ROYAL ACADEMY OF ENGINEERING

# Off-site manufacturing for construction

Response to the House of Lords Science and Technology Committee, 4 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[1] 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.

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.

[1] Systems which can be linked together to form complete buildings without an additional superstructure

## 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[2] 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.

   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.

[2] http://www.crossrail.co.uk/route/stations/custom-house/current-works/

- 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.