategic pipelines can somehow be put in place, there is a danger that it could stall. If that could be addressed in some way, it would be a benefit for all.

**Q32 Lord Vallance of Tummel:** This touches on something we talked about earlier. There is a fragmentation of cultures, which seems to be as much a cultural issue as anything else. Architects, designers, engineers, contractors and the trades all have their cultures. If you are going to align a set of different cultures, you need real leadership and something that has leadership right through the chain. Is there any sign of that arriving?

**Andrew Morris:** I was going to pick up on that exact point. You are absolutely right to say that the first thing that is needed is a willingness to change. As Jaimie has said, although we talk about the construction industry in the same way that we might talk about aerospace or automotive, it is not, really. It is actually a massive infrastructure at one end and small domestic products at the other.

Each of those has its own silo for procuring work and each has its own ways of working that tend to be traditional. The first thing that one has to get over is the desire and the willingness to make a change. The only way in which off-site can work is in combination with design for manufacture, which really means focusing on the end product and putting together the skills necessary to concentrate on delivering the end product. Then, the most important thing is to devise a procurement process that is a contractual environment and an insurance environment that enables the team to focus solely on delivering the end product. That would be a root and branch change.
There are certainly pioneers, which Jane has mentioned, that are trying to do so, but the vast majority of the industry is still happy to stay where it is. I recently read the report of the NBS national construction contracts tribunal, which comes to the very sorry conclusion that the people who contributed to the survey take disputes within the construction industry as part and parcel of the way they work. That is a damning outcome, so I agree absolutely that it requires a change of heart, a change of mind and a change of focus.

This is where public procurement can offer a signal. It can produce exemplar projects and show the way on the changes that need to be made, but first one needs to start to address the whole contractual arrangements in building contracts and the insurance regime to allow that to happen.

**Lord Vallance of Tummel:** As someone who knows nothing about the market, all of this argues for some form of vertical integration. You would then have the whole chain, so if you wanted to change the culture you would have the levers to do it. Is anyone thinking about vertical integration?

**Jane Richards:** The Institution of Civil Engineers is running its Project 13 initiative at the moment. It seeks to address change in the industry, so there are initiatives going on that are being led by the top of the engineering industry. I do not think that everything is in place to make the sort of change that you have described, but some initiatives should be encouraged and worked on. They are also very wide-ranging, and it will take some time to change the industry fully, but a focus on off-site coming out of those initiatives would be a useful thing.

**Jaimie Johnston:** We are seeing some clients starting to address vertical integration, notably companies like GlaxoSmithKline. They recognise that their attitude to risk has to change. Picking up on Andrew’s point, clients tend to put the risk on to the tier 1 contractors, who then put some of the risk on to their supply chain, so it gets passed down.

I do not think we will crack this until we can absolve the contractors of some of their risk. At the moment we are asking them to do something unusual and to try out new ways of working, but the contractual tool has a lump-sum fixed price. There is a constant tension between the need to do what has always been done to get cost certainty and the need of the client to try something different. We see it be successful when a client steps in and says, “Actually, it’s still all my risk. I’ll absolve you of some of that risk and I’ll take a much more active role in developing the brief and understanding the vision and the supply chain. I’ll take some of the pain away”. That enables the behaviours in dispute resolution and hiding behind the contract.

However, Andrew is absolutely right to say that until we get the procurement tools to work better, it is going to be very hard for people to make the cultural shift. At the moment, they are trapped.

**The Chairman:** What incentivises clients to act in that way?

**Jaimie Johnston:** Companies such as GlaxoSmithKline have recognised that they are not getting a fantastic product from the construction
industry. We looked at the figures from one of the big departments, which found that only half of every pound that is being spent ends up in physical asset value. The next biggest chunk is risk, and then an awful lot of non-value-added money disappears into rework, profit on profit and transactional costs. Companies such as GlaxoSmithKline are saying, “If I can get closer to the actual asset cost, I would immediately get buildings an awful lot more cheaply. What would I need to do to cut out some of the inefficiency? I need to step into that space”.

I suggest that there is now enough evidence to demonstrate that off-site can deliver projects that are better quality, cheaper and quicker and that use more diverse people. But to do that you have to step into the space and say, “I will start to drive out some of the waste by putting in place a more efficient, vertically integrated process”. In that way, the customer is more persistent through the life of the project.

Andrew Morris: I want to add to Jaimie’s point. We were both involved in terminal 5 at Heathrow Airport, which was a classic example. The client, the British Airports Authority, took on the full insurance risk, so none of the consultants had to take out individual policies. It put together a combined team of designers and contractors with a supply chain in one place, so that we were all together. It was a project team, and I think that in the end the BAA valued the quality, the cost certainty and the predictability that comes from putting all that together. The product, terminal 5, is there to be seen today.

Lord Kakkar: The sixth question on our list sits quite comfortably here. The focus of the discussion has been on the client perhaps taking more risks and being more imaginative in the way it contracts and deals with the disposition of responsibilities. However, should the Government be doing more to make it more attractive for clients to do that?

Jaimie Johnston: We are starting to see, in the Highways England smart motorways project and the MoJ prison estate transformation, that some of these things are being unlocked. They have started to step into the space and demonstrate how this will work. On the back of the Autumn Statement, there is a piece of work looking at how to take what the MoJ and Highways England have learned and spread it more evenly across other departments.

Highways England has a load of learning that is potentially useful for Crossrail 2, HS2 and HS3, so we are starting to see some of the big infrastructure clients talking together more. The same thing is happening with the MoJ talking to the DIO, so there is some cross-fertilisation. It is helpful that clients are starting to self-reinforce. If they see someone else doing it and they can share in that learning, it gives them confidence and you can accelerate the pace of learning. Rather than lots of people learning the same thing individually in silos, we are beginning to see more sharing. The more we can open-source that learning and make it more available, the more clients will get some confidence and begin to contribute to the journey.

Lord Kakkar: Beyond the Government being an important client, could something be done by way of legislation that would give more confidence to clients and therefore beyond them more broadly to the construction
industry and the participants who have to deliver this, or is that not necessary?

**Jaimie Johnston:** I do not know if it is necessary. We have struggled with this internally, because at the moment I am not sure what you could actually mandate. The term “off-site”, for instance, is so broad that it would be hard to put legislation in place. The measurement of what is off-site value versus what is on-site value is still very vague, so there is not enough definition or articulation of what we mean by “off-site” to put something in place to measure people against.

The Infrastructure and Projects Authority is keen on building up some benchmark data that would start to drive these behaviours. There will probably be a legislative route over the long term, but at the moment it is so vague that it would be hard to write anything that could be enforced.

**Jane Richards:** I would add that the Government have indicated that they are expecting off-site to be a significant component of projects by 2019, which is not far away. There are also some massive regeneration projects in hand, such as 11,000 homes in Barking Riverside. Rather than putting legislation in place, some real incentives could be built into the procurement strategies for delivering such projects so that they automatically leave a legacy that is of benefit to local communities. Off-site is an obvious way to do that.

**Lord Fox:** In our discussion about integrated teams, we seemed to be conflating two things. There are benefits from having integrated teams and there are benefits from off-site manufacture. Are you suggesting that we cannot have effective off-site manufacture unless we have integrated teams, or are they two separate benefits? Could you have the current fragmented model and still have effective off-site manufacture? Which is the chicken and which is the egg in this discussion?

**Jaimie Johnston:** My view is that you must have integrated teams to make this work. You will not do it until you have sharing of knowledge. I do not know if Jane agrees.

**Jane Richards:** Let us look at how it is being done at the moment. We have some pioneers who are making off-site work, so we need to harness some of that. Getting the benefit of the cross-fertilisation of off-site, technology and all that goes with it would be a good step. The integrated team works well and we all have experience of that, but every project being done in that way would be going a bit far.

**Lord Fox:** Coming back to the point made by Lord Kakkar, are there things that we can do in risk management that would encourage the sort of thing that would deliver those teams? Are there legislative things that could change risk management and insurance?

**Andrew Morris:** Taking a lead from the terminal 5 project, let us look at how consultants take out insurance in this country. We work internationally, and quite often we find that in major projects clients are quite happy and prepared to take out project insurance, which is a single policy that covers the whole of the project. It means that individual consultants do not have to take out their own insurance. The simple act of
doing that draws you together, because you are then focused on the task at hand.

So I would have thought that in any public project, if the Government, or whoever is actioning it, are seen as an exemplar client, they could say simply, “All public projects will be covered by project insurance”, and it would take the risk away from the individuals and unite the group. You do not then spend half your time trying to protect yourselves and you can focus absolutely on the job at hand.

Jane Richards: I think you could go further than that. I am not advocating this, but we have had Chinese contractors approach us because they have been mandated by their Government to make a certain percentage of their residential development using modular off-site technology. While I do not think there would be any reason to do that, the approach could be taken that when a very large public regeneration project is being procured, and particularly where there could be a legacy benefit, it could be part of the procurement. Something would be delivered with these outcomes in mind, and one of those could be an off-site manufacturing legacy offer.

Coming back to the original question, there is a beneficial outcome to be had if we put our minds to it.

Baroness Young of Old Scone: Lord Vallance has talked about leadership. It seems to me that this could grow organically, with lots of people doing little bits here, there and everywhere, or is there a burning platform that is going to drive it? If so, what would that be? Why does the efficiency case, for example, not drive it fast? People say that there are benefits in the sheer efficiency of this form of construction.

Andrew Morris: You are dealing with many individual vested interests. As I say, the industry is not a homogeneous sector. Rather, we should look at it as a series of silos that have developed over the years. They have their own methodologies and business models. Something that would work for a commercial building in the City of London might be totally inappropriate for a domestic residential project. You have to look at each of those sectors and ask what can be done to achieve the overall goal of off-site manufacture, which is higher quality in the end product and a shorter period of time. There are better whole-life costings, so it would be a better asset to invest in. That should then be tailored for the various silos.

In the residential market, which is obviously dominated by the big housebuilders, there are a couple of pioneers. Jaimie has already mentioned that the Berkeley Group is already experimenting with how it could introduce off-site into its tried and tested method of building houses—hand-crafted, if you like. However, the majority still abide by their own traditional ways, because they do not see the benefit for them in their business models of additional quality and whole-life costing. In essence, they are building to sell and they have no involvement once they have sold the asset. It is about engaging the investor in seeing the benefit over the long term and thus drawing them into delivering the end product in some way.

Baroness Morgan of Huyton: Miss Richards has touched on the exact
point I wanted to raise. You said that you “would not recommend it, but—
”. Why would we not recommend off-site for a large development? It is
probably too late for Ebbsfleet, but wherever the next Ebbsfleet is, why
would it not be sensible for the Government to say, “Here’s the deal”? We
want to push productivity in the construction sector. Rather than just
having publicly-funded prisons, why can we not say, “In this area of
regeneration, this is what we want to see being done differently”?

Jane Richards: That is exactly where I can see that it would be
applicable. I would not recommend the Chinese approach where an
arbitrary percentage is set and you say, “In the future, you will use X
amount of off-site on all residential projects”. That is too broad, but it can
be tailored to a really good example of where it can be delivered.

Baroness Morgan of Huyton: Because you can demonstrate the impact
of it.

Jane Richards: Yes, that is right. There is a capacity issue and if used
too broadly you could create problems. We need to focus on good
outcomes.

Lord Griffiths of Fforestfach: I want to go back to the point rais
ed by
Lord Kakkar. He asked whether we need legislation from the Government.
Our previous inquiry was on the industrial strategy. Ministers seem to be
quite proud of what the industrial strategy has done in the life sciences
area as well as in the construction sector. Given the success of
GlaxoSmithKline and BAA as champions of this approach, do you think
that through the industrial strategy the Government could do anything in
relation to the construction industry that would bring people together in a
sort of clearing house for ideas and the promotion of this approach?

Jaimie Johnston: The first competition that has come out is for an
innovation hub, which presumably will become the focus for all these
things to come together. That is a massively positive step. As we have
said, there are lots of individual good pieces of work going on in little
pockets. The idea of having the hub as a sort of clearing house to bring all
this together and to start cross-fertilising would be beneficial in
accelerating everyone’s journey.

At the moment, there seems to be a massive duplication of effort in
different pockets. During the 1960s, American automotive made a huge
collaborative effort. If we do not start to share best practice and socialise
some of what we are doing, we are dead anyway. American automotive
started to share at a certain level and said that it would be very cutthroat
about carving up the industry after the fact, but it did everything that it
could to maximise the size of the industry before then deciding what to do
with it.

The hub should be a massive step forward in giving everyone a repository
for this knowledge and a place to access it. As we said earlier, as soon as
you start lowering the barriers to entry so that people can get their hands
on this stuff more quickly, that will accelerate everyone’s journey. For a
first competition, it is a really good starting place.

Q35 Lord Borwick: Can I ask about the business models in the construction
industry, specifically the finance side of it? If you take something like a
housing estate and compare conventional construction with off-site construction, whose cash flow changes in which way? Does the client’s cash flow change even in a big development like an office or student accommodation? Does the main contractor’s cash flow change as a result of moving to off-site construction?

**Andrew Morris:** Yes, it does, because if off-site construction is to succeed, it requires a much greater investment in the design up front. Traditionally, because funding a major project is normally split into two halves, you will find that there is a funding profile and a cash flow profile for the early conception work that normally terminates in a planning application and planning consent.

Once that consent is granted, a long-term funder usually comes in who funds the construction going forward. But that causes a problem, because the long-term funder will normally invest only once he has someone to transfer his financial risk to.

**Lord Borwick:** For the security, I presume.

**Andrew Morris:** Yes, for security. The only person who can carry that risk, who has a balance sheet that is big enough, is normally the contractor. But he is being asked to take that financial risk at a premature stage of the design—the design has not been completed, so there is a lot of guesswork involved—and unless that guess contains a lot of contingency, the likelihood is that the outturn cost is not going to end up anywhere close.

That is the conundrum that you have. With off-site manufacture you are prepared to invest in design and you take the design process much further forward. You prototype, you test, you get predictability and greater certainty, which means that the cash flow is front-loaded to deal with the design process. You then have a much shorter period on site, which means that the cash flow is far lower.

Having said that, I come back to my original point on procurement. You have a completely different procurement model, because buildings are normally paid for by product, materials and workmanship on site as evidenced and signed off. But if all your work is actually off-site, you have to deal with paying the people who are putting it all together and making sure that the ownership is sorted out—who actually owns the product if the contractor goes bust—so you have a completely different arrangement. Provided that you can get all that sorted out, and there is no reason why you cannot—

**The Chairman:** I am afraid that a Division has been called and we will have to suspend the session for 15 minutes.

*The Committee suspended for a Division in the House.*

**The Chairman:** Please accept our apologies for the interruption. Not all members of the Committee have returned, but we should nevertheless resume. I think that Lord Borwick had asked a question and Lord Fox wants to follow up on it. I am sorry. Please continue, Mr Morris.

**Andrew Morris:** Your question was about finance and cash flow. The simple answer is that, yes, off-site manufacture involves a necessary
investment in design up front. That skews the cash flow, so you have to be prepared to invest, but of course the payback comes from the less time that has to be spent on-site, and thus the cash flow is eased at that point.

**Lord Borwick:** So your analysis is that it is sharper and earlier.

**Andrew Morris:** That is correct. As I was explaining, that can create a problem certainly for commercial projects, because long-term construction finance does not normally appear until there is planning consent and a degree of certainty about the concept. It is not normally the same person who invests at the front end, so there is a temptation to reduce the amount of investment at the front end to get to the point where you can start investing in the long-term construction. But of course that requires a transfer of financial risk from the long-term investor to the contractor. He then needs to make up his mind on his promise based on immature design information.

So you already have a conundrum, which leads inevitably to cost overruns, which is one of the major problems. That is because whoever set the budget to start off with and then committed his organisation to achieve that had to do so on incomplete design information. That is one thing that off-site manufacture helps to alleviate.

**Jane Richards:** I concur with Andrew. There is a huge investment in off-site technology at the front end, and obviously the payback comes through in each project after that. Only so many organisations can actually take on that level of investment, which is one of the big drawbacks.

**The Chairman:** That is the point that you made at the outset about the continuity of the pipeline being so crucial.

**Jaimie Johnston:** There is only one thing I would add to that. I referred earlier to benchmarking. There is lots of existing benchmark data for traditional construction, so people can build up a cost plan based on relatively immature information. In the off-site space, because people do not have the benchmark data to rely on they find it very hard to promise it. While we as professionals believe that it would demonstrate cost benefits, when trying to get someone to price it they will lump in a load of the risk for the things they do not know, so at the costing stage the benefits are often not properly priced.

That is a difficulty that we run into quite a lot. You know it will be cheaper, but you cannot get someone to price it accurately at that stage. I think that will change as we begin to get more benchmark data from these projects, but at this moment it is a question of the immaturity of the market.

**The Chairman:** Who should be responsible for getting that data?

**Jaimie Johnston:** More people can start to publish the benefits. However, if some clients knew that they were demonstrating cost savings, they would not necessarily tell everyone that. If contractors knew that they were delivering things more cheaply, they would not necessarily publish that because they would try to keep the benefit. So, again, the clients’ forum, the joint working group on modern methods of
construction within government, can start to document the benchmark data.

The Infrastructure and Projects Authority is leading on this and wants to build up its benchmarking case studies and publish them. The more we publish these things, the more people will start to understand them. That is exactly what happened with BIM; early adopters started to publish case studies of projects where it had saved time and effort through reduced reworking.

**Lord Borwick:** Cash flow that demands cash much earlier and that increases the risk on that cash flow is probably sufficient to slow the introduction of an otherwise bright idea. Is that correct: that the cash flow alone would be enough to cause what we are seeing, which is a slow take-up of an otherwise good idea?

**Jane Richards:** Yes, I think so—and this comes back to my first point. Given that, it is surprising how much advance we have had in off-site. That tells us that there must be huge benefits to it despite that. We all agree that we are at a point with off-site construction generally where there is real momentum. It is no longer seen to be completely high risk and abnormal. It is starting to become more mainstream. There is a real momentum to it now.

**Q36 Lord Hunt of Chesterton:** One thing that I am trying to work out is to what extent the methods used by the different companies or groups are secret. To what extent are the Government, the Building Research Establishment or whatever establishing methodologies that will be common across the industry? I would be interested to know whether there is more common practice in other countries. The impression that I have had from you is that it is all still quite secretive in the UK. The role of the BRE or any government body does not seem to be to enforce openness.

**Jane Richards:** You asked me that question earlier. There is much more secrecy in the private sector, because obviously the investment that we have just been talking about is an individual company’s. We are tied to contracts where we cannot share the information. Laing O’Rourke, to which you are talking in your next session, recently published quite a large body of research that it had done on accreditation and design coding to get some commonality across the industry. It has published that research for all to use. It sees that everyone’s gain is its gain. The more this gathers momentum, and the more people are using the same information rather than having to spend a lot of effort developing their own equivalents, the more everyone will benefit.

**Lord Hunt of Chesterton:** Are the Government pushing that? Is it on their agenda?

**Jane Richards:** It is in the hub that Jaimie mentioned, but I think that more could be done. This would be quite a small thing, but if we could encourage a way of sharing and disseminating that type of information, that would be useful for everyone.

**Jaimie Johnston:** One thing that we had written into the contracts on the Ministry of Justice’s prison estates transformation was that any IP that
we generate immediately goes to the Crown for use in perpetuity for any purpose whatever. Rather than trying to secure that IP for ourselves, we are saying that the benefit comes when more people start to adopt this. We have put out a number of publications over the last year or so.

**Lord Hunt of Chesterton:** Sorry, but who is “we”?

**Jaimie Johnston:** Anything that Bryden Wood has done in the public sector, we have documented and published via the Cambridge Centre for Digital Built Britain. We have been trying to publish our workflows and the outcomes of the things that we have done. We are ensuring that any IP that we generate on public sector projects is then documented and owned by the Crown, whether it is for the Ministry of Justice or Highways England. We recognise that the more we can open-source the things that we can do, the more uptake will increase. There are quite a few people who would not necessarily have the skill set to develop something from scratch but who could certainly contribute to or build on something that is already available. We see that as the way in which we will start to lower the barrier to entry.

**Lord Hunt of Chesterton:** Would it be helpful if this Committee endorsed that in some sense?

**Jaimie Johnston:** Yes, absolutely.

**Jane Richards:** We ought not to generalise too much. Some developers are very much of that mindset and can see the benefits. Even in my Unite days, it allowed us to publish a technical paper—I co-authored one on modular design in high-rise buildings. There are pockets of this, but it is very ad hoc. Something that made that more general would be advantageous for everyone.

**Jaimie Johnston:** If you build that into public sector procurement and say that the rule applies that all IP generated for public sector procurement becomes public, you will start to see a massive uptake and a huge contribution of people building on these things.

**Lord Hunt of Chesterton:** Is that being done in other European countries?

**Jaimie Johnston:** I do not know whether anyone has tried that.

**Andrew Morris:** Our experience working around the world is that our industry, although I have denigrated it, is quite sophisticated compared to the industry in some other places. In North America, in both Canada and the United States, the process is much more industrialised and standardised, but it concentrates on design. It is where we were 30 years ago. People do not start constructing until they have a fair amount of design done. Germany is exactly the same—again, a lot of the design is done before people commit to construction.

They are nowhere near as sophisticated as our industry is. Our industry can still respond to whatever is thrown at it. As long as you can provide a procurement strategy to deliver it, it normally does it excellently. Our experience around the rest of the world is that you are shaped by the industry, so you have to fit in very much to the product that it is offering. I think the reverse is the case in the UK.
Baroness Neville-Jones: I should just say that I have no interests to declare in connection with this inquiry. The point that you have just made is what I wanted to ask about.

From what you have said, it sounds as though there is considerable consolidation in the industry, so you get less variety. Presumably, it is harder for the minnows to compete with the big boys supplying big integrated projects. Is that a risk? I can see that the need for capital up front and for sorting out risk as a barrier to getting the thing going, but I wonder whether down the road there is a downside in extensive consolidation of a kind that narrows choice and makes it hard for small companies to grow and to get in the game.

Andrew Morris: There does not have to be. All the discussion that we have had this afternoon, based on our experience, has been on large-scale projects. We are working with Lewisham Council at the moment on a small residential pop-up, as it is called.

Baroness Neville-Jones: That is what I wondered. You get reduced to being in the small game rather than the big game.

Andrew Morris: It is 24 units, low-cost—less than £5 million—and 95% of the project is off-site manufactured. The work that we have done for Lewisham Council is on a modular, volumetric system. It is low-tech; it is a timber-based system. The idea will be that, rather than having to regionalise the assembly points, wherever you have the housing project you can utilise local labour and materials at a low-key level in a modular off-site manner. We think that has great advantages. Yes, at the other end of the scale you have the Laing O’Rourkes and so forth, which are dealing with large commercial projects and are therefore investing in a different way, but at the other end of the scale, off-site manufacture gives plenty of opportunity to diversify or regionalise the production, especially in the residential market.

Baroness Neville-Jones: It sounds as though the industry would end up being differently structured. I still ask the question, though. Some of the giants started as pretty humble construction companies. Will that continue to be the case, or will you get a layering of the industry such that you have the big boys, you have people who do local stuff and so on?

Andrew Morris: I think you will always have those. Tom Bloxham, the developer who started Urban Splash, which you may have heard of, concentrated a lot of his work in Manchester and specialised in developing in that area. He has recently started up his own construction company based on prefabricated modular units. Because the industry is divided into so many sectors, there will always be opportunity, not so much in the big sector, where you need big investment and lots of bodies, but in the small sector.

Especially now, with the new technological innovations in computing—BIM and 3D printing—manufacturing and technology have never been easier to put together. That spills over into the skills that one can attract. It becomes more attractive for younger people, because it is more technology based. There is every opportunity, through aligning off-site manufacturing with technology, to start to diversify in Britain.
Baroness Neville-Jones: You see no real danger of an anti-competitive situation arising—of a very, very small number of companies competing.

Jaimie Johnston: We are now designing buildings at a much more component level. They are manufactured components rather than things that are made by skilled craftsmen on-site. We are seeing a much more diverse supply chain, because suddenly you are not looking at buying systems from very specialist people, you are looking for individual components, and the supply chain for those is very broad and very wide.

As Andrew says, you can then procure things much more locally. We have demonstrated the skills required to assemble things in a number of projects now. You can start to engage a much more diverse workforce, so rather than needing skilled craftsmen—Jaguar Land Rover cars, for example, are made by people who have been trained in specific tasks—you can take a whole range of people who would not traditionally think of entering construction, be it people returning to work or apprentices, and suddenly your supply chain and labour force gets very diverse and very broad.

So I do not think we will see a consolidation. I suspect that we will see much more distribution. In projects such as Heathrow—a massive piece of infrastructure in the south-east—they are very deliberately trying to spread the economic benefits out into the regions. They want to spread that benefit. I think we will start to see more of that happening—potentially building up quite a distributed network of manufacturing capability. You can procure things much more locally, you can engage a much more local and diverse workforce, and I think we will start to see huge diversification in the industry.

Jane Richards: That is a really good point. In a way, off-site suffers from being so broad, and we sometimes talk about the really big high-investment volumetric modular or the Steetley factory, which I know you are visiting. It is actually about components being made off-site. That can be taken to quite a granular level, and it can still bring benefits to the overall construction process.

Baroness Neville-Jones: That sounds less integrated, if I may say so. The answer to Lord Fox’s question about whether you need integrated teams was yes. Now we are hearing that you can have diversification. I am very unclear which it is.

Lord Fox: And why would the sourcing necessarily be local for the simple components? Look at how the aerospace industry drives costs. Let us say you have a universal tap. You would not buy it in this country; you would buy it from India. What drives local sourcing? On the contrary, once you have standardisation, that drives international sourcing, not local sourcing.

Jaimie Johnston: It gives you the choice. With the MoJ we are starting to look at standard components that can be used in multiple building types. If you can use a component that is good for schools as well as healthcare and residential, you can start to build up the numbers that you need, which you gets into the manufactured space—

Lord Fox: I get that.
Jaimie Johnston: —and then you can decide where to procure it.

Lord Fox: You said that this allows local procurement. On the contrary, it absolutely makes international sourcing much more economic and the route that people are far more likely to take, surely.

Jaimie Johnston: You could buy things internationally.

Lord Fox: You can buy things cheaper internationally.

Jaimie Johnston: For the first iteration of some of the components that we devised, we had them fabricated fairly manually from small local fabricators. For the next iteration, we found a company that did CNC cutting, and the cost immediately plummeted. If was a case of, “I can make those a lot more cheaply using technology that is available”. For the third iteration, they get cheaper again, because that local person says, “If you made the component slightly differently, it would be even easier”.

We are starting to find that we can design towards specific bits of the supply chain. Once you have designed and optimised those, you say, “Right, let’s buy them from anywhere that has the capability to contribute”. We are seeing that rather than buying millions of them from China and paying to ship them, you can buy 100,000 from lots of small local companies very, very close to where you are using them. If you are using standard components that get used across the entire country, you can decide to procure them. They have already been optimised and designed towards a manufacturing approach, so it becomes really sensible to buy them quite close to where you need them, using local skills and local people.

My guess is that if we decided to, we could use that to put more investment into UK manufacturing and bring up the entire manufacturing base of the UK, rather than send that investment across the world.

Lord Fox: But that would be a political decision rather an economic decision.

Jaimie Johnston: There is some thinking that suggests that we are past peak globalisation. For years, the narrative was that everything was heading out to Asia, because the cost base of doing it out there was cheaper. China in particular has more of an ageing demographic problem than we have.

Lord Fox: That is why I chose India.

Jaimie Johnston: Okay, but the same thing will happen: you will start to see a rising middle class, so the cost differential in labour will start to decrease. In additive manufacturing—automation, robots—the cost of a robot is pretty similar all over the world. We are starting to see reshoring in the States, where companies that would traditionally have sent things to China and elsewhere in Asia are bringing them back into the US, because the cost differential no longer stacks up.

Lord Fox: There are a lot of different dynamics.

Q38 Lord Kakkar: My question was asked earlier, but I have one further point to make, if I may.
In terms of all the intellectual property that might be generated from the technological and digital solutions that you described earlier, how important is it that the Government have a strategy to keep the development of the peripheral businesses that hold that technology and that IP in the UK, or does it not matter if they are taken, invested in and developed abroad?

**Jaimie Johnston:** I think they should be taking steps. I am not sure that has been thought about yet, because the thinking on some of the initial public sector programmes is only just emerging. One of the Construction 2025 targets was to massively increase exports, so you could tackle that export question by sending the processes and the IP out and procuring abroad. I do not think that anyone quite knows yet.

I agree that government should have a strategy for this. If it starts to accumulate this IP, it should work out what to do with it before it goes too open source too quickly and it loses its ability to exploit that in some way.

**Jane Richards:** The IP needs to be protected for the very specific details that create the competitive edge for manufacturers who are investing in the R&D. From my experience in the private sector, that is one reason why there is so much secrecy around it. The technology for off-site construction is quite simple. The methodology for construction is simple by its very nature. That is what you are designing it to be: very simple, very standardised, very able to be repeated and easy to use.

In a way, that is the dilemma with it: you are trying to protect something that is very easy to copy and very simple. You have made it simple. All the tooling and some of the digital technology that goes with the production can be more complex, but what you build is quite simple. That is why people are so protective of it at the moment, and any assistance that can be given to enforce IP so that it can be used but not copied will obviously benefit the people who are investing.

**Andrew Morris:** It depends what you mean by IP. There is a lot of intellectual property in the actual conception of the product: how it looks, what it feels like, what it has to do. Being an architect I am sensitive to that. Giving that away is like giving the Crown jewels away. But one understands that when you are involved in public procurement, or even in projects such as terminal 5 with BAA, there comes a point where the project is so large that you have to vest that IP with somebody else.

When it comes to IP in relation to process—how you take that conception, put it together and the processes that you use—there is not so much of a problem, because a lot of how that is done is common knowledge. The use of BIM and 3D printing, and a lot of the process of applying that knowledge to deliver and manufacture a component, is now fairly standard.

One needs to differentiate between what you actually want to save and become part of the public realm and what you are quite happy to share and give away.

**Baroness Morgan of Huyton:** It would be really helpful if you read the transcript of what you have just said about IP and what you said earlier about open source, because I think we have heard some very
contradictory stuff—even, with respect, from your own mouths. I can understand why, because it is a complicated issue and it is hard to differentiate exactly what we mean, but clarity would be helpful to us. I am sure it will help if you read what you have said and perhaps send in to us your further thoughts.

On skills—by all means answer this question briefly, because I suspect we know broadly where you are on it—it is clear that there is already a shortage of skills on-site and that it is likely to get worse because of an ageing construction population and a falling EU workforce, so we know that there is already a problem. How do we manage the existing construction industry while reskilling to meet the quite dramatic changes of the future world? Also, do you accept that the skills base needs to change?

**Jaimie Johnston:** My personal view is that the existing industry will carry on doing what it is doing while this new and emerging industry begins to take over. I do not think there is an issue with having to reskill the people we already have. It will be about engaging a completely new set of people and bringing them into the industry. While the skills gap of the ageing population tapers off, it will be replaced by this new and emerging industry.

**Jane Richards:** I think you alluded to this earlier, but my experience, particularly going back to the Unite Group and its factory in Stroud in Gloucestershire, was that the staff came from the local workforce. The skills needed for off-site technology tend to be different but less when compared with the traditional trades on-site. You can really impact on a local area when something like that factory is set up. It does not take as long to skill people up to deliver the product, because it is a factory process and thus does not require the level of trade skills that an apprentice approach would typically mean.

**Baroness Morgan of Huyton:** Presumably there is a requirement for a higher level of digital skills that are not necessarily in place at the moment.

**Jane Richards:** That is becoming part and parcel of our industry anyway. It is the world we are in now.

**Andrew Morris:** I was going to make the point that Jane has just made. When we look at manufacturing today, it is quite common for the drawings of bridges that we produce almost to be the drawings that go into the patterning machines, and you direct it from there. There is already a lot of technology that goes into it. Once we start to move into

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57 Jane Richards sent the following clarification: “given that we have also stated that a sharing of off-site manufacturing development would be a good thing for the industry generally there needs to be a balance. An appropriate approach would be to protect the specific details of the manufacturing system advances, but to share the wider development advances made through R&D. An example could be the design details of an innovative connection would be protected but the approach to the design could and should be shared. This enables debate within the industry and also encourages further innovation and development more widely.”
the other realm of 3D printing and the next generation of manufacturing, you then start to look at reskilling.

At the moment, what we make off-site is in essence what they make on-site but in a much cleaner and more controlled environment. You are still welding, bolting, bending tin, cutting timber and screwing things together, but it is being done in a much healthier and safer environment.

The Chairman: Baroness Neville-Jones, you have a question about architectural ambition and standardisation.

Q40 Baroness Neville-Jones: From what we have heard, if the industry develops in the way I think you would like to see, with much greater integration of the process, that seems likely to lead to quite a lot of competition on price, which I suspect can lead to some pretty boring buildings. How do you keep architectural ambition and design alive under those pressures and when your client wants a deal on the cost of the building?

Andrew Morris: I will refer to the Leadenhall building, which I mentioned in my introduction. It is probably better known as the Cheesegrater in London. It is a classic example of off-site manufacture with 83% of the building having been made off-site. Laing O’Rourke was the main contractor. In fact, we could have done a lot better, because the journey of that building was of two halves. It started off under one procurement regime, stopped, and was then picked up again.

If we had started from the beginning as we ended, directed at off-site, we could have improved. That building saved six months off the building site contract and saved 7% of the actual construction cost, and the time that was saved at the back end enabled the building to be let more quickly. KPMG worked out that it added something like £29 million of value for the client because of the rental stream coming in early. In 2015-16, that building was voted by BCI as the best office building in the UK. I make these points to show that we as a practice do not see off-site manufacture as a restraint on design and creativity.

At the other end of the scale, there is a perfect opportunity in the low-cost housing market to use the design talent that is pre-eminent in the UK. It is the one thing that we have in abundance—we probably have too many architects if we are looking at it from the competition front. The constraints that we are talking about are more the integration of knowledge and of data, working with the people who are going to make the components and learning from them, letting the delivery of the product influence the concept of the product, and keeping the circle turning.

As we have proved as a practice, we think there is every opportunity here. Even with the first building I worked on, which was the Lloyd’s building for the insurance institution, a good proportion of it was made off-site, and that was more than 30 years ago. All the concrete columns and the toilet pods that could be fitted in were manufactured off-site all that time ago.

We believe as a practice that it should not stifle creativity. It gives the conceptron and the designer an opportunity to work with the deliverer and
the people who are going to do the manufacture, which can only help the quality and functionality. We will still be able to express a great aesthetic object.

**Baroness Neville-Jones:** You do not see a danger of having a lot of boring buildings being punctuated by the odd outstanding one.

**Andrew Morris:** If there is, I would ask that you look around you now.

**Baroness Neville-Jones:** That is exactly what I see.

**Andrew Morris:** It is already the case, and a lot of lessons can be learned by going off-site, perhaps improving on what we currently have.

**Jaimie Johnston:** Can I build on that, because it is an important point? My view is that if we do not embrace this technology, we are more likely to see a dumbing down of design. The IPA has talked about a £600 million pipeline, while the UN states that 2.5 billion more people will be living in cities by 2050. That is the scale of the design challenge we are facing. If we do not adopt these technologies, we will end up with poor design, because no one will have the time to do it properly. A much more positive take on this is the fact that throughout history every new architectural movement is a response to some form of technology. Tall buildings could not exist until steel could be treated in a particular way, and then lifts had to be invented.

**Andrew Morris:** The elevator was the key development.

**Jaimie Johnston:** Yes, and there is an interesting point in this. Architects are good at dealing with and being constructive within constraints. We are looking at a really interesting space and we are potentially looking at a new form of architecture. That is because we can embrace these tools and understand the manufacturing process. We are finding that things like BIM, because it documents a building quickly, give us more time at the front end to do the proper design exploration and understand more design options. There is the potential for a really positive space where we will start to develop a new form of architecture that understands these tools and uses these methods of manufacture. There is a whole generation of eight to 12 year-olds who are playing Minecraft and who are designing all sorts of interesting things using standard components and co-creating within a 3D space. If we do not get this right, there is a whole generation who will not come into construction, but if we do, we will pick up this technology and do things with it that we would never have conceived.

**Jane Richards:** Those two answers have covered the point. All I would say to counter the argument slightly is this: If we go back in history and look at our residential housing, a lot of our Georgian and Victorian development arose from a pattern-book approach and is none the worse for that. We just need good design, and linking that with the new technologies that we have been talking about does not need to be a negative. We need to force that through and make sure that we get good design.

**The Chairman:** Thank you all very much for coming to speak to us. You have been excellent witnesses and we really appreciate that. I must
apologise again for the disruption earlier.
Rolls Royce – Written evidence (OMC0082)

Executive Summary:

To create the required paradigm shift in major infrastructure delivery you require a tailored driving function. For the R-R SMR Power station we defined a vision of constructing the power station in 500 days. This drives a process of assessing and understanding the risk and drivers of schedule and cost, deriving clear principles to deliver build certainty. Opportunities and solutions are being identified to target step change productivity improvements centred on:

- Off-site production in factory controlled environments,
- Minimisation of parts and interface complexity,
- Optimised logistics flow,
- Robustness to weather and environmental variation,
- Standardisation,
- Integrated digital definition and through life data management
- Minimising special processes at site.

A key enabler to this is the design philosophy, integrating all disciplines early in the process to ensure appropriate design for manufacture and construction is implemented. Collectively 30-50% cost and schedule reduction can be achieved compared with traditional construction methodologies.

1. Introduction

This summary report outlines the considerations given to ‘Off Site Manufacture’ in the design of a fleet of Rolls-Royce Small Modular Reactor (SMR) Power Stations. The ideas contained are provided to assist the House of Lords review of off-site manufacture.

To date, nuclear new build has relied on the import of large designs of nuclear plants which have a track record of being over budget and late through the construction phase. Business as usual in the continued use of these technologies threatens the UK’s ability to meet its legally binding carbon obligations, whilst also increasing the cost of electricity to industry and taxpayers. Starting with the ultimate end goal in mind, i.e. an affordable levelised cost of electricity (LCOE) and a realistic overnight capital cost (OCC) which together delivers a commercially investible proposition for a Utility, without recourse to Government support, sets the driving function for the SMR development programme.

2. The Rolls-Royce approach

With costs dominating the diving function for the SMR development programme, the first important step was to understand the costs drivers. For Nuclear New Build this was established as shown in the following Figure;
To create the required paradigm shift in construction, to achieve the level of Predictable Certainty of Build required, an aspirational target of 500 days was set for the duration of the construction phase. This was 60% less than had been previously been achieved for new nuclear build, and drove the fundament change in the design philosophy for the SMR Power Station.

Seven key principles were inferred that provide a philosophy that enables the build certainty requirements to be met and influence the design during preliminary concept design (PCD) included;

1. Maximise Off-Site Build and Assembly:
   (a) Reduce manual building works at site that require skilled labour.
   (b) Maximise repeatable, high quality manufacture off-site in a factory environment.
   (c) Minimise the number of deliveries to site (three orders of magnitude part reduction cited as target).

2. Optimise Logistics Flow/On-site Build:
   (a) Minimise part counts across all areas.
   (b) Enable parallel workflows on site.
   (c) Provide clear access routes for all equipment, tooling and people for all phases of the plant lifecycle.
   (d) Minimise the use of additional temporary parts or support structures for equipment.

3. Standardise Across all Aspects:
   (a) Minimise variation across all areas.
   (b) Standardise buildings and interfaces in terms of feature locations and geometry.
   (c) Standardise methods and processes across work fronts.
   (d) Standardise plans, methods, people and process across multiple builds.
   (e) Standardise package weights to ensure high utilisation of cranes.

4. Reduce and Simplify Interfaces:
   (a) Minimise the number of interfaces between assemblies / parts at site.
   (b) Maximise the use of high productivity jointing processes across all interfaces.
(c) Minimise and standardise containment penetrations.
(d) Avoid the need for overly tight tolerances in the assembly process
(carefully optimise how tolerance is managed and understand where tight tolerance is achievable and where it must be avoided).

5. Robustness to Variation:
(a) The site build scheme should be adaptable to site conditions variation (such as soil conditions) within an agreed limit.
(b) The build scheme should be robust to varying weather conditions.
(c) The build scheme solution should be robust to process variation (such as variations in supply chain demand).

6. Use of a Single Source Modelling and Data Management System for the complete design at all stages of the lifecycle:
(a) Store all data and design intent in a single system.
(b) Use 3 dimensional modelling tools to model plant assembly process for clashes.
(c) Ensure complete final design before release to construction.
(d) Ensure all parties that require information have access to it in a secure and timely manner.

7. Minimise Special Processes On-site:
(a) Transfer complexity from the site to a factory environment where it can be best managed and controlled.

Using the principles derived in the previous section, a conceptual site build plan was inferred. Key aspects of the concept are as follows:
1. Multiple flow lines for parallel work streams.
2. Buildings and Civils structures constructed from prefabricated modular civil elements where possible.
3. Modular civil elements with embedment plates / fixtures at regular intervals / repeated standard grid pattern to mount components and modules.
4. Mechanical and Electrical equipment assembled into modules/skids in a factory environment, transported to site and constructed to form plant systems.
5. Rapid high productivity jointing systems employed throughout to simplify and enable repeatable standardised management of interfaces at site.
6. Plant layout designed for the easy access of cranes, humans and equipment.
7. Plant layout designed around rationalised 3-dimensional grid system.

3. **Implementing the Rolls-Royce approach**

Implementation of the approach followed;
An outline of these activities is as follows;

**Work package 0** is the development of the baseline seven key build certainty principles

**Work package 1** is key to build certainty in that it establishes the baseline traditional build construction schedule to set a baseline position on which improvement approaches can be tested.

**Work package 2** then evaluates this baseline schedule and draws upon wider industry expertise to identify both incremental and innovative improvement ideas that can reduce the civils build schedule and drive towards the build certainty targets. The output of this work would define a set of priority options to pursue to provide confidence in the achievement of the ambitious build certainty targets.

**Work package 3** is coupled to work package 2 in that it furthers the understanding and development of the civils ideas and opportunities. This supported the prioritisation of the civils ideas and opportunities.

**Work package 4** was carried out as an integrated case study, focused on the more complex systems. As a result it would provide a platform on which to explore the key challenges and constraints important to modularisation and explore how electrical, control and instrumentation could be integrated with the process equipment modules.

**Work package 5** was identified to pursue any key general priority enablers to support the
development of the modularisation / build certainty strategy. The bulk of these were actually covered in the case study example but two key areas that were developed were the grid size / maximum modular dimension limitations, and the Knowledge Based Engineering (KBE) approach and toolset opportunity, which has been identified as an enabler to support optimum design of modular process systems.

Finally work package 6 draws upon all activity to consolidate the learning and re-inform the set of key principles for build certainty and feed into the development of the strategy within the PCD phase.

4. Rolls-Royce SMR: enabling attributes

Achievement of the of the project targets, LCOE, OCC and 500 days, assumed these would be delivered by the fifth of a kind build. This implies a fleet approach, and hence economies of volume, against which identification of, and invest in, the required enabling disruptive technologies could be commercially progressed.

Specifically repeatable projects provide the opportunity for;
1. Larger fleet deployment schemes supporting standardisation and learning and generating sufficient demand into the supply chain to enable investment and positive process and behavioural change;
2. Ability to form collaborative programmes to deliver a standard repeatable product

The Rolls-Royce SMR’s other attributes centres around its small size and simplicity. This has enabled;
1. Focus on manufacture and construction methodologies rather than the SMR pressurised water reactor PWR technology, which is already mature.
2. Smaller size (six hectare site) enables
   a. greater adoption of modularisation
   b. plug and socket approach, to ensure isolation of in-ground risks and ensuring 90% of the individual SMRs are repeatable
   c. Capable of constructing a weather-proof site cover over the whole site
   d. Limits size and capital cost of the required manufacturing facilities to provide capability and capacity

For point, 2c, this was initially considered as mitigation against historic problems with Development Consent Orders and Town and Country Planning, requirements, which have traditionally been lengthy and costly. The initial idea to provide protection of the environment from the project and protection of the project from the environment does provide considerable addition benefits in supporting our Predictable Certainty of Build. The additional benefits we see include;

I. Perfect weather conditions 24/7
II. Increased predictability for programme
III. 24 hour working without reduction in productivity
IV. Reduced travel time to welfare facilities
V. Positive environment for work, that will encourage workforce
VI. Optimised crane hook to operatives ratio
VII. Reduced manual handling
VIII. Increased productivity, beyond existing best practice
IX. Opportunity for innovation such as robotics
X. Reusable facility for next of a kind SMR units
XI. Supports the paradigm shift and the opportunity to truly productionise construction

5. Conclusions

1. ‘Off Site Manufacture’ should be considered as an enabler to improved project delivery, it is not a solution in its own right. It is therefore important to define the objective(s) that are required to be achieved for the individual project or programme, i.e. what are the driving functions. Don’t force modularisation where it doesn’t deliver benefit.
2. The project or programme derived driving functions should be used to develop a design philosophy that is embedded consistently within the preliminary concept phase.
3. Larger fleet deployment schemes supports standardisation and learner curve benefits.
4. Larger fleet deployment schemes supports the generation of sufficient demand into the supply chain to enable investment and change
5. Ability to form collaborative programmes to deliver a standard repeatable product is essential.
6. The Supply Chain needs to be developed to support off site manufacture.
7. Consideration must be given to reconciliation of commercial tension and pursuit for value for money with modularisation where the supply chain capability is limited
8. Consideration must be given to how the supply chain is incentivised to invest if economies of volume cannot be guaranteed
9. The capital cost of new manufacture facilities are influenced by the product design
10. There may be other philosophies that deliver the required project/programme benefits

11 May 2018
Introduction
The Royal Academy of Engineering welcomes this opportunity to submit evidence to the House of Lords Science and Technology Committee. As the UK’s national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering.

Through its Fellowship, the Academy has access to highly qualified individuals in infrastructure, systems engineering, construction, digital systems, civil and structural engineering, energy, transport, flooding and water supply. Their expertise spans research, policy making, regulation and practice including the management of major projects. This response is based on the views of Fellows.

What are the opportunities offered by off-site manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose off-site manufacture?

1. Off-site manufacture for construction offers a series of potential benefits.
   There is an opportunity for safer practice as the processes can be highly controlled in a factory environment compared to a construction site. This also ensures better quality control to verify the product and ensure standardisation – meaning off-site manufacture is highly beneficial when there is a continuous supply of similar projects. The pre-assembly element can increase efficiency and reduce the construction time at the site adding significant control to an area which is often the source of project over-run, both in terms of cost and time. There is also the opportunity to reduce the waste created. Off-site manufacture reduces the demand for labour which could be beneficial in order to meet house building targets with anticipated labour shortages following Brexit.

2. In order to be effective, off-site manufacture requires duplication and repetition. Thus far in the UK, this technology has not necessarily been used in its optimal form, instead being applied to non-standard applications (such a Liverpool St Crossrail station platforms) where there is little repetition, so the full benefits are not realised. For off-site manufacture, homes, offices and schools would ideally be of a standard shape but to maximise value for their specific purpose these properties are typically bespoke, significantly reducing the benefits of off-site manufacture. Volumetric modular systems\(^{58}\) need to demonstrate that they can match the flexibility and variability of a wide range of standard building solutions and allow last minute changes to become more appealing. Current procurement practices put the build phase contractor in charge of the delivery method which makes off-site manufacture an unlikely choice. If these elements align there could be an increased demand. However, this demand would prove challenging as the current UK industry has a lack of capacity to respond.

\(^{58}\) Systems which can be linked together to form complete buildings without an additional superstructure
3. Many factors will influence the use of off-site manufacturing processes across clients, architects, design engineers, contractors and the supply chain. Product-based solutions are often unpopular with engineers and architects as they wish to solve the problem themselves. In London specifically, the unusually shaped sites are often combined with an architectural and engineering desire to do something different and to create something iconic.

4. While safety, speed, productivity and sustainability provide benefits, cost is likely to be the main influence when clients are making decisions. Off-site manufacture will have to be priced competitively from the outset to be a viable choice.

Perceived advantages of off-site manufacture for construction

5. **Lower costs:**
   Finding direct cost comparisons between similar projects delivered by in-situ and off-site construction is difficult as the different contractors used and time at which they are built will affect the market appetite and therefore the cost. However, the speed of construction for off-site manufacture is generally expected to be faster and thus can impact costs significantly. In situations where construction interfaces with existing infrastructure then faster construction rates can offer significant benefits in reducing disruption. Over time with increased demand and more standardisation, improved efficiencies should reduce the cost.

6. **Increased productivity:**
   Productivity increase is the area where off-site manufacture potentially provides the most benefit. This will increase with repetition and certainty. However, despite being a one-off the off-site manufacture of Liverpool Street Crossrail station\(^59\) platform delivered quality and productivity benefits quickly. More broadly, the specific productivity benefits of off-site manufacture are hard to measure as the associated manufacturing is taken out of the Standard Industrial Classification (SIC) Part F (Construction) into Part C (Manufacturing). Here it would be useful if the ONS publish more detailed data to assist with tracking the benefits of off-site manufacturing.

7. **Health and Safety:**
   In reducing the number of people and time on site the health and safety conditions are likely to be improved. There are health benefits such as noise reduction, from working in more controllable off-site facilities. Further benefits are realised in the reduction in the amount of work at height or in confined spaces and noise reduction. Off-site assembly should reduce the number of individual component lifting and handling arrangements needed on site and will tend to promote standardised lifting operations. This reduces the potential for accidents. Lessons can be learned from governments in Singapore and Hong Kong who have developed regulations that reduce the unskilled labour on construction sites. A safer, healthier working environment may also support efforts to increase diversity into the construction sector workforce.

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\(^{59}\) [http://www.crossrail.co.uk/route/stations/custom-house/current-works/]
To measure safety appropriately there is a need to ensure the data is collected for the entirety of both construction practices, beyond the current onsite assembly and prefabricated onsite assembly categorisations. Disaggregation of SIC codes such as "manufacture of woods and products of wood and cork" where fatalities are high may provide a more informed view.

8. **Greater provision of new, affordable housing:**
If there is a demand for a high volume of new housing, off-site manufacture could reduce the cost and disruption at the site and potentially improve the quality. Large volume repetition would enable the industry to develop specialists in design, development and construction, thus driving efficiency. Long-term relationships could be established so that all parties are clear about performance, expectations and deliverables and to develop longstanding, single points of ownership in design and construction. However, the application of off-site manufacture should not be limited to just housing.

**Potential barriers to wider use of off-site manufacture**

9. Off-site manufacture goes against many of the conventions in UK construction:
- Given that built infrastructure intended to be in place for decades the construction industry has a naturally higher sensitivity to risk.
- The balance of liabilities between overall scheme designer, off-site module designer, manufacturer and constructor will need to be resolved, as, for example, the risk profile for designing modules that are used many times is very different than that for one off projects.
- The fragmented nature of the sector reduces the opportunities to learn lessons from others making it slow to change.
- The industry is not geared towards incremental improvement and repetition, instead preferring to start from a blank sheet of paper on each project.
- A wide-spread shift to off-site manufacture requires collaboration of a highly competitive, low-margin industry.

10. The following could limit adoption:
- Planning conditions and Building Research Establishment Environmental Assessment Methods (BREEAM) weight in favour of local sourcing and procurement – this is counter to the objectives of fully scaled off-site manufacturing.
- Many Housing Associations’ rules prevent them paying for anything before it is onsite, as ideal clients for standardised off-site manufacturing this prevents projects being funded.
- The transport regulations limit component size to 2.85m (not including straps and tolerance), but the construction industry works with 1.5m modules, increasing the transport limit to 3m components would be beneficial for off-site manufacture.

11. The current procurement model doesn’t encourage off-site manufacture:
- Procurement practices put the build phase contractor in charge of the delivery method.
- A limited number of suppliers have access to current facilities, which complicates fair procurement (at least in the public sector).
12. Need for investment:  
   • There is a need for up-front investment in manufacturing facilities. Justifying such facilities is challenging in a low margin sector where workflow is rarely guaranteed at the required scale to achieve housing targets, so requiring largescale investment without guaranteed demand.

What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?  
13. While many construction products are already made off-site and installed on-site some re-skilling of the construction workforce will be required to facilitate increased adoption of off-site manufacture. For example, designers will need to have a greater understanding of manufacturing, assembly, maintenance and operation activities to be able to consider these upfront in the design process. Furthermore, the shift from on-site construction to off-site manufacture will require re-skilling, this may prove attractive for the workforce.

14. There is a need to develop T-shaped skills; covering both the required breadth and depth of professional knowledge and practical skills. Professionals will require an understanding of materials and manufacturing processes through modules such as building physics, construction materials, systems engineering, manufacturing and data science. Many current construction site practical skills will still be valuable on-site or transferable to manufacturing while additional skills can be developed through apprenticeships.

15. The incorporation of technological advancements such as augmented reality could improve on-site training. This has the potential to help individuals develop their understanding through being virtually connected to the building and the design model using augmented reality, helping them with a wide range of tasks from locating tools, equipment and products for installation to visualising the correct installation methods and sequencing. Visual data capture and laser scanning can be used for creating inspection records and getting immediate feedback on installations, programmes and tracking.

16. In order to encourage adoption, education will be required to change behaviours in the planning, procurement and design stages to understand when the benefits of off-site manufacture can be realised.

Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?  
17. The use of off-site manufacturing techniques does not have to be a limitation on architectural form. Techniques such as volumetric modular construction affords a significant potential for variability and development of an innovative off-site manufacturing supply chain will open up opportunities to more bespoke solutions.

What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?  
18. In order to realise the benefits of off-site manufacture the first step is creating alignment between contractual practices and the technologies. As the technology is largely established we need to understand why so much
construction is still fabricated on site, giving particular thought to the contractor’s motivations in choosing the project delivery method.

19. The availability of more scientific evidence on the benefits would support the case for wider adoption of off-site manufacturing. Tracking manpower on both conventional construction sites and through the off-site manufacture process would outline the true productivity benefits and allow productivity goals to be defined.

20. Enabling development and scalability is vital, however, there is still a role for fundamental research in the related areas of engineering sciences, management and design, to maintain technical leadership. High quality research creates opportunities for off-site manufacture in the form of patents, innovative spin-out companies and new technical expertise for established firms. This research could be funded through a series of open competitive calls, with a reasonable chance of success and an informed panel, funding a critical mass of post-doctoral positions and PhD students. Both successful and unsuccessful candidates would benefit from feedback.

21. Radical transformative change is needed in order for productivity in the construction industry to match other major manufacturing industries, such as the aerospace and automotive industries. Opportunities for transformative change should be investigated more comprehensively than incremental development. Directly funding work on business models, platforms and production systems could support this change.

(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

22. Upon submission of this evidence the construction sector deal had not yet been published. However, aiming for a coordinated, innovative approach to the construction industry off-site manufacturing could be beneficial for major civil engineering infrastructure.

23. In order to create the coordination across the sector even more development will be needed in areas such as underground construction and transport infrastructure where the up-take of off-site manufacture is still in its infancy.

What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

24. The procurement process can be used to mandate design for manufacture and assembly and the requirement for evaluation. Local planning clauses that encourage more density with volumetric modular construction could be considered. On government projects, elements of off-site manufacture such as modular toilet pods, could be mandated.

25. By allowing developers to build bigger modular units than regular (e.g. if there was a 3-5% increase in plot ratio for modular or permitting the width of all module joint walls to be excluded from area calculations, off-site
manufacture could be incentivised. The risk for manufacturers would be reduced by maintaining nationally consistent codes for volumetric modular construction.

26. Another change would be to encourage the early engagement of manufacturers, along with contractors, during design development to ensure all options are explored before scheme designs have progressed to a point where decisions taken could inhibit off-site manufacture.

4 May 2018
Perceived Advantages of Offsite Manufacture for Construction

1.0 What are the opportunities offered by offsite manufacture for construction? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

Availability of skilled labour – use of offsite construction reduces the amount of skilled labour required at site, of particular benefit in remote or rural locations.

Coordination – providing design teams with the opportunity to fully understand appearance, interfaces and installation prior to construction. Development of components in three dimensions allows this to be thoroughly tested prior to manufacture. No external wall panels were rejected at Dumfries and Galloway Royal Infirmary (DGRI) due to design coordination.

Flexibility – standardised components on DGRI allowed for panels damaged during transportation or installation to be replaced with other matching complete panels to mitigate delay.

2.0 It is often claimed that offsite manufacture can lead to:

lower costs, faster delivery and increased quality;

Programme – potentially shorter through use of offsite manufacture. A 30 month construction programme for DGRI was six months shorter than traditional construction, resulting in reduced preliminaries and labour costs.
Value – an earlier completion date provided significant savings to DGRI’s operating costs and rental cost on existing buildings. Cost was a key criteria at ITPD stage, however the project team approached this by demonstrating better value for money rather than capital cost.

Quality – offsite manufacture allows for components to be fabricated in controlled conditions to ensure quality prior to delivery to site, rather than constructing in potentially inclement weather conditions in rural or remote locations.

Use of a precast external envelope system at DGRI allowed the building fabric to be fully detailed before construction and reduced the number or interfaces or flashing where weakness in the envelope normally occur.

increased productivity;

Standardisation – use of repetitive components reduces the number of component types and interface details, making more effective use of resource and increasing output. For this project, the initial envelope design included approximately 20 unique panels, plus a small number of specials at corners and pitched roofs.

It is important to retain rigour of standardisation and allow for some material redundancy in components. The drive to minimise the amount of material in the panels at DGRI resulted in a substantial increase in the number of panels and interface types, significantly effecting productivity.

improved health and safety;

Use of offsite construction for external envelope on DGRI significantly reduced vehicle movement and crossover of trades on site. Installation of external wall panels, structural frame and suspended floor planks manufactured offsite via crane meant that no scaffold was required on DGRI, reducing the risk of falls from height.

3.0 What are the drawbacks to offsite manufacture for construction?
Requirement for a significant amount of work at the earlier stages in the project than if traditional construction methods are used. With significantly longer lead times, the technical design of components is brought forward to allow early fabrication to meet programme. This is often prior to contract agreements, increasing risk. There is very little recognition or opportunity for this in most procurement routes. This shift needs recognition in appointments and design programmes.

Any delays in fabrication, delivery or installation of components manufactured offsite could potentially delay the construction programme due to sequencing. Structural nature of precast sandwich panels used for the external envelope means that inability to install a panel could delay follow on trades. Standardisation is key to reduce potential delays. Potential delays due to weather. High wind affects craneage of components with will potential impact on programme and follow on trades.

Components manufactured off site are delivered complete and installed on a working construction site, often ahead of when these elements would normally be installed. Increased potential for components to be damaged and remedial work. A significant amount of remedial work was required to bathroom pods to replace wall linings damaged during construction or affected by water ingress. Temporary weather protection needs to be addressed and considered more thoroughly to reduce impact.

General water ingress to be addressed to avoid damage to internal fit out before envelope is complete. At DGRI, internal fit out began once each floor’s external walls and floor slab was complete. More care is needed to protect riser openings, joints to external wall panels and floors to protect pre fabricated components of potentially high value.

Increased storage of components on site unless ‘Just in Time’ methodology used. The intention on DGRI was for panels to be craned immediately from delivery to installed position, however this often wasn’t practical.

4.0 What reskilling of the construction workforce is required to facilitate a change to more offsite manufacture for construction?

A different set of skills is required both before and during construction. For components that are developed and fabricated to tight tolerances using digital technology, the installation of the components at DGRI was still very reliant on manual techniques which increases required tolerances between panels. There is an opportunity to reskill construction teams to use digital technologies during installation to improve quality and tolerances.

Knowledge and understanding of digital technologies used for offsite construction is still limited. A better understanding and use by design teams and contractor teams will provide better opportunities for quality and appearance.

5.0 Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?
Yes, by fully understanding the parameters of the components throughout the design process. The success of DGRI is through close development of the architectural language with the contractor from concept stage and embracing the process from the outset – this wouldn’t have been achievable if offsite construction was only considered at a later stage.

6.0 What R&D is needed, and by whom, to realise fully the potential benefits of offsite manufacture?

Systems and interfaces – focus on development of full process, from design to installation for specific uses and sectors. Optimising components for specific functions and working within key parameters. DGRI, and healthcare in general, required higher floor to floor heights than other sectors (up to 4.5 metres). The constraints of casting beds and transportation for panels of this height reduced the potential panel width and resulted in internal joints in clinical spaces compromising infection control. Focus on the end use of offsite construction and development of parameters across various sections will provide a better overall solution.

Further research and development to understand how valuable components get from the factory to the installed position – how they are transported, lifted, moved, installed, propped and protected. Fully understanding thermal movement of finished products installed in unprotected spaces.
Government actions

7.0 (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain / what is missing?

The three key areas set out in the construction sector deal can work hand in hand to promote and improve opportunities for offsite construction. The inclusion of digital technologies and skills is important, but it needs to ensure this extends to address the challenges faced in the installation of components manufactured offsite and not just focus on design and fabrication.

What changes could be made to public procurement processes to encourage more economically and environmentally.

Visibility and consistency of pipeline will encourage more investment in the infrastructure, research and development required for increased offsite construction.

Shift in focus from capital cost to lifecycle costs – Capital costs for offsite construction used at DGRI still higher than traditional build, but better value for the client when considering savings on operating costs for current estate.

26 April 2018
Severfield, NG Bailey and Laing O’Rourke – Oral evidence (QQ 41-49)

Transcript to be found under Laing O’Rourke
Email from Martin Kelly, Strategic Business Development Director, Severfield plc, following an evidence session on 8 May 2018.

Can you explain your Company’s approach to Offsite, to help the Committee understand the range of what you do? A few examples would be helpful, together with an understanding of the benefits.

Severfield plc is the UK’s largest provider of structural steel. We operate from five production facilities in the UK and one in India. We have the capacity to fabricate 150,000 tonnes of steel in the UK which is approximately 15% of the UK market. The structural steel industry has been a pioneer in the offsite market and has been successfully providing offsite solutions with minimum assembly on site for over 40 years.

We typically design the steel frame for a structure or bridge in a 3D model (in whole or just the connections), then we procure steel from a steel mill such as British Steel, fabricate the steel using a range of Computer Numerically Controlled (CNC) equipment, assemble and weld the connections, paint / fire protect the finished assembly and then despatch it to site in an erectable load. Once on the site the finished steelwork is lifted into position and fixed. The 3D modelling and accurate fabrication techniques used ensures that steel structures fit together as planned and the on-site labour is kept to a minimum. In addition, any coatings or fire protection are applied in our facilities rather than on site.

How do you see offsite solutions developing in the future for your own business and for the construction and house building sectors as a whole?

We see offsite solutions developing in our own business through greater levels of digital innovation and automation to further improve the efficiencies of the offsite process. Also, we expect to work with other related specialist contractors to provide a wider range of integrated offsite solutions.

Do you have any suggested recommendations the Committee could make that would help increase the momentum of offsite solutions in the construction industry?

We have established that, in our sector, offsite solutions take place on every project we are engaged in. However, there are competing methodologies that could be employed for a similar structure which would not be delivered offsite. Eg a structural frame using steel will be fabricated offsite whereas a structural frame using reinforced concrete will be constructed and poured on site. The opportunities to increase momentum of offsite in the construction industry relate to a preference for designs which prioritise offsite and also a widening of the specialist trades that work with one another to deliver a more finished solution to the construction site which requires greater collaboration between specialists.

The drivers of behaviour in the construction industry are often the requirements of the end user or client. If offsite construction methodologies provide a tangible
benefit to end users / clients then we would see instructions being given to Architects and Design Engineers to factor offsite into structures at an early stage and monitor the output to ensure the offsite requirement is not diluted as the procurement model works through the various tiers and trades in the industry. These tangible benefits could be in the form of financial benefits, such as tax incentives.

In addition, the public sector could lead the way and insist that there is a minimum offsite requirement for all publicly procured projects. This route was very effective in the introduction of Building Information Modelling (BIM) which has now been widely adopted across the private sector.

**How can companies in the construction sector be encouraged to collaborate and work together to facilitate the wider use of off-site manufacture?**

The industry is fragmented and traditionally works in silos. We have had experience of working collaboratively with other specialist contractors but recognise that this does not currently fit with “traditional” industry training and methodologies. Contracting structures do exist to facilitate collaboration, however the culture and mindset of the industry has limited expertise and experience in collaboration.

Again, we see the role of the end user / client as pivotal to ensuring that the appropriate procurement strategies are adopted to ensure that the structure has been set up to best manage risk, reward and maximise collaboration. The operation of these structures must also be monitored to ensure that the right behaviours are encouraged.

Offsite and collaboration techniques should be a core part of construction education in our Universities and Colleges. We need to build an industry that doesn’t compare a new way of working to a “traditional” method but one that accepts the benefits of offsite and collaboration and can focus their effort on making it work for all stakeholders.

**In each of the above, is there a difference between the different sectors of residential, building and infrastructure markets.**

There should not be a significant difference between building, infrastructure and residential (where the residential client is a knowledgeable buyer eg. Private Rented Sector, Social Housing etc.). Traditional low rise, individual housing is suited to the manufacturing techniques of offsite construction as house types are often repeated and the overall product is relatively simple. However, as it is sold directly to consumers is likely to be influenced by a range of factors personal to each buyer and may not see adoption of offsite construction as quickly as other sectors.

**What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture and to evidence those benefits? How can the sector be encouraged to play a greater role in R&D?**
R & D is required by all parties in the construction industry. The professionals advising clients need to consider the offsite options at an early stage before a concept design is finalised that does not lend itself to an offsite solution. This means they will have to create alternative methods of concept designing that can incorporate construction methodology as well as the concept scheme.

R & D is required by contractors and building products manufacturers. Historically building products suppliers have been suppliers of goods, often that lend themselves to offsite manufacture, and contractors have been providers of on site services. What is now required is a combining of these skill sets and a collaboration between contractors. This will require investment and some certainty that the investment will be repaid through future sales.

A demand pull from end users / clients is required together with assistance from incentives, such as Catalysts / Catapult organisations, R & D tax credits and Innovation funding.

21 May 2018
Perceived advantages of offsite manufacture for construction

1. The advantage of offsite construction brings to the industry is primarily speed and of manufacture standardisation of quality. We work with Architects and designers to research different methods of approach to affordable and sustainable housing. Modular construction is not a new concept but has traditionally been looked upon as a poor relation to traditional build. Although with new machinery, materials and modern methods of construction; the ongoing research into the aforementioned means the ideas of the “PRE FAB” are beginning to be seen as not in detrimental ways but a system that can bring aesthetically pleasing and sound, sustainable and economical and affordable housing to the market. Designers and architects we work with are looking to produce a building that can be manufactured and built for many types of schemes. Supply chain frameworks appear to be guided to traditional build by influences from the more traditional companies. Contractors are guided by architects and we are seeing more architecture and design firms looking to modular constructed buildings.

Look to bullet points in summary

2. It is often claimed that offsite manufacture can lead to:
   - Lower costs
   - Increased productivity
   - Improved health and safety
   - Greater provision of new affordable housing

We can only give examples of our experiences the costs can be kept lower as there is less wastage in the factory environment and all goods are delivered prior to commencement of manufacture. We can deliver a project of 28 x 2 bedroom housing units to site in 8 weeks and installed in a further 2 weeks (these figures from actual completed project for a local authority). Health and Safety is much easier to monitor in a factory environment as the staff are primarily in 1 (one) building and can be supervised continually. Whereas on traditional building sites multi trades are often from different companies and are spread throughout the site. We have invested in new machinery that will increase productivity significantly and allow us to grow the business and give it sustained growth over the coming years. This new method of construction will allow architects and designers more flexibility in their concepts. Affordable housing will be manufactured in as greater quantity when given the opportunity by local authorities and developers though the cost of building land often restricts affordable housing to a low percentage of the project. This does very little to help single people and young couples get on the housing ladder or simply achieve their aim to own their own property.
3. Potential barriers to wider use of offsite manufacture

- What are the drawbacks to offsite manufacture for construction

Many of the problems for offsite manufacture have been eliminated with Architects and designers moving towards offsite manufactured buildings in their designs.

As green energy is becoming more readily available the heating and power of modular buildings must turn to electrical forms of heating as individual countries move to green energy wind power will probably see the decline in coal powered power stations in favour of the greener options

- The buildings are considered temporary by the traditional build companies in the construction industry

The long term benefits of modular construction are overlooked in preference to traditional build.

- The re skilling of the workforce is not a major problem; the move to a factory environment for many is probably an issue that would have to be overcome as the freedom of a building site and working hours is not easily achieved in a factory.

- Many of the standardisation benefits can now be realised without affecting the Architectural ambition in the social housing sector though consultation with architects and designers at a more ambitious design criteria would involve more co operation between parties.

- What R&D is required and by whom to realise the full potential for modular construction

- As a company we carry out the development of our products continually there are grants available to companies like ourselves.

We also try to use young graduates and experienced engineers to work together to develop new ideas and solutions for our products.

Our use of sustainable materials is a way we look at developing our buildings and hold meetings with engineers and designers to take in their input and thoughts.

To summarise

- The modular building industry must be able to shake of the label of PRE-FAB and local councils should release more land at low cost to developers and manufacturers to assist them in rebuilding their housing stock of houses that can be rented out to low income families or put into schemes that can assist first time buyer s to gain afoothold on the housing ladder.

- Look at frameworks that limit companies from being able to supply quality local products and favour housing associations that have limited suppliers through internal frameworks This would enable councils to free themselves to make structured decisions on individual housing needs as many projects only release 10 to 15% for social housing

- We must look at developing more socially acceptable housing developments to assist the low and middle income populace.
Summarise advantages of modular

- Assured quality through factory management and supply chain regulation. A complete supply chain audit can be made (unlike off site where a trade may just nip into the local DIY shop and buy unspecified products) you have the ability to say exactly what is in your buildings, where it comes from and the ecological, environmental and life time characteristics of the product(s)

- Time scales can be assured, constructed in dry conditions which means reduced moisture contamination of products left outside on site and increased working windows (build times not weather dependant)

- Long term visions the Factory enviroment has the potential to source green energy and adopt good recycling systems to enable an additional tier of environmental consideration to the lifetime footprint of the product, not really possible on traditional sites.

- Reduced waste is important, Factory's can order in specific cutting lists and stream line material use and wastage to reduce the impact on landfill and over production.

- Steel frame modules, although have a potentially higher embodied energy than timber counter parts, can be reduced by recycling the frame or metal sections after use.

- Easy deconstruction at the end of the life cycle, many components should be recyclable.

- Easy adaption and extension

- Low ground impact (small scale foundations, modules can be elevated to reduce ground impact, this allows less ground disturbance, waste removal and easier land reclamation once the building has been deconstructed.

26 April 2018
SPECIFIC Innovation and Knowledge Centre – Written evidence (OMC0045)

1. SPECIFIC Innovation and Knowledge Centre (www.specific.eu.com) is an academic and industrial consortium led by Swansea University, with strategic partners Akzo Nobel, NSG Pilkington, Tata Steel and Cardiff University. It is funded by the Engineering and Physical Sciences Research Council, Innovate UK and the European Regional Development Fund.

2. Our aim is to transform buildings by enabling them to generate, store and release their own energy. SPECIFIC welcomes the committee’s inquiry into off-site manufacture for construction and is pleased to provide evidence on some of the benefits and wider issues surrounding offsite manufacturing. We would also like to expand on these in more detail by providing formal evidence to the committee as well as inviting the committee to visit SPECIFIC to understand more about the technology which SPECIFIC is developing and for the Committee members to see the technology first hand applied to offsite manufactured buildings.

3. New homes and buildings constructed in line with SPECIFIC’s new vision for the built environment can optimise the many benefits delivered from offsite manufacturing detailed by the Committee in its call for evidence, and more importantly boost these benefits by using advanced integrated renewable generation and storage technologies’ to functionalise the building to become an “Active Building” as referenced by the recent Transforming Construction Industrial Strategy Challenge Fund bid. This approach demonstrates how Active Buildings are already becoming a fundamental part of a smart, flexible energy system. However, traditional market approaches, including conventional construction practices, are stifling the significant benefits Active Buildings offer for the UK economy.

Question 1: Advantages and Opportunities

Some benefits of Active Buildings when combined with offsite construction include:

- Active Buildings, aspire to being “energy positive” – i.e. self-sufficient for heat and power for much of the year. This requires high levels of performance from the fabric of the building, specifically regarding continuity of thermal insulation and high levels of air tightness – offsite manufacturing is best placed to provide this level of quality assured construction product.

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60 Active Building definition: “a building which integrates solar generation and storage technologies for both electricity and heat within its construction, rather than being heated by gas, and which is controlled by an intelligent system to optimise energy management and comfort for inhabitants. Active Buildings aim to be net energy generators, and have the potential to utilise the surplus energy to “trade” energy with the grid, surrounding buildings and electric vehicles.”

Industrial Strategy Challenge Fund – Transforming Construction: Active Building Centre, April 2018
b) Speed of construction. Working with Wernick, a modular construction company, SPECIFIC have designed and built an Active Office within a 6 month timeframe. See below for more information.

c) By using a combination of building integrated solar electricity and grid provided electricity, Active Buildings, have no requirement for gas for space heating or hot water. As such, there are significant benefits for UK plc, by reducing reliance on imported gas supplies.

d) As Active Buildings generate their own energy, and have energy storage capability, they have a wider benefit for the local and national electricity networks, in that they reduce peak loading demands, reduce the need for additional reinforcement works, and can be used to provide balancing services to the network. Taking an integrated offsite approach helps to reduce the additional cost associated with the provision of these services.

Question 2: Offsite Considerations

4. Having visited several offsite manufacturing facilities (in the UK, Europe and Japan) it is worth noting that there is an incredibly wide variety of approaches contained with the umbrella term of “offsite”. This is true both in terms of the construction system and of the level of automation. Different offsite construction systems are well documented, e.g. volumetric, panelized, precast etc, but an interesting angle is to consider the level of completeness of a building when leaving the factory. With a SIPS system (structurally insulated panels) the construction process is still almost entirely conventional onsite with just the main building structure being factory produced. Conversely the most sophisticated Japanese systems, allow the end consumer to visit a high street showroom to choose their house design and their level of internal fit out (including skirting boards, blinds etc), which is then entirely produced within an automated factory environment before going to site. Minimal finishing onsite is required and the property comes complete with a 60 year warranty (see Panahome, Toyota Home, Sekisui House). In the UK the most advanced operations are tending towards this level of sophistication. However many more offsite manufacturing businesses have a relatively low level of automation and simply recreate conventional construction practices within a covered environment. In summary, the completeness of the product leaving the factory environment is important, as is the level of automation within the factory. One aspect which can be benefit greatly from a factory production process is continuity of insulation and airtightness, i.e. a fabric first approach.

Question 3 – 6: Barriers

a) There are of course many barriers to offsite construction, and in our experience additional costs can be incurred. When cost savings are realized then this is often to the detriment of quality.

b) Given sufficient consideration at design stage, architectural quality can be achieved and there are a number of ways that this can be achieved. A
common technique is to give building entrance ways great architectural detail and design input. There are some limits to the extent of building form, for example unusual shapes are difficult to achieve.

c) A common perception within the modular construction industry is that getting architects and building designers onside is key to the future of the industry (for example, Wernick, who are SPECIFIC’s partner on the Active Office building, see below, are sponsoring a number of seminars with RIBA).

d) Further work to support greater levels of factory automation is required to support the UK offsite manufacturing industry

Further information – our case studies

5. Active Buildings have already gained significant traction within government, with BEIS supporting the “Building 2050” research programme which is using SPECIFIC’s Active Homes Neath project, led by social housing developer, the Pobl Group, to evaluate elements of this approach. The Active Homes Neath project is also being used as the flagship scheme for the Swansea City Deal. The development of 16 homes uses timber frame with Structurally Insulated Panels (SIPs) which is a form of offsite manufacturing (although a great deal of construction onsite remains). Construction will start in late May and has a construction programme of 12 months.

6. Additionally, SPECIFIC with financial support from Innovate UK is currently approaching the completion of a 2 storey office building. This will be known as the Active Office and uses a steel modular/volumetric form of offsite manufacturing provided by a local manufacturer, Wernick. The project has progressed from initial design idea to completed build within 6 months. Based Swansea University’s Bay Campus, the project incorporates SPECIFIC’s vision for buildings which generate more heat and power than they require with a high quality offsite manufacturing approach. Because we integrate the renewable energy generation technology to the building, the additional cost of this approach is sufficiently low to make the end product competitively priced with other offsite manufactured building and with conventionally built buildings – the intention is for Wernick and Swansea University to offer “Active Office” buildings as a commercial proposition. The Active Office will be opened by Secretary of State for Wales, Alun Cairns on 21st June. A further benefit of the modular steel built approach is that the building is suitable for recycling at its end of life, with the steel elements retaining a high value (a “design for deconstruction” approach can be taken).

7. SPECIFIC has also completed an Active Classroom building, a 180m² teaching facility based on Swansea University’s Bay Campus. This building was constructed over the course of 4 months in 2016, using an offsite panelized steel frame system and is sponsored by TATA Steel. The building incorporates a range of integrated technologies including salt water based

61 http://www.buildingfor2050.co.uk/
power storage, a fully integrated solar roof, a solar wall for heat generation combined with heat pump and heat recovery devices – as such the building generates more energy than it consumes. The products used on the building include a variety of equipment from external partners and some devices which have been developed in-house at SPECIFIC through our research and development programme. Please do read our case study on the Active Classroom which is available on our website, which should be considered as part of our submission.63

8. As discussed, there are many benefits and critical challenges which remain to deliver this vision of Active Buildings in combination with offsite manufacturing at a scale required to make an impact. SPECIFIC would be delighted to discuss these benefits and challenges in greater detail with the Committee.

26 April 2018

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Potential barriers to wider use of offsite manufacture

3. What are the drawbacks to offsite manufacture for construction?

Stride Treglown Response:

3.1 Internal remodelling of volumetric units – there is a perceived lack of flexibility to change to alternative uses to respond to changes in demand at a later date which means that a traditional structural and internal fit-out solutions are chosen.

3.2 Some clients and Design & Build Main Contractors, are unwilling to risk so large an investment in a single supplier responsible for the volumetric delivery where the sum is so large a percentage of the overall project value.

3.3 A procurement setup and or design team that are averse to early decision making or expecting to make changes after the prototyping stage is complete.

3.4 Inefficiencies resulting from trying to convert accommodation designed to be constructed traditionally into Offsite Manufacture, i.e. not considering it from the outset.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

Stride Treglown Response:

We believe, they can. Responses below primarily refer to Volumetric OSM (offsite manufacture) where the assemblies of components can provide a pre-finished room which includes some element of furnishings and/ or services installations:

5.1 As an overall approach, the internal fit-out design for the volumetric unit can still provide individuality much like variances in car interiors, for example: materiality; controls; functionality etc.

5.2 Economies of scale still enable project specific (bespoke) assemblies to be designed and manufactured eg. Room sizes/Windows/ fixed furniture etc.

5.3 Technologies of assembly, transportation and other client drivers are still evolving which all drive design expression of the volumetric unit providing opportunities for individuality.
5.4 Containerised modular for example, is self-supporting and can achieve dramatic cantilevers, be fully insulated and watertight and so require the external fabric to be fully detailed as such and yet demountable for creative reuse on another site.

5.5 Using the automotive industry model, it is likely that technological advances, cultural shifts and commercial pressures on accommodation products will continually drive change in volumetric product design, providing creative opportunities for architects and designers.

5.6 The UK Planning system often largely dictates the façade expression regardless of the building’s assembly within, which requires architectural input. It is likely this will continue even if developer clients start approaching Volumetric OSM’s directly with the expectation that they will secure all necessary approvals.

5.7 Considering the current ‘cookie cutter’ façade house designs provided by many Volume House builders in the UK, which often look largely the same for very different sites, it seems unlikely that offsite construction will change the ‘bland’ housing design that already gets built. Rather, the façade designs may evolve to appear more ‘prefabricated’ as tastes change and High-tech becomes more valued than traditional construction.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

Stride Treglown Response:

6.1 Offsite School of Management to initiate a Design Competition – to be open to teams of industrial, architectural and manufacturing designers to develop a standardised house (Model T Ford equivalent) that can be fabricated using a variety of offsite technologies. This will hopefully stimulate supply and drive costs down for new housing down as offsite suppliers gain the confidence to commit to greater mass production.

6.2 BRE/NHBC/BOPAS or similar, to create generic ‘housing design standards’ based on the above prototype (Model T Ford equivalent) to promote diversity within the housing sector whilst creating a framework for delivery for suppliers promoting confidence and so still getting the benefits of mass production.

6.3 MHCLG to develop new routes to encourage OSM for appropriate Model housing development by linking up with sites already defined as ‘Permission in principle’ or a similar mechanism. Essentially creating an easier process at local level that promotes OSM for housing on brownfield sites already identified in the local plan. This would take the standardised Model House in 6.1 and ensure that
urban design principles for layout etc would be established via Design Guides leaving room for contextual elevational design responses to be consented via reserved matters or similar.

24 April 2018
1. **What are the opportunities offered by offsite manufacture for construction?**
   What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

The housebuilding sector in the UK had an estimated £24bn of economic output in 2015 (HBF/NLP, 2014 base data), of which the timber frame manufacturers and housebuilders contributed £6.6bn or 27.4% of the total. Offsite manufactured structural timber system contributes circa 5% of all construction GDP and are a key contributor to the circa 750,000 employed in the construction supply chain. In comparison, construction provides more jobs than aerospace - 268,000; automotive - 247,000; chemicals and pharmaceuticals - 658,000.

**What the Offsite Structural Timber Sector Offers**

- The Government’s number one priority is the provision of housing and the Structural Timber Association, its associates and member companies are ideally placed to deliver the fastest response to this pent-up demand

- The Government has identified offsite manufacture as the solution to building more homes quickly, placing the structural timber sector as the ideal delivery partner

- Structural timber technology is the material of choice to enhance construction schedules, delivering cost and programme certainty, developing airtight and energy efficient buildings at a rapid rate - reducing capital and on-going running costs

- With the emergence of cross laminated timber (CLT) as a key building material, structural timber is now routinely being utilised in buildings of over four storeys and increasingly up to ten storeys with the capability to go beyond

- Current capacity is typically run on a single day shift only; making rapid increases in output by multi-shifting relatively easy to do.

- The timber sector is an engine of economic growth, with a presence in almost all UK counties, improving local economies by providing the wealth necessary to sustain them

- There is a willingness to lay down new manufacturing investment where demand is known

- The Structural timber sector has the capability to exploit the opportunities provided through standardisation and customisation

Architects, designers and engineers have to orchestrate a collaborative design protocol and help to conceive products for a manufacturing process, as well as
know how to integrate them into a design. This re-skills rather than de-skills. They set the goals for the components within the design parameters, but offsite construction brings manufacturers and pre-fabricators to the fore. Manufacturers know how the materials and processes they use best come together, how to control waste and quality, and how to learn from previous experience. By understanding the purpose of each component and working collaboratively with the manufacturer, architects can take these virtues from the factory to the building. When architects realise and not all do, how to design for and with manufacturers, they can design buildings that are easier to build, less wasteful of resources, more enjoyable to use and more valuable to their owners.

2. **It is often claimed that offsite manufacture can lead to:**
   - lower costs, faster delivery and increased quality;
   - increased productivity;
   - improved health and safety;
   - greater provision of new, affordable housing.

   What is the evidence for this?

Rider Levett Bucknall have just launched the preliminary findings of their Cost Comparison Report for Affordable Housing. The purpose of this report is to gain an appreciation of the comparative costs and establish the basis for a more detailed study. The report compared two build methods – timber frame and masonry, for a typical affordable two storey housing design. The house type designs were prepared by HTA Architects with structural engineering input by Milner Associates. It is assumed that the foundation design is similar for both build methods. The detailed specification was included, and the drawings issued to four contractors to cost in both masonry and timber frame. The full report can be provided.

Potential barriers to wider use of offsite manufacture

3. **What are the drawbacks to offsite manufacture for construction?**

The procurement is one of the key challenges for those looking to drive offsite construction forward. The approach taken to the procurement of construction projects in the UK is generally one which follows a tried and tested route from client, to designer, to contractor, to subcontractor, to sub-subcontractor. Each party being seen as a separate part of the process – with little to no engagement taking place with specialist subcontractors or suppliers until much later on in the project. Where offsite construction is concerned, this traditional approach simply doesn’t work.

New procurement strategies focusing on collaborative working between consultants, contractors and manufacturers are vital for offsite construction to be successful and early engagement with the supply chain is paramount. This will no doubt require a change of mind-set for the industry but could bring about significant benefits.

New frameworks are already beginning to appear across England, Wales and Scotland which operate on an alternative ‘design, manufacture, supply and installation’ approach. Integrated design processes like the Design for Manufacturing Assembly (DfMA) model are also being used to demonstrate a new
approach which facilitates off-site manufacturing and engages multi-discipline and multi-tier suppliers early in the design process.

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

The Structural Timber Association support the re-structuring of CITB to take into account the new skills required to deliver offsite manufacturing for construction. The work on site becomes more assembly than building and more work is transferred to the factory.

5. **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

Yes of course. The best examples come from Ocean Housing in Cornwall who use the same standardised units to produce £3m private housing and terraced affordable homes. Simon Caklais will be able to provide examples.

6. **What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?**

I’m not best placed to answer this one

**Government actions**

7. **(If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?**

If the report published by Construction News is correct, then the Government has got it about right. Construction has landed one of the first sector deals as part of the government’s industrial strategy to boost productivity across the economy.

8. **What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?**

Currently supply chain members have to price first and discover the true extent of the works and the attendant risks later. Their view is that main contractors rarely, if ever, procure supply chain involvement on the basis of the outcomes they want to achieve. Usually procurement is based on ‘price led strategy’ with little understanding, still less communication, of the outcomes wanted, inadequate detailing of the work required and a lack of engagement to discuss what works will be necessary, how they could be carried out more effectively and what the major risks are likely to be. Instead, the assumption appears to be made that those tendering for the relevant works will be able to sort out any gaps, assess the risks and price accordingly.

*26 April 2018*
Our Offsite Manufacturing Experience:

Swan Housing Association is leading the way in the use of off-site construction in the Housing Association sector. We have invested £3 million in our own factory in Basildon, Essex which uses Cross Laminated Timber to build modular homes which are delivered to site fully fitted out, before being installed, the exterior walls and roof added. We have already delivered our first modular show homes to site and are now marketing our first shared ownership and private sale modular homes. Our factory will be able to produce up to 500 homes a year.

Our “NU build system” won the “Best Approach to Modular Construction” at the Inside Housing Development Awards 2017. The judges noted that we had been able to fund the factory set up and running costs through our £130m regeneration of Craylands; the creation of local jobs; and the delivery of high quality homes in 50% of traditional construction times, with 90% savings on waste and initially 10% cost savings, with further savings expected as efficiencies increase.

We have significant construction experience having already completed over 1,200 starts on site throughout our own in-house construction company NU living using traditional construction methods. We’ve built over 900 homes to date generating over £60m which has been reinvested in affordable homes and services for our residents.

About Swan:

Formed in 1994, Swan Housing Association has been providing high-quality and affordable homes to rent and buy for over 20 years. Today, Swan locally manages over 11,000 homes in Essex and East London, specifically in Tower Hamlets, Newham, Barking and Dagenham, Redbridge and Havering; supported by dedicated, local staff. We were awarded Housing Association of the Year at the WhatHouse? 2017 Awards for our approach, including our innovative offsite construction project.

We have built-up a specialism in large-scale regeneration schemes, such as £300m Blackwall Reach in Tower Hamlets and Laindon Shopping Centre in Essex. The former will see the existing 252 Robin Hood Gardens properties replaced by over 1,500 homes during the next decade and has already won the ‘Award for Planning for Housing Growth’ at the Planning Awards 2015. The latter will use modular construction to build a new town centre and the designs for this scheme
have already won national and international recognition as set out in our response below.

Our social purpose: “delivering homes and services to those who need them” underpins everything we do and that is why we focus on large scale regeneration as we can build mixed tenure sustainable communities, where homes for private sale and commercial uses subsidise the provision of affordable homes. Our corporate strategy challenges us to generate £250m this way by 2027 to reinvest in homes and services.

Swan is committed to helping the Government achieve its house-building objectives and our ambitious corporate strategy targets us to build an additional 10,000 homes by 2027. Our secured development pipeline of over 6,500 homes includes the £1bn regeneration of Purfleet on Thames which will deliver up 2,850 homes along with a new town centre for Purfleet as well as one million square feet of film studios and even a new university campus for a leading London University.

With the Committee looking specifically at “The Perceived advantages of offsite manufacture for construction”, Swan would like to share its experience with the Committee to aid its timely and important inquiry.

**Perceived advantages of offsite manufacture for construction**

1. **What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

**What are the opportunities offered by offsite manufacture for construction?**

For Swan the key opportunities offered by offsite manufacture are:

- **Time:** we can reduce both the overall time taken to construct new homes and the risk of delay that exists with traditional construction:
  - Off-site modular housing manufacture enables a significant overlap between the onsite activities (infrastructure, foundations etc) and the offsite construction and fitting out of homes saves around 50% of construction time.
  - Manufacturing the homes in a sheltered, fully serviced factory significantly reduces the risk of delay due to weather.

- **Efficiency:** we have been able to introduce efficiencies through the use of less specialist labour; reductions in waste; and more standardisation.

- **Quality:** we have achieved improvements in quality through the introduction of a manufacturing approach:
Our factory operates on a LEAN basis, by building quality control into all processes and purposefully designing the homes so that they can be assembled, rather than built, in a factory in a safe and controlled environment.

The modules are constructed to millimetre fine tolerances and so we can ensure levels of consistency that enable us to standardise the components that we install into the modules to such a degree that we can pre-order kitchen work tops for and know they will fit.

- **Mitigation of labour/ skills shortages:** By creating a high-quality manufacturing environment, as opposed to a traditional onsite building environment, we can attract people who might not otherwise want to work in construction. This will help us address the labour shortage and enable us to attract skilled workers who may no longer wish to work on site. Working on shifts enables flexible working and we are already seeing the benefits of this environment for encouraging a diverse workforce. We are supporting for example one employee, who is on the spectrum, and who is able to work with us in the controlled factory environment, whereas he would be likely to struggle on site.

- **Sustainability:** We are able to deliver a home that is sustainable for it’s lifetime. We use Cross-laminated timber (CLT) which is a sustainable construction material, it is tough, long lasting and used widely throughout Europe and the USA to construct homes. Structurally it can produce CLT units from 1 to 12 floors, it’s an easily machinable, large scale product which is thermally and acoustically efficient. Off-cuts of CLT are used to heat and power the factory. Our experience shows we can also achieve up to 90% reduction on waste compared to a traditional building site.

- **Customer Choice:** we can offer purchasers of the private sale modular homes up to 36,000 combinations of layouts and external and internal finishes in just one of our houses. The customer can design their own home, much as they would a new car, seeing the price of each option reflected in the cost of the home with each choice made. We have created a bespoke “online configurator” to allow buyers to do this from the comfort of their own home. This in turn enables us to create a varied street scene.
at Beechwood where no two homes will be the same but using a design guide approach will complement each other across the estate. This also helps us to attract buyers to the area, which pre-regeneration may not have been one they would have considered, helping build a mixed tenure, sustainable community.

- **Less disturbance to communities surrounding regeneration sites:**
  We are able to realise benefits for the environment and for residents’ local to the construction site as modular creates less disturbance and less fuel used for deliveries etc.

**What influenced Swan to pursue an off-site construction approach?**

- The decision to open our own factory was driven by the opportunity presented by the development of the Beechwood Village scheme in Basildon, Essex, where we are building around 570 homes over the next 6 years as part of the regeneration of the Frierns and Craylands area.

- Unlike most housing associations (HAs), Swan has its own in-house construction team, which was set up in 2007 to enable more control over the construction process and cost savings.

- In March 2015, we completed 28 homes at Beechwood and a further 125 affordable homes were handed over in June 2015 (121 rent) and July 2015 (4 shared ownership) with the assistance of funding from the Homes and Communities Agency, now Homes England (HE).

- The scheme had been very difficult to deliver on time due to a combination of bad weather and issues with some key sub-contractors. Both the fit-out and timber frame contractors went into administration during the contract.

- In early 2015, we started to look at the existing market for the supply of modular homes and commissioned a detailed study comparing various systems and options including one of developing our own factory.

- From this review it was clear that the existing market was quite immature and had limited capacity. The market had very high overheads, which we believed arose from the need to build in contingency for lack of continuity of work and a higher profit target than traditional construction.

- In addition, traditional construction necessarily included the extra costs of rent and business rates arising from the operation of a factory.

- In the case of Beechwood Village, the overhead was in the region of 25-30% compared to a traditional main contractor’s margin of 6-8%.

- As a result, we developed a business plan predicated on building around 100 homes a year – initially in a factory capable of producing three times that number. The business plan showed that we could build new homes at around 5% lower cost than we were at the time, even when producing only 100 homes.
As additional capacity in the factory is fully utilised, we expect to save a further 10%.

With our development programme currently delivering around 700 homes a year, we believe we are ideally placed to ensure the factory operates at optimum efficiency in the future, by having a guaranteed order book that Swan is fully in control of.

2. It is often claimed that offsite manufacture can lead to:
• lower costs, faster delivery and increased quality;
• increased productivity;
• improved health and safety;
• greater provision of new, affordable housing.

What is the evidence for this?

- We have already delivered our first modules to Beechwood, our £150m regeneration of a failing 1960’s Radburn Estate in Basildon, Essex. We are now moving into full production at our factory and through that full production we will:

  - **lower costs accelerate delivery and increased quality**: we will deliver up to 500 homes (or 1000 modules) per year. These homes will be delivered in 50% of the traditional construction time and we expect to achieve 15% cost savings when in full production. Due to the precision manufacturing process and the controlled production environment (tolerances are to millimetres) defects are significantly reduced and residents will have a higher quality home.

  - **increase productivity**: Now that we have established our “NU build System” and set up our production line on our factory, the move into full production will see us deliver 10 homes a week.

- **Maintain and enhance health and safety**: As a traditional contractor we have a clear focus on ensuring the highest standards of health and safety on all our sites. The factory however, presents an opportunity to have a very controlled production environment with all tasks clearly documented and carried out in a clean, dry factory environment with clear visibility of all works. The use of significant cutting and lifting machinery does need to be properly managed but again, this is happening in a stable, controlled environment.
Be able to deliver greater provision of new, affordable housing: We are using our factory, which was viable at 100 homes, to deliver far more at up to 500 homes. These homes will be used to provide both private sale and affordable homes at the regenerations set out below. However, the Committee should note that even where private sale homes are provided, because of our business model, with all profits being invested in either new affordable homes or services for our residents, these private sale homes will subsidise further affordable homes including homes for social rent as well as shared ownership helping us deliver our 6,500-home secured development programme making schemes more viable through the benefits outlined above:

- Beechwood Village (above left)
- Laindon Place, Laindon Essex: 222 homes: 69 shared ownership apartments and houses; 155 private sale apartments and houses
- Watts Grove, London Borough of Tower Hamlets (image left): 65 homes: 45 apartments for shared ownership and 20 for rent.

3. What are the drawbacks to offsite manufacture for construction?

Our experience of opening our factory have highlighted the following challenges to successful production, although these are not necessarily “drawbacks” as we have been able to overcome them:

- Finding a suitable, affordable factory building in Essex or east London – we have invested £3m in a factory in Basildon, just a few miles from the first two of the regenerations that we will use modular construction to deliver.

- Understanding the accreditation options and processes to ensure mortgageability – we have secured BOPAS accreditation (Buildoffsite Assurance Scheme) for our new homes.

- Recruiting a suitable MD for the business – We have appointed Paul Williams, who is vastly experienced in the manufacturing field at an executive level and is bringing a fresh perspective to the manufacture of the homes.

- Front ending all the design: You must do this all up front to ensure that the product can be produced in the factory and seamlessly delivered to site in what is a new way of working for everyone. Our manufacturing and construction teams, our architects and engineers etc all must be involved. There is also a cultural divide between the construction team and the
manufacturing teams – they literally speak a different language. The manufacturing team focus on lean thinking, production processes and designing out issues – they can design in standardisation because of the high level of tolerances which streamlines production to a level that you cannot achieve on site – e.g. worktops can be templated and pre-made as the kitchens will be made to precise measurements. However, we have overcome this with the right teams on the ground, this can be overcome and both teams have learnt from each other in a positive way!

- **Overcoming the design challenges of creating the custom build product** – we worked closely with our architects and Basildon Borough Council planning team to agree an approach which will enable reserved matters to be used to quickly deal with custom build selections.

- **Productivity** – you need to build in time for the teams to develop the processes and product – R&D is standard in the manufacturing sector for a reason. Prototypes take time to develop but all that learning contributes to a speedy but high-quality production line later.

- **Securing another long-term project, like Beechwood, to ensure continued production** – we will use modular housing at both Laindon Place and Watts Grove.

In the future:

- **Ensuring that the factory output is matched to on-site processes to avoid either a lack of production in the factory or an oversupply of modules which will have to be stored.** Our intention is to use modular as a base, using traditional construction on top, that way we will always have a core of work going through the factory, accelerating the delivery of homes.

- **Finding incremental efficiencies in the manufacturing process to further drive down costs.**

- **Finding ways to enable us to deliver extra capacity to meet future demand.**

4. **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

It is our experience that whilst specialist manufacturing experts are required to ensure a precision manufactured approach can be applied to production, the construction of the modules requires skilled multi-trades construction tradespeople, the majority of whom we have found are easily able to adapt to working in the factory environment. We are working with PROCAT to develop the first modular construction apprenticeships at our factory. We also have been partnering with Essex County Council as they recognise that modular construction will be a key construction method of the future and want to ensure that there are training young people to have the appropriate skills to work in this sector.
5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

- The projects that we are delivering through modular manufacturing demonstrate that there is no need to hamper architectural vision. We have worked closely with our architects on both schemes with the result that both are architecturally visionary:

- At **Beechwood West**, we have worked with our architects PTE to create an ambitious scheme. A sense of arrival, new human scaled streets and a substantial green heart form the focus of the new masterplan. Each of the new houses has been organised around a series of streets and green spaces to create a variety of different characters and places of interest. The new public realm will offer a highly legible layout that is both attractive and easy to navigate. A series of “Linked Greens” connect the significant public amenities adjacent to the site. The homes themselves are steeped in the Arts and Crafts attention to detail that is so sought after today, whilst remaining contemporary in appearance and boasting 21st century environmental performance.

- Beechwood West was highly commended at the National House Awards 2017 in the Best Scheme in Planning category (losing out to Laindon Place our other Essex based modular regeneration). The NHA 2017 judges said they wanted to highly commend Beechwood because it was “a refreshingly different submission, not only with the design of the homes but also the self-build/customisation. It shows outstanding community engagement and the use of innovative construction and local labour is fantastic and deserves recognition.”
Swan Housing Association – Written evidence (OMC0076)

Laindon place (above) will deliver a new High Street for Laindon, with shops, a new integrated medical centre, Swan office, high quality public realm and 224 new homes. Laindon Place, designed for us by PTE and CF Moller has already been recognised nationally:

- scooping the coveted Best Scheme in Planning at the National Housing Awards 2017;
- the Best Regeneration Award at the Housing Design Awards 2017; and
- was shortlisted for Masterplan of the year in the Architect’s Journal Awards 2017.

The NHA judges said about Laindon “A great scheme that is both regenerative and visionary and brings together residential and commercial uses to create a new heart for the town.”

Laindon Place has also received international recognition being Highly Commended in the MIPIM/ Architectural Review’s Future Project Awards for Regeneration and Master Planning. An award which showcases outstanding architectural projects from around the world proving that offsite manufacture need not hamper architectural vision.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

Systems need to be mortgageable and acceptable to our lenders in terms of charging as we rely on borrowing against completed homes to fund our future developments. Some funders are cautious about accepting too many modular homes as security as it is a relatively new product. Further guidance and R&D to support this would be useful. We have already achieved BOPAS (Build Off-site Property Assurance Scheme) accreditation which entails an independent assurance that our modular homes will last a minimum of 60 years, and our developments will come with a 12-year warranty in line with traditional
construction but further guidance for lenders would help accelerate adoption of this approach.

7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practises in the construction industry and facilitate off-site manufacture?

Central and local government can help to accelerate the development of more off-site manufacturing facilities. They can set clear targets for the adoption of off-site manufacture on sites that they own, they can incentivise councils and housing associations to build affordable housing using these techniques through prioritising grant funding for such projects, and they can encourage the sharing of knowledge and best practice.

4 May 2018
Introduction:

1. Tidal Lagoon Power (TLP) has been granted a Development Consent Order (DCO) for the construction of the £1.3bn Tidal Lagoon Swansea Bay (TLSB) project. Further detail of the project can be found at the website below. http://www.tidallagoonpower.com/projects/swansea-bay/

2. TLSB is the scalable pathfinder project that catalyses a new tidal lagoon industry. An unrivalled commitment to British industry means that the world’s first tidal lagoon will give UK engineering, construction, steel and manufacturing industries the first-mover advantage to capitalise on a significant new UK and global market.

Opportunities offered by off-site manufacture for construction:

3. The construction of the TLSB project offers a fantastic opportunity for a major component of the scheme, the turbine and sluice structures, to be manufactured off-site. The reinforced concrete requirement for the TLSB structures is approximately 300,000 m$^3$. The fleet-wide requirement of reinforced concrete for 6 UK tidal lagoon projects, including TLSB, is approximately 9,000,000 m$^3$.

4. TLP has adopted Design for Manufacture and Assembly (DfMA) principles, in particular off-site manufacturing and modularisation, for the design and construction of tidal lagoon projects in an attempt to maximise productivity, improve product quality, reduce rework and site defects, improve health, safety and environmental performance, minimise cost, de-risk construction and optimise construction schedules by minimising on-site activities. For example, through application of DfMA principles we have been able to reduce the overall construction schedule for the TLSB project down from 5.5 years to 4.25 years.

5. Working in collaboration with industry-leading DfMA experts, TLP has developed a preliminary DfMA-based design to enable off-site manufacture of the concrete structures.

6. Off-site manufacture has been used to great effect in the housing and building industry, particularly if there is a repeatability, or standardisation of components. In simple terms, a tidal lagoon power station’s turbine and sluice structure (see Fig. 1) is a high rise building lying on its side and involves identical, repeatable and standardised components which lend themselves to off-site manufacturing.
7. The original construction methodology of the TLSB project included construction of the turbine and sluice structures using conventional in-situ construction methods. Due to the turbine and sluice structures needing to be constructed in a temporary, de-watered, cofferdam (see Fig 2.), this prevented the civil works from commencing until the cofferdam was completed – a duration of approximately 15 months.

8. Through utilisation of offsite manufacturing techniques, the fabrication of the components for the structures can now commence in parallel with the construction of the cofferdam resulting in a significant time and cost saving. As the cofferdam is completed, the pre-cast concrete components can be transported and assembled in the cofferdam. In developing the DfMA concept, TLP focused on standardising the design of as many of the components as possible, as well as simplifying them to allow any established and new-entrant pre-cast facilities the opportunity to manufacture them. The weight of any individual unit was kept within the limits of normal road transport requirements which opens up the market to pre-cast yards which do not have quayside access. Fig 3 below shows the typical pre-cast components for a single turbine unit.
9. In addition to the benefits described in paragraph 4 above, utilisation of off-site manufacturing techniques has also reduced the interface complexities with the turbine installation contractor which has led to optimisation of the on-site construction and commissioning activities and a significant reduction in on-site personnel being required to work in a harsh environment within the confines of the cofferdam.

Re-skilling Requirements and Opportunities:

10. Off-site manufacturing in construction will require re-skilling of sections of the workforce as the industry shifts from a predominantly site-based workforce of steel fixers and concreting operatives to a process-driven factory environment, however, this provides an opportunity to de-risk the skills shortage for those traditional skills across the competing major infrastructure projects within the UK.

Summary:

11. By utilising and investing in off-site manufacturing techniques on the TLSB pathfinder tidal lagoon project, it provides a template to enable the supply chain to establish facilities and skills which can then be utilised and replicated across the roll-out of full-scale tidal lagoon projects.

12. TLP believes that the early adoption of and the honing of skills for off-site manufacturing techniques on the TLSB pathfinder tidal lagoon project will ensure that the UK industry can achieve market leading efficiencies and prices such that none of the industrial and economic value associated with design and construction of tidal lagoons is lost overseas. Furthermore, the specific skills and IP developed on DfMA techniques will create a genuine UK export product to compete with the traditional domestic civil works markets on overseas tidal lagoon projects.
24 April 2018
Perceived advantages of offsite manufacture for construction

1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?

- When speaking about off-site construction it is essential to understand what is generally referred to as off-site construction and volumetric engineered off-site housing. Off-site construction is essentially where the superstructure of the house is constructed in sections in a factory, mainly from timber and SIPS panels, and transported to site for erection. The house is then completed in the traditional way using carpenters, plumbers, bricklayers, plasterers, tilers, decorators etc. but is obviously quicker because of the speed of the completion of the superstructure. This approach requires the same skilled trade staff as traditionally built housing and guarantees little better quality or energy performance. There are no architectural drawbacks to off-site except for it’s inappropriate use in high rise buildings.

Volumetric Engineered Housing is where the houses are factory manufactured in an engineering environment and 90/95% complete when leaving the factory, requiring simple erection on site and virtually no requirement for the traditionally trained skilled trade operatives as this job role is non-existent in Volumetric manufacturing. The obvious advantages in this approach are speed of completion because of little influence from the weather and improved build quality because of the clean and controlled manufacturing environment. A serious weakness in traditional housing is the lack of energy efficiency since the Government dispensed with the Codes of Sustainability. Code 4 was previously the perceived aim for all new housing but currently there is no requirement to do anything other than meet Building Regulations, resulting in greater energy costs, increased carbon emissions and less disposable income for residents. Other benefits of volumetric production are less waste and consequently less materials going to landfill and less local disruption to existing residents because of the speed of completion. Finally, the requirement for a new workforce will provide many new job opportunities and the commitment to greater number of houses being produced, will inevitably see a reduction in cost as the new supply chain is developed. Volumetric is totally suited to high rise buildings but has a restriction of a five metre width if transported via the road network. Five metres width presents no serious architectural challenges and no restrictions on living conditions.

Likely Opportunities
Totally Modular Ltd – Written evidence (OMC0007)

- Local economic development LEP priorities more fully realised through local employment
- Quality controlled manufacturing capabilities
- Greater speed of production
- Lower carbon footprint
- Higher building performance
- Reduction in national burden to develop sufficient typical ‘construction trade’s as we move to a more production and in-house engineering skills solutions
- Volumetric supply chain efficiencies will disaggregate local market ‘pricing’ from the supply chain leading to significant cost benefits. Currently if you buy a car in Scotland, it’s the same price as in London. This is contrary to the current situation with traditionally constructed housing. Current supply chain construction companies are based on local pricing models to improve returns to shareholders.

Likely drawbacks are:

- strong cultural perceptions amongst current supply chain and buyers that off-site and Volumetric property construction is inferior (not bricks and mortar so can’t be any good...)
- Poor track record of some MMC construction projects - with excessive faults, poor design and poor construction skills - have informed the debate in a negative way.
- Lack of supply chain skills - most small volume builders do not have the necessary skills or knowledge to take advantage of Off-Site or Volumetric housing products and are unlikely to want to embed the required skills into their current business model
- Current supply chain contracting models are unfit for Volumetric manufacturing and would need separating from ‘Construction’ if significant development for the advantages of Volumetric production are to have any significant impact.
- Significant new investors are urgently required by volumetric manufacturers if they are to increase their capacity and spread the risk. With £3.5 billion in reserves held by the top 20 Housing Associations, the Government should demand that a proportion of this money should be used to fund the creation of volumetric factories, following the successful precedents set by Swan HA and Aspire HA.
- The current supply of large scale housing development is driven by a small group of larger contractors who possess all 4 of the above drawbacks and therefore have no real appetite for in seeking long term significant investment from their shareholders into Volumetric production.
- Local vernacular design may be compromised if creative architecture is not employed.

2. It is often claimed that offsite manufacture can lead to:

- lower costs, faster delivery and increased quality;
- increased productivity;
- improved health and safety;
- greater provision of new, affordable housing.
What is the evidence for this?

- There’s no evidence base for successful Volumetric Construction of housing per se in UK because no major schemes have been undertaken within a suitable supply chain framework.
- Great danger of descending into a ‘zero sum circular reference argument of ‘no volume in supply therefore no benefits demonstrable’, no confidence in product because no evidence. We believe it is the Governments responsibility to break this cycle which could be achieved by following our recommendation to compel housing associations to make the investment from their abundant reserves. Should the foregoing environment be created, the results set out below could be anticipated.

  - Completing 95% of the house in engineering factory conditions, ensures that every house conforms exactly to the design requirements ensuring the quality is standardised unlike the current poor quality of traditional housing. Due to the reticence to embrace volumetric/modular housing, the current prices are comparable with traditional construction but without the advantages of volume procurement. Savings of 10-20% could be achieved with the creation of a new supply chain. The requirement for much simpler foundations increases the speed of completion and reduces the materials being moved around and shifted from site.
  - Productivity is obviously greater in a factory environment unaffected by the weather and embracing modern engineering methodology. With the advent of greater production enabling the investment, robotics will inevitably further drive down the cost and improve quality.
  - Engineering factories are infinitely safer than construction sites and with the house simply being delivered to site and connected to the services, minimal time is spent on site.
  - The national house builders will not and cannot build any more than they are currently building. With an ageing workforce, the lack of young people attracted to construction, the lack of good FE provision to train apprentices and the exodus of Eastern European trades staff, the house builders will be fortunate to build the current numbers over the next ten years. Volumetrically engineered housing will enable the creation of a new semi- skilled workforce to produce the houses required at an affordable cost in factories located near the places of demand to reduce the carbon footprint. The scale of the challenge should not be underestimated!! Each 30000 sq ft factory will produce approximately 500 houses/year and with a requirement for an increase of 100000 homes/year, it will require 200 new factories and a new workforce of 20000 to meet this demand alongside the increased jobs created by the provision of 100000 steel frames, kitchens, bathrooms, doors, windows, tiles, insulation etc.

Potential barriers to wider use of offsite manufacture

3. What are the drawbacks to offsite manufacture for construction?
It is essential to define the difference between off site and volumetric housing. Off-Site is a construction process where the house is made in panels in a factory, transported to site, erected with the internal and external finishing and roof being completed on site. Volumetrically engineered housing is 95% completed in the factory, including insulation, windows, doors, kitchen, bathroom, toilets, roof and decorating and delivered to site ready for connecting to the pre-installed services and occupation. For volumetric there are no drawbacks in the manufacturing process save if the house needs be transported, it cannot be more than 5 metres wide due to highways legislation.

4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

- There will be no re-skilling of the current construction workforce who will all be required to maintain the current output of traditionally built housing. Volumetric Engineered Housing will require a new workforce of factory-based operatives. We are currently working with Dudley FE College, the country’s leading BIM, CAD and Volumetric facility, the Institute of Engineering and Technology, the Institute for Apprenticeships and the new National Housing Academy to create an Apprenticeship in Volumetric Engineering to produce the necessary workforce.

5. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

- The benefits of standardised factory manufacture greatly outweigh the limitations of architectural ambitions. Our portfolio of house/apartment/bungalow/homeless units has been created by architects well versed in the housing sector and consists of a variety of types, internal and external finishes. The specification of good quality internal components coupled with the benefit of production in an engineering environment will greatly reduce the future maintenance costs which for simply the 4 million social housing properties is £12 billion/year, all of which adds not one penny to the value of the property!

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

- Enough R and D work had been undertaken by volumetric manufacturers for the commercial sector building hotels, hospitals, prisons etc.. Architects and planners need to become familiar with the production process, the quality of materials, the requirement to commit to volume production to reduce costs and be aware that the BOPAS guarantee on volumetric houses is 60 years against the 50 years for traditional housing.

**Government actions**
7. (If published) does the construction sector deal correctly identify the issues faced by the construction industry and the actions that the Government and other stakeholders need to take to address them? What should it contain/what is missing?

- The construction sector and national house builders are the major stumbling block to success of factory produced housing! They have a current model that works well for them, as new housing numbers are controlled to keep prices high for a product that is far from satisfactory in relation to real value for money. The only way that the Government will deliver an extra 100000 good quality houses/year is to create a completely new supply chain of factory produced volumetrically engineered houses with a newly trained workforce. A perfect example of the existing players not moving the agenda forward is demonstrated in the awarding of a grant of £32million to Laing O’Rourke to create a modular factory two/three years ago that has not built one house to date!!!

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

- The recent debacle with Government procurement practices with Carillion, Serco, Capita, A4E etc has exposed a real weakness in the OJEU process that does not serve the public purse well. The awarding criteria for Government contracts limits the opportunities to large national and multi-national companies, many of whom engage medium sized regional companies to undertake the work as their subcontractors. This automatically adds 30% to the cost of the work as they apply their management fee and profit to the subcontracted cost. It is no secret that the French and German Governments do not approach OJEU procurement with the same rigour as in the U.K. and therefore moves should be made by Government to open the market to more small/medium sized companies who are currently unable to access the system because of the specified financial criteria.

19 April 2018
Trowers and Hamlins LLP – Written evidence (OMC0053)

Trowers and Hamlins LLP is an international law firm specialising in Real Estate advice and helping businesses and governments change the way we live and work for the better. We do this by providing our clients with commercial advice geared towards tackling tomorrow’s challenges.

We are fascinated by the future of our towns and cities and, especially, the point where commerce, communities and culture intersect. As a firm, our work contributes to this dialogue every day, whether we are connecting business with municipality in Abu Dhabi, individuals with communities in Manchester, or investors with opportunities in the City of London. We combine local knowledge and specialist skills in teams across our offices enabling clients to benefit from an efficient and effective service.

Put simply, we’re committed to building better business – for our clients, for society and for the wider economy.

As a law firm, we have taken a keen interest in the development of modular construction, particularly in the housing sector, and we were involved in some of the early modular projects for social housing providers including the first Housing Corporation (now Homes England) funded modular scheme in the UK for the Peabody Trust at Raines Court N16. We also advise the Education & Skills Funding Agency on the Component Primary School Modular Framework.

Recently we have been working with our Real Estate clients to overcome the legal barriers to create efficient processes to deliver modular construction projects and have held roundtable events to discuss these issues in London and Manchester in January and April 2018.

Our response to the inquiry is a collation of Trowers & Hamlins LLP’s experience of legal issues arising on modular construction projects and a summary of the roundtable evidence provided by the attendees, who are all key players within the construction sector. We refer to the attached report: "Modular construction: Is it time that we started taking modular construction seriously?"

Perceived advantages of Off-Site Manufacture for Construction?

Question 1
What are the opportunities offered by Manufacture for Construction?

Mark Farmer's report, Modernise or Die, has highlighted the opportunities that modular construction offers to combat the current problem faced by the construction industry, including structural skill shortages and ongoing quality problems. Mark Farmer chaired the Trowers’ roundtable in London in January 2018 and confirmed that the speed and efficiency of a modular construction process are obvious advantages, however, in order to maximise those benefits, projects need to be of sufficient scale, digitally enabled, formally accredited and underpinned by a new set of competencies and skills. Please refer to "Thoughts from the Chair, Mark Farmer" in the attached Report.
Question 2
Evidence to support that Off-Site Manufacture can lead to lower cost, faster delivery and increased quality, improved health and safety, and greater provision of Affordable Housing.

In our Report, we highlight two projects demonstrating the benefits of modular construction. On the Berkeley Homes development, Kidbrook Village in Greenwich, a whole row of terraced housing was constructed at twice the speed of a traditional build. Customers have confirmed that they cannot tell whether these have been constructed using off-site fabrication. Berkeley have been so impressed by their experience at Kidbrook using a third party manufacturer that it has now secured a 165,000 square foot site in Kent to build a factory that will produce its new modular project delivering initially 1,000 units per year for Berkeley Homes projects.

In the Affordable Housing sector, Swan Housing Association opened its own factory in Basildon in 2016 and it is committing significant investment to modular. Swan's 85,000 square foot manufacturing site produces cross laminated timber and it is capable of manufacturing up to 400 high quality modular homes on its production line, and has delivered 560 in the first phase of Swan's regeneration of the nearby Craylands Estate. Again, Swan is determined to ensure that the modular units are indistinguishable from traditionally built homes and the development has been awarded the Best Approach to modular construction at the Inside Housing Development Awards.

Both schemes demonstrate that in order to deliver successful Modular Housing projects on-site, detailed research development and planning needs to be undertaken into designing the product, investment in IT and manufacturing processes.

For more detail, refer to the "Guaranteeing quality" section in our Report.

Potential barriers to wider use of Off-Site Manufacture

Question 3
What are the drawbacks to Off-Site Manufacturing for Construction?

The main drawbacks highlighted by our roundtable events are linked to the supply and demand conundrum, essentially the need to create sufficient commitment from commissioning clients for manufacturers to achieve economies of scale. Lack of understanding of the quality of the finished product and how the modular product can be maintained are also perceived barriers for funders and investors but can be overcome by promotion of the benefits and demonstration of quality.

Please see the "Guaranteeing quality" section of our Report.

Question 4
What re-skilling in the construction workforce is required to facilitate a change to more Off-Site Manufacture for Construction?
As set out in the "Skills shortage; where will labour come from?" section of the Report, it is undisputed that there is a construction skill shortage but limited efforts have been made to encourage more interest into the sector. Trowers & Hamlins LLP are working with Class of Your Own who have designed a course, Design, Engineer Construct (referenced as a case study in Mark Farmer's Modernise or Die Report), which teaches 11 to 18 year olds about the construction sector and covers design, planning, surveying and enables practical use of design tools such as Revit. Osco Homes in the North West are retraining ex-offenders both within a factory located on a prison site and post-release to work in modular construction: www.oscohomes.com. However, small pockets of best practice are not sufficient and it was the views of attendees of the roundtable events which Trowers & Hamlins held that government intervention in the current education system to train and educate at an early age has to be the solution.

**Question 5**
Can the benefits of standardisation and manufacture be realised without hampering architectural ambition? (If so how?)

We refer to the "Standardisation and collaboration; Key to helping modular succeed" section of our Report. Our roundtables did highlight that in a new modular environment all construction professionals need to rethink their traditional roles. The architect attendees at our roundtables confirmed they do still have a role to design the product but working closely with manufacturers rather than main contractors in the future and that building information modelling will be an essential tool in creating these products efficiently. Architects also confirmed that they felt their place shaping role would not be diminished with greater use of modular construction.

**Question 6**
What research and development is needed and by whom to realise fully the potential benefits of Off-Site Manufacture?

The views of the roundtable attendees was that the commissioning clients in both in the public and private sector need to lead on research and development to shape the manufacturing market.

**Government actions**

**Question 7**
Does the construction sector correctly identify the issues faced by the industry and what actions do government and other stakeholders need to take to address them?

We have not answered this question since this was not the subject of our discussion topics at our roundtable.

**Question 8**
What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the Construction industry to facilitate Off-Site Manufacture?
Our roundtable events highlighted there are two aspects of the public procurement system which need to change to reflect the shift in responsibilities on modular construction projects compared to traditional construction projects.

We refer to our Report "Standardisation and collaboration: Key to helping modular succeed?" and the work that Trowers & Hamilns have undertaken with Kings College London for the Innovation in Buildings work stream for the Construction Leadership Council. One of the key issues that the Construction Leadership Council has highlighted is the need for demand to be aggregated and Trowers and Kings College London are working on research into a model form of framework alliance agreement which would allow public sector commissioning clients to collaborate with each other and jointly appoint contractors and manufacturers to aggregate demand and provide certainty of pipeline for the factories. Therefore one of the key elements of the public procurement regime of requiring competitive tenders for construction works contracts over certain thresholds can be a barrier to long term collaboration. Procuring and entering into long term framework alliance contracts (utilising the framework alliance contract FAC 1 adapted specifically for modular construction) would be a solution which Trowers and Kings College London are recommending as part of their research for CLC.

Another barrier created by the current public procurement regime is the current lack of engagement between the supply chain and the ultimate clients. Again, creation of framework alliances between supply chain members including manufacturers and traditional contractors is a solution to overcome these barriers.

Although the current public procurement regime does enable commissioning public sector clients to appoint on an overriding quality criteria there is a risk that pressure on public sector budget means that suppliers are selected on a lowest price basis which again would inhibit the use of modular construction, which currently is likely to be a more expensive option at commissioning stage but can demonstrate long term value throughout quality and production of management and maintenance costs. Therefore, the public procurement regime should be utilised to select on the basis of social and economic value and emphasise the social value benefits which can be derived from modular projects, such as addressing skill shortages and environmental and sustainability targets.

26 April 2018
UK Finance – Written evidence (OMC0051)

UK Finance is a new trade association which was formed on 1 July 2017 to represent the finance and banking industry operating in the UK. It represents around 300 firms in the UK providing credit, banking, markets and payment-related services. The new organisation brings together most of the activities previously carried out by the Asset Based Finance Association, the British Bankers’ Association, the Council of Mortgage Lenders, Financial Fraud Action UK, Payments UK and the UK Cards Association.

Consultation response approach

This response will focus on those questions most relevant to mortgage lenders and so will not answer every question posed.

Q1. What are the opportunities offered by offsite manufacture for construction? What are the likely drawbacks? What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose office manufacture?

Q3. What are the drawbacks to offsite manufacture for construction?
1. Lenders support action to increase the supply of housing in the UK. UK Finance and individual members are working with the Government and other stakeholders to ensure that modern methods of construction, including offsite construction, can play a part in increasing housing supply.

2. The UK has a diverse building market with a wide variety of construction methods used. The lending industry has no overall preference on construction method and will advance mortgages against properties constructed by many different methods.

3. Some types of non-traditional construction have a relatively poor track record compared to more traditional construction methods. This can lead to lenders, whether they are providing individual mortgages for home-ownership, or finance for newly-built property in the social rented sector, to take a cautious approach to new methods of construction which do not have a proven track record.

4. Where properties are constructed by modern or innovative means, including off-site manufacture, lenders need to be satisfied that designs meet certain standards. Lenders need methods of construction that provide:
   - Durability – homes need to have a long life span (perhaps 60 years or more); during that time the maintenance cost of the property needs to be comparable to traditional methods of construction; and it should be possible for repairs to be carried out by most trained professionals using parts that are readily available.
   - Warranty – homes should meet recognised standards of manufacture and build quality, and have an acceptable warranty by a mainstream provider
that covers the whole building. It should be possible to take out standard building insurance on the property.

- Attractiveness to consumers – homes should have the potential to be generally appealing to prospective and future buyers, including the ability to be adapted and extended as desired.

5. For homes in the social housing sector, it is also important that the method of construction does not make them harder to let or reduce the rent they would achieve.

6. Assessing the quality of offsite manufacturing is important for lenders. UK Finance is part of a Government-sponsored Joint Working Group on Modern Methods of Construction looking at how lenders and other stakeholders, such as warranty providers, can better assess the manufacture and construction standards of homes built by Modern Methods of Construction (including offsite construction). We hope that this will result in lenders being to be increasingly confident about Modern Methods of Construction properties.

26 April 2018
UK Research and Innovation – Written evidence (OMC0074)

1. UK Research and Innovation welcomes the Committee’s inquiry into off-site manufacture for construction.

Who we are

2. UK Research and Innovation brings together the seven Research Councils, Innovate UK and Research England into a single organisation that aims to ensure the UK maintains its world-leading position in research and innovation.

3. UK Research and Innovation is responsible for delivering the Industrial Strategy Challenge Fund (ISCF), part of the government’s Industrial Strategy which aims to raise productivity and earning power in the UK. ISCF is a core pillar in the government’s commitment to increase funding in research and development by £4.7 billion over four years. It invests in the UK’s world-leading research base and highly-innovative businesses to address the biggest industrial and societal challenges of the day. One such challenge is the Transforming Construction Challenge (“the ISCF challenge”), which will award up to a total of £170 million to innovative projects that harness technology to deliver safer, healthier, more energy efficient and more affordable buildings in which to live and work.

4. This ISCF challenge brings together the construction, manufacturing, energy and digital sectors. Each of the three main elements of the lifecycle costs of buildings will be tackled: designing and managing buildings (through digitally-enabled performance management), constructing quality buildings (through an offsite manufacturing approach) and powering buildings (through embedded active technologies and improved quality of build). An underpinning research programme will ensure that these issues are tackled in more a coordinated way than with previous interventions.

5. The programme is strongly linked to the Construction Sector Deal and the Infrastructure and Project Authority’s (IPA) Transforming Infrastructure Performance strategy (TIP). The outputs from this challenge aim to create the conditions necessary to deliver buildings with greater certainty of meeting budget and timescales for delivery, 50% faster and 33% cheaper than at present, while halving the lifetime carbon emissions and eliminating the productivity gap between the sector and the rest of the economy.

Q1) What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

6. Off-site manufacturing offers the opportunity to deliver buildings and infrastructure in a way that mirrors advanced manufacturing sectors such as automotive and aerospace. Such an approach should lead to faster, lower cost construction, increased productivity and quality (by standardising the
production system and processes), a diversification of the workforce geographically and greater certainty in the delivery of construction projects.

7. Clients are increasingly concerned with building performance and operational costs. Buildings account for around 40% of total energy consumption and 20% of our greenhouse gas emissions\(^{64}\), yet new buildings are consuming on average 3.5 times more energy than they are designed to.\(^{65}\) Digital and manufacturing technologies will enable better design and modelling of buildings, improved project management and facilitate the incorporation of new technologies, such as sensors, smart systems and next generation materials that enable generation, storage and management of energy.

8. For example, the SPECIFIC Innovation Knowledge Centre – jointly funded by Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK - has built the Active Classroom at Swansea University to demonstrate how cutting edge technologies (that are not yet commercially available) can be integrated into a single-storey teaching facility. The facility can generate, store and release its own solar energy and has been running off-grid for the past year.

9. Off-site manufacture provides an opportunity to more easily facilitate the incorporation of digital technologies into the design of buildings, as the modular approach and robust advanced manufacturing processes lead to greater consistency of key components. Digital technologies also offer the potential to better understand building performance during occupation, for example through networks of sensors, helping in turn to inform future design requirements. EPSRC and Innovate UK currently fund the Centre for Smart Infrastructure and Construction at Cambridge University which is a centre of excellence in the area of sensors and data analysis for infrastructure.

10. The digital design and manufacture of buildings off-site offers the potential to significantly improve the safety of buildings through more robust certification of components and standardised systems of assembly, tracked through digital models.

11. Current construction is labour intensive and relies on an ageing and migrant workforce with artisan skills.\(^{66}\) 30% of the construction workforce are expected to retire in the next ten years.\(^{67}\) For the current construction workforce to meet the demand of the National Infrastructure Pipeline, a 22% increase in labour productivity would be required. Moving towards off-site would enable the sector to plug that gap and shift towards a higher productivity model.

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\(^{64}\) House of Commons Climate Change Committee
https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/705/705.pdf


\(^{67}\) Figures from the Office of National Statistics Labour Force Survey and the Construction industry Training Board
12. Perceived drawbacks of offsite manufacture include increased restriction on creative architectural design and flexibility. This is addressed in question 5. Limitations in the level of flexibility to make changes to a building on-site may also be seen as restrictive.

Q2) What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?

13. Surveys of the construction industry and case studies of specific projects point to the following key barriers to wider uptake of off-site manufacturing approaches: a lack of investment in innovation; entrenched cultural practices within the design and construction sectors, in particular their reluctance to break from their existing, established networks of contracting bodies and/or architects; transport and logistics barriers; the availability of key skills; and the ability to undertake off-site construction across the supply chain.

14. The ISCF challenge is closely aligned to, and will work with, the Sector Deal and the Transforming Infrastructure Performance (TIP)\(^68\) programme to overcome these barriers, enabling faster delivery of high performance “smart” buildings and accelerating the industry’s adoption of new materials and technology developed by the UK’s research base by leveraging public money to de-risk and unlock increased levels of matched private investment. The TIP will use government’s purchasing power to build critical mass in sectors amenable to modern construction methods (including offsite manufacture), starting with five government departments working together under the IPA’s guidance to develop a presumption in favour of off-site construction from 2019. The Transforming Construction Challenge will develop the standardised designs and processes for government clients to create an open marketplace for off-site solutions.

Q3) It is often claimed that offsite manufacture can lead to: • lower costs, faster delivery and increased quality; • increased productivity; • improved health and safety; • greater provision of new, affordable housing. What is the evidence for this?

15. Moving the industry towards offsite manufacturing could yield a 5–10 times labour productivity improvement\(^69\) reducing the demand on traditional skilled labour while creating skilled factory jobs. The production of components in controlled factory environments will require fewer workers to be on construction sites, thereby improving safety. This is evidenced by case studies collected by McKinsey in its report to the Construction Leadership

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Council of February 2017. The opportunity to incorporate advanced energy
generation, storage and release technologies at the point of manufacture,
means the affordability of housing can be further improved by addressing
fuel poverty and reducing or eliminating grid dependence.

**Q4) What re-skilling of the construction workforce is required to
facilitate a change to more off-site manufacture for construction?**

16. A move towards off-site manufacture for construction will see the creation of
both skilled and low-skilled factory jobs, as well as changes in roles on-site.
Advanced skills through PhD training is a key tool in facilitating the change to
off-site manufacturing. Off-site manufacture will require a workforce that has
capabilities in management, digital design, data science, systems
engineering, materials, robotics and manufacturing; collaborative doctoral
training provides the construction sector with the opportunity to adopt
smarter, more modern methods by drawing on this diverse pool of expertise.

17. Supply of skilled people within off-site manufacturing of high value steel,
glass and coatings, for example, will become increasingly important, in
particular when coupled with an understanding of the on-site challenges of
construction. EPSRC funds a number of Centres or Doctoral Training in
relevant areas of manufacturing research; one example is the COATED2 CDT
which is training over 50 students in industrial coating technologies relevant
to off-site manufacture of high-value coated steel products. In a project run
under the Digital Build Britain programme with the Ministry of Justice, low
skilled work to produce high quality manufactured components for
construction was carried out by offenders as part of their rehabilitation.70

**Q5) Can the benefits of standardisation and factory manufacture be
realised without hampering architectural ambition? If so, how?**

18. It is likely that the more widespread adoption of off-site construction will
change the role of the architect, and require a different set of skills and
approaches. There will still be huge scope for creativity, however. The
Transforming Construction Challenge seeks to develop an open platform
approach to standardising processes and component families for social
infrastructure.70 This will still involve bespoke solutions being found for
individual building projects, but using manufactured components based on
standardised sizing and ways of fitting these together to ensure quality. This
should also encourage a wider diversity of components and make it easier for
manufacturers to incorporate novel materials and technologies, for example a
solar generating roof versus a more traditional material. Modularised
components still offer design choice, especially where factory processes such
as advanced coatings offer added functionality as well as aesthetic quality
and difference.

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70 Platforms – Bridging the Gap between Construction and Manufacturing (2018) Digital
Built Britain
https://www.cdbb.cam.ac.uk/Resources/ResoucePublications/2018Platforms_Bridgingthe
gapbetweenconstructionandmanufacturing.pdf/view
Q6) What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

19. The ISCF Challenge will make up to £170m of funding available between July 2018 and March 2022. This will provide the programme, facilities and grant support for the construction, manufacturing, energy and digital sectors to come together and overcome the barriers to wider adoption of digital manufacturing for construction. It is vital that projects are truly cross-sectoral and interdisciplinary in order that the full potential of the ISCF Challenge can be realised, which will foster a greater understanding of how to overcome non-technical barriers such as public and professional attitudes, supply chain management, changes to working culture and professional identity.

20. The ISCF Challenge will support research and development to tackle the three main elements in the whole lifecycle cost of built assets: designing and managing buildings (through digitally-enabled performance management); constructing quality buildings faster (through a manufacturing approach); and powering buildings (through embedded active energy technologies).

Q7) What changes could be made to public procurement processes to encourage more sustainable practises in the construction industry and facilitate off-site manufacture?

21. TIP is part of a shift towards taking a whole-life performance and whole-life value approach to the procurement of built assets. This means balancing cost drivers on delivering the asset against through-life use, as well as considering the value of the services the asset enables and how to maximise these. A key feature of the ISCF Challenge will be research and development to better understand how to optimise such an approach and enable a shift to procuring on outcomes for a built asset. This covers readily measurable outcomes such as energy performance through to harder to currently ascribe objectives such as pupil performance in schools.

About the UK Research and Innovation councils.

22. UK Research and Innovation brings together the UK Research Councils, Innovate UK and Research England into a single organisation to create the best environment for research and innovation to flourish. Three of the councils have a focus on off-site manufacturing in the construction industry: Innovate UK, The Engineering and Physical Sciences Research Council (EPSRC) and The Economic and Social Research Council (ESRC).

23. Innovate UK drives productivity and growth by supporting businesses to realise the potential of new technologies and make them a commercial success. Since 2007, Innovate UK has invested £2.2 billion in business-led innovation projects, matched by a similar amount in partner and business funding. This has enabled around 8,000 organisations to add £16 billion in added value to the UK economy and create nearly 70,000 jobs. Within the built environment sector more specifically, Innovate UK has to date invested

71 Innovate UK delivery plan 2017-18
more than £80 million in over 600 projects that have supported the development and adoption of more modern methods of construction.

24. EPSRC invests in world-leading research and postgraduate training for future UK prosperity, leading to a healthy, connected, resilient and productive nation. Our £4.6 billion research and training portfolio attracts £1.2 billion additional investment from over 3,800 business and other partners, contributing to £80 billion of economic activity and cost savings. EPSRC has a current portfolio of over 125 research and training grants, having invested a total of £295 million in research that is of wider interest to the construction sector. This underpinning and enabling investment is crucial in enabling the next generation of innovation to support transformation in the sector.

25. ESRC funds research on the social and economic questions facing us today. It supports the development and training of the UK’s future social scientists and also funds major studies that provide the infrastructure for research. ESRC supports research and evidence synthesis around housing through the UK Collaborative Centre for Housing Evidence (CaCHE). Through our research grants call we have supported research into innovation in the construction industry, policy incentives for affordable home building, and understanding the motivations and experiences of self-builders.

3 May 2018
Rethinking the Inevitable: The future of Construction Industry in the UK

Terms of reference
This report serves as the University of Brighton, School of Environment and Technology response to the Call for Evidence launched by The House of Lords Science and Technology Committee as a part of The House’s inquiry into off-site manufacture for construction. It sets out to answer some of the challenges put forward within the call and to draw attention to some additional points which authors believe are important in this regard. It is not meant to be an exhaustive document but aims to offer a holistic solution if this matter is to be taken into consideration by The House to help the construction industry break out of the deadlock it is currently in.

Definitions
Different studies, reports, documents and commissions have used different terminologies to denote alternative, novel and emerging approaches to construction methods and technologies including but not limited to off-site manufacturing (OSM). While the authors of this report does not challenge any connotation suggested by the precedent cases, they feel the need to emphasise that a common denominator of all those non-conventional approaches, referred to thus far in any form or shape, is to shift as many activities which were conventionally carried out on-site in the process of construction of a building to a controlled environment of a factory typically known to be, but not necessarily, off-site as possible. For a comprehensive account of terminologies denoting non-conventional methods of construction please refer to Piroozfar and Farr (2013).

Introduction
The construction industry in the UK is one of the largest sources of economic output with an average contribution of 6% to the gross value added (HoC 2016). In 2016, it was the second largest industry in terms of employment with 311,380 employees (ONS 2016). It is also considered one of the most fragmented industries, both vertically and horizontally, amongst all. Small to medium enterprises (SMEs) form 99.9% of active businesses while large companies account for only 0.01% of the sector (ONS 2016). As of the beginning of 2015, with just under a fifth of all SMEs working in the construction industry and a self-employment rate of 40% (compared to an average of 15%), it ranks the highest in both number of SMEs and rate of self-employment across the whole economy (BSI 2015).

On the other hand, the construction industry is admittedly more conservative in introducing change, embracing new technologies, investigating emerging processes, adapting alternative approaches and models, developing novel systems and innovative solutions, adopting advanced materials and investing in R&D. To respond to an industry-wide call to address such issues, targeting local and national markets with an eye on international leadership, a number of academic, industry-led and practice-based research projects and task force reports have been commissioned, funded and carried out. Latham 1994, Egan 1998, Venables et al. 2004, NHBC 2006, Wolstenholme 2009, HCA 2010, Fox et
al. 2011, Farmer 2016, are just to name a few. The aim has been to particularly facilitate pragmatic ways to help the construction industry tackle some of aforementioned issues where one of the common denominators has been higher uptake of OSM. Classically fashionable, a desire to follow the footsteps of other industries has overshadowed a sustained and continuous improvement in the construction industry. For instance, the industry has long been suffering from recurring bouts of Henry Ford Syndrome: Why can we not mass-produce houses, standard, well-designed, at low cost – in the same way Ford mass-produced cars (Piroozfar and Farr 2013)? The stigma probably began as early as 1927 with a manifesto in ‘Vers Une Architecture’: ‘Une maison est une machine-à-habiter’. The fact of the matter is however that: As much as a house – and the whole construction industry – needs to adopt and adapt to the ways in which a manufacturing product – for instance ‘a car’ – is being designed, procured and manufactured, a house simply is NOT a car and it may never be or become one. Although there have been attempts, evidence-based practice, and pockets of improvements in documented case-based success stories, the AEC industry still suffers, collectively and across its different sectors, from preoccupations, deficiencies, fixations, shortages and dearth of a holistic insight in those areas. The industry lags behind other industries in stepping into Industry 4.0 era and in keeping up with the pace at which other industries have already started this migration.

**Perceived advantages of off-site manufacture for construction**

Drivers for off-site manufacturing can be classified under different categories such as cost, time, quality, H&S, and sustainability each of which are perceived to offer some advantages (CIRIA 1999, 2000, Blismas et al. 2012). Higher sustainability standards, potential advantages in terms of build quality, speed of delivery, construction health and safety, energy-in-use, whole-life carbon footprint, and reduced transportation are also amongst widely believed advantages of off-site manufacture (CIC 2013). The GSK’s “Factory in a Box” reportedly cuts the construction programme by 67% and offers an estimated saving of 30% compared to the same facility built conventionally. Laing O’Rourke’s mnemonic, “70:60:30 towards 0”, describes the company’s aspiration for Design for Manufacture and Assembly (DFMA) as: 70% of any given project constructed using DFMA, leading to a 60% reduction of on-site labour and 30% reduction in programme – all in comparison to a traditionally constructed alternative, aiming for zero accidents and towards-zero carbon emissions (EEJ 2013). A study of embodied carbon and energy showed that a house built using an MMC (Modern Methods of Construction) (with timber frame and larch cladding had, in total, 34.6 tonnes CO2 (or 405 kgCO2/m2 of useable floor area) attributed to it. An alternative MMC with timber frame and brick cladding showed 45.6 tonnes CO2 in total (or 535 kgCO2/m2 of useable floor area). When compared to a traditionally built masonry house, where the total embodied carbon was 52 tonnes CO2 (or approximately 612 kgCO2/m2 of useable floor area), a saving of 33.4% for the first and 12.3% for the second MMC scenario were recorded. Attributed embodied energy figures follow the same pattern correspondingly (Monahan and Powell 2011). A study of current practices and future potential in MMC identified potential areas for reducing site waste (including packaging material waste streams and building product/material waste stream) for key types of MMC where volumetric systems scored the highest with an estimated reduction of 70-90% (WRAP 2007). A volumetric approach allowed a development to be completed with a quarter of the on-site labour required
using more established methods, reducing the on-site build time for the whole development from 39 to 16 weeks and on-site construction duration by half (NAO 2005).

Out of the total of 813,126 newly built homes in 2010 in Japan, 126,671 (15.6%) were estimated to be prefabricated (JPA 2012). Total newly built homes in the UK for the same period sums up at 136,990 (MHCLG 2011) with insignificant number of prefabricated units. In a submission to GCR, Steinhardt and Manley report that “many prefabricated home builders in Japan are very large and operate advanced manufacturing facilities, with the largest producing more than 10 thousands houses annually”, where the housing industry is pushing towards “mass customisability” (GCR 2015). A University of Brighton study into opportunities to facilitate knowledge and technology transfer from Japanese off-site housing sector to alleviate the housing shortage in the UK in 2017 investigated two major Japanese off-site housing providers in details to provide a basis for a cross-sectional survey of the UK construction industry. It revealed very interesting lessons which can be learnt from to take a more proactive approach to off-site construction. Table 1 demonstrates some of the findings of the study.

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72 About 84% of detached houses in Sweden use prefabricated timber elements. In Germany 9% of new residential building permits are for prefabricated buildings, while in the Netherlands 20% of all new housing use wood or concrete prefabrication (GCR 2015, DTI 2004)
Table 1: Japanese off-site housing – a comparative analysis of two off-site system providers (2017)

<table>
<thead>
<tr>
<th></th>
<th>Company A†</th>
<th></th>
<th>Company B†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-bedroom (50m²)</td>
<td>£1,630</td>
<td>£1,230</td>
<td></td>
</tr>
<tr>
<td>house</td>
<td>£81,500†</td>
<td>£61,500†</td>
<td></td>
</tr>
<tr>
<td>2-bedroom (70m²)</td>
<td>£114,100†</td>
<td>£86,100†</td>
<td></td>
</tr>
<tr>
<td>house</td>
<td>£163,000‡</td>
<td>£123,000‡</td>
<td></td>
</tr>
<tr>
<td>3-bedroom (100m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>house</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>Volumetric (box) steel frame system</td>
<td>Timber frame panelised system</td>
<td></td>
</tr>
<tr>
<td><strong>Number of factories</strong></td>
<td>Seven factories spread in different geographical locations in Japan</td>
<td>One large scale factory in special economic zone in the Philippines</td>
<td></td>
</tr>
<tr>
<td><strong>Factory</strong></td>
<td>Nominal representative</td>
<td>The entire company</td>
<td></td>
</tr>
<tr>
<td>Site area (m²)</td>
<td>77,000</td>
<td>540,000</td>
<td></td>
</tr>
<tr>
<td>Floor area (m²)</td>
<td>37,200</td>
<td>45,000</td>
<td></td>
</tr>
<tr>
<td>Building area (m²)</td>
<td>26,500</td>
<td>45,000 (mostly 1-story buildings)</td>
<td></td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td>Nominal representative</td>
<td>The entire company</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75 vol. units/day or 5.77 house/day</td>
<td>17.78 house/day (Ave. for Feb 2016)</td>
<td></td>
</tr>
<tr>
<td><strong>Number of labour</strong></td>
<td>276 (Nominal representative)</td>
<td>20,113 (Total)</td>
<td></td>
</tr>
<tr>
<td><strong>Portion of construction in factory (off-site)</strong></td>
<td>90%</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td><strong>Automation</strong></td>
<td>Highly automated using robotic arms and unit rotation chamber to reduce labour</td>
<td>Man-power based on use of cheap local labour</td>
<td></td>
</tr>
<tr>
<td><strong>Days of on-site assembly (for houses under 150 m²)</strong></td>
<td>1 day</td>
<td>5 days</td>
<td></td>
</tr>
<tr>
<td><strong>Days to complete on-site (for houses under 150 m²)</strong></td>
<td>About 30 days (22% of traditional construction length in Japan)</td>
<td>About 45 days (33% of traditional construction length in Japan)</td>
<td></td>
</tr>
</tbody>
</table>

† Anonymised to comply with research ethics and confidentiality agreements.
* In 2016, the nationwide average construction cost in Japan was 197,000 Yen/m² (~£1,298/m²) [http://japanpropertycentral.com](http://japanpropertycentral.com)
‡ Does not include land price, and transportation costs may vary depending on the distance between the production facility and the construction site

**Potential barriers to wider use of off-site manufacture**

It is believed that there are constraints to wider uptake of off-site manufacturing which can be classified under site, process and procurement constraint categories (CIRIA 1999, 2000, Blismas et al. 2012). There are no significant regulatory or other barriers from the housing sector for off-site construction methods (CIC 2013). The cost still remains a major perceived barrier where the
most expensive off-site manufacturing solutions have been reported to be more expensive than established methods by up to 30% (NAO 2005) and there are certainly significant commercial challenges to the increased use of offsite construction solutions (CIC 2013). It is evident that even in a country like Japan, where car manufacturing industry has been closely and proactively involved in housebuilding since 1960s and state-of-the-art has been transferred across on a regular basis, the cost is not the strongest aspect of off-site manufacturing (Table 1). This has not however been used as a stern excuse to reprimand, shelve or defer application of non-conventional approaches to construction. It is suggested that faster construction and reduced on-site work bring financial benefits to developers by less on-site inspection, less snagging, shorter borrowing period and earlier rent which can add up to £90/m2 (NAO 2005).

There still is a compelling need for a systematic LCCA (Life Cycle Cost Analysis) to take all direct and in-kind costs involved in the UK construction both off-site and conventional. Local [planning] requirements in certain locations may introduce variability which may jeopardise the cost-effective use of offsite solutions and make it more difficult for them to compete (CIC 2013). Skanska perceive barriers to off-site prefabrication as: i) the need for initial capital investment, ii) high transport costs and, iii) the financial instability of offsite manufacturers. They used an Innovate UK grant to pilot “Flying Factories” – a concept initially coined by ModCell, a company specialised in straw-bale construction – to fabricate fully serviced “utility cupboards” for flats in Phase1 at Battersea. Several allegedly successful attempts have been made to tackle or address one fragment or few pieces of what has now turned into a compartmentalised problem.

After Ronan Point disaster, industry-wide attempts have been made to avoid ‘the bad odour of prefabrication’ (Dietz 1971). Terms73 have been coined and efforts have been made to alleviate the repercussions of the tragedy with very limited to no avail. As a result, some psychological barriers to wider adoption of the alternative (non-conventional) methods of construction in the UK have existed to date and put off what is a natural choice in housebuilding in some other countries such as Germany, the Netherlands, Scandinavia and Japan. A significant number of industry-wide surveys have been carried out merely based on or to gauge stakeholders’ perceptions which have not been able to overcome the stigma of accidents associated with prefabrication. However, it is not believed that there are any significant barriers in the form of lack of awareness of offsite solutions on the part of house-builders or their supply chains (CIC 2013). Associating off-site manufacturing closely and unconditionally with mass-production (see Piroozfar and Farr 2013) has led some to believe that some elements of the offsite supply chain have created their own obstacles to the wider use of offsite solutions where the traditional expectations or understanding of the economies-of-scale may not seem evident (CIC 2013), whilst even the manufacturing industry as an originating discipline for mass-production has now long departed and dissociating itself from the concept of mass-production and its associated connotation of economies-of-scale (Piroozfar 2008).

Recommendations for UK Government actions

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73 Terms such as Off-Site Fabrication (OSF), Off-Site Manufacturing (OSM), Off-Site Production (OPS), Modern Methods of Construction (MMC) and the most recent “pre-manufacture”, just to name a few.
We live in an era in which technology is developing at an unprecedentedly fast pace, new materials are being developed, novel manufacturing techniques, engineering solutions, production/fabrication methods are being developed, facilitated and offered through Industry 4.0 internet-based solutions. If the UK construction industry is set out to keep up with this fast pace and win its global leadership role back, fundamental changes need to be introduced to guarantee continuous improvement models and techniques are in place, regularly monitored, constantly updated and strictly followed. Vertical and horizontal integration enabled through systemic thinking remain a key factor in achieving such industry-wide effort. It cannot be initiated, coordinated, driven, implemented and accomplished successfully unless the UK Government takes a more proactive role in this regard74.

It is therefore recommended that the UK Government invests in Research and Development to work collaboratively with both academia and the industry to establish a national Centre of Excellence for Research and Enterprise to nurture continuous innovation and improvement enabled through research, implementation, testing, monitoring and dissemination of the findings of comprehensive, systemic, integrative and holistic solutions devised, applied and evaluated to help the UK construction industry re-structure and re-equip itself with more agility, higher flexibility and better capability to fast-response proportionate to the pace of change. Areas to include in such a coordinated holistic approach include but is not limited to: design (including Design for Manufacturing and Design for Disassembly); production, manufacturing, fabrication and assembly; process and supply chain planning and management; transportation and logistics; skilled workforce and labour training; cash-flow, investment, business model and insurance; codes and regulations; sustainability, Life/Cost Cycle Assessment and Environmental Impact Assessment; Post Occupancy Evaluation and performance gap; H&S; decision-making and policy; and last but not least, innovation management, continuous improvement, productivity, facilitation and enablement.

26 April 2018

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74 As a precedent, the UK Government Construction Strategy 2011 (also known as BIM Mandate) has shown a very effective initiative taken by the UK Government to ensure that the UK construction industry is keeping up with the pace of BIM development worldwide. Reportedly, in just under 2 years, it helped the UK construction industry to catch up with if not exceed the levels world-leading construction industries had achieved in over a decade.
Definition:
Off-site manufacture is the production of non-volumetric components, such as pre-cast concrete walls, beams, flooring or volumetric (modules), such as bathrooms, kitchen pods etc. in a factory and their transport and erection into their final position onsite.

A. Perceived advantages of offsite manufacture for construction

1.1 **Off-site manufacture offers the opportunity** to employ an efficient production line and well-organized working environment. This leads to a) predictability of the daily output\(^{75}\), b) improved quality of the end product through standardised processes\(^{76}\), c) up to 70% reduction of material waste compared to conventional construction\(^{77}\), d) improved working conditions as employees are protected from harsh weather\(^{78}\), and e) sustainability (e.g. precast concrete manufacturing in the UK has reduced carbon emissions by 26%, mains water consumption by 31%, and waste to landfill by 95% over the period 2008 to 2016)\(^ {79}\).

1.2 The **main drawbacks** of off-site manufacture for construction are associated with: a) the transportation challenges of off-site manufactured “products”; mainly due to the size and weight of the prefabricated “products” and the potential shortage of space for trucks to manoeuvre onsite\(^{80}\), b) difficulty achieving economies of scale due to the customized nature of construction projects in terms of size, shape etc.\(^{81}\), and c) difficulty in making changes to designs at any stage of the construction project due to restrictions of factories’ production lines\(^{82}\).

1.3 The main **factors influencing clients** to choose off-site manufacture\(^{83}\) include the potential to achieve significant reductions in programme time and improved quality of the end product\(^{84}\) (e.g. Travelodge chose modular

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\(^{75}\) http://ciria.org/buildoffsite/downloads/off-site_production_june09.pdf
\(^{76}\) http://ciria.org/buildoffsite/downloads/off-site_production_june09.pdf
\(^{77}\) http://ciria.org/buildoffsite/downloads/off-site_production_june09.pdf
\(^{78}\) http://ciria.org/buildoffsite/downloads/off-site_production_june09.pdf
\(^{80}\) http://ciria.org/buildoffsite/downloads/off-site_production_june09.pdf
\(^{81}\) http://www.arcom.ac.uk/-docs/proceedings/ar2011-0105-0114_Pan_Arif.pdf
\(^{82}\) https://doi.org/10.1080/01446190601071821
\(^{83}\) https://doi.org/10.1080/01446190500184444
\(^{84}\) https://doi.org/10.1080/01446190500184444
construction for a new hotel in London that resulted in faster completion time leading to an increase in revenue of £179,000\textsuperscript{85}). **Contractors are influenced** by the opportunity for increased cash flow and turnover through self-production of the off-site “products”\textsuperscript{86}. **Architects and design engineers are likely to be influenced** by the opportunity to improve the quality and performance of their designs by the use of standardized and detailed off-site “products”. This should reduce the number of design errors which are a major cause of rework in construction and can add up to around 5% of the total construction costs\textsuperscript{87}.

2.1 One of the objectives of offsite manufacture is to **reduce total construction cost** (capex) (in particular due to improved certainty of delivery and reduced programme times) however there is surprisingly limited data and evidence to verify this. A comparison of the total cost of eight case studies undertaken in the UK, Spain, Canada and USA and covering a wide range of project types such as housing, education, health care, retail, and industrial facilities, concluded that modular construction achieves on average a 16% cost reduction compared to conventional construction (Figure 1)\textsuperscript{88}. Seven out of these eight case studies were also compared in terms of programme time and it was found that this is reduced on average by 39%, with a maximum reduction of 60% down to a minimum of 25%, when compared to conventional construction (Figure 2)\textsuperscript{89}. The main reason for this programme time reduction is that off-site manufacture allows several tasks to progress in parallel (e.g. whilst the foundation is being constructed in-situ, the superstructure can be prepared off-site).

2.2 **Off-site manufacture can increase productivity** as labour costs may be reduced due to improved efficiencies in a factory setting as many of the detrimental factors reducing productivity on conventional sites are removed. A survey carried out in the USA, evaluated the impact on labour productivity

\textsuperscript{85} http://www.designforhomes.org/wp-content/uploads/2012/03/ModularSteel.pdf
\textsuperscript{86} http://www.arcom.ac.uk/-docs/proceedings/ar2013-0667-0677_Vernikos_Nelson_Goodier_Robery.pdf
\textsuperscript{87} https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9364%282009%29135%3A3%2828187%29
\textsuperscript{88} http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report
\textsuperscript{89} http://www.modular.org/HtmlPage.aspx?name=foundation_offsite_PMC_report
of 83 factors and concluded that the main causes of low productivity are related to mismanagement (e.g. availability, quality, and lack of construction equipment, materials, tools and consumables)\textsuperscript{90}. A survey in Hong Kong found that overcrowded sites and rework can reduce labour productivity by 5.1 to 13.6 man-hours per week per person\textsuperscript{91}. At present there are no cost effective or automated methods for monitoring productivity and the development of such methods, for example using computer vision techniques, offers a significant opportunity for the industry\textsuperscript{92}. Reducing labour costs is crucial for the improvement of construction. Note that labour productivity in construction globally has grown by just one percent per year over the past two decades\textsuperscript{93}.

2.3 **Health and safety** of construction workers is improved with off-site manufacture. A report on sustainability published by Buildoffsite\textsuperscript{94} shows that the UK manufacturing sector has 29\% less major injuries and 52\% less fatalities when compared to the UK construction sector. This conclusion is based on data provided by the Health and Safety Executive (HSE)\textsuperscript{95} (see Figure 3).

2.4 The potential for reduction of programme time and labour cost also applies to housing. In particular, the better quality of product implies that less maintenance will be required. A study by McKinsey reports that **housing projects can be built by up to 30\% less** if off-site manufacture is chosen\textsuperscript{96}.

B. Potential barriers to wider use of offsite manufacture

3. **Some drawbacks of off-site manufacture for construction** suggested by the top 100 UK housebuilders are as follows\textsuperscript{97}:

\textsuperscript{90} https://doi.org/10.1061/(ASCE)0733-9364(2009)135:5(397)
\textsuperscript{91} https://doi.org/10.1016/S0263-7863(03)00061-9
\textsuperscript{92} https://doi.org/10.17863/CAM.20613
\textsuperscript{94} https://www.buildoffsite.com/content/uploads/2013/01/Sustainability-Characteristics.pdf
\textsuperscript{95} http://www.hse.gov.uk/statistics/tables/
\textsuperscript{96} https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Urbanization/Tackling%20the%20worlds%20affordable%20housing%20challenge/MGI_Affordable_housing_Executive%20summary_October%202014.ashx
\textsuperscript{97} https://doi.org/10.1080/01446190600827058
a) 68% percent of the respondents identified the large capital cost required to build a facility for offsite manufacture as the primary barrier to adoption (e.g. the investment required for a factory in the US to build 12,500 houses per year is $30 million (≈ £21.6M))

b) 43% argued that it is difficult to achieve economies of scale with off-site manufacture because there is a lack of design standardization and lack of available product range,

c) 29% identified the difficulty involved in changing designs as a barrier, and
d) 29% of the respondents converged to the conclusion that the complex interfacing between building systems i.e. in-situ production/prefabrication, is also an important barrier.

4. At present, there is a skills shortage in the UK construction sector. With higher productivity in the factory environment it is expected that less workers will be required, however they will need to be trained in new techniques that differ depending on the levels of factories’ mechanisation and the type of off-site “manufactured” products. A survey has indicated that manufacturers tend to prefer employees with mainly general/semi-skilled abilities instead of traditional craft skills.

5. The potential constraint on architectural ambition can be overcome with innovative building materials and systems. The latest advances in façade technology allow differentiation of building aesthetics. For example, Laing O’Rourke’s off-site facility provides an unlimited variety of façade panels.

6. Research to support the development of more flexible production lines to expand the range of current products offered to the industry could help factories achieve the economies of scale and throughput needed to cover the original capital investment.

C. Government actions

7. The construction sector deal focuses on three key areas: a) procuring for value, b) industry led innovation, and c) skills for the future. Within these areas, work streams on digital engineering, manufacturing and performance provide a very comprehensive and robust programme. The sector deal provides a unique opportunity for implementing disruptive and transformative improvements in the construction sector that should deliver significant improvements in productivity and performance. The responders believe there is considerable scope to include provision for independent, objective research within the sector deal to obtain the evidence base and data required to

98 https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Urbanization/Tackling%20the%20worlds%20affordable%20housing%20challenge/MGI_Affordable_housing_Executive%20summary_October%202014.ashx
99 http://www3.imperial.ac.uk/pls/portallive/docs/1/40873.PDF
100 http://www3.imperial.ac.uk/pls/portallive/docs/1/40873.PDF
support policy decisions by government and industry. At present there is a
dearth of such evidence available in the construction industry as whole.

8. For the benefits of off-site manufacture to be realised, design for manufacture
and assembly needs to be adopted from the very start of the public
procurement process and not retrospectively introduced to modify a design
based on conventional construction methods. The maximum value is likely to
be achieved if the key stakeholders in the supply chain are also involved at
the earliest stage of the process. The public procurement approach
called “balanced scoreboard” that has recently been adopted in the UK to promote
criteria such as sustainability alongside profit could be extended to promote
off-site manufacture as well. This might be achieved by specifying the use of
off-site manufacture at the tender stage. (e.g. design complexity, location,
size) of each project type (e.g. housing, health-care, and education).

D. RECOMMENDATIONS

9. Implement an independent academic study to demonstrate the value of off-
site manufacture across different sectors in the industry. CIRIA is currently
planning a small pilot study to this effect however a more extensive and
detailed investigation should be supported.

10. Implement research, in collaboration with the supply chain, to design and
implement standard but flexible interfaces and joints between building
components and services.

11. Establish new procurement strategies to incentivise off-site manufacture
by including whole life performance and sustainability criteria in the
evaluation process.

12. Provision of a longer term pipeline of projects suitable for off-site
manufacture, supported by framework agreements to provide certainty of
long term demand, will incentivise the large capital investment needed to
build the factories required to deliver the off-site components.

13. Support development of digital design configurators and tools to facilitate
off-site construction.

14. Support both academic and vocational training schemes for stakeholders
(e.g. architects, design engineers, procurement teams, clients, contractors,
supply chain partners and operatives) on the off-site building systems and
processes. For example, the Construction Engineering Masters Programme
(CEM) at the University of Cambridge educates emerging leaders in the
construction industry on the innovations needed to transform the construction
sector and more specifically, the implementation of the latest digital
engineering and off-site manufacturing technologies.

26 April 2018

t_data/file/560247/Balanced_Scorecard_paper.pdf
104 https://www.construction.cam.ac.uk/
The following evidence gathered is of particular relevance to offsite manufacturing for construction in the domestic sector in the UK. Offsite manufacturing for construction is referred to in this report as the process of planning, designing, fabricating, transporting and assembling building elements for rapid site assembly to a greater degree of finish than in traditional on-site construction (Blismas and Wakefield 2009).

Evidence described in this report has been drawn out of a study conducted by Oliveira et al., (2017) entitled ‘Making modular stack up - modern methods of construction in social housing’ and prepared in partnership with seven housing associations from across the east of England led by the Flagship Group.

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Questions 1, 4 and 6 outlined in the call have been responded to as below using numbered paragraphs. Evidence described below has been drawn out of a study conducted by Oliveira et al., (2017) entitled ‘Making modular stack up - modern methods of construction in social housing’ that gathered both secondary and primary data to examine effects of different modes of offsite delivery in the context of social housing in the UK. Primary data included four case studies represented by architecture firms including nine participants. In all instances participants had over 5 years’ experience working on housing projects using offsite methods of delivery. In some instances, participants included partners and directors with over 20 years’ experience working in the housing sector using offsite modes of delivery. Secondary data included academic and grey literature including organizational, governmental and institutional resources.

Question 1) Perceived advantages of offsite manufacture for construction:

1. Opportunities offered by offsite manufacture in the international domestic sector vary according to mode of delivery, however, are broadly suggested to be:

- **Construction waste reduction** as suggested by Jaillon et al., (2009)\textsuperscript{105}; Blismas and Wakefield (2009)\textsuperscript{106} to be on average 52% lower than traditional building. Jaillon et al., (2009) study is based on questionnaires administered to 354 professionals in the building industry and actual field measurement of...


waste generation in fourteen recent building projects (this study was only focussed on residential buildings in Hong Kong).

- **Improved working conditions** as suggested by Blismas and Wakefield (2009). Blismas and Wakefield (2009) employed a variety of methods to collect data, which included industry workshops (3 workshops with forty-five participants, ranging from clients, designers, constructors, suppliers and researchers) including case studies (seven case examples, spanning four states) and interviews conducted across Australia.

1.2 Drawbacks to offsite manufacture in the domestic sector are:

- **Longer lead in times and accuracy upfront.** HCA (2010)\(^{107}\) reviews the output of the Design for Manufacture Competition 2005 focussing on the 10 winning schemes on site and up to completion. The study notes that the adoption of offsite can provide significant benefits, ensuring that methods used offsite correspond and connect with in-situ work.

- **Difficult financing and procurement.** The primary data collected in study conducted by Oliveira et al., (2017) echoes some of the observations made in the literature related to difficulties in procuring offsite housing projects due to established ways of working amongst mainly private housebuilders. In most instances participants in the research (discussed in section 3 of the report) observed the need for new procurement routes and an acknowledgement of the important place a manufacturer has in the process. In all instances procurement was viewed as directly related to the choice of material.

- **Poor supply base.** On the question regarding the commercial integrity of suppliers being an issue for future supply, Kempton (2010)\(^ {108}\) notes that economic climate is a key factor in the responses received.

- **Issues with maintenance.** Long term maintenance and management was viewed in the study conducted by Oliveira et al., (2017) as either dependant on client preference of mode of delivery and or choice of material. Obstacles were seen in how products were warranted; with many manufacturers providing warranties based on assembly in factory – not on site. Access to modules in order to manage repairs was also discussed as a key component of long term management in order not to end up removing large areas of the building fabric to repair small problems.

1.2 Factors likely to influence architects in deciding whether to choose offsite manufacture are:

- **Established capacity and capabilities** in designing with particular manufacturers and working in certain materials (for instance volumetric vs panelised and CLT vs steel). Most participants discussed the evolution of offsite housing design capability in their firm as led by building a large offsite profile. For example, one of the participants discussed the importance of building a profile linked to a reputation in a particular mode of delivery and material capability.

- **Environmental and sustainability aspirations** of a practice. In addition to describing choice of material as key to expertise regarding offsite housing, often the choice was justified in environmental terms and overall

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sustainability aspirations of the practice. One of the participants describes choice of CLT in this instance as superior to concrete or steel based primarily on environmental terms as well as on ease of construction.

- **Reputation.** One of the participants described how his firm developed expertise in offsite housing design by speaking to a lot of different manufacturers thereby ‘developing a reputation for being interested’. This then led to one of the manufacturers (turned developers) approaching them to design offsite system housing.

**Question 4) Reskilling of construction workforce**

Whilst the study conducted by Oliveira et al., (2017) did not focus on reskilling needed in the wider construction sector, it did identify key issues of particular relevance to design professionals especially architects working in the housing sector. Reskilling is identified as being required both at the firm/organizational level as well as project team/individual levels to include:

**At the firm/organizational level**

- Developing **social skills** in communicating and obtaining influence and support from the wider supply chain. Most participants described the need to gain support and obtain influence throughout the supply chain. Participants discuss ‘hands on involvement’ from helping ‘set up the factory’ so that better standard of fittings and fixtures are used to getting contractors involved early. One of the participants suggests those making components also need to be involved in their design. Support was viewed as needed from a client, manufacturer but also local authority, planners and associated stakeholders to ensure a particular mode of delivery (whether specific material choice or mode (volumetric, hybrid or panelised) is considered early.

- Developing **organizational abilities** to invest and resource teams earlier in projects. In addition to investing time and resource early in the process, participants discuss offering more during tender in order to enable accurate pricing.

- Enabling **attitudes of after care** especially with regards to handover approaches and follow up.

- **Business model innovation** to enable innovating procurement methods including partnerships to limit issues with the supply chain of what become major subcontract packages with major implications for delay and payments.

**At the team/individual level**

- Developing **technological skills** and knowledge in material capabilities and modes of delivery

- Developing **information management abilities.** Coherent and manageable handover information and links through BIM/Digital Design development. Information management is key to successful installation and maintenance of off-site methods linked to developments of BIM and improved handover information generally.

- Developing **analytical skills** to review offsite construction systems against sustainable design requirements regarding climate change predictions.

**Question 6) Research and Development needed**

546
Overall a number of areas are identified in study conducted by Oliveira et al., (2017) as needing further research and development including:

- **Post occupancy evaluations** of completed housing focusing in particular on resident experiences and performance of systems. There is a dearth of published empirical post occupancy studies of housing developed and built using offsite methods. Resident preferences and expectations are often viewed as key barriers to wider uptake of offsite delivered housing in the UK (NHBC 2016\(^{109}\)). Evidence gathering resident views of living in housing delivered using offsite construction is greatly needed.

- **Understanding of the differences in offsite design and build processes** mapped against different modes of delivery. There is little empirical evidence available and even less discussion that relates to differences between different levels of off-site construction.

- **Guidance** for housing associations that discusses approaches to offsite construction delivery applicable to social housing in particular is suggested to be required

26 April 2018


NHBC Foundation
Response overview
Six years of R&D and investment into modular came to fruition for Urban Splash in 2018 when the company acquired its own offsite construction factory, vertically integrating its modular operations into its core property development and regeneration business.

Founded in 1993, the core business has won more than 400 awards for its innovative approach to urban regeneration and redevelopment which has seen it transform disused buildings, sites and brownfield land across the country into contemporary spaces in which people can live, work and play.

Driven by a desire to not only challenge the identikit approach of volume housebuilders – by giving its customers choice and the option to customize their homes – but also to help increase efficient housing production in the UK, Urban Splash began investing in its offsite concept in 2012. The company’s first foray in modular construction had come in 2006 when it created the Moho modular apartment scheme in Manchester. Then, working primarily with architect shedkm, the company began developing ideas for an adaptable, customizable Town House which would work within urban environments around the UK.

The result, Urban Splash Town House, was first launched in 2016 at the New Islington site in Manchester; 43 Houses are now completed, sold and fully occupied there, each of them designed by its owner who chose from either a 1000 sq. ft., two storey or 1500 sq. ft., three storey option before then commanding a layout suitable for their requirements. Thanks to non-load bearing walls the layout can be changed in the future.

The sales success of the first scheme, which demonstrated a strong demand for modular housing meant that Urban Splash soon began creating the product for other developments; 72 Town Houses swiftly followed at Irwell Riverside – with two and three storey homes available – just three of which remain on the market – whilst in May 2017, 24 Town Houses were assembled at Smith’s Dock in North Shields, where just four remain on sale. Planning was granted in late 2017 for Town Houses at a site in central Birmingham.

In March 2018 Urban Splash teamed up with architect, TV presenter and modular construction advocate George Clarke to develop 10 two-storey homes known as Fab House; created in the same offsite environment as the Town House option. The properties are now installed on site at Smith’s Dock in North Shields and launched for sale in March / April; they were visited by more than 500 people on the opening weekend. George’s MOBIE (Ministry of Building Innovation and Education) concept is the educational charity for home design innovation and advanced manufacturing – it is the chosen charity and educational charity of House.

During this process in February 2018, Urban Splash completed its acquisition of the former SIG Building Systems factory in which all of its modular products had
been created. By vertically integrating the factory, operations and 70 colleagues, the company has streamlined and taken control of the production of its Houses.

It now has plans to roll out two further housing typologies, including an apartment concept created using modular, with capacity to create 400 dwellings per year.

26 April 2018
Executive summary

The situation now:

- The Construction industry is traditionally craft based, manual tasks are similar to those of ‘fitters’ in manufacturing industry 40 years ago;
- Supply chains suffer contention and are not well integrated in terms of knowledge, business objective or risk-sharing; business quotes often include cost of litigation;
- There is an unbalanced focus on reduction of capital cost rather than optimisation of operational cost reduction or whole-life value;
- ‘As built’ is often not ‘As designed’; separate ‘cost engineering’ can erode quality, safety and cost of operation;
- Cost and time overruns are unpredictable and rife;
- There is considerable materials wastage (some commentators suggest 30%);
- There is much to be learned from modern manufacturing and operating practice;
  - Digital tools used to create and evolve specifications interactively with clients
  - Design for manufacture and assembly
  - Digitally-integrated knowledge and information flows from design to manufacture (BIM-CAD-CAM)
  - Well-connected, objective-sharing supply chains
  - ‘Right first time’ principles
  - Predictive maintenance and ‘Smart Facilities Management’
  - Performance assurance through on-line monitoring.

The situation as it might be if Offsite Manufacture (and possibly on-site Automated Assembly) were adopted:

- Reduced build time, build time and cost variability and hence reduced risk;
- Reduced whole-life expenditure, and better maintainability;
- Altered workforce skills needs;
- ‘As-built’ specifications that meet clients’ requirements, with new features potentially available;
- Potential, with in-use live performance monitoring, of new, evolved business models;
- Materials uniquely identified, logged and tracked electronically to assist maintenance and re-use at end-of-life.

The principle blockers are associated with corporate culture and behaviours on the part of clients, finance houses and construction companies with their associated supply chain partners. The technologies to support off-site manufacture and automated on-site assembly are largely available, or ready for
scale-up. Demonstration at scale is vital to establish confidence in capability and market momentum.

**Perceived advantages of Offsite Manufacture for Construction**

1.1 Opportunities include reduced construction time and risk, potential for lower whole life costs (TOTEX) – although material costs may be higher in the first instance – and buildings that match their design objectives. An associated drive towards standardisation of components, sub-assemblies and methods has the potential to drive down material costs through economies of scale. Standardisation also helps simplify assembly techniques and training needs.

1.2 Positive claims are evidenced both by comparison with manufacturing industries, where the principles under discussion have been in place for many decades (e.g. in the automotive sector), and where finished products are assembled from automatically fabricated components without the need for human fitters. Evidence is also available from large construction projects, such as those undertaken by General Electric (GE) for the pharmaceuticals industry. Evidence is also beginning to emerge from house-builders in the UK.

**Barriers to wider use of Offsite Manufacture**

1.3 Drawbacks include a potential reduction in the ability to make late changes during construction, elevated material/component costs (although this may be more than offset by reduced wastage and by ultimate economies of scale), a constraint on design flexibility (perceived by architects) and perhaps by an initial skills insufficiency. The necessary investment in large manufacturing plant is an inhibitor, but recent developments (for example by ZedFactory) have used temporary, smaller-scale ‘pop-up’ factories, mitigating this issue. Manufacturing close to the point of consumption is an important consideration in minimising the logistics overhead.

1.4 With the introduction of offsite Manufacturing and on-site Automated Assembly, the need for traditional ‘fitting-centred’ manual building skills will diminish. However, the demand for professional engineers and technical staff with systems design and integration expertise will increase. This may be aligned with a trend towards ‘vertical integration’ in major construction and services companies. Moreover, offsite manufacturing plant will require a range of human activities from manual handling of raw materials and finished goods to production engineering, materials science, test analytics, design and management.

1.5 There are examples of how modular standardisation of building sub-systems and elements has not unduly inhibited architectural design freedom or

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110 [https://www.theengineer.co.uk/issues/january-2013-online/prefab-pharma/](https://www.theengineer.co.uk/issues/january-2013-online/prefab-pharma/)
112 [https://www.zedfactory.com/](https://www.zedfactory.com/)
aesthetics. Japan was one of the first countries to deploy apartment modules in high-rise residential buildings. To make the overall design more attractive, the modules can be arranged with different angular dispositions (rather than in a regular array). This gives the impression of design flexibility without losing the benefits of offsite manufacture, although architects may still complain about the constraints it imposes.

1.6 The R&D needs of the sector may centre more on socio-technical interfaces than pure technology, but they nevertheless span all Technology Readiness Levels. At low (1 – 4) TRLs, better understanding is needed of the drivers and methods for changing corporate cultures (including new business models for build and use), communicating design intent down supply chains and sharing both risk and the benefits of innovation. R&D at higher (close to deployment) TRLs, needs to focus on the demonstration of technologies and at-scale applications of off-site manufacture and on-site assembly. Also, the technical and economic factors associated with off-site manufacturing close to the point of consumption should be investigated. In use monitoring (e.g. via Internet of Things devices) is also an important theme with the ability to drive down Opex. Cybersecurity must be designed in from the start for in-use monitoring and control systems (BMS), and research is needed in this area. Recent off-site example cases have used aerospace manufacturing approaches (e.g. GE have been commissioned to build modular pharmaceutical factories), but this approach may not be the ultimate destination for the sector. Lessons from excellence in design for manufacture and ‘right first time’ may be better exemplified by the automotive sector.

Government actions

1.7 While there is a ‘burning platform’ with respect to housing shortages in the UK, and government action has been promised to address this, the urgency to adopt new technologies by the construction sector has yet to fully hit home. This is likely to change given the low margins and high risk endemic in the sector. Drivers for change in the sector include all aspects of ‘digitalisation’, importantly the adoption of Building Information Modelling (BIM level 2 is mandatory for government projects) Digital Built Britain, and advances in operational monitoring. (The latter may make new variants of PFI attractive again, as comprehensive digitalised views of operational performance become available.) This highly conservative and craft-centred sector has been generally slow to adopt new technologies, but innovation does diffuse in both directions in the supply chain. It is likely that the deeper involvement of the client, beyond initial specification to improve the likelihood that ‘as built’ matches ‘as designed’ will help. Technologies (e.g. visualisation) that promote this enhanced engagement will be of significant value.

1.8 Government procurement policies seem to be an effective alternative to regulation in achieving target outcomes, although more track record is needed to properly evidence their effectiveness. Additionally, the influence of

government procurement policies on creating ‘best practice’ that is substantially emulated in the private sector might be hoped for, but is not clearly evident. Off-site manufacturing has the potential to reduce capital cost variability, and dynamic monitoring of performance in use can positively impact operation costs, so both might be elements of future government contracts, and could be considered as important procurement levers.

Biographical note

Jeremy Watson CBE FREng is Vice-Dean in the UCL Faculty of Engineering Sciences and Professor of Engineering Systems in the Department of Science, Technology, Engineering and Public Policy, he is also Director of the £25m PETRAS Cybersecurity of the Internet of Things research hub. Concurrently, Jeremy is Chief Scientist and Engineer at the Building Research Establishment (BRE). He was previously Arup’s Global Research Director, and Chief Scientific Advisor in the Department of Communities and Local Government (DCLG). Jeremy has senior experience of research and technical direction in industry and universities, governing board membership at Innovate UK and EPSRC, plus service with NERC and HEFCE. He has served on two government SAGE panels and a Blackett Review on Cybersecurity of the Internet of Things. Jeremy was appointed to a one-year term as President of the Institution for Engineering and Technology in October 2016. He is a Fellow of the Royal Academy of Engineering (Chair of the Engineering Policy Committee and interim Policy Centre lead), the ICE and the IET.

23 April 2018

ANNEXE

Case studies

Industrial buildings

1. General Electric’s (GE) KUBio pharmaceuticals factory

KUBio, an innovative prefabricated factory on wheels for making biologics developed by GE Healthcare Life Sciences was used to produce a sixty-two module factory for the Taiwanese biologics manufacturer JHL Biotech site in Wuhan, China. The KUBio modules were produced in a controlled environment for quality control, where electrical, water and ventilation were installed and tested in Germany, Sweden and U.S. before travel to China.

- Key benefits / impact (cost saving, socioeconomic, agility, etc.)
  - Built in 550 days (from planning to use)
  - Lowers financial risk as manufacturing investment required later phases of drug development
  - Help JHL make affordable biologics for markets where they are otherwise prohibitively expensive
  - Manufacturing drugs in single-use disposable plastic containers eliminates the need for costly cleaning and sterilization
o Facilities can be smaller, and more efficient
o Configured to switch quickly between different drugs
o Achieving structural completion in such a short timeframe means more focus on testing and adding more infrastructure like power and site utilities.

2. Laing O’Rourke
Invested £104m in offsite manufacturing facility in Worksop and received £22m grant from Government. Now partnering with Stanhope and Network Homes for a five-year housing development programme for OSM using Laing O’Rourke’s DfMA 70:60:30 offsite manufacturing concept (if you can pre-assemble 70% of the project, you can reduce workforce by 60% and schedule by 30%).

Projects include:

In partnership with Stanhope and Network Homes, project worth £200m for 550 homes next to Southall railway station in west London – 350,000sqf development comprising of Build to Rent, market sale and 180 homes for shared ownership/affordable rent, plus 20,000sqf retail and commercial space and flexible work space for start-ups and local small businesses - Construction to start in 2019 for completion 2021.

At Two Fifty One, 41-storey residential tower in Elephant & Castle 70% of the frame and MEP systems are designed for offsite manufacture – lead to 50% cut in worker hours and 33% reduction in schedule time.

- Key benefits / impact (cost saving, socioeconomic, agility, etc.)
  o When fully operational factory unit will be capable of delivering 10,000 new homes a year – a third cheaper, in half the time with 50% saving in emissions
  o Over 1000 new sustainable jobs throughout supply chain
  o Help to deliver the UK Industrial Strategy for Construction; 33% lower costs, 50% faster deliver, 50% lower emissions and 50% improvement in the import export trade gap
  o 90% of the houses manufactured in factory – easier to control costs and quality simultaneously – due to stabilisation and consistency of people (the work force) and process.

- New opportunities
  o 21 ‘Best in class’ Consortium partners, including BRE allows for sharing the knowledge and skills
  o Permanently located factory-based work will diversify construction workforce, attracting a wider range of people

- Any blockers, technical or behavioural
  o £53.1m net loss in European operations in 2015 largely due to challenges with the new offsite manufacturing - In the UK Laing O’Rourke Construction Ltd racked-up another £26.6m in exceptional costs on contracts involving its offsite prefabrication plant
  o Production of firm’s prototype was delayed in 2016 due to equipment delays at the plant
- Collateral (unintended) consequences (good or bad)
o Fined £3.8m over death at offsite factory in Steetley, Worksop in 2014.

**Domestic buildings**

**3. Legal and General**
Developed modular housing prototype outside its factory in Leeds.

- Key benefits / impact (cost saving, socioeconomic, agility, etc.)
  - Leeds factory site is building capacity to produce 3000 of homes per year across eight production lines, employing hundreds of local people.
  - Constructing homes from CLT stores one tonne of CO₂ in every m³ of CLT
  - Homes use less energy to run
  - Less concrete foundations mean quicker, cheaper and easier build - time spent building onsite will be reduced by ~50% compared to traditional techniques

- New opportunities
  - Employment of over 400 workers at permanent factory in Leeds

- Any blockers, technical or behavioural
  - Factory required large up-front investment of £55m.

**4. House by Urban Splash, New Islington Manchester**
Urban Splash worked with architects Shedkm to produce offsite volumetric housing to develop 43 terraced Town Houses in New Islington in Manchester, built in factory and pods delivered onsite.

- Key benefits / impact (cost saving, socioeconomic, agility, etc.)
  - Flexibility allows owners to choose internal layout, colour and size of new home.
  - External cladding can be adapted to suit local requirements
  - Homes completed in 20 weeks (16 weeks for construction, 4 weeks for internal finishes)
  - Factory built – high standards and precision to keep on budget
  - Open plan, removing corridors – increasing point to point viewing distances by 80%.
  - Full height glazing to maximise daylight – bigger and lighter rooms – improves wellbeing

- Any blockers, technical or behavioural
  - Sequencing and coordinating delivery access of pods, location of cranes and landscaping of house plots needs careful consideration throughout process.

**Infrastructure**

**5. SES Engineering Services – Queensferry Crossing**
2.7km-long Queensferry Crossing spanning the Firth of Forth – the longest three-tower cable-stayed bridge in the world – towers 200m+ high and 23,000 miles of cable supporting 122 sections of road deck.
Key benefits / impact (cost saving, socioeconomic, agility, etc.)
  - Using BIM and prefabrication enabled reduced costs, programme time and amount of labour hours working at height – reduced time to two hours per module installation, calculated that its 100,000-hour build time was 25,000 hours less that if built bridge with traditional onsite methods.
  - BIM helped cost predictability and waste reduction.
  - Onsite Prism factory to produce prefabricated modules to reduce transport delivery times and costs – only required 2 lorries travelling 500 miles to deliver modules instead of the 60 lorries that would have travelled 24,000 miles if produced modules at original factory in York.

New opportunities
  - Set-up of new onsite Prism factory led to local jobs created.

*Case Study researcher: Katie Plumridge*
Tuesday 24 April 2018

Watch the meeting

Members present: Lord Patel (Chairman); Lord Borwick; Lord Fox; Lord Griffiths of Fforestfach; Lord Hunt of Chesterton; Lord Kakkar; Lord Mair; Lord Maxton; Baroness Morgan of Huyton; Lord Renfrew of Kaimsthorn; Lord Vallance of Tummel; Baroness Young of Old Scone.

Evidence Session No. 1 Heard in Public Questions 1 - 8

Examination of witnesses

Professor Jeremy Watson CBE, Phil Wilbraham and Professor Jennifer Whyte.

Q1 The Chairman: Good afternoon to our witnesses. Thank you for coming to help us with this inquiry today. Also welcome are those to whom we often refer as members of the public, but shall I say interested observers? I will start by asking you to introduce yourselves from my left so that we get it on record. If you want to make an opening comment, please do so before we start asking you questions that might help us with this inquiry.

Professor Jeremy Watson: I am professor of engineering systems at University College London and vice-dean of engineering sciences. I am concurrently the chief scientist and engineer at the Building Research Establishment—BRE. I split my time between those two. Previously, I spent some time with Arup as its global research director and was also in government as chief scientific adviser to the Department of Communities and Local Government, or the Ministry of Housing, Communities and Local Government, as I should say now. I spent most of my life as a practising electronic engineer in the manufacturing sector and moved into academe more recently. I also served as president of the Institution of Engineering and Technology last year, which was a formative and interesting thing to do.

I come to this whole challenge space from the point of view of inter- and multi-disciplinarity. In the concepts around construction you can draw some interesting analogies between different sectors; sectors that we believe perform well in cost and risk management. I might cite the electronics industry, ship manufacture and so on, where there is a very tight supply chain, both in the knowledge that is shared up and down it and open-book policies with respect to technology and costs. For example, you find that people who are competitive in the marketplaces share common technology platforms and understanding, and industry associations that are very strong and which set research agendas and so on.

For the construction industry we have a fantastic opportunity to transfer some of the culture and technology across from some of the more well-
formed manufacturing industries to replace some of the craft activity and
the fitting at the last minute in buildings where things are not necessarily
designed precisely before they are assembled, and the assembly
sequence and pattern at a systems level are not prescribed exactly in
many cases. We can transfer some of that information across and use
digital methodologies.

Chairman: We have a lot of questions to come and it was whether you
wanted to make a short statement about yourself.

Professor Jeremy Watson: I am sorry. I thought you meant about the
problem.

Chairman: Thank you very much. I do not want you to have to repeat it
when we ask the questions.

Professor Jennifer Whyte: I am a professor at Imperial College London
in the Department of Civil and Environmental Engineering. I have a Royal
Academy of Engineering Laing O’Rourke chair in systems integration. I
also lead the Centre for Systems Engineering and Innovation that has
themes around production systems, infrastructure interdependencies and
life cycle of infrastructure. I am involved in the Alan Turing
Institute/Lloyds Register Foundation programme on data-centric
engineering. I am a co-curator of the World Economic Forum Engineering
and Construction Transformation Map.

Phil Wilbraham: Many thanks for inviting me here this afternoon to talk
a little about how Heathrow Airport is using off-site manufacturing. I have
worked at Heathrow for about 20 years. I am currently the Heathrow
programme director for expansion, which means I am accountable for
delivering the third runway and all the infrastructure that goes with it.
Before that, I led the construction on terminal 5. I worked on that project
for 10 years, and then I led the construction on terminal 2. I am a civil
engineer. I am also involved with Constructing Excellence, where I am a
co-chair, and I am also co-chair of i3P, which is an infrastructure
innovation port.

My real interest at the moment is the third runway at Heathrow and how
we can do more off-site manufacturing and use our logistics hubs. We
intend to set up four of them around the country to consolidate loads, to
assemble things that have been made in factories around the hubs and to
bring things efficiently to Heathrow—to reduce the number of people we
need constructing and assembling at Heathrow and to ensure that we use
the full supply chain around the country as we expand Heathrow.

Q2

The Chairman: I will kick off with the first question. What factors make
people decide that the construction of anything or a major part of it could
be off-site? Who makes that crucial decision when you have architects,
civil engineers and others involved? What is it that makes them choose
off-site?

Professor Jeremy Watson: My immediate stab at that would be where
you have regularity and standardisation in the item you are constructing
from modular sub-elements, and where there is a cost saving, it might be
the architect but, equally, it might be the engineer who recognises the
opportunity for the client of off-site manufacture for cost and risk reduction.

Professor Jennifer Whyte: I think clients play a big role here and Phil will expand on that, I am sure. With off-site manufacture it is really important that you have the manufacturing expertise brought in earlier in the process. It is inefficient when design work has been done and it has to be done again. You end up doing it once in situ and then with an off-site methodology. It is important for off-site manufacturing to bring in that expertise around how things are made, manufactured and assembled earlier in the process.

Phil Wilbraham: I completely agree with that. It is really important to have an early decision that one is going to use some off-site manufacture. That decision probably comes from the client or the client’s representative, so either the client themselves or the project manager, the programme manager and so on. It is so important that the first stage of the design is carried out with off-site manufacture in mind, because otherwise designers will generally design the way they always have and we will get the same answer. It is really important to brief the designers to think about how they are going to design in a component-led way, because the real win here is if components are made in factories and they are the same again and again, and those components can be produced and used as the building or civil engineering infrastructure is constructed and assembled on site. Early decision-making probably has client or project management involvement.

There will be pull sometimes from the engineer, the architect or the supply chain when they have done this before. At the moment, because it is still quite a new idea, it needs some early input from the client. On a major piece of infrastructure some targets probably need to be set to enable the teams to understand that this is important. Of course, the reason we are doing this is, ultimately, to reduce cost and time and to get better quality and better health and safety, because it is safer to make things in a factory than it is to make them on-site.

Lord Fox: At the moment would you say that scale is perhaps the driver for considering off-site manufacture, in that making it on-site becomes much harder if it gets bigger? Is there also a political dimension? I do not want to drag you into the particular project you are involved in, but clearly spreading across a supply chain is possible when you do it off-site. Do political and scale considerations tend to be the drivers at the moment?

Phil Wilbraham: There are both those drivers. Scale is really important because if we deliver Heathrow’s expansion the same way we delivered Heathrow’s terminal 5 and terminal 2, we will be looking after about 15,000 colleagues on-site at peak during the construction. At terminal 5 it got up to about 8,000 or 9,000. We do not think that is a sensible scale to be operating a construction site. Therefore, to reduce that scale we need to do more work in different places. One of our drivers is to reduce the scale of what we do on the construction site.

The Chairman: When I asked the question I should have declared my interests. May I remind my colleagues that when you speak for the first
time you should declare your interests? You do not have to do it again after that. I have no interests to declare in relation to this inquiry.

**Lord Fox:** May I belatedly say that I have no interests related to this inquiry.

**Lord Hunt of Chesterton:** As regards interests, I am a fellow of the Royal Society, an honorary fellow of the Institution of Civil Engineers and I have a consulting company. I wanted to say that I did some research at the BRE back in the 1970s on how people got blown over when they went near tall buildings, so I have a connection.

What I was surprised about your three replies was that none of you said—which I thought you might have done—that with off-site you may be able to be more accurate and do things that are more complex and different from what you do when you are doing it on-site. Would you like to comment on that?

**Professor Jeremy Watson:** For me that was in the risk reduction. It was rolled into the more predictable assembly. Certainly, as you say, at BRE we have examples of domestic buildings that have been built off-site and assembled very quickly. In a visit we had the other day, visitors observed cracks in the traditionally built buildings after three months, but the ones that were made off-site fitted perfectly, exactly because the pieces were designed according to manufacturing techniques. I completely agree with you on accuracy and repeatability and I think that reflects in risk and cost reduction.

**Lord Maxton:** Building the third runway is your major concern, but you have other clients as well. I have heard airports jokingly described as “shops with runways”. You obviously have other clients. How do they fit in to the overall pattern of constructing?

**Phil Wilbraham:** You are absolutely right that there are other companies that build things at Heathrow and they develop shops, hotels and those sorts of things. Currently we require them to use some of our methods and encourage them to use others. For instance, at the moment we have a logistics hub at Heathrow—Colnbrook Logistics Centre—where we consolidate things, and if you are building a hotel you have to use our logistics system so that we know what is coming on- and off-site. The criticality at Heathrow is that we have 78 million passengers being served there and the building of a hotel or runway cannot get in the way of that huge operation. We need to control trucks coming into and off the site at Heathrow. We do that through consolidating loads. In that situation we will ask our partner to work with us. In the future, with our logistics hubs around the country, we want to share that knowledge and encourage people to use those. If there is a better way of building a hotel by making more of it in the Midlands, or whatever, one hopes that that will be used by the people who will come along as our partners to develop the rest of the infrastructure.

**Q3 Lord Renfrew of Kaimsthorn:** What are the main drawbacks to off-site manufacture for construction?
Professor Jeremy Watson CBE, University College London, Heathrow Airport and Professor Jennifer Whyte, Imperial College London – Oral evidence (QQ 1-8)

Professor Jeremy Watson: In the first instance there will be a cost element because we do not yet have the economies of scale. There are issues around standardisation reuse versus bespoke pieces and there is a whole scale of cost benefits and potential disadvantages there, but in the long term, when the whole system is geared up to do this as a norm, there are very few disadvantages.

Lord Renfrew of Kaimsthorn: Is not transportation sometimes a problem?

Professor Jeremy Watson: Indeed. Going back to BRE, one particular building was put up that required 60-tonne loads which were too large for some of the motorways so we had to choose the route. Again, that is a case of systems design, how you break it down and what granularity of the modularity you are seeking. The smaller you get it—think of Lego blocks—the more flexible you can be with the solution. Also, manufacturing close to the point of consumption, as was said by Phil, is absolutely key. We do not want one big factory off-site in the middle of the country and an overloaded infrastructure. There are some so-called pop-up factories these days. For some domestic buildings, for example from Bill Dunster’s ZEDfactory, they will put up a temporary manufacturing unit and take it down again when they have finished.

Lord Renfrew of Kaimsthorn: I see. That is interesting.

Professor Jeremy Watson: I hope I have answered some of those questions.

Professor Jennifer Whyte: The opportunities outweigh the drawbacks. There are a lot of opportunities around safety of workers, quality assurance, speed, productivity, reduction of waste, and greater traceability of materials. There is a need to do off-site well and thus a need to make decisions up front and to get tolerances right, so that when things come to be assembled on-site they fit together. There is a need to consider maintenance and maintainability. All these push us to think through the life of assets at that early phase so that when we are putting buildings together we have an idea about how we are going to get into bits of the building to maintain it.

That all pushes towards designers needing a greater understanding of manufacturing, assembly, maintenance and operational activities so that they can consider these up front in design. I completely agree that that is partly about thinking in terms of components and platform approaches to design. We are seeing some very good innovative thinking about that in the sector at the moment. Bryden Wood, for example, has done some work on that with the Centre for Digital Built Britain. In the Centre for Systems Engineering and Innovation that I lead we have research looking at design for manufacture and assembly and the processes needed to ensure that designers appreciate materials, maintenance and operation phases.

An example of that is on the Heathrow terminal 5 roof subproject. We did quite a lot of research on that. That was a location where I saw designers and subcontractors working together to understand materials and therefore being able to use standardised products and be quite innovative in the way that they thought about them and put them together.
**Phil Wilbrahram:** One example of a potential drawback is that the factory will work at a particular speed and the construction site at another. There have to be really good logistics between the site and the factory and the hub or whatever, because the factory will want to work at the speed it wants to work at to be efficient, to make it cheaper, but you have to tie that in with how fast you can build on-site. There are extra logistics, and construction becomes about logistics and assembly rather than the traditional construction where there are lots of people doing their different trades on-site, as Jeremy was saying earlier. We need to change the skill set of people and for them to understand that it is about logistics and assembly rather than about trades coming to site to finish things off.

**The Chairman:** That leads nicely to Baroness Morgan’s question, but Lord Griffiths first.

**Lord Griffiths of Fforestfach:** To what extent are architects part of the drawback? Successful private companies—the tech giants, say—can splash out on new campuses and so on, and they can attract the best architects who are going to make statements. But if you are constructing a public sector building and the taxpayer is ultimately financing it, and you are subject to the audit office and so on, to what extent, in the end, will this engineering process drive a wedge between these two worlds?

**Professor Jeremy Watson:** Architecture has to be viewed on a scale. At one end you have the signature architects—the Fosters of this world—and we admire their work and they are wonderful. At the other end you have the real pragmatic architects who are doing, as you say, the public works or even domestic buildings and so on. The signature end, going back to my Arup days, is a little averse to anything that drives the way it designs things. It is their idea and has to be uniquely theirs. As you reduce the granularity of the modular approach, so you get to more and more flexibility. In Japan, there are examples of high-rise blocks which use the same apartment preassembly but offset by a certain number of degrees, so as you go up the building you get the corkscrew effect and it does not look like a prefabricated approach. With a pragmatic approach to architecture somewhere on that scale, you will have architects who will adopt that and celebrate it and say, “We are into modular construction. We are proud of this. We are experts in this area”. At the other end I think there will probably be a slow transition. There are interesting changes, and I guess Jennifer can speak to this. Modern computer-aided design tools which drive building information modelling and allow parametric design allow you to take a design feature, adapt it in scale or rotation or whatever and create subassemblies you can make from that. In fact, that is quite close to what architects like to do.

Another point you raised was very interesting and I hope we will have a chance to talk about it a bit later: the concept of in-life total cost, not just capital cost versus running cost. Ownership models, of course, drive minimum capital costs and never mind how much it costs to run. As Jennifer said, maintainability is really key. If you can build instrumentation and sensors now we have the digital internet of things, you can tell how well the building is working and perhaps arrange—I hesitate to use the words PFI here—a sanitised version of PFI which feeds back the performance of the building to allow a contract to be satisfied.
Lord Fox: It strikes me we are not waiting for anything to be invented to make this happen. Prefabs existed a long time ago, so what on earth has stopped this from happening in the natural/market way? Is it the balkanisation of the construction industry? Is it snobbishness about prefabs? What is the major impediment?

Professor Jennifer Whyte: I would argue it is that you cannot change technologies of production without changing business and procurement models. We have known that for a while. Joan Woodward was doing work on that in Imperial in the 1950s.

Lord Vallance of Tummel: If it is to do with procurement and this, that and the other, why does the UK seem to be behind the race versus a number of other countries? Is there a differential in terms of the procurement between, say, Japan or Germany or wherever and ourselves? Is it planning agreements? What makes us behind the race?

Phil Wilbraham: I think it is the way you set up your project, your programme, at the start. Procurement is part of it, but you need to set it up such that you have a team around you who understand that things can be done in this way. You need some early technical input so that you can understand that things can be done differently; otherwise, people will follow the traditional route. The traditional route of our procurement means that generally you do a little bit of design and another designer comes along and they follow the traditional route.

Going back to what we are taught at university, generally we are taught to do things in situ and on-site. There is an education piece here as well and we cannot just turn a tap as a client from going on-site to off-site. There needs to be an understanding in the supply chain of what that means as well. There are a number of things, but a good starting point is a client who wants to do things in a slightly different way and getting the right technical experts around them such that the procurement can follow at the right pace in the right way. I do not think there is anything from our perspective whereby procurement ultimately stops this change. It is a matter of small changes on all sorts of things.

Lord Vallance of Tummel: Has any other country got it right?

Professor Jennifer Whyte: There are pockets of excellence in the UK as there are elsewhere. The Singaporean Building and Construction Authority (BCA) brought their construction industry over to Imperial precisely to learn about design for manufacture, assembly and integrated digital delivery. Singapore does a lot of this, but it recognises that there are excellent projects in the UK. The question is: given that there are people doing this, why is everybody else not following? That is a question about business models and procurement models which really enable this.

Baroness Morgan of Huyton: I should declare my interests. I am a non-executive director of Countryside Properties plc and vice-chair of King’s College London. We have already touched on some of this. It would be really useful if you could expand for us on the issue of skills. In what we are talking about, how different is the skill set from the traditional skill set? In the new skill set where are the gaps and the opportunities? What is the good and the bad in the story of the gaps that we have currently in
skills and what we would have in the future model?

**Professor Jeremy Watson:** We have come from a world of craft and fitting. There was a time in manufacturing when we built steam engines and locomotives where things were not built precisely and you had to file and adjust, and tolerances were not understood in the same way. We are still there in construction at the moment. What we will see is a diminution of the fitting element, because, as Jennifer said, if the tolerances are right, things will fit together. Of course, it would be disastrous if the tolerances were not right because we would still have fitting and modular construction. You really have to have it right first time. I think there will be a migration more towards design skills and perhaps some of the manual skills will go in to these regional factories, where they can still be used in a similar way, but, equally, there will be an upskilling towards systems engineering and design.

**Professor Jennifer Whyte:** We believe that systems engineering is important in this new environment. We are beginning to look at providing CPD around systems engineering out of Imperial and through UKCRIC—the UK Collaboratorium for Research on Infrastructure and Cities. I would say that there is a need for a fundamental research base here as we move to more digital fabrication techniques. There are opportunities around technologies such as AI and robotics as we move forward that I think it is important we have the research base to support. It is not a one-off transition in a sense. There is a transition that is required and that is about business/procurement models. There is also the skill base that is going to support advanced manufacturing approaches to construction as we move forward into 2030, 2040, 2050.

**Baroness Morgan of Huyton:** How do we excite young people who are currently at school in thinking about this future? I ask that particularly because I have to leave early to speak about women in STEM, so I am wondering if there is something I can take from here. Seriously, it strikes me that in many ways this is potentially attractive to people who are not currently attracted to this industry. Is there any evidence of that yet and what are the lessons for how we try to encourage young people at an early age to think about this?

**Professor Jennifer Whyte:** I think the built environment is extremely exciting to young people. They get the idea that this is about their houses, the roads that they walk on, the schools that they go to and, if they are unlucky enough to go to hospital, the hospitals they go to. They understand this is really about the world that they live in. The opportunity to make that at a higher level of quality and to be able to think through how we put that together and how we operate and maintain it long term is exciting to young people, so I think there is real opportunity to excite them about this.

**Professor Jeremy Watson:** User-centric design is really interesting. As you bring the user into the simulation of what it is going to be, there is much more creativity associated with the process rather than it just being delivered and not being quite what you expected.
**Professor Jennifer Whyte:** There is a lot of cool technology that can play into that. Artificial intelligence and robotics are cool areas of technology that begin to connect with this world.

**Phil Wilbraham:** The other side of this is we still spend too much time explaining what fun it is to be on a construction site. That is not the point. The point is there is some really interesting work to create something that is extremely easy to build. We need to trade the bit at the first stages of the work rather than pictures in magazines of people in hardhats, which is what we still seem to trade. People creating things on screens would be a much better way to explain—to my kids anyway—that it is not all about muddy boots and those sorts of things.

**Lord Hunt of Chesterton:** You did not answer at all the question about what is wrong with the UK in housebuilding. The French are building twice or even three times as many houses as we are. One argument is that in France—and I have been on committees looking at French nuclear—they have centralised teams or the administration des ponts et chaussées for the roads. Do you not think that the planning structure and organisational structure of the UK fails to match up to this pretty efficient system in France where the houses come out and they are built and do not fall down? My wife designed our own one in France and it works very well. You have not answered that question. You have said there is expertise here and there and so on.

**Professor Jeremy Watson:** That is a political question, I think, because it reflects back to Napoleon’s time. Napoleon did some good things.

**Lord Hunt of Chesterton:** Tell us what you think.

**Professor Jeremy Watson:** When I was at DCLG as its chief scientist we had regional spatial planning. Somebody had a global idea of how the UK should be laid out. That seemed like a good idea to me—unpolitically, just from a rational point of view—and if you have linear assets such as rail lines to build, you plan that holistically. We are a tiny country, after all, so why would we not think holistically? That, mapped out into the rest of the space we are discussing, will articulate some of the problem. We need to have some sort of centralised pull towards some of these outcomes.

**Lord Hunt of Chesterton:** Does that correspond with your idea of comparing the UK with other countries?

**Professor Jeremy Watson:** In as much as I know anything about other countries, which is not as much as colleagues, I am sure, if you look at the extreme of China; the Chinese achieve some amazing projects using off-site manufacturing in infrastructure, for example, deployed at very high rates. Obviously, they have access to huge amounts of finance. That is the other key thing. For us, we need a more coherent view collectively of where we are heading. That should be our response to it and ensuring that we have the investment available to create the momentum.

**Phil Wilbraham:** That is a key point because there needs to be enough of this, particularly in civil engineering and infrastructure, where it is worth while for people to invest in their factories such that there is throughput. The price will come down only if there is throughput. There is a virtuous circle. If we get started on this and encourage people to use...
off-site manufacture, the factories will be created and will fill and everyone will realise that that is a cheaper, quicker and safer way of doing it and it will move. However, it will take a big push and it takes the bigger clients. Government clients are the big clients in that situation. They are the ones that need to help us get to a point where these factories become efficient, because if there is not efficiency in the factory, this will not be cheaper, and we will go back to doing it the way we have always done it.

**Lord Maxton:** I think what is being argued is: what is the planning problem? Is it that planning permissions are not being given?

**Phil Wilbraham:** I think there is enough knowledge of the infrastructure workload now. It takes a long time to come through and I think it is key that the public sector clients that look after that have a will to move to this type of way of doing it. It will not come from a private sector client doing something different because, to be honest, everyone else will carry on as they are. With our four logistics hubs we are talking about two other programmes with the aim of those programmes coming with us on that journey, so the hubs become really busy and the factories around them become really busy. That is fairly early work and we are keen to ensure that this gets embedded and becomes a legacy.

**Lord Maxton:** I should declare that I do not have any interests.

**Baroness Young of Old Scone:** I declare my interests as chancellor of Cranfield University, chairman of the Woodland Trust, which has an interest in wooden buildings, and honorary fellow of the Royal Society of Edinburgh. Lord Griffiths stole my question, so I dreamt up another one and then you answered it before I could even get that far, so I am left with the scrapings of what I want to ask. It is really about this business of scale-up. Where are we on the trajectory of scale-up? Is it really tiny and it is going to need an exponential increase to get to these levels of efficiency in the off-site manufacturing process, or are we halfway there? Where are we on the growth curve?

Secondly, on the idea of the Government as a driving client, my experience of public sector buildings of various sorts is that Governments are only too keen to step back and let some other agency run with the design concepts because they do not want to have the egg on their face if it all goes horribly wrong. What do we need to do to get the Government to act as a large-scale responsible client to help drive this? Should that be in public sector commercial buildings—non-housing—or is housing a good place to start?

**Professor Jeremy Watson:** Housing for me is where we have the real gap in capacity against the objectives the Government have, and we are massively underperforming there. There is quite a lot of investment going on in various housebuilding companies and in some of the case studies that we have submitted they have been able to demonstrate benefits. At BRE we have a number of full-scale houses that were built on-site that people live in to try them out. This type of off-site manufacture can be quite small scale. It can be done in pop-up factories or in small local units. I guess that contrasts with, say, Laing O'Rourke which has a factory in Steetley working on very large concrete reinforced structures, which...
are very specialised and more bespoke. There is a whole spectrum and that is probably less advanced but some countries are leading edge. At the housing end we are probably just a procurement gap away from doing much more of it because it is not that difficult to set up.

There are some other interesting points you raised about the Government’s interventions, and those of you who have looked at building information modelling—BIM—which of course was mandated as of April last year or the year before, will know that government procurement above £5 million-worth has to use building information modelling, which is an essential ingredient for what we are talking about today. It is an essential ingredient but it does not specify off-site manufacture in itself. The point there is that the procurement rules can be very effective. The residual question around procurement when I started thinking about it—it sounds great, the Government procures against certain requirements—is: will the private sector follow, will shareholders of public companies say, “The Government are doing this so why are we not?” I do not see much evidence of that at the moment and that deserves some research and understanding.

**Lord Vallance of Tummel:** May I follow that up a little? Sticking with the private sector for a moment, on the face of it we are saying that off-site manufacturing of houses can be cheaper and better so you would think that if the market was operating as markets usually do and you can produce something that is cheaper and better and there is no demand for it apparently, or no supply of it, what is standing in the way? This is the bit I do not really understand.

**Professor Jennifer Whyte:** I would argue that the forward understanding of the work pipeline is really important here because of the up-front cost of investing in the facilities to produce off-site. We start to see some volumetric production in the housebuilding industry, but that forward understanding of the pipeline is crucial when you are putting in that capital investment.

**Lord Vallance of Tummel:** I can see that, but if the demand is there at the end user—in other words, you have something which is cheaper and better and therefore there should be the demand—why does the production not follow it? If you are putting any new product in you have to take the risk of building a factory to produce it. That is part of the game and it is like any manufacturing game. I do not see the difference here. I cannot see quite what is holding this back unless it is a whole concatenation of architects, different trades, public sector procurement, planning, whatever. Is it in that area?

**Professor Jeremy Watson:** It is probably in planning and development with developers sitting on land and not developing, that sort of thing, and the marginal—if that is the right term—cost of the risk, “Why would I take the risk when I know I can build it with a team of people doing craft and fitting?”, and not necessarily having a perception of the extra margins. The construction sector has been living with tiny margins for years.

**Lord Griffiths of Fforestfach:** Is there a prejudice against prefabs, going back to the early post-war days? Is that part of that atmosphere of caution?
**Professor Jeremy Watson:** I have not perceived it personally but I have not necessarily been working in the right sector to perceive the client view. I reflect on the fact we do not like wooden-framed buildings as they have in the US which are essentially prefabbed panels. Culturally, we like brick-built buildings. But you can still have brick-built buildings with brick facades that look just like a house but with off-site manufacture.

**Professor Jennifer Whyte:** I would say something about the availability of the skill set to deliver in this way.

**Lord Fox:** Professor Watson, you helpfully provided a briefing before this meeting, which is an on-the-record document. Under “Government actions” you say there may be no immediate burning platform to change technology. You have just been talking about massive underperformance in building housing, and we know that to be true. What constitutes a burning platform if massive underperformance in housebuilding is not a burning platform?

**Professor Jeremy Watson:** I was thinking from a business point of view, the housebuilders may not see anything that drives them.

**Lord Fox:** That needs to be clarified given that this is an on-the-record document. Now you have said it, the meaning becomes clear.

**Professor Jeremy Watson:** If there is a way that I can modify and resubmit, I will do that. I apologise that the meaning was not clear.

**Lord Griffiths of Fforestfach:** I should have acknowledged an interest that at one stage I was a mentor to someone on an executive development programme in Laing O’Rourke. May I come back to Lord Vallance’s question? I think it is really interesting. If, for example—and I know you were in the retail business—you could see ahead a stream of income, and you have figured out what your costs would be, you could say that you either do it or you do not. To what extent in this area—and since my colleague on my left said planning permission is much easier in the north than in the south—is it government intervention in the market through planning permission that makes predicting the medium- to longer-term demand much more difficult than it would be if you just had a normal market?

**Lord Maxton:** Is not the problem that the planning permissions are not given by central government but by local government?

**Professor Jeremy Watson:** It is.

**Lord Maxton:** If I want to build a new conservatory on my house, I have to go to a planning committee and get planning permission.

**Professor Jeremy Watson:** I would reflect on what I said before, that there is value in taking a central view with the correct local democracy to balance that, naturally. Yes, I think that is the point I would make there.

**Baroness Young of Old Scone:** May I go back to Lord Fox’s excellent burning platform search? I feel the need for a burning platform. Will the skills issue become a burning platform? Everyone is predicting with Brexit that all these wonderful bricklayers are going to go back to wherever they came from and we will end up with a lack of traditional construction skills. Is that wishful thinking or is that not going to be a burning platform?
Professor Jeremy Watson: It could very well be. I do not know whether we truly appreciate that. Certainly to be able to do what we are doing at the moment at the cost we are doing it will not be possible because the wage expectations might be different between the different nationalities and so on. That could well become a margin driver for companies to have to look for ways of cost reduction.

Phil Wilbraham: In certain parts of the country that will become a driver and already is. At Heathrow we have started work with Lord Blunkett, who is running our skills task force for us. We are looking at what the need for skills will be as we construct the new runway at Heathrow. Again, it is trying to look into the future, as we have been here, as to what those skills will be and to work out how we can create those skilled people around Heathrow, so working with the local education colleges, et cetera, to ensure that we are skilling people up in the right way so they will be able to work at Heathrow in the future. It is a simmering platform, to be honest. At the moment we are still able to carry on as we are and maybe it will start to really catch fire in about 10 years’ time. It seems to keep on simmering and people are putting it out rather than it taking light.

Lord Fox: Is the fact that the developers effectively control supply keeping the platform from setting fire? If the supply was to meet the need rather than the developers’ ambition, the platform would be on fire because there would not be the skills and the supply chain to deliver the hundreds of thousands we need. Is it the developers who are maintaining control over the supply?

Phil Wilbraham: From my perspective at Heathrow we ought to crack on and develop as quickly as possible and we will add fuel to the fire.

Professor Jeremy Watson: I believe that has been a major issue in housing and the Government are looking at interventions to cause the release of land for development. I agree with you. If you had the step change in demand that would tend to drive it, I think.

Professor Jennifer Whyte: The only thing I would add is that 10 to 15 years ago, when I was in an innovative manufacturing research centre, we were looking at housebuilding in terms of single-family dwellings, and yet what I observe in innovative approaches to housebuilding in the UK at the moment is these multi-storey student accommodation blocks, for example. HTA Design is doing some of the volumetric blocks in Wembley. It has the tallest modular building in Europe. That is really where innovation is happening, in residential that is multifamily, which is of a reasonable height and is in urban areas. That is quite a different problem to crack from the suburban problem.

The Chairman: Baroness Young, did you have a question?

Baroness Young of Old Scone: I did, although I think it has been answered. I must admit with that last remark I suddenly had Ronan Point in the back of my head—multimodular, high-rise, east London. Are we better at it now, do you reckon? You are clearly too young to remember what Ronan Point was.
Professor Jeremy Watson: Thank you for that. I take it as a compliment.

Baroness Young of Old Scone: I was thinking of your colleague actually.

Professor Jeremy Watson: Clearly, I am not.

Lord Kakkar: May I return to the question of research and development? You have mentioned certain areas—AI, robotics and so on—but what else might be needed in this area? I am particularly interested in how much the university departments are doing in this area. How much of a focus is there on fundamental research to drive this area of economic activity? Are the research councils involved in it? Is UKRI going to have a lead role in this? Are there going to be challenge funds that focus on developing the knowledge base to develop this area and make it truly productive for our economy?

Professor Jeremy Watson: Jennifer is from Imperial and I am from UCL, and UCL East out at the Olympic Park has put up a large robotics laboratory that is sponsored by the civil, environmental and geomatic engineering group, which is very interested in on-site automated construction from off-site manufactured pieces—how to put them together, which is a point we have not really covered today. For example, in Japan, to reduce injuries on-site and to increase the speed of working, you can use robots very effectively for construction. Jennifer mentioned UKCRIC, which is a £140 million investment the Government made with match funding from industry, which is putting together the capital infrastructure to enable a number of universities, including Cambridge—Jennifer can articulate which ones, I am sure—to put together a capability for doing research with and across the patch in that sort of area. Under the industrial strategy fund, UKRI and others are playing a key part in connecting universities with research technology organisations such as BRE and others to put together an integrated capability of people who understand the early technology readiness levels with those who interpret technology in practice and the practitioners as well.

I am certain there is more that can be done but the Government are getting it. Perhaps we need to make sure that it is under some sort of collective umbrella that is being not so much managed as ensuring that communications happen so we do not reinvent wheels.

Lord Kakkar: I should also have added at the beginning that I have no interests to declare. How does the R&D you describe in our country compare with the global research effort in this area? How competitive are we compared to others?

Professor Jennifer Whyte: It is interesting because my focus has shifted east, I guess. I have been in Hong Kong at the construction productivity event where they invited some of us over to talk to them. We have been hosting Singapore and both Hong Kong and Singapore are doing substantial things in practice, but are also interested in this in a research capacity. We work with the University of Hong Kong. There are interests in this area in Switzerland, where they are doing a lot of work on digital manufacturing. In Germany, there is a lot of good work being done...
on digital, and in the US of course. The UK is seen as a leading player in
digital because of the investment that the UK Government have made as
a client into Digital Built Britain.

Professor Jeremy Watson: We were seen as the leader in building
information modelling until very recently. We were quite brave in the
government procurement policy around building information modelling,
which gives us a lead-in ramp to being expert in off-site manufacture.

Professor Jennifer Whyte: The EPSRC has invested over many years in
the manufacturing area and so we have a capability in the universities.
Indeed, some of that capability was built through the innovative
manufacturing research centres that it funded 10 years ago, so there is
capacity. It is really important to sustain the research base and refresh it
towards that next generation of technologies.

Lord Kakkar: What actions need to be taken to achieve exactly that: to
refresh and to retain that established base?

Professor Jennifer Whyte: I think some of the actions are beginning to
be taken through the industrial strategy challenge fund. I was pleased to
hear that there are calls coming out through the EPSRC, through Innovate
UK and through the ESRC indeed on the back of some of the larger
investments. It is important that small-scale experiments are happening
across the UK and there is a network and they are co-ordinated in some
way. We also need the ability for some of the excellent researchers in
universities across the UK to do work in this area and to help propel us
forward.

Lord Kakkar: Does any of this research effort in our universities, or
indeed in industry more generally, depend upon European funding or is it
all specifically domestic funding?

Professor Jeremy Watson: Absolutely. I used to be the UK
representative on the European Construction Technology Platform and we
were seen as key thought leaders in the research area. We instigated a
€2 billion public/private partnership on low-energy buildings called E2B,
and I believe also a similar project around infrastructure, which I was not
part of but which my colleague Terry Hill at Arup started. The UK
benefited enormously from the funding that was available—and still does,
I guess—from agendas that we had helped shape. The partnerships with
major companies, which we all know very well, such as Bouygues and
others in the UK and ACCIONA in Spain and so on, are doing collaborative
research and sharing outcomes.

Lord Hunt of Chesterton: What you have just said is interesting, but of
course something this Committee has looked at is that after Brexit we
may participate in certain programmes but we will lose our leadership
role, and you see this across the board. What I was going to say is this
has to be implicit in thinking about buildings and walls and so on, but of
course a hugely important part of housing is energy. Most new small
houses have independent energy. Is that desirable or is it just because
individuals want to do it like that? The Government are very concerned—
we all are—about energy use. The way we are doing it, by comparison
with German public housing, is quite different. How do you see that?
**Professor Jeremy Watson**: We are on the cusp of an amazing revolution which at BRE we have demonstrated through building three or four houses which have photovoltaics on the roofs, with batteries—we have heard about Elon Musk and Tesla batteries—with 10 kilowatt hours of storage which, say, in the south of England you can easily get on anything other than the darkest winter’s day. You store the energy during the day when most people are out and use it in the evenings. You can almost achieve zero energy imports. When it is even sunnier, you can be exporting that energy. The feed-in tariff is very small and has been reduced after those early heady days of whatever it was—nearly 40 pence a unit. Nevertheless, if you can use the energy you create—and these are all modular concepts so modular roofs which have built-in photovoltaic cells that do not look like unsightly photovoltaics but look like roof tiles—those are available now. There is a long way to go on cost-reduced energy storage and management because the volume is not there yet, but with the increase in the use of electric cars that technology will come across into the built environment. We could see a real transformation in terms of distribution and energy and very much more autonomy and, I would say, resilience as well from the grid system, and give the grid operators the flexibility to adjust the balance of power so they do not have to increase the rating of conductors.

**Lord Hunt of Chesterton**: Will the same factories be used for the energy systems as for putting together the beams?

**Professor Jeremy Watson**: The assembly, say, of roofs, would involve the inclusion of photovoltaic devices built into prefabricated roofs, but not the semiconductor manufacturing; that is probably done somewhere else.

**Q6 Lord Fox**: You have mentioned en passant the industrial strategy and the industrial strategy challenge fund. A key element of the industrial strategy is sector deals. What should be included in the construction sector deal to bring to fruition the promise that we see from off-site manufacture?

**Professor Jennifer Whyte**: It is a hard question to answer because, of course, we do not have the sector deal draft in front of us.

**Lord Fox**: I am not asking you to draft it.

**Professor Jennifer Whyte**: I would push the argument that it is important to have in that the higher-skills agenda and that is around PhD students, around the knowledge economy; it is around sustaining and developing capabilities to be competitive in our manufacturing processes. The question about international comparisons is well made because we are not the only country that has noticed the opportunities and the benefits of off-site.

**Professor Jeremy Watson**: I would also cover the other end of the skills scale, so continuing professional development, the uplift and maintenance of skills, people changing their engineering jobs to match the changing technology. That requires the professional institutions and universities to be offering, perhaps by distance learning, ways of getting on top of these new technologies without taking huge amounts of time out of the working day.
The other thing for the challenge fund would be funding at scale, serious demonstrators. We tend to build something that is not quite enough to convince everyone. We need something that cannot be denied—the O2 Arena or something of that sort of scale—which uses a particular approach and clearly demonstrates well-evidenced measured benefits which can pull the momentum through the industry.

**Lord Vallance of Tummel:** It seems to me that rather than just a sector deal you are looking for a holistic strategy. You have governmental issues of planning regimes, public procurement and developers’ motivation, various vested interests in threatened professions such as architecture and various trades as well, and you have the R&D and technology bit of it. You have a whole host of stuff here. There is a risk that you end up—I should not be answering this question—sorting some of the things that go naturally into a sector deal without taking a holistic view of the whole environment in which this operates. Is that right?

**Phil Wilbrahama:** I think there is a lot to change, ultimately. All change needs to be taken in bite-sized chunks. The important thing is that the sector deal picks up some of the points you make. It probably will not pick them all up but, ultimately, people will start using those things and move on to the next point. All that will not change in the next five years. It will be a steady process. Also, we would want to bite off the things that are easier to do first. It is easier to do off-site manufacture with relatively small bits of, say, concrete and steel and do that really well and prove that it works and make it completely and utterly digital. You could work on some bits that can really be done well and prove they work on a normal site, in a normal development. I agree with you that to try to solve all this in a oner is not possible, so we have to pick bits off and different people have to attack different bits.

**Lord Vallance of Tummel:** But if you do not tackle the market inefficiencies, because it seems to be full of them, no matter what you do elsewhere, you are not going to crack it.

**Lord Mair:** I ought to declare my interests. I am a fellow of the Royal Academy of Engineering and of the Royal Society and emeritus professor of civil engineering at Cambridge. Laing O’Rourke collaborates with my university. I am also president of the Institution of Civil Engineers and I chair the Science Advisory Council for the Department for Transport, which is a major infrastructure provider. I am sorry, this will not take too long. I should also say that I am a consultant to Laing O’Rourke, but I do not have any involvement with its off-site manufacture. I am primarily a consultant to it on underground matters—tunnelling and so on.

My question is really about the distinction between buildings and other forms of civil engineering infrastructure. We have touched on that and, obviously, Phil, your world at Heathrow is not only about buildings and what you are currently addressing, but most of the discussion has been about buildings. I would like to hear from the three of you about the potential for off-site manufacture in our other forms of civil engineering infrastructure.

**Phil Wilbrahama:** I think there is a potential in civil engineering just as much as there is in buildings. In the past, we have probably done more in
buildings, but if you go back to the terminal 5 days, we determined that we should precast 60% of our concrete. It was not the flat concrete but all the other concrete. We set a target and we built river walls out of precast units. People said, "You'll never do it", and a lot of people said we were mad, but we did it and those river walls are still there 14 years later and they do not leak. There is a mindset here as well as proving the case. Certainly for civil engineering, it is so embedded that you design it, you do your reinforcement, you build it on-site, et cetera, and we need to un-embed some of that. With the civil engineering that we are about to embark on at Heathrow, we will be setting targets about how much of it is going to be precast and whether that is precast in a factory. Earlier we built a little factory near Heathrow. There are different ways of doing it. We could build a little factory near one of our logistics hubs. There are lots of different ways of getting at it. It will encourage designers to think differently. Ultimately, you get fewer wet trades on-site and hopefully no hot trades on-site. That is where all the trouble comes, all the danger is, all the joints are and where the problems come later in maintenance, et cetera. In civil engineering there is massive opportunity, but I do not think it has been tapped in to as much as in the buildings. In the buildings it is more obvious and you can see bits of it on the back of trucks. For a long time people have been trying to do their mechanical and electrical—M&E—off-site. We have done that. You put them into big modules and you put it all together and that is great. Again, that is quite simplistic and there is a lot more we can do to bring together bits of buildings.

I was at Laing O'Rourke's yard and they have whole bits of a side of a building coming out now. You can see the bits of the building sitting in the yard ready to go to London and they will be literally installed. That is a combination between civils and buildings. The last multi-storey carpark we built at Heathrow was 80% built in a factory and there you have the same thing again and again—repetitive—and it is built much more quickly, and it is much safer and much higher quality. Ultimately, it will be cheaper. It is back to the scale question; we need scale to get it cheaper.

Lord Mair: Do you think in general that the mindset all around the country at present, if it is thinking at all about off-site manufacturing, is thinking about buildings, and there are all sorts of other projects—local authorities—which are not buildings, and that is probably the biggest barrier?

Phil Wilbraham: There is more progress in buildings. If you ask where we are on the scale, we are probably 10% to 20% in buildings and 5% to 10% in civils. There is a great example on the A14 at the moment where a huge viaduct is being built alongside where it is being put up. There are little pockets of the civil engineering world.

Professor Jennifer Whyte: I would bring in examples from Crossrail. Custom House is an example of prefabrication being used on major infrastructure projects. Both with buildings and infrastructure there is the problem of how you sequence the people you bring in to do the work. If you bring designers in ahead of fabricators, you can end up with an in-situ solution that you are trying to solve post hoc.

Q8 Lord Borwick: First, I declare my interest as a property developer,
mainly of housing sites but also other developments. May I ask about public procurement yet again because we have touched on it on several occasions? The November 2017 Budget said that the Government were going to encourage off-site construction, particularly in transport and health, and the Department for Education, Ministry of Justice and Ministry of Defence would all adopt a presumption in favour of off-site construction by 2019. How many of those will achieve it?

**Professor Jennifer Whyte:** There are some good early signals. There is the work that Bryden Wood has done with the Ministry of Justice, which builds on the work that it has done with it on Digital Built Britain. Digital and off-site are not quite the same thing, but they often go hand in hand, because they allow you to think about building, or indeed about infrastructure, in terms of components, and you can start to think about how you fabricate those. There are good early signals that there is the potential at least for government departments to seize the opportunity for the efficiency savings and all the benefits that we know off-site brings.

**Professor Jeremy Watson:** That is very likely. Government can provide some very useful signposting, and the infrastructure of research and capability can naturally ease a rather conservative and slow industry towards better places. It is also moving incrementally because not only are we doing off-site manufacture but the component manufacturers are also coming along quite well. You are starting to see the parts from which buildings are made being very much more accurately made, with much more standardisation, repeatability and so on. That is driving it top-down and bottom-up at the same time. It is not such a bad position in that way, but some big projects will drive further through.

There is one point I did not get a chance to respond to Lord Mair on and that is around infrastructure. You know much better than I do that things such as tunnel linings, footbridges for motorways and all sorts of similar things have been made for years in prefabricated off-site ways. An opportunity that emerges is that by tracking materials through their life you can do closed loop and you can use materials at the end of their life as well, particularly steel, which is typically melted down, with a huge use of energy and huge inefficiency. We can potentially start to think of a national Lego kit for putting things back together in different ways. That is where modularity and the tagging of materials with smart devices can assist.

**Lord Hunt of Chesterton:** One of the critical factors, presumably, in getting more efficient and effective building programmes is for the customers to be educated as to what they should expect and what they should ask for. Look at us here in Parliament: we do not know very much and yet we are making decisions. Similarly, members of councils and all sorts of industries are making very important decisions about this or, for example, Heathrow or the Olympics. Do you think that more could be done to educate or to inform, to show them other countries before they make their decisions? My feeling is that we have not done very well in creating intelligent customers, particularly for this area.

**Phil Wilbraham:** It is absolutely critical that the people who are making those early decisions know an awful lot about their environment, what they want and what they can see as the outcome, and that they
understand how the thing works, how it operates. We sometimes leave these decisions to professional programme managers, who are very good at getting things designed and constructed, but we need capable owners, as I call them, who can really get behind this. I have been fortunate to be at Heathrow for 20 years. The people who operate the buildings have to put up with what I have done. We have great conversations about, “Wouldn’t it have been better if ...”, et cetera, and the learning you get through people understanding how buildings and infrastructure operate is fantastic. There is a huge piece to ensure that the—

**Lord Hunt of Chesterton**: Do you do this in the programme that you were talking about at Imperial? Does that have an element of teaching and creating intelligent customers?

**Professor Jennifer Whyte**: We would be keen to work with major infrastructure owners. We work with the major projects, which are their delivery clients, so they are not the eventual owners and operators, but they are the owners through that delivery process.

**Lord Hunt of Chesterton**: Are councillors and other people going to universities to get some training? That is what we are talking about, is it not? I do not think it is happening.

**Professor Jeremy Watson**: I would reflect on it in two ways. When one of my previous employers—Arup—did the King’s Cross St Pancras underground we simulated that with virtual reality. You could wear 3D goggles and go up and down the escalators. We could check the signage was right with the client before anything was ever dug in the ground or cut. The other side of it, of course, is the mass training that is needed. Again, at my present employer—BRE—we have an academy. We have put literally thousands of people through CPD modules and training, keeping their skills up and making them fit for purpose.

**The Chairman**: A quick question from Lord Vallance and a quick answer.

**Lord Vallance of Tummel**: I do not have another question, but I should declare my interests, which I failed to do before, as chairman of the Edinburgh Business School, which is part of Heriot-Watt University and which no doubt has an interest in this somewhere.

**The Chairman**: We overran slightly, but thank you very much indeed for kicking off this inquiry extremely well. Thank you for coming.
Professor Jennifer Whyte, Imperial College London, Professor Jeremy Watson CBE, University College London and Heathrow Airport – Oral evidence (QQ 1-8)

Transcript to be found under Professor Jeremy Watson CBE, University College London
1a - What are the opportunities offered by offsite manufacture for construction?

Greater control over work conditions bring advantages: worker safety, quality assurance, speed, productivity, reduction of waste, traceability of materials. Many are documented by UK researchers. Four opportunities are to:

1. **Provide value to clients and end-users** through improved quality and a shorter construction period. Quality can be improved through a more rigorous attention to testing in the offsite environment. KPMG research finds increased costs for one-off offsite, but financial net savings of 7% due to a shorter construction period, which allows buildings and infrastructure to come into service quicker. Ultimately, where the government is involved procurement, this is about value to tax-payers through better quality of schools, hospitals and homes.

2. **Use platform-based design strategies**, in construction as in other industries. There are particular opportunities and challenges around this as use of computational techniques can automate the more repetitive design generation processes. Offsite manufacture for construction can benefit from new forms of data-science.

3. **Improve sustainability**, as there is greater traceability of products through the supply-chain and the potential to make demountable systems. This provides new opportunities to consider the circular economy.

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116 There is substantial work by the World Economic Forum on the *Future of Construction*.


119 Such as those being developed through the Lloyds Register Foundation/Alan Turing Institute Programme on *Data-Centric Engineering*.

120 This is important because construction is resource intensive. Concrete is often described as “the second most used material on the planet after water”(e.g. in Crow, J. M. (2008) *The concrete conundrum*. *Chemistry World*: 62-66). Five to eight tonnes of building materials are used per person per year in Europe, according to McMullan, R.
4. **Foster regional innovation ecosystems** around offsite construction. There is the potential to promote employment outside of the south east and to retain and grow UK expertise.\textsuperscript{121}

1b - **What factors are likely to influence clients, architects, design engineers, contractors and the supply chain in deciding whether to choose offsite manufacture?**

1. **Business and procurement models:** You cannot change technologies of production systems without changing business and procurement models.\textsuperscript{122}

   Other sectors (e.g. i-phone; car industry; aerospace) have transformed by understanding platforms, modules, high-value manufacture, new service models: as we have learnt from other industries, some companies will fail to make the transition.\textsuperscript{123} Construction is a manufacturing process that needs to be improved\textsuperscript{124}, but systemic innovation is difficult in this sector,\textsuperscript{125} as there is no central systems integrator and hence it requires different stakeholders in the process to collectively change. The current structure of the industry in the UK impedes innovation; with low margins, focus on consultancy hours and cash flow, and a range of vested interests in the status quo. However, as the committee has heard in oral evidence, there are lots of good recent examples of digitally-enabled off-site manufacturing practices in this industry. Clients (public and private) play a role here – Fundamentally if clients are asking for the wrong things, they can’t be surprised when they don’t get what they want. Contractors are brought on board too late in design work; meaning projects are designed twice - once in-situ, then with offsite manufacturing.

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\textsuperscript{121} In the Centre for Systems Engineering and Innovation, we are currently working with the Royal Academy of Engineering to map the regional innovation system, both large and small firms, and start-ups and systems integration in the supply-base in the ecosystem around Sheffield, Derby and Nottingham.

\textsuperscript{122} This insight is built on work by Joan Woodward in the 1950s at Imperial College London, which showed that successful firm strategies were related to their means of production Woodward, J., *Industrial Organization: Theory and Practice*. 1980 [1965], Oxford: Oxford University Press.


(2012). Environmental science in building, Palgrave macmillan. Statistica shows \textbf{4,100 million metric tons} of cement produced worldwide in 2017; with the UK producing \textbf{24.6 million cubic meters} of ready-mix concrete. There is ongoing research at Imperial and elsewhere on sustainable construction materials.
processes. There is a need to spend enough time framing the problem. Changing how the government makes investment decisions is important.

2. **Statistical evidence:** At a national level, we cannot track the benefits of offsite construction, as the manufacturing associated with off-site construction is taken out of the Standard Industrial Classification (SIC) Part F (Construction) into Part C (Manufacturing).

This makes the productivity of off-site construction and its impact on safety hard to measure in the Office of National Statistics (ONS) data and Health and Safety Executive (HSE) data. Efficiency gains as a result of offsite construction, which may be partly through the offsite activities, do not become fully represented as productivity in construction in graphs that use this data.

Part F (Construction) includes assembly on the site [41 Construction of buildings; 42 Civil Engineering; and 43 specialised construction activities]; Part C (Manufacturing) includes the manufacturing of prefabricated buildings and components made of concrete, metal, wood (codes 16,22,23,25), etc.

We need to work with ONS and HSE to access different kinds of evidence to understand the impact of off-site construction on productivity and safety.

2 - **What are the drawbacks to offsite manufacture for construction?**

1. **More decisions need to be made upfront in a project,** tolerances need to be understood and designers need to have a greater understanding of manufacturing, assembly, maintenance and operation activities, and to be able to consider these in the design process. Using platform approaches (as discussed above), more solutions can have tested components and design attention can be focused to customisation of options. There is a need to

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126 UK 2017 [Standard Industry Codes](#).
128 HSE (2017) *RIDIND - RIDDOR reported fatal and non-fatal injuries in Great Britain by detailed industry* [http://www.hse.gov.uk/statistics/tables/ridind_xlsx](http://www.hse.gov.uk/statistics/tables/ridind_xlsx). These HSE statistics use the SIC codes, in the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) detailed data. While there is not the detailed data to distinguish which parts of the manufacturing statistics relate to offsite construction, the statistics imply offsite is safer as the categories included in Construction (41,42,43) has 30 fatalities of employees and 19 of the general public in the period 2012-2017 (this includes traditional onsite assembly and prefabricated onsite assembly), compared with 5 fatalities in the associated manufacturing categories (16,22,23,25). All these SIC codes have higher accident rates than average, but only one related manufacturing category “manufacture of woods and products of wood and cork” has higher rates of fatal and non-fatal injuries per 100,000 workers than construction.
130 In the Centre for Systems Engineering and Innovation we have ongoing research on Design for Manufacture and Assembly (DfMA), and the processes needed to ensure designers appreciate materials, manufacture and operations phases (e.g. Tees, R., Davies, A., Whyte, J., MacAulay, S. (2017) Modular Components, Integrated Practices: Managing Complex Collaboration in Temporary Organization, *Academy of Management Conference*, Atlanta, Georgia, 4-8 August; Hsu P-Y, Aurisicchio M, Angeloudis P, 2017, Supply chain design for modular construction projects, *25th Annual Conference of the International Group for Lean Construction (IGLC)*, Crete, 7-12 July.)
Professor Jennifer Whyte, Imperial College London – Supplementary written evidence (OMC0080)

consider structural stability and safety in all temporary conditions through the build process.  

2. **There is less flexibility as resources are committed**: Many contractors do not directly employ the labour on the construction site giving them a lot of flexibility. Offsite construction needs capital investment in fabrication equipment and materials, which makes it less easy for firms to upscale and downscale production in response to cycles in demand and so there is greater need for certainty in the forward order book.

3 - **What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?**

1. There is a need for a **systems approach** and **systems engineering**, which brings with it a greater emphasis on testing (verification and validation) in order to understand overall performance and interdependencies and tolerances between different components as more is committed upfront in the design process. There is a need for higher skills and new professional skills. Design for manufacture and assembly can benefit from advanced new knowledge in areas of manufacturing processes and materials, systems engineering, robotics and data science.

4 - **Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?**

1. **Yes. Modularity is an efficient design strategy.** The smartphone in the hands of the user is a bespoke and customised experience – it shows the potential of standardizing what is not seen and customising what is seen.

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131 A recent example of a major incidents with prefabricated construction on site is the Florida bridge.

132 Some derive a portion of profit from cash flow management, withholding payment from sub-contractors, see: Smyth, Hedley (2018) *Castles in the Air: The evolution of main contractors*, The Bartlett School of Construction and Project Management, UCL Report. There is also a Research Briefing on the Collapse of Carillion and open Commons inquiries (Public Administration and Constitutional Affairs Committee; and joint Work and Pensions Committee/BEIS Committee).

133 It is useful to consider the assurance processes across the production process (and to distinguish between panels, pods and volumetric offsite production). The Ronan Point block used off-site panel construction, and its collapse due to a gas explosion in 1968 led to changes in Building Regulations. It is also important that the system is understood well in refurbishment (and eventual demolition) and that there is effective monitoring from design onwards (see Hackett, J. (2017) *Independent Review of Building Regulations and Fire Safety: interim report*, Ministry of Housing, Communities & Local Government.

134 This is recognised, for example by Singapore industry. In the Centre for Systems Engineering and Innovation at Imperial College London, we hosted colleagues from Singapore, in collaboration with Singapore’s Building and Construction Authority Academy, for continuing professional development as their industry seeks move to Design for Manufacture and Assembly (DfMA) and Integrated Digital Delivery (IDD) – see also [https://www.bca.gov.sg/citm/](https://www.bca.gov.sg/citm/).

There is a lot of innovation in the use of computation design approaches, platform-based design and design for off-site manufacture in leading architectural practices in the UK. There is the potential for standard processes and standard and customised components, where finishes can be customised and those things that are not seen by the end-user can be fully standardised.

5- What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

1. **Fundamental research:** It is important to have fundamental research in the related areas of engineering sciences, manufacturing, management and design. Scale up is vital, but if you only invest in applied research you are in danger of not being able to sustain technological leadership. Leading research capability in the university base leads to the educated people and skills needed for start-ups and established firms, and supports the wider ecosystem of innovation.

2. **Distributed and agile:** There is value in supporting a distributed and agile rather than centralised approach to innovation, rather than a single investment. We need a critical mass of post-docs and PhD students, across the UK that can compete and foster innovation through experiments with related new engineering and manufacturing technologies.

3. **Sociotechnical research:** this is needed on business models, platforms and production systems as well as technical work on new materials, new data science and new manufacturing process, to provide systematic underpinning evidence to inform practice.

6 - What should the construction sector deal include?

The sector deal should include the higher skills agenda, to take the industry forward to maturity over the 20-year time frame, and provide the skills needed for industry transformation.

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136 There is substantial university research in other countries, such as the Digital Fabrication work in ETH Zurich [http://www.dfab.ch/] - there is excellence also in the UK, but this needs promoted to keep the industry internationally competitive in the medium to longer term.

137 Much innovation happens through small scale, distributed, experiments, as argued by Garud, R., & Karnøe, P. (2003). Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research policy, 32*(2), 277-300. My own work has examined 30 years of development of structural glass, through episodes of innovation in and around London that brought architects, engineers (notably Dewhurst Macfarlane and Partners), fabricators and material suppliers together, and led eventually to the Apple Store glass staircases (though Steve Jobs is the first name on the patent).

138 There is a rich tradition of research in the UK, seeking to understand the wider inter-relationships between technologies of production and the organization of work, which could be usefully extended and focused on this issue. The tradition stretches back to the work of the Tavistock Institute: e.g. Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the Longwall Method of coal-getting: An examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. *Human Relations, 4*(1), 3-38.
WPI Economics has released two reports on the value of off-site construction to UK growth and productivity. The reports include modelling of the potential effects of a movement towards off-site construction on GVA and productivity for regions across the UK. They also provide detailed case studies from the house building and infrastructure sectors which demonstrate how off-site construction is already being widely used and how it can be further deployed. Additionally, the reports explore the potential barriers and drawbacks that exist with regards to offsite construction, and the measures that industry and government could take to overcome them.

1. What are the opportunities offered by offsite manufacture for construction?

Increased per-job productivity and higher GVA:

Results from our economic modelling show that if the construction industry were able to increase the use of off-site construction such that 25% of all work is undertaken off-site, it would be associated with an increase in GVA per job of 3.6%.

Off-site construction will make the most of construction expertise across the UK and spread the investment and economic benefit across the UK regions:

Productivity in the construction sector varies significantly across the UK. Recently published data from the ONS shows that over the last 10 years, London and the South East have enjoyed between a 10-15% productivity advantage compared to the rest of the UK, while some regions suffered a productivity deficit. Our findings show that boosting employment, providing significant supply chain opportunities for SME’s and utilising skills and expertise outside of the capital could lead to GVA in regions outside of the capital being £5.5 billion higher than would have been the case without a move to increase off-site construction.

139 The WPI Economics reports on off-site construction can be found here: http://wpieconomics.com/publications/off-site-construction/

140 Our economic model takes in to consideration the extent to which off-site construction leads to increased per-job productivity compared to standard on-site construction methods and the increase in proportion of work in the construction sector that is undertaken off-site. Our model’s baseline for this is a low coverage figure of 25% (although some industry experts believe that it will be possible to undertake up to 70% of all construction activity off-site, we believe that the 25% figure is deliverable over 5-10 years, whilst the 50% coverage should represent a longer term aspiration for the sector). Results are obviously not definitive, precise impacts will depend on a range of factors, including the nature of growth in off-site construction, the parts of the construction sector that embrace it and wider factors like technological change.
Cumulatively, this represents over a boost of over £30 billion to growth outside of London between 2018-2025.

**Example 1: Heathrow’s use of off-site construction:**
Heathrow Airport will use 4 logistic hubs for its expansion. These will source products from local supply chains, and either combine them in to efficient shipments, or to pre-fabricate whole modules of the building or component that will be used for the expansion project. Therefore, 60% of the procurement spend will be outside of London- spreading the benefits of local investment and potentially boosting growth and productivity in the UK. This is reflected in the wider job creation figures for the Heathrow expansion project, which are forecast as around 108,000 in total outside of London and the south east. Additionally, these logistic hubs will continue to exist after expansion, forming a lasting body of construction expertise and providing a long-lasting economic boost to the area in which they are located. They will provide a vital focus for regional skills and growth strategies and spread the benefits of the airports expansion across the UK.

**Reduced wastage and environmental impact:**

By reducing traffic flows to and from the construction site, there are significant benefits from reduced congestion and, by implication, pollution in the local area. Recent research based on case studies has suggested that projects using off-site construction can deliver a reduction of between 20% and 60% in metric tons of CO2 associated with project transport. Substantial benefits in terms of waste are also possible. Traditional methods are associated with 10%-20% raw material wastage, however with more advanced techniques, for example the use of CAD / CAM, off-site construction can produce the same assets with just half the waste. The energy use associated with the completed assets can also be lower. Estimates suggest these savings could be as high as 25% over the asset life.

**This approach also causes far less disruption to the surrounding area, and increases the support of construction projects from local residents:**

The vast majority of the UK population support the development of critical infrastructure and housing. However, there are often challenges with gaining support from both residents near construction sites and planners due to concerns about the construction process itself. For example, responding to qualitative research for a recent report one local authority Director of Planning argued that “...they [local residents] don’t actually object to the new houses... It’s the lorries, the diggers and all that sort of stuff.” By reducing time, headcount and the range of activities that need to be completed on site compared to traditional on-site methods, off-site construction leads to projects that are completed more quickly with less noise, less local air pollution and less traffic disruption, easing the concerns of local residents.
2. It is often claimed that offsite manufacture can lead to:

- **Lower costs, faster delivery and increased quality**
- **Increased productivity**
- **Improved health and safety**
- **Greater provision of new, affordable housing**

**What is the evidence for this?**

**Faster and more reliable delivery:**
On-site methods are impacted by the weather and site and access conditions. With off-site methods, these factors are controlled within a factory environment, providing greater certainty and allowing improved delivery. A clear example here is Portakabin Group, who delivered nearly 100% performance in delivering off-site projects on budget and on time over a 12-year period. The industry average over the same period across all construction projects was 40% for timeliness and 30.7% for budget accuracy.

**Increased productivity and speedier project completion:**
A 2016 survey showed that just 68% of construction projects finished within budget and only 41% came in on time or better. However, with off-site construction there is a higher rate of completing construction within budget and time. This is partly because activities can take place concurrently and be scheduled for “just in time” delivery, when needed on site. The NAO previously demonstrated that off-site construction methods could reduce onsite build time for housing by over 50%, and more recent work at the BRE innovation site has shown that a house can be built in just one day. Industry case studies suggest that overall this means that homes constructed off site can be built 30% more quickly with 25% lower costs. Just 7% of construction is currently undertaken this way. However, by increasing this proportion to 25%, this report shows that productivity could grow by 3.6% by 2020.

**Example 2: Birmingham New Street Station**
Off-site construction was used during the redevelopment of Birmingham New Street Station. This was manufactured externally and was installed with no disruption to daily operation. This was finished off site in 9 months, and reduced the number of on-site operatives by 75%.

**Example 3: Lynch Hill Enterprise Academy**
Lynch Hill is a 1140 place academy free school. It is one of the largest schools in the UK to have been built using modular construction. Around 65% of the building was manufactured off site at the Mcavoy group’s production centre in Northern Ireland where large sections of the building were manufactured and then shipped, resulting in faster on-site construction and the need for fewer deliveries to site, increased productivity, and a highly predictable construction process. Work was completed on the school in only 53 weeks, some 17 weeks ahead of schedule, and approximately six months quicker than site-based construction of an equivalently sized school.
Lower costs, faster delivery and increased quality:
Off-site methods are associated with a 50% reduction in the project costs of dealing with “snagging” and reduced whole life costs of assets due to improved quality of assets, standardization and simplification of processes. These benefits typically arise from the fact that the factory environment facilitates the use of tighter controls and more consistent and standardised processes. As well as the obvious benefits of improved quality, this drastically reduces the need (and associated cost) of re-design and re-work. This can ultimately lead to improved quality and a greater provision of new, affordable housing.

Off-site construction methods result in improved working practices, a safer working environment and higher rates of workplace safety:
An average of 2.2million working days were lost to work-related injuries and ill health in the construction sector each year between 2013/14 and 2015/16. At its most extreme this led to 43 fatal injuries, representing nearly a third of all fatal workplace injuries in the UK. The overall costs of workplace injury and work-related illness in the construction sector is around £1.2 billion a year. Off-site construction has the potential to significantly reduce the risk of accidents and ill health due to a range of potential advantages, including that it provides a controlled, clean and warm environment, uses production line techniques and standards, reduces the need to work at height or below ground and reduces exposure to UV.

3. What are the drawbacks to offsite manufacture for construction? / 4. What re-skilling of the construction workforce is required to facilitate a change to more off-site manufacture for construction?

Our reports identify the clear benefits of off-site construction and demonstrate that the Government and industry bodies are keen to take action to improve this method. The challenge for the UK government and construction industry going forward is to both increase uptake and innovate this approach. In order for off-site construction to be successful, the government and local industries must work together to incentivize it. The lack of existing and committed future demand consequently means that there is uncertainty surrounding investment in developing off site construction centres. Policy makers in many countries are considering how to increase adoption. Additionally, the approach requires the construction sector to collaborate and build a wide range of new capabilities and skills. Combined with an existing skills deficit in the construction sector, this presents a real challenge.

6. What R&D is needed, and by whom, to realise fully the potential benefits of off-site manufacture?

Following the identification of many of the problems faced by the UK construction sector, the Government’s Construction Sector Deal has committed to achieving four key objectives by 2025:

- A 33% reduction in the cost of construction and the whole life cost of assets;
- A 50% reduction in the time taken from beginning-to-end of new build and refurbished assets;
- A 50% reduction in greenhouse gas emissions in the built environment; and
• A 50% reduction in the trade gap between total exports and total imports of construction products and materials.

To achieve these ambitious targets, the construction sector will need to modernise by embracing and taking up new technology and modern methods of construction- including off-site construction. The government has a role to play in opening new markets for UK businesses to export to and grow into; boosting skills; facilitating investment in research and innovation; and helping spread growth across the UK.

8. What changes could be made to public procurement processes to encourage more economically and environmentally sustainable practices in the construction industry and facilitate off-site manufacture?

It is encouraging that the Government has recognised the role that off-site construction can play by committing to the Presumption in Favour of Off-Site Construction. However, more action is needed to cement the progress made to date. In particular, the Government and the construction sector need to work together to ensure that the steps taken so far result in a tangible increase in the proportion of UK construction that is undertaken off site.

In order to ensure that this has the impact the Government should:

• Commit to a target of moving 25% of construction to off-site methods. As part of this, the government should commit to a target of at least 30% off-site construction in major projects procured over the next 5 years.
• Report yearly from 2019 on the proportion of government funded construction that is undertaken off site. This should be complemented by work across the whole construction sector to ensure that the coverage of off-site construction is measured.

This reporting will ensure that the government and sector can be held to account in delivering both the presumption in favour of off-site construction and the training and skills development needed to support a move to off-site construction.

Attempts to do this are currently frustrated by the fact that data on the proportion of total UK construction that is undertaken off site is hard to come by. To tackle this work should be undertaken across the whole construction sector to ensure that the coverage of off-site construction is measured. Given their role in driving the needed skills across the sector, CITB could be an appropriate body to take this work forward. Ensuring that this measurement takes place will ensure that the Government and sector can be held to account in delivering both the presumption in favour of off-site construction and the training and skills development needed to support a move to off-site construction.

26 April 2018
WSP – Written evidence (OMC0014)

Author: Jane Richards, WSP Head of Structures

Introduction
WSP was invited to take part in the House of Lords Science and Technology Select Committee’s inquiry into off-site manufacture for construction. In anticipation of Jane Richards providing oral evidence to the Committee on 8th May, we are delighted to share a succinct piece of written evidence to help inform the inquiry, as well as background information on WSP.

About WSP
We are one of the world’s leading engineering professional services consulting firms. We are technical experts and strategic advisors including engineers, technicians, scientists, architects, planners, surveyors and environmental specialists, as well as other design, programme and construction management professionals. With 37,000 talented people in more than 500 offices across 40 countries, we engineer projects that will help societies grow for lifetimes to come. Across the UK, we have 8,000 experts working on every aspect of the built and natural environment, from the Shard to Manchester’s Metrolink, and from HS2 to the Geological Disposal Facility.

About Jane Richards
Jane is a member of the Executive Leadership Team at WSP in the UK. She is also Head of the Building Structures business, which employs around 500 people, responsible for strategic growth, technical excellence and expertise of this discipline. Jane is involved in the delivery of some major multi-disciplinary projects, particularly those involving high-rise towers and deep basements with complex below-ground constraints, such as 150 Bishopsgate, Clapham Junction over-build and 40 Leadenhall Street. Jane is also actively involved in research & development and implementation of modular construction and is co-author of a paper titled ‘Modular Design of High-rise Buildings’.

Defining Off-site Construction
For purposes of clarity, we have opted to share our definition of Off-site construction, which we understand to cover all elements fabricated off-site and includes basic manufactured components up to complete building systems. The categories of off-site construction are summarised in the following table:
Question 1

Off-site manufacture for construction enables modules or elements of buildings to be constructed off-site under controlled factory conditions using the same materials and designing to the same codes and standards as conventional buildings, but in much reduced timescales and with better construction quality management, and in a safer environment than traditional sites.

For architects and clients, modular construction companies today can work with levels of design and construction sophistication that compare favourably with conventional construction. This means that designs can be developed with some flexibility to adopt off-site techniques without significant compromises to layouts or loss of area to the finished building.

Other factors which impact the decision to choose off-site construction will include the availability and certainty of supply. The off-site manufacturing companies have invested and grown over the last 10 years, but suffered significantly in the downturn of 2008-2012 and this checked progress. There is currently a significant R&D investment in off-site techniques, which is leading to new systems becoming available.

For example Berkeley Homes, one of the UK’s largest residential developers, is developing their own system to manufacture modular housing up to 20 storeys in height, which will be in production by 2020. Similarly Laing O’Rourke are extending their significant off-site capability to include volumetric modular housing of similar height. Vision Modular has enhanced their system to be capable of building over 40 storeys. A lot of this investment benefits from government sponsorship. As more off-site options become available and with sufficient flexibility to suit a range of construction projects, clients and supply chains are more likely to select them.

The following factors also tend to influence choice:
Perception of quality
Accreditation and attitude of mortgage lenders to new building techniques
Need to fix designs earlier to allow manufacture
Certainty of supply/capacity
Scale of development to leverage buying gains
Repeatability of cores systems designs like structures and services
Question 2

Evidence from the off-site modular projects that I have been directly involved in indicates the following.

The diagram below helps clarify:

Cost savings currently result primarily from the overall time-saving achieved. This can be from earlier return on outlay and/or reduced preliminaries and logistics costs on sites. However, in future, as off-site manufacture increases then the economies of scale will also be expected to bring down costs.

There are greater health and safety risks and hazards with onsite construction work that can be mitigated by offsite construction.

- More work can be carried out in a controlled factory environment resulting in less time and fewer people on site
- Fewer crane lifts and less time working at height
- Less manual handling and material lifting
- End of life dis-assembly is easier and safer

The evidence shows that modular off-site construction is currently primarily delivering housing in the private and social rented sector. The recently signed agreement between manufacturer-contractor Laing O’Rourke and the developer Stanhope is a good example of how off-site construction is being planned for the future delivery of large volumes of affordable housing. This Agreement aims for 10,000 residential units per year.

Reduction in materials waste through manufacturing efficiencies are also an important benefit to sustainability targets. The growing construction industry’s maturity in BIM and Digital Construction is a further complementary benefit.

Question 3

Some drawbacks are:

- A high degree of standardisation is required to maximise value and reduce costs. This can impose constraints on architecture
- Higher upfront payment is typically required by the client to reflect off-site materials
- Due to the relatively short time that full off-site construction has been available, accreditation and mortgage Company preparedness to lend to
buyers can be an issue. This is being addressed by the newer system developers but is not yet fully established

- Early decisions are needed to co-ordinate and freeze design
- Early appointment of the manufacturer is desirable to avoid delays
- There is still uncertainty about capacity to supply for an increasing off-site requirement

**Question 4**

WSP’s experience of the UNITE Modular Solution’s factory in Gloucestershire, on which we worked was that re-skilling was easily achieved and effective. The degree of automation and production line approach to the process was complemented by the labour involvement finishing the product within the factory. Skills required for this were lower than for an equivalent tradesperson on site, but still represented an opportunity to provide training and skills for a local workforce.

**Question 5**

Whilst modular and off-site construction requires high standardisation within the architectural design, there is still opportunity for flexibility and creativity. Off-site/modular design should be viewed as a kit of parts and an approach. Design flair and creativity can then still flourish.

**Question 6**

There is an opportunity with off-site manufacture to make advances in our use of technology in construction. There are many separate R&D projects at the moment. These are being led by developer-manufacturers, developer-builders and academic institutions. An over-arching co-ordination of the advances being made would be interesting, but would need to reflect commercial confidentiality principles.

**Question 7**

The Construction Sector Deal focuses on three key areas:
• Procuring for Value – procure and build based on whole life value, rather than just initial capital cost.
• Industry-led Innovation – encourage and harness the industry leading initiative into digital construction, materials development, manufacturing and off-site technologies/capabilities.
• Skills for the Future – a reform in construction training to make it more strategic and industry led, including investments from the Apprenticeship Levy, to provide the skilled labour force to serve the innovation.

As this is relatively recent, the detail of who, how and when are still crystallising, but WSP supports they key areas which are aligned with our own WSP global initiative of “Future Ready”.

**Question 8**

We welcome the fact that the Chancellor recently stated that major central Government Departments “will adopt a presumption in favour of off-site construction by 2019 across suitable capital programme, where it represents best value for money”. WSP believes this shows commitment to the opportunity, and looks forward to bringing forward real live examples and champions with both the private and public sector to gain traction.

WSP sees merit in using large regeneration projects to create opportunities to establish off-site local capabilities, which have legacy value. We also believe that constraints on public procurement process that result in low-innovation, low sustainability practises achieving winning scores need to be removed.

WSP advocates for the creation of clear procurement briefs and score matrices that truly reward innovation and highly sustainable design and construction. WSP would support an approach which engenders a culture of continual improvement and sharing of this knowledge as an industry as opposed to the opposite to try to obtain a competitive advantage.

*25 April 2018*
WSP UK, Bryden Wood and Rogers Stirk Harbour and Partners – Oral evidence (QQ 30-40)

Transcript to be found under Rogers Stirk Harbour and Partners
Zurich Insurance – written evidence (OMC0054)

About Zurich Insurance

Zurich provides a suite of general insurance and life insurance products to retail and corporate customers.

We supply personal, commercial and local authority insurance through a number of distribution channels, and offer a range of protection, pensions and investment policies available through financial intermediaries for the retail market and via employee benefit consultants for the corporate market.

Based at around 20 locations across the UK - with large sites in Birmingham, Cheltenham, Farnborough, Glasgow, London, Swindon and Whiteley - Zurich employs approximately 5,000 people in the UK.

Summary

The need for the housing sector to modernise its methods of construction has been increasingly identified as a key concern, with it commonly suggested that traditional brick and block methods are unable to achieve the output required to meet the demand for new homes. Off-site construction and the use of prefabrication are now, therefore, a growing trend in the UK with both becoming viewed as a key building method to meet the demand for affordable housing. However, we are witnessing an acceleration of a number of modern methods of construction (MMC) beyond off-site construction and prefabrication which we believe must also be considered as part of this inquiry. We, therefore, do not confine our response to off-site construction and focus on modern methods of construction as a wider concept and highlight the following:

- Modern Methods of Construction (MMC), including off-site construction and prefabrication, present genuine opportunities for the construction industry and the housing sector.
- However, as MMC becomes more prevalent, trends are emerging around serious problems that can be experienced when implementing MMC, particularly issues relating to the durability of the development, and the increased risk of large scale flood and fire damage representing an increased risk to the wellbeing and/or displacement of the occupants.
- For example, the use of combustible lightweight materials such as wood, polystyrene and recycled materials have the potential for a greater degree of fire spread, leading to an increase in repair costs and timescales. Due to a decrease in the resilience of a property, poor practice during construction can exacerbate these risks further, for example, by the presence of concealed voids through which smoke, toxic gases and water can permeate through a building.
- There is an urgent need, therefore, for the consideration and mitigation of these risks to be fully factored in during the design, construction and inhabitation phases of the lifecycle of properties built in this manner.
We are also seeking clearer and simpler building regulations and the need for clear enforcement mechanisms to ensure that new buildings built using MMC are truly fit for purpose, are resilient and are ultimately safe.

1. What are the opportunities offered by off-site manufacture for construction? What are the drawbacks to offsite manufacture for construction?

Modern Methods of Construction

1.1 Construction practices and technology are developing rapidly, leading to the erection of taller and more complex buildings – often using modern methods of construction (MMC). As well as off-site construction and prefabrication the term MMC also encompasses manufacturing techniques such as steel or pre-cast concrete frames, panelised units, modular and volumetric buildings, structured insulated panels and timber frames – many of which do involve off-site manufacture.

1.2 These new technologies are used in the construction of a variety of buildings from small blocks of flats to education, health and leisure centres, all the way up to the latest major construction projects.

1.3 Zurich is clear that the potential benefits of innovation in construction can be far reaching with the use of MMC providing a range of benefits which are particularly attractive to the social housing sector, local authorities and housing developers looking to construct public buildings and housing developments in the most efficient manner whilst also meeting the latest standards on sustainability and environmental performance.

1.4 Indeed, these methods, if used appropriately, can: minimise waste; deliver quality architecture; reduce costs and build times; and satisfy green energy requirements. However, many popular MMC solutions also introduce added risks and reduce resilience when compared to more traditional builds, both during construction and throughout a building’s lifetime.

Modular Construction

1.5 One method of MMC, that of volumetric or modular construction, allows for factory-produced ‘modules’ to be placed straight on to prepared foundations, allowing for construction projects to be undertaken much more quickly. However, problems can occur after completion if the lower level modules or units suffer damage, such as in the event of a fire or flood. These units may not be able to be repaired in situ and may need to be removed and replaced, causing disruption to and removal of the surrounding units and external finishes.

1.6 We would also emphasise that bad practice during installation of these units can lead to hidden voids through which smoke, toxic gases and water can permeate through a building, meaning a small incident, such as escape of water or a small fire, can cause disproportionately high damage to the
building, increasing the risk to life, repair costs and disruption to the occupiers.

**Timber-Framed Buildings**

1.7 Timber frame buildings are a similarly popular modern method of construction. However, timber-framed structures are susceptible to ignition sources both during and after construction and if a large-scale timber-framed building were to catch fire, it would likely involve the total destruction of the site involved. Due to the ferocity of such fires we have witnessed spread to adjacent buildings. These timber-frame buildings are also highly susceptible to compromise through poor workmanship, specifically in relation to fire stopping defects. We have seen several examples where seemingly minor defects have had catastrophic consequences in respect of the buildings performance in a fire event.

**Consideration of New Technology**

1.8 Many MMC are new and innovative and contractors may have little or no previous experience of the materials, systems and assembly techniques required. This again could lead to additional risks, particularly in relation to fires if maintenance contractors are unaware of hidden combustible insulation, than if more traditional methods had been used.

1.9 Indeed, Zurich recently assisted two customers who had experienced near identical issues at their respective housing developments which had been built using common MMC such as timber frames, wooden cladding and components manufactured off-site. Just a decade after construction the customers were alerted by staff and tenants to a number of concerns including cracks appearing in walls, uneven floor surfaces and windows and doors not fitting properly in their frames. Given the nature of the construction such movement raises significant concern as to the remaining integrity of the fire stopping within the buildings, given that there is minimal inbuilt resilience to such defects within these structures.

1.10 Structural engineers conducted an intrusive survey of the developments which raised a number of concerns including: the existence of large voids in the internal structures which would allow fire to move quickly and undetected throughout the entire building; holes in the walls and around fires doors breaching vital firebreaks as a result of structural settlement and drying out; and large holes in firebreak walls and floors as a result of contractors installing piping and electrical services and not subsequently back filling them.

1.11 Excellent contractor selection and management is, therefore, essential in order to ensure a full understanding of the MMC techniques being utilised, their likely performance including life cycle requirements, and how resilient they are to changes and adaptions throughout the life of the building.

**2. What factors are likely to influence clients, architects, design engineers, contractors and the supply chain to choose or not to choose off-site manufacture?**
2.1 As previously outlined, the use of MMC provides a range of benefits which are particularly attractive to the social housing sector, local authorities and housing developers looking to construct public buildings and housing developments in the most efficient manner whilst also meeting the latest standards on sustainability and environmental performance. Indeed, these modern methods, if used appropriately, can minimise waste, deliver quality architecture, reduce costs and satisfy green energy requirements.

2.2 However, the inappropriate use of materials arising from a focus on cost and energy performance is often without due regard to the form and function of those materials, their longevity and the consequences of introducing them in combination into a structure without taking into account the size of the structure to which it relates.

2.3 In particular, we would highlight that whilst there may be lower up front building costs associated with properties built using modern methods of construction often, in the medium to long-term, other factors across the lifecycle of the building may mean that it is not such a low-cost alternative and may prove to be more expensive in the long-run. Indeed, for example, repairing pre-fabricated, component parts in pods can be incredibly difficult with sometimes the only option being to remove the entire pod and install a new one to replace it which incurs additional costs.

3. Can the benefits of standardisation and factory manufacture be realised without hampering architectural ambition? If so, how?

3.1 It is important that we learn from errors in the past and ensure that any standardisation is of robust quality and does not contribute to potential fire growth, through the use of combustible structures, materials or insulation.

4. What R&D is needed, and by whom, to fully realise the potential benefits of off-site manufacture?

4.1 MMC risk is not easy to assess. As such, it is essential that the industry endeavors to stay abreast of new technologies. In particular, witnessing fire and flood performance tests on materials. Developers and owners need to consider how the use of MMC will affect total costs over the lifespan of the building, how the building will be affected in the event of a fire or a flood. Everyone involved in managing the building in the long term needs to be comfortable with the use of MMC the benefits, but also the negatives that are associated with it including all relevant stakeholders, architects, financiers, insurers and even local fire authorities.

4.2 There is also an urgent need for the consideration and mitigation of the insurance risks to be fully factored in during the design, construction and inhabitation phases of the lifecycle of properties built using modern methods of construction to ensure that the potential benefits can be realised. It is important, therefore, to consult with the insurance industry to ensure the buildings are acceptable for insurance cover.

4.3 Understanding how developments built using MMC achieve the required building fire resistance during the inhabitation phase can be particularly
challenging. For example, the installation of new services through walls and floors or the installation of electronic equipment/devices could potentially breach fire compartmentation and, in the event of a fire, allow much more rapid and extensive fire spread into hidden voids.

4.4 It is essential that if any aspect of a development built using MMC is altered during its lifecycle, but particularly during the inhabitation phase, any firebreaks are reinstated and not compromised.

5. What changes could be made to public procurement processes to encourage more sustainable practices in the construction industry and facilitate off-site manufacture?

5.1 There is a clear need for robust enforcement of regulations and improved quality control requirements for new build and refurbishment schemes. The regulatory framework is in need of review in addition to the actual technical requirements within the regulations. Building regulation approval (Building Control) is subject to commercial pressures and opens up the potential for differences in the quality of service provided for approval and inspection of building works in relation to compliance with Building Regulations.

5.2 Indeed, actual Building Regulations in specific terms may be considered appropriate in wording, but the adequacy and clarity of associated guidance in Approved Documents requires much improvement. There is a lack of linkage between differing parts of the Building Regulations, for example, Part L: Conservation of Fuel and Power should make specific reference to Part B: Fire Safety in relation to the fire performance of energy performance guidance, selection of insulation materials etc.

5.3 Similarly, fire safety legislation for existing buildings is flawed in that there remain, after a number of years, poor understanding of the issues an effective Fire Risk Assessment (FRA) should include and address. For example, we have questioned how a Fire Risk Assessment carried out under the Regulatory Reform Order (RRO) for a residential apartment block, not take into account fully the accommodation that immediately adjoins and interfaces with the communal parts. The legislative framework requires simplification to ensure that not only responsibilities are clear, but that the resulting requirement for a robust and all-encompassing fully effective FRA is achieved.

26 April 2018