CONSTRUCTION METHODS MODULAR

Modular construction is touted as the future of the building industry, but while the sector is rapidly growing in some areas, there are still obstacles to overcome. **Alex Hyams** of **Alinea**, **Ed McCann** of **Expedition Engineering** and **Hugh Ferguson** assess the pros and cons of volumetric modular offsite construction

01 / INTRODUCTION

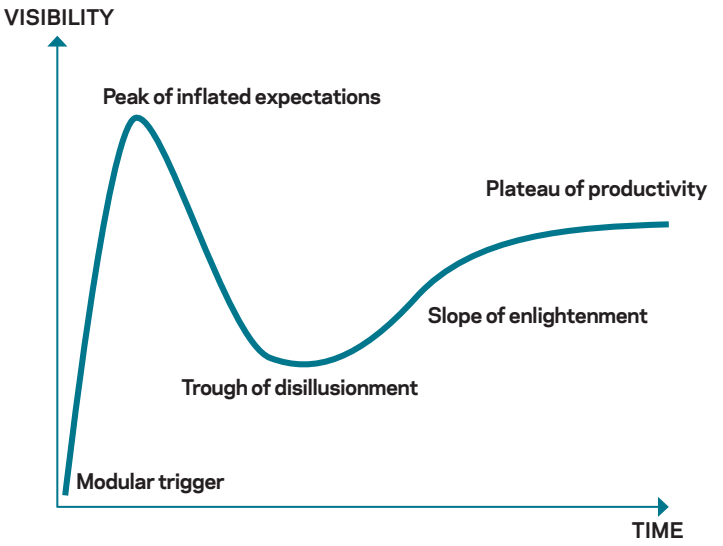
Is modular construction the future for the UK building industry as its supporters have long maintained, or is it a hopeless effort to translate factory techniques into an unsuitable industry? The question has divided opinion since the benefits of modular were hyped up 20 years ago.

In the wake of the 1998 Egan report, Rethinking Construction, enthusiasts claimed the quality, speed and cost savings achievable with factory production of modular units offered irresistible benefits to the building industry. The anticipated revolution did not happen, and those who experimented found the benefits did not always materialise.

The pattern has all the hallmarks of the Gartner hype cycle for emerging technologies, which shows the way technology is adopted, with the "peak of inflated expectations" followed by the "trough of disillusionment" (see figure 1). The 2016 Farmer review put modular in the spotlight again as part of the solution to the building industry's ills. So is modular now climbing Gartner's "slope of enlightenment" to reach the "plateau of productivity"?

To find out, this study rehearses the potential benefits of modular construction and explores the barriers that have limited uptake of prefabrication in the UK – including a failure to understand the business model and an overwhelmingly negative public image. It examines where successes have been achieved, where they have not and where the greatest potential for future development is.

Figure 1: Gartner hype cycle, showing a technology's journey to mainstream acceptance



WHAT IS MODULAR CONSTRUCTION?

Modular construction describes substantial elements of a building that are factory-produced and delivered to site for assembly. It comes in several forms – the principal focus of this article is volumetric modular systems.

■ Volumetric modular systems – prefabrication is used to create complete 3D structural units, usually using steel framing or light-gauge steel sections but also precast concrete, timber or a combination of these.

The modules may be fully fitted out in the factory, including services and internal fixtures and fittings. They are then driven to the site and craned into position, with combinations of modules – often stacked – used to create larger buildings.

Some volumetric modules have load-bearing walls. They rely on the wall panels for structural strength, either for vertical load bearing or for diaphragm action to resist lateral loading.

Other volumetric modules are "frame + infill", using posts and beams – typically formed from hot-rolled steel sections – to frame the units. Non-structural infill panels are inserted between the posts to form the walls, providing greater flexibility in room layout than a solid-wall module. Floors and ceilings span to the perimeter of the frame.

Mapleton Crescent, by Vision Modular

TIDE CONSTRUCTION / VISION MODULAR

■ Panel systems (or flat panel systems) – 2D panels are prefabricated, delivered to site and craned into position, then connected to form a structure. Materials are typically precast concrete, timber, cross-laminated timber or structural insulated panels. Finishes and services are usually installed on site after assembly.

■ Pods are relatively small prefabricated modules, usually fully fitted out, which may be used in conjunction with another construction method. Common examples are bathroom or kitchen pods.

■ Hybrid systems may combine volumetric or panelised systems with other precast elements and/or a primary structural frame.

02 / POTENTIAL BENEFITS

Speed
Programme savings of up to 50% are possible compared with traditional forms of construction. Furthermore, the programme can be more predictable than when using conventional methods – if errors do occur during fabrication, the effect on the overall construction process can be more easily managed, since repairs are limited to one particular module and can be completed offsite.

Space
A smaller site area is required on site as fewer construction materials are stored there. With careful management of the delivery and installation of modules, temporary storage can be minimised or removed altogether.

Cost savings
The repetitive nature of modular construction, which is tailored to a factory environment, creates lower costs – though these savings are not always achieved in practice, as explained in the next section, below.

Savings in labour costs are possible, by more efficient use of labour or by avoiding city centre wages. Standardised details can reduce overall design fees and a more predictable construction programme reduces the risk of increased costs due to delays on site.

The shorter construction programme can also reduce the costs of site management and facilities costs, while producing a faster return on investment, with reduced financing costs.

The manufacturer's cost base should be more predictable as there is greater control of the workforce, who are likely to be on more permanent or fixed contracts, than with site-based alternatives where operatives move from site to site looking for better pay and conditions. Transferring from trade-based delivery to a more task-trained operative scenario not only reduces cost but also improves access to labour and can help alleviate some impending construction skills capacity issues.

Health, safety and wellbeing of staff
In the controlled factory environment, risks such as working at height and exposure to bad weather, noise and dust are reduced or eliminated, while other hazards can be better identified and mitigated. Fewer trades and personnel are required in the more dangerous site environment. Also, the workforce in a static factory has longer-term job prospects, extending beyond completion of the current project.

Quality
Assembly in a factory can consistently deliver airtight, thermally efficient construction, with lower running costs. The air gaps between modules in volumetric construction assist in providing acoustic separation between units. Factory production can deliver more durable construction, which requires less maintenance.

In a controlled factory environment, strict quality assurance procedures can be more easily achieved, resulting in improved quality of construction. There is a reduced risk of moisture ingress during construction, and workmanship is not affected by bad weather.

Reduced numbers of errors mean fewer snags and fewer defects on handover, and consequently a reduction in the associated costs and delays.

Sustainability
More construction offsite means less waste as the controlled conditions enable work to be more precise and there are fewer mistakes, and waste produced in a factory can be more easily recycled. On a residential building, most of the lifetime energy use is due to space heating: the better airtightness and thermal performance obtainable in factory conditions, particularly with volumetric modules, translates into lower energy use and lower running costs for occupants.

03 / OBSTACLES TO ADOPTION

Cost
Feedback suggests that in some areas such as Ministry of Defence work, student housing and even budget hotels, modest savings are being achieved, but in the mass market and the emerging build-to-rent (BTR) sector capital costs remain higher than for traditional contractor delivery.

The explanation lies in the nature of the business model and – in particular – the current lack of competition in the modular market.

The suppliers of volumetric modules are operating a manufacturing business with large initial investment and relatively high overheads associated with running the factory and its fixed labour force. They need, above all, a steady flow of work. Keeping unit costs low depends on high utilisation, which can be much more difficult to achieve in construction than in, say, a car factory because the offsite manufacturer is multiple steps removed from the commercial/sales decision making.

Consequently there can be large variations in unit costs depending on the level of utilisation. If suppliers with low utilisation discount too much to generate demand, they go bust, so they tend to keep their prices up (see figure 2, overleaf).

When the factory's utilisation rate is high, unit costs come down. But this corresponds with periods of high demand, so there is no financial incentive for the supplier to pass on the savings to the client. So although costs may come down, prices often remain high – though this "risk margin" is difficult to identify because modular contractors do not provide detailed cost data in the same way as traditional contractors.

On top of this, many clients fail to understand that modular construction requires a different approach to procurement, in which details are designed with factory construction in mind and design is finalised before procurement. This leads to avoidable extra costs due to late changes and costly detailing.

As a result of these factors, some clients see no cost savings, or even pay more, though they may still receive the programme and quality benefits. Indeed, many early users see speed of construction (and hence an early return on investment) as the key driver, so driving down construction cost is seen to be of lesser importance.

Competition
There are a limited number of suppliers, partly because of the reasons above, and capable competition is lacking (see table 1, page 50). Suppliers try to maximise their profits, so in a supply-limited market, prices will rise to match the cheapest alternative, usually conventional construction.

As both demand and capacity for offsite grows, the market will hopefully become more competitive and behave as expected; passing savings on to "good" clients that adopt the new practices needed to maximise the benefits of offsite (see figure 2, overleaf).

Negative public perception
The public's distrust of modular lies in the history of prefabrication. Back in the mid-19th century there were spectacular successes: Joseph Paxton's Crystal Palace in Hyde Park for the 1851 Great Exhibition and Isambard Kingdom Brunel's wooden Renkioi Hospital built during the »

John Dodgson House, a budget summer residence owned by UCL and built by Premier Modular
PREMIER MODULAR

» Crimean War. However, both enterprises excluded Britain's architectural establishment, which may help explain why prefabrication was not repeated for the next half century, and rarely thereafter.

In the 1940s, post-war prefab housing was built quickly to meet an urgent need when materials, labour and money were in short supply. Modular came to mean temporary accommodation such as site huts. Consequently, prefabrication and modular came to conjure up images of cheap, cramped construction.

The stereotyping has been reinforced by the way the recent British volumetric modular construction industry has developed – emerging from the temporary accommodation market, sometimes with few efforts to disguise the fact. Some manufacturers may be unaccustomed to appointing architects with experience of designing high-quality, permanent buildings and, conversely, few architects are familiar with the design of volumetric modular units.

Design

The most obvious constraint is how large and heavy a module can be. To be transported by lorry each module must be within the limits of 2.9m wide, 4.2m-4.5m high and 18.75m long (or a little larger for an "abnormal load"). A lightweight volumetric unit can usually be lifted by a medium- to heavy-duty all-terrain mobile crane, although incorporating concrete floors into the modules can double the load. There is also a limit to the height to which units can be stacked, although the limit depends on the type of module and the form of construction.

There can also be constraints on layouts. Some forms of modular construction require load-bearing partitions to stack vertically through the height of the building, with limited scope to accommodate large openings in these walls. These also limit the flexibility to alter the layout between floors, meaning, for example, that a late change in the mix of apartments for a housing block would have a major effect on the design and could also require further changes to the layout of apartments on the floors above and below. Greater flexibility can be achieved by combining factory fabrication with sub-assembly into larger units on site.

Many facade types and finishes used with modular construction reflect the industry's background in temporary accommodation, with a perception of mere functionality, and lack of durability. However high-quality finishes can be achieved, and a panellised facade system can be fixed to the units after they are installed on site.

Flexibility

With traditional construction it is common for design to overlap with construction, such as the design of kitchens and bathrooms continuing while the structural frame is erected. However, for modular, the space planning, detailed design and service integration all need to be completed earlier than on traditional projects, since the costs of incorporating late design changes to the modules can be very high. Clients who realise this too late find that their costs rise, or that their required changes are too expensive to implement.

Of course, suppliers try to keep their factories full and their utilisation rates high, so once a programme of construction has been agreed, it can be difficult to alter the rate of delivery. Acceleration may be impossible due to other orders, and delay may mean "missing the slot" and incurring contractual penalties.

Procurement

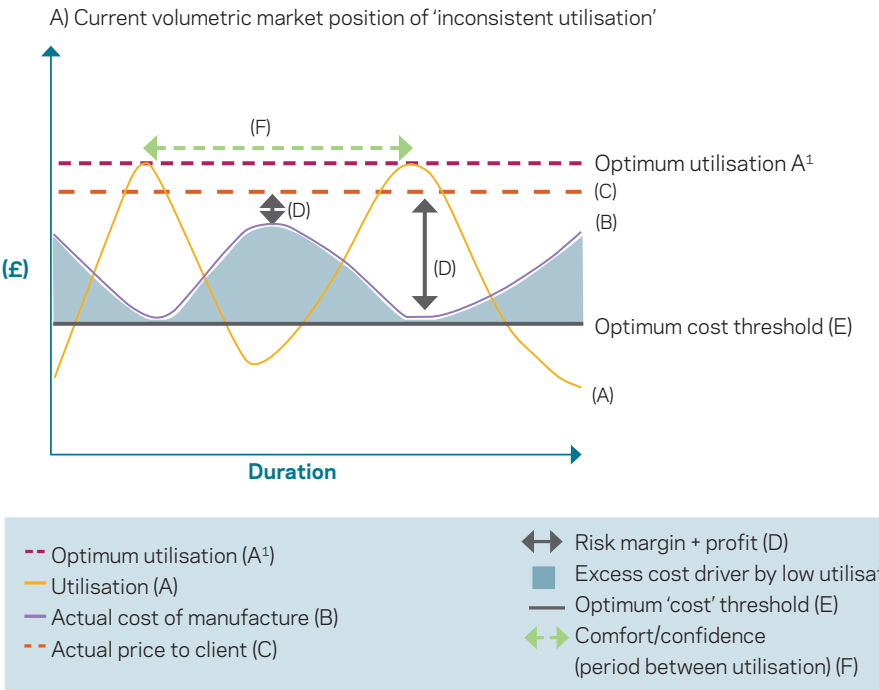
Once engaged with a particular supplier, there is usually very little scope to source modules from an alternative company if the original supplier fails to perform. So careful choice of supplier and developing a close relationship with that supplier are particularly important.

At present, most UK suppliers use simple forms of construction, largely because the industry is still in its infancy and suppliers are avoiding over-investing in heavily automated fabrication systems. This may help limit the supplier's risk, but it also limits the benefits that full automation could bring.

Accreditation

Building regulations, planning permission and insurance and mortgages for residential property can be a barrier, as they are with any construction innovation, because they take time to catch up. Mortgage lenders generally expect a design life for the structure of at least 60 years, while non-structural components are expected to last no less than 15 years. Durability of new systems is difficult to demonstrate, but suppliers are able to address concerns with the Buildoffsite Property Assurance Scheme (BOPAS) certification or alternative assurance schemes.

Figure 2: Explanation of utilisation and effect on cost and risk



Notes:

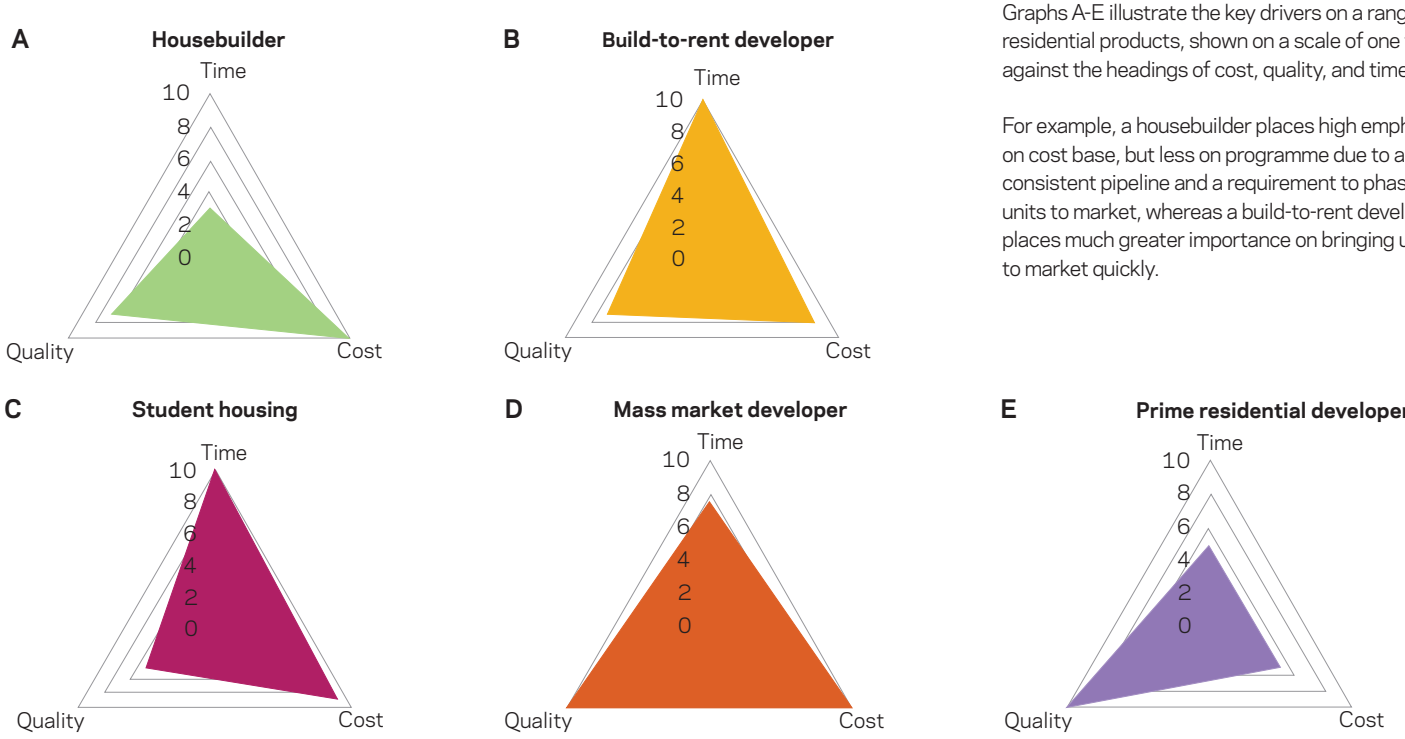
Actual cost (B) driven by utilisation levels (A).
Actual price level (C) driven by confidence – the shorter the period (F) drives a lower risk margin (D) and ultimately a lower price.

In periods where manufacturers risk margin (D) and optimum cost threshold (E) drops below the actual cost of manufacture (B), losses will be made which if (F) remains wide then a company risks going under.
The answer/solution is to be able to control utilisation levels through a consistent pipeline:

- Decrease (F)
- Reduce (B) towards level of (E)
- Ability to reduce (D)
- Reduction in (C)

04 / KEY DRIVERS ON RESIDENTIAL PROJECTS

Figure 3: Relative importance of key drivers



Graphs A-E illustrate the key drivers on a range of residential products, shown on a scale of one to 10 against the headings of cost, quality, and time.

For example, a housebuilder places high emphasis on cost base, but less on programme due to a consistent pipeline and a requirement to phase units to market, whereas a build-to-rent developer places much greater importance on bringing units to market quickly.

05 / WHAT IS MODULAR CONSTRUCTION SUITABLE FOR?

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Apex House, Wembley, student accommodation, which is the tallest modular building in Europe

Modular's level of suitability for different projects can be explained by the traditional construction triangle of quality, cost and programme (figure 3, above). The ideal is to optimise all three areas – time, quality and cost – but in practice there is always a trade-off. Modular offers potential benefits in all three areas, as explained in the "Potential benefits" section (page 47).

Success stories

Take-up has been generally at the lower end of the market, wherever repetition is achievable, speed of construction is particularly desirable and high quality is not necessary. Examples include student accommodation, where Vision Modular has delivered a number of successful schemes such as Apex House and Felda House in Wembley, north-west London, as well as Chapter in Lewisham, south-east London.

In key worker accommodation both Premier Modular and Caledonian have delivered schemes at Hinkley Point for construction workers at the nuclear power station. Pocket Living's Mapleton Crescent scheme in Wandsworth, south-west London, was completed by Vision Modular.

Budget hotels such as Premier Inn and Jurys Inn have been constructed using volumetric. Other notable schemes include a number of schools and Project SLAM (Single Living Accommodation Modernisation), an accommodation programme for the Ministry of Defence taking in 52 locations across the UK.

Areas for improvement

It has had little or no take-up in commercial offices, where large, open interior spaces are required and where, most significantly, the market is highly cyclical, providing little or no potential base-load of utilisation for a factory.

Nor, so far, has modular had much impact in markets where speed of construction is less critically important, including the middle to upper range of the housing market (apart from details such as toilet pods and prefabricated facades).

Benefits have been demonstrated in terms of snag-free compliance and functionality, but few are convinced that modular can provide the less tangible aspects of high-quality development – to create spaces that people really want to live and work in and that people delight in.

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06 / WHERE IS THE GREATEST POTENTIAL FOR FUTURE DEVELOPMENT?

A large client with a strong pipeline that has some potential for standardisation is a good candidate for modular. A substantial client can establish strong long-term relationships with one or more suppliers, offering a large and steady flow of work in return for competitive pricing and attentive service. Such clients include the public sector for school or hospital buildings as well as affordable housing, military barracks – and large housebuilding companies for mass-market housing and the emerging BTR sector.

Much has been achieved at the lower end of the market to demonstrate that well-designed volumetric modules can deliver good quality that looks more appealing than stacked site huts. But much more needs to be done, perhaps by engaging talented architects to work with housebuilders and suppliers to develop imaginative designs that create more interesting and varied spaces from a limited palette of modules – and that create the "delight" factor lacking in modular design so far.

Another essential ingredient is to sell the business model to housebuilders. Berkeley Homes is already building a modular factory at Ebbsfleet in Kent, and Legal & General Modular Homes has established a factory near Leeds, though both are still several years from consistent production.

The issues may be different in city centres from those in suburban or town housing. In city centres, the key concern for housebuilders at the moment is not construction but land values and planning. That could change quickly, with the increasing difficulty in sourcing skilled labour at an affordable cost in city centres. If quality starts to slip due to poor workmanship, housebuilders are hit by extra costs for repairs and, worse, by damage to their reputations. Modular construction can shift the bulk of the work to a factory away from the city centre, where labour costs are lower and where quality can be more readily controlled.

Out of town

Out of town, where land values are lower, a higher proportion of the price of a home comes from the construction cost. Here, modular construction offers the chance to substantially improve the quality of housing without increasing the cost, and to provide more variety, including some medium-rise and higher density, which could help to recreate communities.

Housebuilders also have a business cycle that suits modular construction, with peaks and troughs but always a base workload, even in the worst downturn. A housebuilder could decide to supply all of this baseload using modular construction, which would provide a steady, stable output ideal for maximising the benefits of factory production while retaining flexibility to supply the peaks. This could provide the basis for a close long-term business relationship with a chosen supplier. Or the housebuilder might establish his own modular factory. There have been some spectacular failures or near failures as a result of builders trying to become manufacturers, but there could be a successful integration of the manufacturing and funding process by L&G (see Building's interview with L&G Homes boss James Lidgate, page 26, 13 July 18) or others.

So, modular construction has so far followed the hype cycle up and over the "peak of inflated expectations", down and through the "trough of disillusionment" and is now ascending the "slope of enlightenment".

It is no longer seen as a cure-all for building construction, but solid experience is demonstrating where – when correctly applied – it could make a transformational difference, and nowhere more so than in housing. The potential for further cost savings could be substantial if some of the points we have noted are addressed. Modular is not an instant panacea for Britain's housing crisis. But perhaps we are just waiting for one major housebuilder to seriously adopt modular construction, and we will enter the "plateau of productivity".

Table 1: A list of Buildoffsite members with full volumetric capabilities

Buildoffsite is a UK-based membership organisation that links together all parts of the value chain to enable the increased use of offsite methods across all sectors. Buildoffsite encourages collaboration to deliver innovation, improved productivity and high-performing construction projects

Volumetric manufacturers	£50m+ projects (all sectors)	£50m+ projects (residential)
Actavo		
Caledonian Modular	●	●
Eco Modular		
Elements Europe	●	●
Elliott Group	●	
Enegroup		
Extraspace		
Ideal Modular		
Ilke Homes		
Legal & General Modular Homes		
LoCal Homes		
McAvoy	●	

Volumetric manufacturers	£50m+ projects (all sectors)	£50m+ projects (residential)
M-Ar		
Modular Wise		
Modulek		
Premier Modular	●	●
Pod Living		
Rollalong		
Simply Modular		
Swan Homes/Nu Living		
Thurston Group		
Urban Splash		
Vision Modular	●	●
Yorkon	●	