Standardised Component Sets

ADDITIONAL PROJECT INFO:
All DfP discovery phase 2 projects are match funded by the i3P and the MTC. Each discovery project is carried out over a timescale of 6-8 weeks, which makes use of input provided by the i3P within this timescale to support the projects. A review of industry best practices / technologies for each discovery project has been drawn selected according to criteria agreed with each discovery project sponsor.

Background

Problem Statement

The global construction market is forecast to grow more than 70% by 2025. The government aims to lower the initial cost of construction and whole life costs by 33%, lower greenhouse gas emissions in the built environment by 50%, reduce overall delivery time from inception to completion by 50% and to achieve a 50% reduction in the trade gap between total exports and imports for construction products and materials (HM Government, 2013). In 2014, construction, demolition and excavation generated 59% of waste in the UK (Department for Environment Food & Rural Affairs, 2018).

Summary of General Observations from Survey Feedback

- The construction industry is seeing significant benefits in terms of better quality, faster builds, reduced on-site labour and better Health & Safety, with use of approaches such as DfMA and offsite construction.
- The ratio of onsite to offsite construction is still highly dependent on the application under consideration , which can range from large infrastructure projects to schools.
- There is now a degree of overall acceptance towards offsite construction, driven by the development of standardised components and offsite technology.
- The growing trend towards the use of offsite construction is often underpinned by the use of digital design management systems, particularly Building Information Modelling (BIM), and the use of Common Data Environments (CDE) to accelerate designs into the supply-chain.
- However, offsite construction designs and processes need to develop further , in order to significantly reduce costs.
- Modular and offsite design is seen to be supported by clients in general. However, the drive may come from a more strategic level within the client organisation , and this can be resisted at an operational level due to the need for the development of new approaches. The drive is also less prominent in bespoke , one off designs. It is seen to be accepted by contractors as necessary , and is encouraged, also at a strategic level. However, again there is a lack of understanding in how this change can be driven at an operational level, meaning there is an element of pull in regards to modular designs, due to risk. Consultants are generally seen to not be actively looking for use of modular technology. There are some examples of involvement with modular designs, however the use is dependent on the consultant's acceptance of risk, and the drive often comes from elsewhere.
- Some still see modular and offsite construction as suitable only for more temporary applications.
- The use of offsite construction is generally perceived to be cost neutral in comparison to traditional building methods. There is seen to be a larger initial investment, which is then compensated by faster build times, and reduced labour requirements. The potential for cost savings using offsite construction is seen to be dependent heavily on the context of each project. Quality and build time is also largely agreed to improve with the use of offsite construction, however again this is dependent upon the context of the project.

i3P Survey Responses on Areas of Interest

Assessment of Standardised Component Sets and Modular Design Approaches/Platforms used across industry and linked to Government Strategy

Yes / No Preference / No Feedback

i3P Discovery Projects	Deployment Strategies/Methods: Volumetric	Modular	Sub-Assembly	Prefabrication	Traditional	Off site	On site	Design Management: Building Information Modelling (BIM)	Product Lifecycle Management (PLM)	Project Information Model (PIM)	Asset Information Model (AIM)	Computer Aided Facilities Management (CAFM)	Logistics: Delivery	Supply Chain	Materials & Manufacturing: Engineered Timber	Concrete	Steel	Digital Technologies	Robotics & Automation	Wearables for Health & Safety	Fixed Asset Technologies	Legacy Data	AR, VR, MR	Construction 4.0
Arup																								
Atkins																								
Balfour Beatty																								
BAM Nuttall																								
Mace																								
ch2m																								
Costain																								
Heathrow																								
Bentley																								
Mott MacDonald																								
Vinci																								
Taylor Woodrow																								
Laing O'Rourke																								

Deployment Strategies/Methods

Volumetric/Modular

- There is discrepancy around the terms "modular" and "volumetric", which are interchangeable for some. Others define the difference dependent upon whether the unit will become part of the actual building, or will be fitted into a space left in the building e.g. bathroom pods.
- Modular and offsite technologies are currently being used mainly for standard rooms/pods, e.g. in construction of schools. However they have been used in the construction of several bespoke train stations.
- They are seen to generally improve project time, cost, quality and safety. However, there are several associated constraints around the supply chains, transport and erection of the builds. A significant volume of builds is seen to be required for this method to be economical, they are generally not used for complex/ bespoke engineering solutions.

Sub- Assembly

- Frequently utilised in the form of pre-castings, sub-framing, panalisation, modular wiring, windows, and Mechanical, Electrical and Plumbing (MEP) corridor units etc.
- Advantages include quality issues being resolved sooner, and a faster installation onsite. Disadvantages include storage and transportation of sub-assemblies, increased cost of manufacture (although yielding overall project savings) and the production of sub-assemblies which are so small, that they provide few advantages over traditional onsite building methods.

Standardised Components

- Agreed to be beneficial in construction, helping to deliver consistent appearances, cost reductions, and leads to a simple and efficient manufacturing process which can begin before a project starts. Standardisation is already commonly utilised at the project level, and for high volume components such as beams. However, there is little standardisation from one project to another.
- Communication is required early on in the design stage between construction professionals, and the architects and clients, to drive standardisation.

Onsite manufacture

- Onsite manufacturing is seen to have several current issues, including quality control, material supply/removal and production efficiency.
- New techniques are being considered to improve onsite manufacturing such as the Mace 'Jump Factory'.

Offsite Manufacture

- Involves most other building methods mentioned. Offsite construction helps to reduce the number of people onsite and improve quality control. Most have adopted some form of offsite construction, such as for sub- assemblies and electrical/ controls instrumentation (which are factory tested prior to installation).

Design Management

BIM

- BIM is generally considered as an approach which will create a step change in the way that construction projects are carried out. However, it is recognised that as an industry there are still developments to be made, and that knowing in advance how the BIM data will be used throughout the project is difficult.
- BIM is useful in particular for modelling in ways which can facilitate direct transfer to CNC machines for manufacture, without the need for traditional drawings. BIM is also being currently used for clash detection, ensuring multidisciplinary design coordination, scheduling, onsite access to data, and supply chain integrations (addressing their requirements earlier in the project).
- Object oriented authoring platforms are required, such as Revit with plug-ins like Coins Timber Frame and HSB CAD for modular solutions.

Product Lifecycle Management (PLM)

- Some consider PLM to be irrelevant and that it is applicable to product manufacture only. Others believe BIM is essentially PLM for construction. PLM is also considered by some to be handled by the supply chain.
- Standard product information is usually captured within a range of documents and software.

Common Data Platforms

- Common data platforms are used by most, utilising several different platforms and software to achieve this. Advantages are seen to be the prevention of poor individual file management, through forced procedures and applied standards.
- Some disadvantages include the requirement for a login, and specific software, meaning that new starters may not have quick access to the latest information. The platforms can be complex to navigate correctly and require training. There are also potential data security issues around cloud based systems.

Commercial Off-the-Shelf Items

- Where possible, the use of readily available components to avoid unnecessary bespoke component manufacture is a standard process for most. This is largely to reduce the cost of manufacture. However it may constrain the supply chain, reducing competition.
- The use of a combination of several off-the-shelf software is common. Some adapt off the shelf equipment specifically for construction use, such as the use of drones and GoPro cameras.

Logistics Models

Flat-Pack Delivery

- Flat-pack is utilised both for delivery and for materials storage onsite.

Container/Sylloage Deliveries

- Used to minimise onsite work. Examples include an offsite consolidation centre for all MEP/ cladding, 'fit out' materials, which are picked and packed then delivered onsite.

Minimised/Reusable/Recyclable Packaging

- Most agree that reducing the environmental impact of construction is a key strategy within their respective companies. Packaging is however considered generally the supply chains responsibility. Some participate in 'take back' schemes, where certain pallets and sylloage's are returned to the supplier after use.
- Some are investing in new technology to recycle previously hard to recycle materials, such as a portable compressing unit for polystyrene packaging recycling onsite, and a trial programme for Correx protection recycling.

Materials and Manufacturing

Engineered Timber

- Engineered timber is being used currently by some. In one example it has been highlighted as up to 36% faster and £478k cheaper to build the frame of a 9 storey building using engineered timber as opposed to concrete framing. There were also significant stated environmental benefits, with fewer operatives, fewer delivery, and less waste sent to landfill.

Plastics and Recycled plastics

- Only used for standard items, such as seals, windows, doors, pipes, cables, floor covering and insulation.

Concrete

- Concrete is used by many, including the use of pre-cast columns, twin wall, Omnia deck and pre-cast stairs. Pre-casting is perceived to have benefits such as higher quality, in factory testing, increased safety and a reduced project duration. Research into technology such as self-healing concrete is being driven for potential use in construction.

Steel

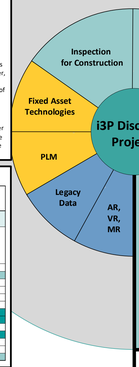
- Steel is currently often used for sub-assembly construction, and this can lead to improved quality. Some are exploring the capability of using new steel technology, such as pre-manufactured lightweight steel frames.

What i3P thinks - Summary of survey responses

Breakdown | Problem Scale | Best practice industry | Breakdown of technology | Examples | Findings

Scoring Criteria: 5 Excellent; 4 Above average; 3 Average; 2 Below average; 1 Poor

Cost | On-Site Time | Flexibility | Quality | Onsite Risk | Development Costs



Standardised Component Sets

Build Method

"In 2015 only 69% of projects (in the construction industry) were completed on budget and only 40% on time", (KPMG, 2016) There is a need to enhance the method of building and to improve lead times and costs.

There may be a shortage of skilled workers in the future of the construction industry. The government-commissioned Farmer review identified that the number of skilled workers in the industry is likely to decline by at least 20% over the next decade (Farmer, 2016). This potential shortage drives the need to develop modular and standardised technology, to reduce labour intensity and the number of highly skilled staff required to complete the construction.

Traditional methods of construction will no longer be able to meet the aims of the UK Government. There is a drive for the development and mainstreaming of new build methods and technology in the construction industry.

Volumetric / Modular

Prefabricated elements assembled offsite and transported onsite, as a fully finished, enclosed space. A particular form of prefassembly, which produces a complete unit.

Volumetric usually refers to pods which can be incorporated or fitted into an existing building

Modular usually refers to units which become the building itself.

Elliott – Modular buildings. Single and multi-storey. Includes electrics, plumbing, heating and internal finishes.
Aspin – Modular train platforms and extensions. Platform extensions constructed offsite and are installed to allow increased passenger capacity. Aspin
Portakabin- Permanent and temporary, portable and modular buildings. Portakabin
Legal & General cross – Offsite factory based in Leeds. Laminated timber volumetric housing modules.
Urban Splash, HoUSe Project – Factory built large modular house systems. HouSe Project
London Heathrow T5 Nodes – Manufactured offsite, where Bryden Wood designed 12 nodes.

Cons:
- Restricted applications (education, offices, housing etc.)
- Must be capable of being delivered on site, where road widths, bridge heights etc. must be considered
- Time consuming proposals
- Significant initial investment required to develop designs and manufacturing processes
- Less client demand (except in housing), hence less reason to invest in the technology
- Improved supply chain in UK necessary

Sub-Assembly

Prefabricated elements which are partially assembled and are connected to the build. This helps reduce the critical path of the building as components can be built in parallel. i.e. bathroom pods

Automotive Industry- Car parts manufactured, and then assembled into sub-assemblies, before final assembly.
Balfour Beatty – Pipe work, plant skids, modular electrical systems assembled offsite and delivered onsite. Balfour Beatty
Laing O'Rourke, Explore Industrial Park – pre-cast cement, columns, beams, smart walls etc. Manufactured offsite, delivered onsite.
Ormskirk District General Hospital: (Mersey design group, Costain, NG Bailey). Pipe modules fitted into frames, then the pre-fab assembly is connected onsite.
Birmingham New Street Station – Reconstructed station. Collaboration with Mace, Network rail, NG Bailey. Used modular service spine units.

Pros:
- Logistics of individual module assembly require rigorous planning
- Shipping air
- Potential for damage during transport

Cons:
- Interfaces must be accurate, tolerances are critical
- Must be capable of being delivered, more in depth logistics required
- In-house labour utilised, taking away from local trade
- Packing for shipping less efficient due to shipping sub-assemblies
- Spend time investment in assembly development

Kit of Parts

Elements manufactured (and potentially assembled, to test, then disassembled) offsite, then packed and delivery onsite, with all required elements included and packed in the reverse order of use for construction. E.g. flat pack furniture.

IKEA- World leaders at packing efficiently and effectively.
(IKEA & SKANSKA, BoStick) – Housing delivered onsite as a mix of sub-assemblies and flat pack deliveries.
MUF HAUS – Customised homes, manufactured offsite in Germany and delivered in flat pack form, assembled onsite. MUF HAUS
Baufitz- Individually designed timber homes, delivered in flat pack form. Assembled by Baufitz.
Grumitt Wade – Flat pack extensions. Foundations and electrical work needed onsite
The OX Flat-Pack Vehicle – Components & sub-assemblies arranged within its own frame, with a separate transport crate housing the engine and gearbox

Pros:
- More efficient shipping
- Reduced need for specialist equipment onsite
- Complex process completed offsite, easier to assemble onsite
- Reduces number of parts to be managed

Cons:
- Later design changes are much harder, therefore early design sign off is crucial
- Preparation of site is usually required and must be planned rigorously
- Suitable lifting equipment must be available
- Costs can rise when non-standard/one off units are required
- More in-depth expensive design phase
- Increased packaging waste can occur as each module is packaged for transit
- Limited design options
- Reduced resell value particularly in residential buildings
- A mistake in the mass production of prefabricated elements is a risk

Traditional/ Masonry

Uses onsite labour and resources to build assets using raw materials and some prefabricated elements e.g. bricks. Construction is linear and usually one process must finish before the next can begin.

Stone and timber were used for hundreds of years before the mass production of bricks began in England, in the 1850's.

During the 20th Century, iron, steel and concrete were developed as construction materials, in particular for high rise construction.

Cathedrals are a good example of the size, aesthetics and complexity of building that traditional construction can achieve.

Pros:
- Building construction begins offsite, in parallel with the foundation construction onsite
- Weather conditions have less impact
- Health and safety risks are reduced and monitored
- Tighter quality control
- Lower levels of traffic and noise surrounding site
- Reduces waste
- Fewer vehicle movements
- Future flexibility with removal
- Everything you need from a single supplier
- Drives manufacturer earlier return on investment
- Lower weight materials require less energy to transport
- Standardised design modules reduces need for specialist design input onsite
- Just in time delivery to site, less storage required onsite and less material theft/damage
- Reduce costs of transporting workers to a remote location
- Reduced requirement for local skilled labour

Cons:
- Capable of achieving quick adaptations to changing client requirements and design
- Public opinions of build quality are high

Pros:
- Material can be pre-cut, pre-processed, reducing onsite manufacture time
- Less skilled labour required
- Consolidation of materials is checked
- Efficient shipping

Cons:
- Ability to design bespoke/one off structures
- No high initial costs to create an offsite factory or provide special training
- Less reliability on cranes
- Less up front cost and rigorous planning required
- No offsite factory required
- Durable buildings require little maintenance even in adverse weather
- Uses local skilled workers
- Well established methods means cheap local suppliers are used

Standardised Components

Use of components where there is regularity, repetition and a background of successful practice. Standardisation can be used at different levels, worldwide, nationally, by supplier or by project etc. It utilises a set of prefabricated standard size elements, which designers use when creating their plans, allowing for benefits of continuous improvement processes.

Second Severn Crossing – Standardised pre-cast elements and optimised the existing heavy lifting equipment. Standard thickness elements discovered to be cheaper than material savings from varying thickness. John Laing
Bryden Wood, GSK's Factory in a Box – Uses colour coded standardised components, designed using DfMA, based on standard GSK functions such as storage areas, cleanroom rooms etc. Bryden Wood
Laing O'Rouke – Digital engineering and manufacturing facilities (Explore Industrial Park). Automated processes to manufacture construction components. John Laing
Alder Hey Children's Hospital – DfMA (and BIM) process used to produce the hospital structure and mechanical and electrical modules. Over 15,000 components built off site. BDP
Heathrow T2B Phase 2 – Balfour Beatty were main contractor, who chose Byrne Bros. due to their ability to meet Balfour's aspirations for aligning with their principles. Heathrow Balfour Beatty Byrne Bros

Pros:
- Reduces costs by reducing need to review new parts and suppliers, and designs
- Re-use manufacturing technology
- Without applying standardised components, offsite construction will lose many of its benefits
- Economies of scale, reducing costs of modular units
- Compatibility with other companies
- Consistent quality and size of components
- Reduced no. of tools needed
- Decreases time and effort to assemble
- Readily available replacements
- Quality easier to maintain and assess
- Better traceability

Cons:
- Less suited to building one off/ bespoke projects
- Suppliers rely on each other, creating greater chance for errors from miscommunication
- Problems can arise around intellectual property and competition
- Extensive communication and planning required across clients, designers and contractors
- Issues surrounding need for varying capabilities of structures such as roads and rail bridges due to variation in loading, geometry etc.

Materials for Construction

For many years there has been little innovation surrounding the materials used in construction, as the existing materials were capable of meeting demands.

With growing demands on the construction industry to produce greener, safer buildings in a shorter timeframe with a smaller budget, new construction methods are being developed. The materials used in construction will need to adapt to suit these new methods.

Digital Built Britain (DBB) is a partnership to create a digital economy for infrastructure, buildings and services. An aim of DBB is to support the UKs industries to reach BIM level 3. They aim to achieve more "right first time" builds & to improve the efficiency of builds.

Another reason for introducing digital methods into construction is to maintain an attraction to the industry for future generations. There is a current shortage of workers in the construction industry, and if the industry falls behind other industries even more on a digital front, the interest of those who have grown up in a digital world is likely to drop further. (Farmer, 2016)

The construction industry differs from product engineering in that there is not a clear project manager through the design and build of the construction. Each stage can pass their work to the next, from architect through to final fit plumbing and electrics; there is not a consistent point of contact to maintain the original design intent of the construction.

Design Management

A very broad term that describes the process of creating and managing digital information about a built asset.

Volume

Meeting demands of high volume production and faster construction.

Availability

Readily available materials are often chosen for their cost and convenience. The development of local supply chains and mass production of materials can improve availability.

Cost

Using innovation of the materials used in construction to reduce the cost of the project.

Building Information Modelling (BIM)

Asset Information Model | Computer Aided Facilities Management | Project Information Model (PIM): | Product Lifecycle Management (PLM): | Computer Aided Design and Manufacturing (CADCAM)

Project completion, source of information relating to a built asset, used during operational phase.

Tools to track, plan, manage, and report on facilities information.

Made during project. Begins at design intent, develops to virtual construction model. Includes BIM and data from client's info model.

CAM uses models and assemblies created in CAD software to generate tool paths, driving machines that turn designs into physical parts.

Managing data on the process and production needed from cradle to grave, or in some cases through to cradle again.

Autodesk Revit – BIM software that allows 3D design, annotation with 2D elements, and access to building information.

H2 Ltd – identified £250m worth of savings through use of BIM on their project. H2

Design Creation & Optimisation

Design For X

Design for manufacture is reducing complexity of the manufacturing operations.

Design for a product assembly is concerned with reducing the assembly cost and minimising the number of assembly operations.

Design with consideration to the customers requirements i.e. servicing / disassembly / 2nd life.

Zaha Hadid Architects – Uses Tekla software to create complex geometries. Tekla

Cross North America – Provides CNC solutions for construction. Work with glass, plastic, stone, and wood to automate the construction of building elements.

Mazak – Provides a range of multi-tasking, 5 axis, milling turning etc. CNC machines.

ICB – Use Teamcenter on NX software to implement PLM. To manage and release all design iterations and generates a BOM. Logo all parts, monitors for reuse & phase out of old parts. Reports all held in one place. ICB
SIEMENS

Pros:
- Faster time to market
- Fewer errors
- Standard compliance
- Improved communication
- Better resource utilisation
- Better reporting and analytics
- Organised team
- Can buy software as an off the shelf product
- Traceable change control
- Improved product quality
- Improved resource utilisation

Cons:
- Legal issues not clear yet
- Lack of experts
- Can be seen as an added unnecessary cost if project is renovating an existing building
- Variation in BIM ability across contractors, SME's lag behind, leading to lack of feedback, causing project to run over
- Investment into technology and training required

Cons:
- Legal issues around sharing data across companies
- Cost of software and cloud data
- PLM is designed specifically for manufacturing products
- Standardised data formats necessary

Design Management

A very broad term that describes the process of creating and managing digital information about a built asset.

"Super Speedfit" tube connector, John Guest – Plastic push fit tube connector concept which allows instant tube-coupling without the use of tools, where previously zinc or brass connectors were used, which required more effort and tools. This reduced the overall time required to construct houses, by allowing watertight pipe connections to be created in seconds. The reduced skill necessary to build justified the increased parts cost.

Cross Laminated Timber – Made from many layers of lumber which are layered with the grain of each layer perpendicular to the last. This prevents the wood from warping due to moisture absorption and improves the strength to weight ratio. Panels are cut offsite, often using CNC milling, speeding up the build. The relatively light weight also allows for taller high rise buildings to be constructed.

Mace Metropolitan Police Service's Training Centre - BIM level 2, a 3D model of centre was created. Used to manage design and detect potential clashes.

SKANSKA- M1 Junction 19. 3D model created, used to determine optimum positions for cranes etc. Changes were communicated using BIM, use of field tools, prevented reliance on printed documentation. Even land ownership info & animal migration data was overlaid in the model. SKANSKA

Laing O'Rouke, Francis Crick Institute – the Institute was constructed several times and the installations were rehearsed in the digital model. mace

The time required for manufacture/ assembly of construction materials is key to increasing the volume of structures capable of being built in a given time period. Traditional methods are too slow to meet the governments demand to reduce delivery time of a project by 50%. New build methods use both new materials, and create new ways to use traditional materials, to reduce the overall times. Materials for components which can be handled by robots for automation and easily assembled by as few people as possible are growing in popularity.

To be used in a large volume of construction projects, a material should be responsibly sourced, and recyclable and/or reusable. An example of this is the reuse of tyres in asphalt. A high demand for a material could lead to a large impact on the environment, and this should be reduced where possible.

There are concerns around the capability of new materials to produce bespoke and high quality structures. As standardised methods become more common, a greater variety of options will become available as solutions to more complex construction issues are addressed.

An offsite construction site can be located in a chosen site, where there is space, cheap and constant labour and a close source of materials. Freedom to choose where components are manufactured can reduce dependency on local availability of materials and labour.

Currently, the most readily available materials (e.g brick) are developed for traditional masonry, not offsite construction.

Supply chains for traditional methods are well-established, yet those for offsite manufacturing are only just emerging. As the drive for offsite grows, there is an opportunity for new supply chains to grow develop.

There has been little innovation in construction materials, as the demands of the industry were capable of being met with traditional methods/materials. However, with recent higher demands, there is an opportunity for the development of new materials which compliment new innovative methods of construction. Their availability will increase with popularity.

Standardising materials reduces installation and maintenance costs, and allows for economies of scale.

The Just-in-Time (JIT) approach means materials are less likely to be damaged/stolen whilst onsite waiting to be used, reducing material waste. BIM also leads to less waste and cost savings, through in depth planning of material requirements.

According the to the UK Homes & Communities Agency, the use of offsite manufacturing is predicted to lead to a 10% reduction in the cost of building a home and a reduction of 5% of the onsite waste.

Product manufacturing industries often increase production costs to ultimately reduce labour costs. Through processes such as DfMA, the parts may become more expensive to manufacture, but this is compensated by the savings in labour costs due to an easier, faster assembly/ installation process. This approach could be adapted and applied to the construction industry.

Construction of Offsite & Onsite Manufacture & Assembly

Onsite Manufacture & Assembly

Potential Use Across All Build Methods

Off Site Manufacture

Potential For all methods to be Hybridised

Case Study
Alder Hey Children's health park
Location: **London**
Engineers: **ACORN consortium & BDP**

Design for Manufacture and Assembly was crucial to the speedy delivery of the hospital, with over 15,000 components built off site, ranging from lattice floor, twin wall and pre-glazed external panels to mechanical, electrical and plant modules and bathroom pods. Digital engineering was also essential in the speed of information transfer between the design team and manufacturing facilities. This proved particularly pivotal in the coordination with Expanded and EIP to design and track more than 12,000 precast elements, including the facade panels which give the building its distinctive character.
The project took 130 weeks - 20% faster than any previous project. The site is a more sustainable construction as 60% of energy is generated on site.

The BIM levels explained by NBS
https://www.thenbs.com/knowledge/bim-levels-explained

Level 0 BIM
In its simplest form, level 0 is no collaboration. 2D CAD drafting is utilised, mainly for Production Information. Output and distribution is via paper. electronic prints, or a mixture of both.

Level 1 BIM
This typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and Production Information. CAD standards are managed to BS 1192:2007, and electronic sharing of data is carried out from a common data environment (CDE), often managed by the contractor. Models are not shared between project team members.

Level 2 BIM
This is distinguished by collaborative working – all parties use their own 3D CAD models, and do not necessarily work on a single, shared model. The collaboration comes in the form of how the information is exchanged between different parties – and is the crucial aspect of this level. Design information is shared through a common file format, which enables any organisation to be able to combine that data with their own in order to make a federated BIM model, and to carry out interrogative checks on it. Hence any CAD software that each party uses must be capable of exporting to one of the common file formats.

Level 3 BIM
This represents full collaboration between all disciplines by means of using a single, shared project model which is held in a centralised repository. All parties can access and modify that same model. This is known as 'Open BIM'. Current nervousness in the industry around issues such as copyright and liability are intended to be resolved – the former by means of robust appointment documents and software operator /read/ write permissions, and the latter by shared-risk procurement routes such as partnering.

Case Study
Mace Jump Factory
A new on site assembly method
Location: **East Village, London**

The self-contained factory is housed in a giant 10 storey 'tent' which is built around the perimeter of the new building. Inside, the building is constructed floor by floor and when one is completed, the factory is 'jumped' to the floor above to repeat the process, revealing the completed building below.

"You get repeated quality, it's safer for the workers, it minimises noise and dust for the surrounding environment, we can't be rained off and the factory is rated up to a force 12 gale."

Case Study
Fast Construction Programme
Capella Laboratory, Cambridge
Location: **Cambridge, UK**
Architect: **Fairhurstes Design Group**
Main Contractor: **Kier Group and Arup**

PCE Ltd worked with Kier Group on this large scale project to develop a superstructure design, and completion on-site off-site 'Hybrid' pre-cast projects.

Minimising vibration
The building was designed to provide world class scientific and research facilities with requirements to minimise vibrational effects when very sensitive scientific equipment is in use.

Hybrid Construction
The structural frame design is made from pre-cast columns with a combination of pre-cast concrete edge beams, and structural steel 'Deltabeam' spine beams, supporting 300mm deep hollow core planks, and a 300mm reinforced structural concrete topping.
PCE's approach was to use BIM techniques in order to allow integration of the complex servicing strategy.

PCE was awarded Winner of Winners for best use of concrete technology with this ground-breaking work at the Offsite 2018 awards.

Case Study
The New Karolinska Hospital and Institute
Use of BIM to level 2
Location: **Stockholm**
Construction Engineers: **Skanska**

The New Karolinska Solna (NKS) Hospital project involves an overall investment of $3.0 billion (including $1.6 billion for construction). When completed, the hospital – which will cover 320,000 m^2 – will have over 12,000 rooms, 35 theatres and 17 MRI units.

BIM
Skanska adopted an advanced BIM model across the entire lifecycle, creating a single data platform on which designers, contractors and eventually facility managers could collaborate (BIM Level 2). Starting with entering the design specifications and performance requirements, the architects and designers create 3D designs; with key attributes and locations of items. Once completed, the object list will contain about one million items.

Sustainability
The site is a Skanska Green Site: an on-site concrete plant prevented 20,000 truck trips within the first three years, and an on-site crushing plant reduced off-site transport activity as well as landfill. Hybrid and lower-emission trucks were used, and deliveries are scheduled to minimise interference with local traffic patterns. Waste is systematically analysed with the aim to reduce it to zero (in 2010, only 5% went to landfill). The environmental cabins minimise energy consumption with heat pumps, and there is a recycling facility on-site.

Case Study
Legal and general
Location: **Leeds**
Engineers: **Legal and General**

Material
Legal & General's modular housing factory will become capable of supplying 3,000 homes a year using Cross Laminated Timber (CLT). Their construction techniques mean they use less concrete foundations. CLT is made from strips of solid sustainably sourced softwood, glued and pressed into sheets. These sheets are glued together with the grain in each layer at 90 degrees to the previous layer. This creates an incredibly strong and solid cross laminated timber sheet. CLT has already been used in the UK to build buildings up to 11 storeys high.

Homes will arrive on site almost complete. Kitchens, bathrooms, doors, ironmongery, painting and carpets - all fitted in the factory and certified as defect free.

Manufacture
The assembly line transformed the automotive industry; labour became fully trained and highly skilled, quality became paramount, materials and components were honed to be fit for purpose. Legal and General imagine a home built in controlled factory conditions by fully trained and highly skilled labour, using computer control and materials and components selected as best-in-class, with every home produced being defect free.

Development Strategy

Strand 1 - Modular/Volumetric
Work required by i3P to standardise and define module size e.g. Department for Transport to review necessary changes to UK road networks and legislation to optimise module size with simple shipping constraints.
Complete value mapping - Where does use of modular/volumetric add value e.g. plant room, bathroom pods or domestic builds.
Supply chain evaluation - Determine what frameworks across the UK and availability of the supply chain for materials/build methodologies. At present bathrooms are imported from Europe, is this the best method?
Development of standard interfaces with architectural input to allow for mass personalisation - link to Strand 6.
Develop standardisation for compatibility of modules- How high? How wide? How deep? With associated product assurance within these bounds. Potential collaborative development opportunity with the Building Research Establishment.

Strand 2 - Sub-assembly
i3P to share current best practice - Best practice manual required for where this works well and why.
General training/promotion is required for clients to understand that part cost may increase but assemblies are higher value and have lower through life cost which is further improved through re-use of sub-assemblies.
Demonstration project to benchmark sub-assembly approach cost model against traditional low value materials with high value add on site.

Strand 3 - Kit of Parts
This approach enables the first step to standardisation to be achieved quickly through automated bill of materials.
Complete parametric design and configuration demonstration including virtual supplier organisation (Amazon for construction) e.g. Tesco automated ordering based on suggested recipes or Ikea furniture configurator.
Development of specialist supply chain kitting services including quality checking.

Strand 4 – Traditional
There is a current focus on offsite manufacturing but traditional construction will remain for the foreseeable future for specialist new builds and also for maintenance and refurbishment of historic buildings. Optimising traditional approach through special purpose machines, DfX, automated processes and de-skilling will reduce the time, cost and quality risks of completing these projects.
Pareto analysis is needed to determine time, cost and quality issues with conventional construction, maintenance and refurbishment approaches to best identify where improvements can be made.
Demonstrator projects to develop special purpose tools, fixtures, designs to showcase improvements.

Strand 5 - Standardised Components
The construction industry has already standardised components but these are at a granular level and allow too much variation for optimisation.
Development of standardised assemblies and processes is needed e.g. pre-hung door systems. These can be fully optimised through volume manufacturing approaches such as error proofing (Poka Yoke) parts for assembly.
Industry wide agreement is required on which changes are necessary? Identify which sectors have an appetite to do this.
Work to standardise customers specifications across industry, it may be necessary to over specify some products to achieve standardisation allowing for reduced costs through economies of scale.
Pareto analysis of components used presently that can be improved, this would be especially suited to applications which are hidden e.g. standardised wiring harnesses, standardised building services connections.

Strand 6 – Design Management and Contracting
Develop innovation contacts for collaborative supply chains deploying solutions multiple times - pay for it once, use it many times.
Government should pay for work on future portfolios and mandate it across projects on the basis that it will be paid back on delivery of projects e.g. Schools, hospitals, prisons etc. Use Pareto analysis to cover 80% of projects and to use conventional approaches for the difficult 20% of projects. Models like Procure 21 framework support this. Government needs project framework and supplier accreditation.

Strand 7 – Digitally Enabled Design
Requirement for clients to understand the need to spend more resource on planning and design to mitigate un-known costs during delivery and to reduce total cost of ownership.

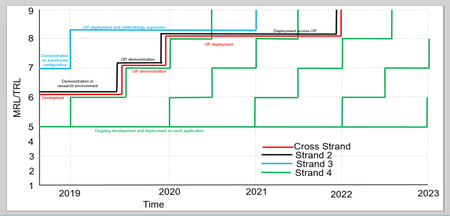
Hand book/guide of best practice – collection of case studies.
Translate the New Product Introduction processes from other manufacturing industries to re-define and encompass RIBA process, contracting mechanisms, PLM, APQP processes i.e. automotive quality management processes.
Demonstration projects showing benefits of all approaches against traditional methods with life cycle cost analysis.
BIM needs to be rationalised to ensure it adds value rather than becoming a burden to the industry and an opportunity for parasitic costs.
Best practice transfer to be completed from other manufacturing industries.

Strand 8 - Materials Strategies
UK supply chains should be developed for materials which make up the frame of construction e.g. forest management for cross laminated timber, specific steel supply chain for construction relevant materials with focus on advanced methods of manufacture.

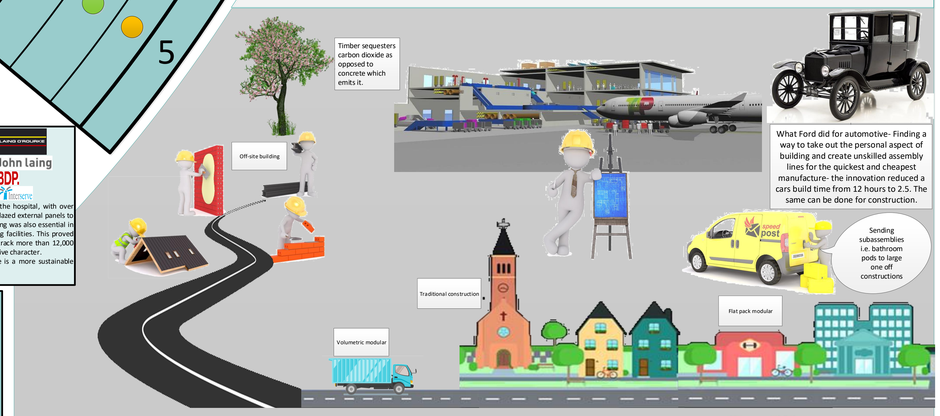
Cross Strand Work
High level decision making support tool required to enable main cost drivers to be understood at a very early stage based on project size, geographic location, number of repeat units, standard volume/space (typology) – e.g. Bryden Wood approach - Small (room), Medium (open plan office), Large (Warehouse).

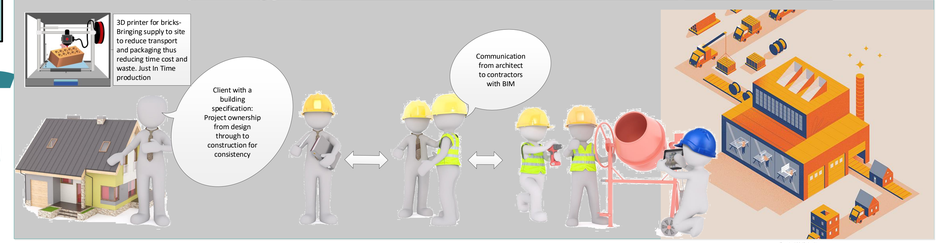
The programme proposed for the core innovation hub bid by the Transforming Construction Alliance will further develop the work outlined, but i3P engagement and match funding is required to complete.

Demonstrator staircase



Production Concept





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Author: Mitch Bryant