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Automated Construction:

Why manufacturing is the future of the sector

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Learning Objectives

- Explore the barriers that have prevented us from making the shift from 'construction' to 'manufacturing' before.
- How we can harness the benefits of standardization without relinquishing individuality and quality of design.
- How we need to change the design process to realize these benefits.
- What this might mean for the 'construction site' of the near future

Description

Construction is the last sector (after agriculture, manufacturing, and mining) that continues to throw thousands of people at a problem, working with chronically low productivity in physically and mentally challenging conditions. The time has come to apply learning from other sectors and vastly increase productivity in both the design and delivery of assets. The shift to digital design is accelerating, thanks to sophisticated, data-driven tools that go beyond BIM (Building Information Modeling). Algorithmic simulation, machine learning, and generative design vastly accelerate the process. Better still, they generate far more possible solutions, which means better outcomes. Meanwhile, new forms of construction are harnessing the benefits of manufacturing. Construction “platforms” combine design, manufacture, and procurement principles holistically to ensure a greater degree of rationalization and integration. Manufactured components can be used across sectors creating high, constant demand and economies of scale.

Speaker

Having joined Bryden Wood, a tech-led team of designers, shortly after the practice’s formation in 1995, Jaimie leads the application of systems to the delivery and operation of high performing assets. This includes both physical (Design for Manufacture and Assembly - DfMA) and digital (data analysis and digital engineering) systems for projects in the UK, Europe and Asia with clients including GlaxoSmithKline, Heathrow Airport and several government departments.

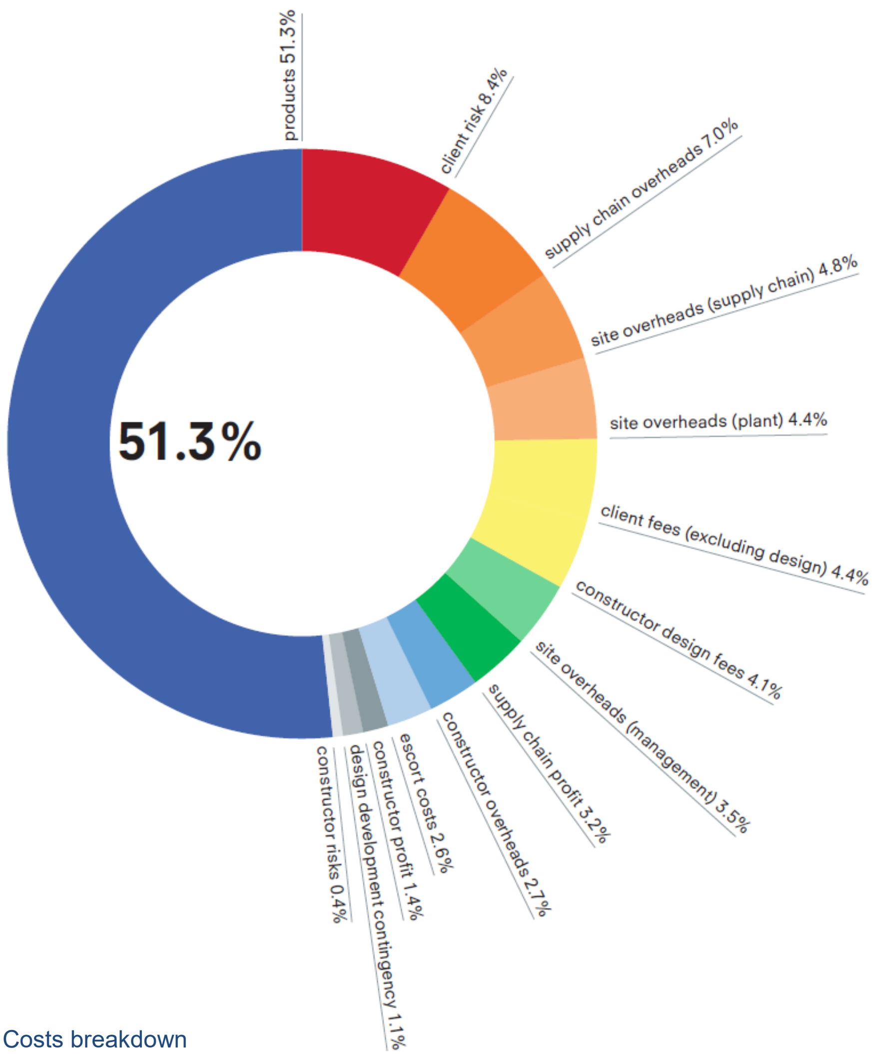
Jaimie was the author of the strategy documents 'Delivery Platforms for Government Assets: Creating a Marketplace for Manufactured Spaces' and 'Platforms: Bridging the gap between construction + manufacturing'. These have been adopted as a key articulation of the UK Government's aspiration to adopt a more manufacturing-led approach to construction. This work was reflected in the Infrastructure and Project Authority's call for evidence relating to the 'proposed adoption of a Platform approach to Design for Manufacture and Assembly' (P-DfMA) issued in 2018.

Jaimie is the Design Lead for the Construction Innovation Hub, which in late 2018 was awarded £72 million to drive innovation and technological advances in the UK construction and infrastructure sectors.

Introduction

The challenges facing the construction sector are widely recognized and well documented; they include:

- Low productivity;
- Low predictability;
- Structural fragmentation;
- Low margins, adversarial pricing models and financial fragility;
- A dysfunctional training funding and delivery model;
- An ageing workforce;
- Lack of collaboration and improvement culture;
- Lack of R&D and investment in innovation;



Costs breakdown
for a typical project

To put the extent of the problem into context, data from one UK Government department shows that of every pound spent on construction, only 51% ends up as residual asset value (see diagram, left); the majority of the remainder is spent on:

- Waste and rework;
- Transactional costs and inefficiency.;
- Risk inherent in the design and construction method.

Enormous value can therefore be created by addressing the issues outlined above. While the benefits are large, however, realizing them requires significant changes to the current processes of design, procurement and delivery.

Why hasn't the shift to manufacturing happened before?

The 'offsite revolution' has been discussed for many years, with only marginal increases in adoption. However, the conditions now seem right for a fundamental shift in the industry:

- Issues relating to construction cost, labor availability and productivity, fragmentation in the market etc. are now so widely recognized that the need for a new approach is becoming more acute;
- Shared global drivers – for instance, United Nations figures estimate that the world's urban population will increase by 2.5 billion by 2050. We will not keep up with growing demands for social and physical infrastructure without developing much more efficient design and delivery approaches;
- Digitization in construction –BIM is increasingly becoming 'business as usual', so the digital tools that would support a manufacturing-led approach are in place. This a precursor to more sophisticated digital controls and workflows;
- Other technological advances in the digital, manufacturing and commercial sectors that could be harnessed by a platform-based approach (which is described in more detail later).

Introduction to construction 'Platforms'

Bryden Wood have developed a number of different design for manufacture and assembly (DfMA) solutions for clients in various sectors over the past 25 years, with significant benefits in time, cost, quality etc. From this experience we are developing a more generalized approached that we believe could be widely adopted by the construction sector.

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.

Industries that have adopted a platform-based approach have experienced the following benefits[1]:

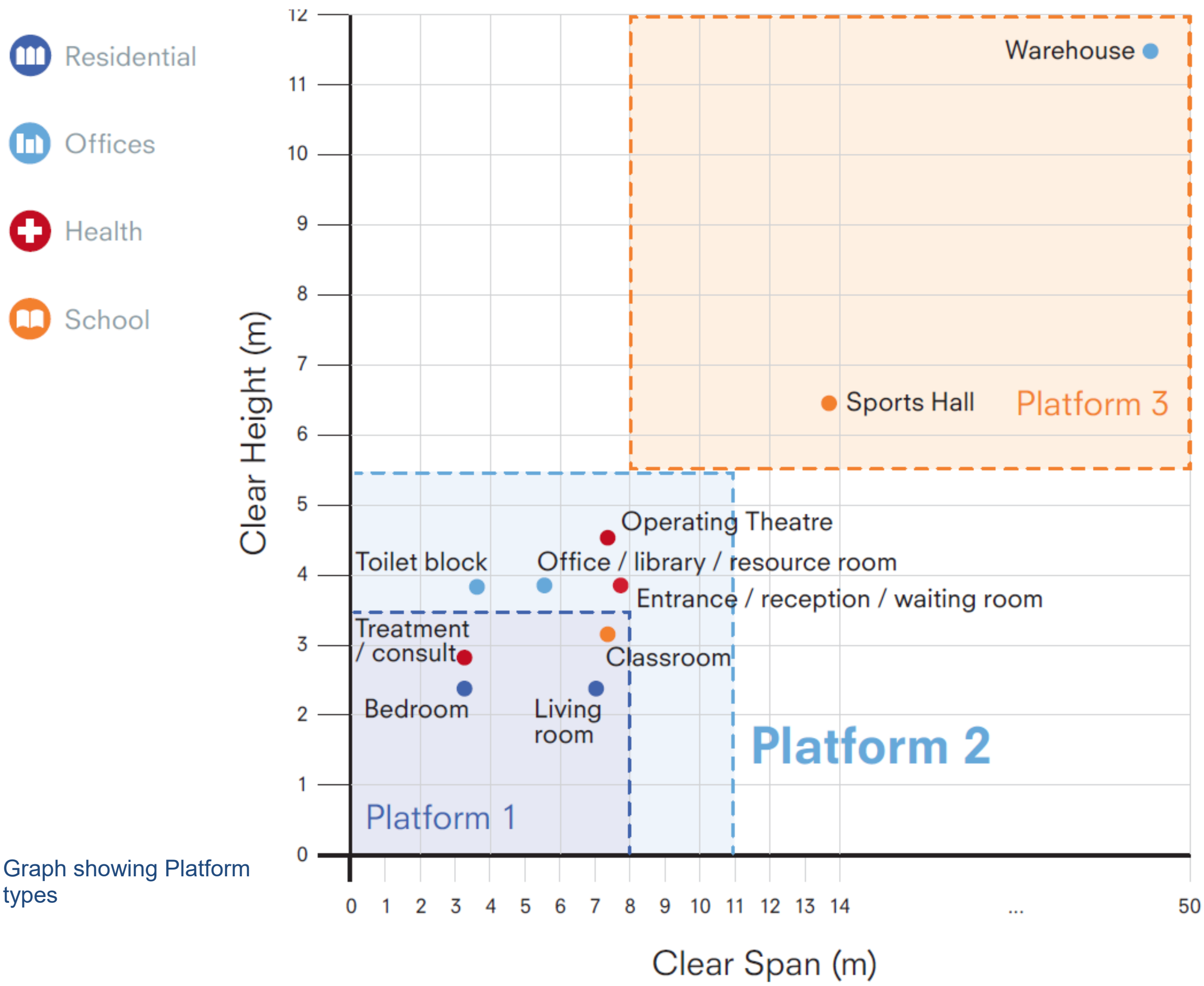
- Savings associated with transactional, fixed costs;
- More efficient product development processes through the re-use of common elements and adoption of 'modular' designs (in this context 'modular' relates to conceptual elements of design rather than physical modules);
- The ability to quickly evolve secondary or derivative products, and flexibility in product feature design;

[1] For a more detailed analysis of manufacturing and software platforms, refer to Gawer, Annabelle, and Michael A. Cusumano. 'Industry Platforms and Ecosystem Innovation.' Journal of Product Innovation Management 31, no. 3 (September 4, 2013): 417–433.

- The ability to broaden the applicability of a product to meet changing customer needs and keep pace with technological advances while maintaining economies of scale;
- The ability to adopt ‘mass customization’, combining the flexibility and personalization of custom-made products with the low unit costs associated with mass production.

This approach is typified by ‘continual improvement’ - the components are improved or expanded over time by incorporating lessons learnt and innovations in materials science and manufacturing processes. This is very different to the ‘constant reinvention’ of traditional construction where there is a lack of standardization and components tend to be designed from first principles for every new asset.

A construction Platform comprises a versatile and customizable construction system. It is made of common parts all made from readily available materials which have been designed to go together in known ways. Each part of the platform system has been optimized or ‘designed to value’ based on its performance requirements. This extends from using the right amount of material through to adopting manufacturing processes which are familiar to the industry and considering how safe and easy each part is to move.



Graph showing Platform types

The Platform system saves effort throughout the entire process – the design, manufacturing, delivery and assembly. Design effort should be spent where it can add the most value – creating places that people want to live and work. This standard kit of parts can be configured to offer a broad range of building products without limiting design ambition. If a design idea cannot be achieved with the current platform system, then the parts list is expanded.

Harnessing standardization benefits without relinquishing quality of design

One critical aspect of any DfMA solution, which sits at the meeting place of quality and value, is the balance between standard and bespoke elements. Highly industrialized production lines are very efficient but work best when producing completely standard products. At the other end of the spectrum, hand crafted goods may be completely bespoke but are costly and labor intensive.

In delivering any type of asset there is an inherent tension between the desire for standardization (which may increase value as defined above but constrain quality of design) and the need to make unique spaces and places which are a direct response to the brief and context.

It is therefore necessary to identify a solution which sits in the 'sweet spot'; providing enough standardization to create efficiency, with enough flexibility to maintain quality of design. This is something that e.g. the automotive sector does very well - customers can select from a range of options to create a mass customized vehicle, which nonetheless benefits (in terms of cost, quality and reliability) from using standardized components and manufacturing processes.

In order to identify where standardization should be applied to add value without compromising functionality, solutions will be interrogated and refined through a process of:

- Rationalisation;
- Standardisation;
- Optimisation.

Rationalization

This is the process through which potential solutions are analyzed, testing them to ascertain whether the degree of variation within the group (i.e. the range of different solutions to the same problem or brief) is necessary or whether a common solution could be adopted. Rationalization should be taken as far as is achievable without compromising the architectural outcome.

Standardization

The rationalization process invariably yields several common solutions with a high rate of occurrence. These will provide significant benefits in terms of speed of design, ease of construction, opportunities for standard working etc.

The size of the repeatable elements (the degree of granularity) will vary according to the size and nature of their function, degree of complexity and frequency across likely asset types. For some elements, standardization at the level of an apartment (as set out in the Product Book) may be beneficial, in other cases standardization at the level of a room type might be more appropriate, and this approach will continue down to typical connections or interfaces.

These standard elements can then be refined with stakeholders and, where appropriate, the likely supply chain to develop consistent and reliable layouts, interfaces, details and materials specification to ensure regulatory conformity, long life and minimum defects.

Quality of design is maintained by ensuring the standardization of components and processes still allows customization in configuration in end product

Optimisation

Further benefits may be realized by continuing to refine certain components; highly repeatable elements will justify significant time and effort in refining the design. The cost of the product can further be reduced by optimizing the use of materials (specification, thickness etc.) to meet the requirements for robustness and durability without being over specified.

This approach is particularly beneficial where it facilitates programme wide procurement with associated benefits of mass production and manufacture at an industrial scale.

Platform characteristics

The underlying principle in developing Platforms is to identify where a high degree of rationalization or standardization can be achieved without compromising quality. A platform must also reliably deliver reductions in cost and time at equal or superior quality compared to traditional construction.

Platforms can be considered in terms of a series of conceptual, physical and digital elements.

Conceptual elements

The process of rationalization and standardization results in a series of platform rules e.g.

- Dimensions for primary structural grids and layout planning grids, floor to floor heights etc;
- Maximum spans for structural components;
- Procurement and supply chain principles.

Physical elements

At component level Platforms manifest as a 'kit of parts' of pre-engineered components, assemblies and products that go together in pre-defined ways. These are holistic include superstructure, envelope, MEP and fit out.

Components, and the interfaces between them, are designed to enhance productivity through the use of standard, repeatable processes in both manufacture and installation, so:

- Are highly optimized and require the least amount of raw material to achieve the appropriate technical requirements and robust whole life performance;
- Are repeatable and can be manufactured at scale by a wide supply chain;
- Require no specialist skills or equipment that is not widely available;
- Can be manufactured, assembled and pre-tested using rigorous quality assurance to maintain consistency across the programme (in construction and into operation);
- Can be manufactured and assembled using local, semi-skilled labor (following standard training in relevant tasks) to facilitate the creation of apprenticeships and expansion of manufacturing skill sets;
- Require minimum materials handling and processing (which inevitably introduces waste and non-value adding activity);
- Use (where possible) materials that are widely available in the local / regional market.

The impact of all of these is to vastly increase health and safety, both in terms of physical and mental health. This is covered extensively in the body of the report but in summary:

- Physical health and safety are improved by, for instance, reducing the number / weight of components and reducing or eliminating work at height. Using manufacturing and assembly techniques allows more time for training operatives to carry out highly planned and ergonomically optimized work;
- Mental health and wellbeing are improved by, for instance, engaging a more local workforce and creating new skills and training. This reduces the need for a transient workforce working in difficult conditions, often removed from their families and communities (which is deemed to be a highly significant factor in construction having a suicide rate in young males ~3x the national average[2]).

Digital elements

The standard components obviously lend themselves to the creation of a data-rich digital library. This, combined with the parametric conceptual rules, facilitates the use of automated or semi-automated configuration apps which vastly increase the speed of design, and the quality of information generated.

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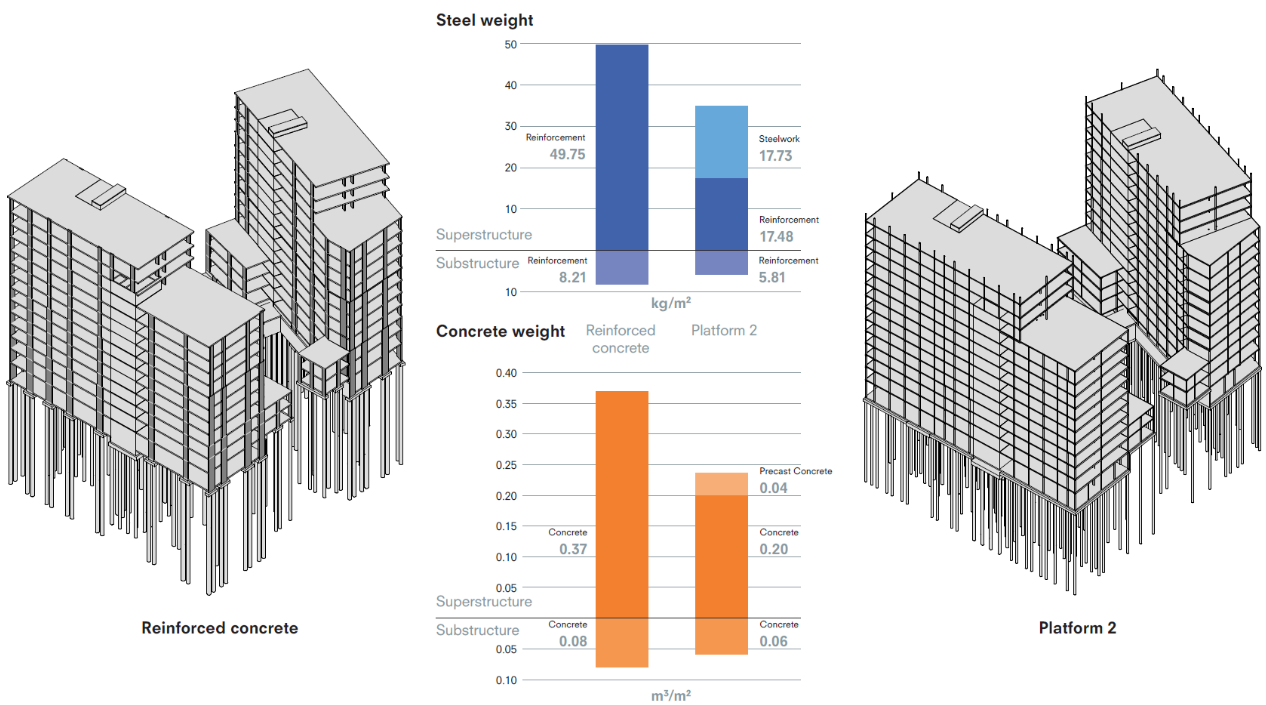
[2] https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/suicidebyoccupation/england2011to2015#main-points

Platform benefits

Key benefits include:

- Low levels of fabrication - the majority of components use no fabrication, very low or low levels of fabrication (these can be thought of as 'dumb' components). As much 'intelligence' as possible is then placed in the interfaces (e.g. bracketry which is self-locating to control tolerances and is color coded to ensure correct application etc.) The 'intelligent' components are small, manually handleable and accurately mass produced;
- The component supply chain already exists - the steel sections required can already be purchased directly from steel manufacturers, smaller components from a wide and diverse supply chain of small to medium sized organizations;
- Low weight of components - the steel components in Platform 2 have been designed to be as light as possible so that they can be transported extremely effectively with regard to logistics. In addition, components can, for the most part, be handled safely by one or two operatives without the need for large lifting plant;
- Mass is provided by in situ pumped concrete since transporting wet concrete (or batching on site) is effective from a logistics point of view, the main mass of the building can be pumped into position, not craned and a large area of in-situ concrete can be pumped in a single, tightly controlled operation;
- Rapid assembly – work to date shows a Platform superstructure being erected in approximately half the time compared to traditional construction, with significantly fewer people.



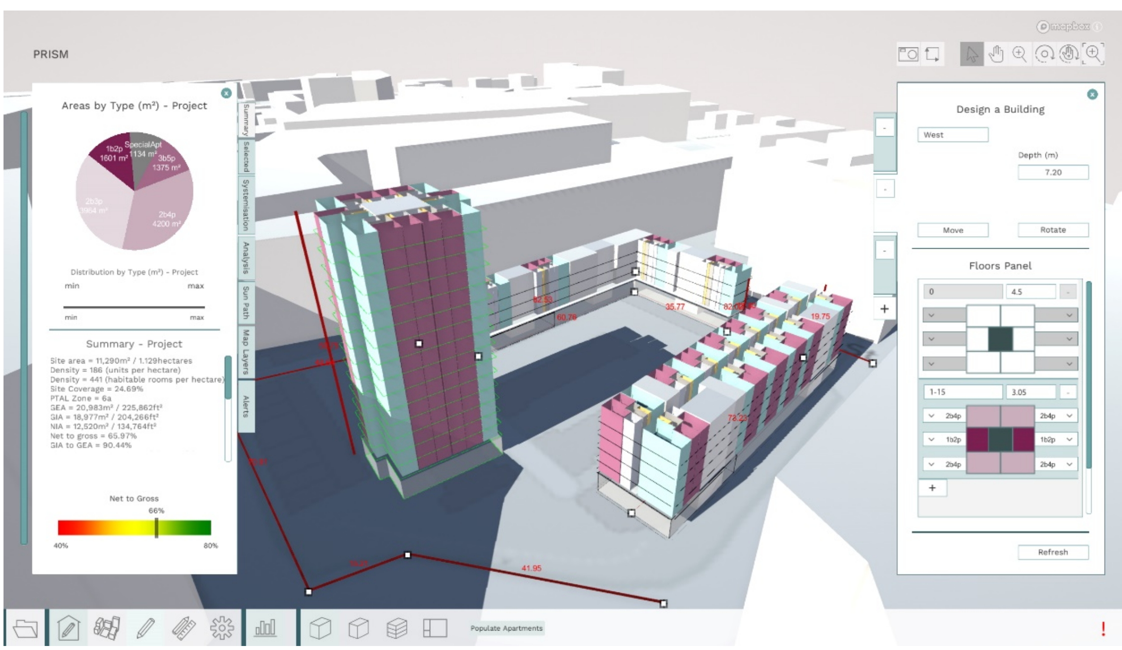
Relative weight of material - Platform vs. traditional construction

How we need to change the design process to realize these benefits

If we start to think of our future assets as unique configurations of standard components, it becomes more obvious that we need a new set of tools to help. Rather than start with a 'blank sheet of paper' we should build on an existing pool of systems and solutions. The creative challenge is in finding the best configuration for a given brief and site and enhancing our 'kit of parts' to make it better performing and more adaptable. We should remember that the term DfMA describes the process – DESIGN for manufacture and assembly – not the product.

The issue is that we need to find a way to engage a large community of designers in this new process, by providing digital tools accelerate their adoption of new ways of working. Rather than carrying out a traditional design process and retro fitting DfMA, we need to provide the tools that facilitate this thinking from the earliest stages of design.

This led us to develop the new free to use, web-based, open source digital configurators that we launched recently: PRISM (for housing) and SEISMIC (for schools). PRISM embeds manufacturing logic for a range of delivery systems; from modular to flat pack. It's critical that we can keep our options open in the design phase, to ensure that we chose the delivery system that best fits the site and build requirements. Configurators help designers do just that. They enable the consideration of many different possibilities, creating a huge range of different options, which can then be narrowed down based on the client value drivers and site-specific context. As DfMA matures, we, as designers, need to be comfortable using a range of systems, to find the right solution for the right site.



PRISM app screen shot

Better design for a bigger population

70% of our Creative Technologies team (who develop our web apps as well as developing advanced digital workflows) have an architectural background, and everyone at Bryden Wood is committed to creating the best possible built environment. It's liberating to use these apps to focus on ideas rather than regulatory detail, but the importance of these new digital tools goes much further. Let's be honest, human kind faces a massive design challenge. The UK government alone expects to spend £600 billion on infrastructure over the next 10 years, while the UN predicts the world population will reach 11.5 billion. That's around 4 billion more people who'll need the best housing, education, healthcare and mobility we can provide, and we won't achieve it by designing as we do now.

Digital tools can do much of the arduous, detail tasks, freeing architects and designers for creative, challenging work such as master planning and place-making. Our apps are so quick to use that architects, can choose the best solution from a far wider range of possibilities than it is currently possible to generate. That means better architecture and design – which will be increasingly important as resources are stretched and infrastructure needs to do more with less.

Upskilling the designers we have

As an AU delegate, you'll know how fast digitization is progressing and the importance of design (the key word) for manufacture and assembly (DfMA). At present, these kind of design skills are in short supply, but by working with PRISM (which automatically applies manufacturing logic) many more designers can produce schemes that are deliverable through systemization. This brings design and manufacturing closer together which is much preferable to retrospectively applying 'DfMA' which generally achieves poor results.

Democratising the design process

The apps can give every stakeholder a central place in the design process. It's true that stakeholder engagement sessions can be helpful in building a brief; while post occupancy evaluation may provide useful feedback on the difference between actual and planned performance. But these apps allow a new way of working by embedding clients, users and funders in the design process. Local authorities, teachers and pupils can undertake a rapid site feasibility study without the time and cost of involving a design team in a traditional study. We're already getting positive feedback about this way of working; from the Mayor of London to primary school children

Engaging the designers of the future

Architecture is a long, expensive course, yet starting salaries tend to be fairly low. This, together with construction's poor image, make it difficult to attract the high-quality people that we'll need to overcome the challenges ahead. So, let's not overlook a valuable human resource that we can draw on – the new generation of 'digital natives' that have already developed 3D digital skills by playing Minecraft and Terraria. We deliberately developed the SEISMIC app to be instantly recognizable to them, and in beta tests, even nine-year olds were able to use it intuitively. (You can see their reactions in our video.) In the hands of a new wave of young people, these tools can release a flood of creativity.

What this might mean for the 'construction site' of the near future

The combination of Platforms and the new digital workflows that support them mean that the way we design and deliver our assets could change dramatically, very soon.

Digital tools enable design for assembly which makes it easier, faster and safer to put a building together on site. Far fewer tower crane movements are required, for example, and with each one averaging 20 minutes per lift, the time savings are obvious. Just as importantly, design for assembly means that workers can be effective after relatively short periods of training. This offers employment to new groups and a solution to the looming skills crisis.

A new creative freedom

Automated construction has the ability to free architects and designers of dull, repetitive tasks so that they can contribute creatively through ideas and place making. This is where their input has most value yet, ironically, they currently spend 80% of their time on documentation. So there's the potential to unlock creativity and push the boundaries of what is possible on site.

Increasing support from government

Our work has been highly influential on UK government thinking and policy. A series of announcements and initiatives show increasing support for a platform approach with increasing levels of detail. The recently launched IPA (Infrastructure Projects Authority) 'Proposal for a New Approach to Building: Call for Evidence' describes a platform approach to design for manufacture and assembly or "P-DfMA"[3] as "currently the most promising trend in the construction and engineering sector".

The government has £600 billion of investment in the pipeline for the next decade, and a responsibility to spend it effectively. It looks as if this will provide the critical mass that automated construction needs to disrupt the industry and drive exponential adoption. Ultimately, it's about enough of us seeing things the same way, and if we do, the future looks bright.

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[3] https://www.gov.uk/government/consultations/proposal-for-a-new-approach-to-building-call-for-evidence