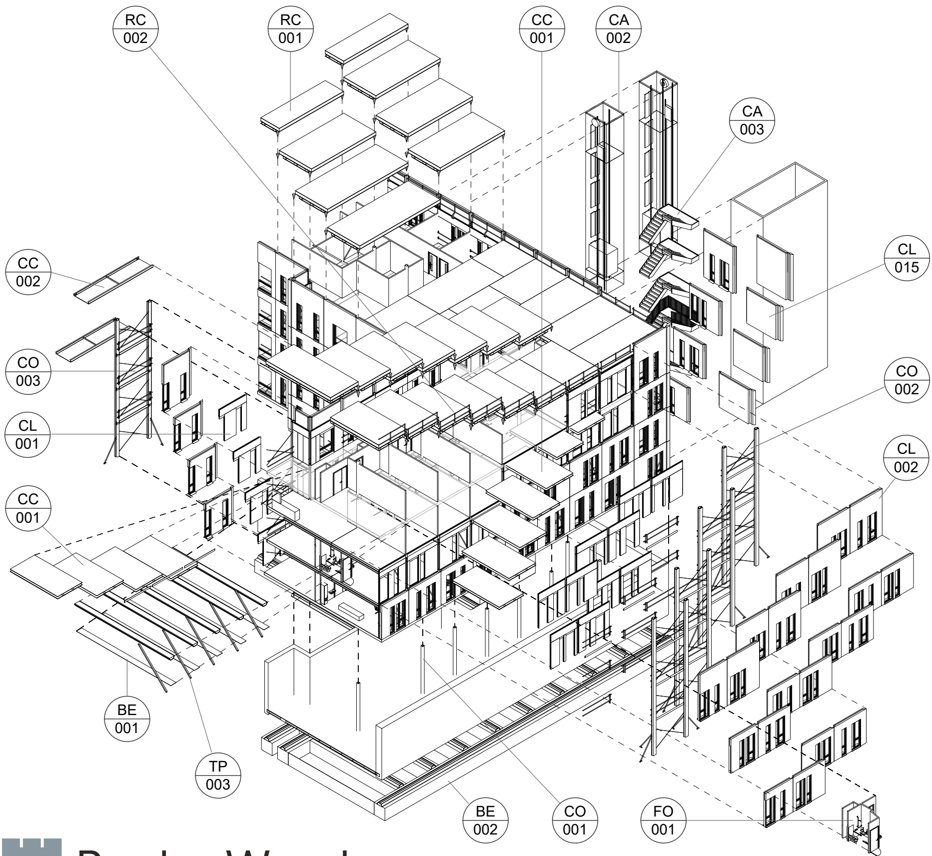
2017
Book 1

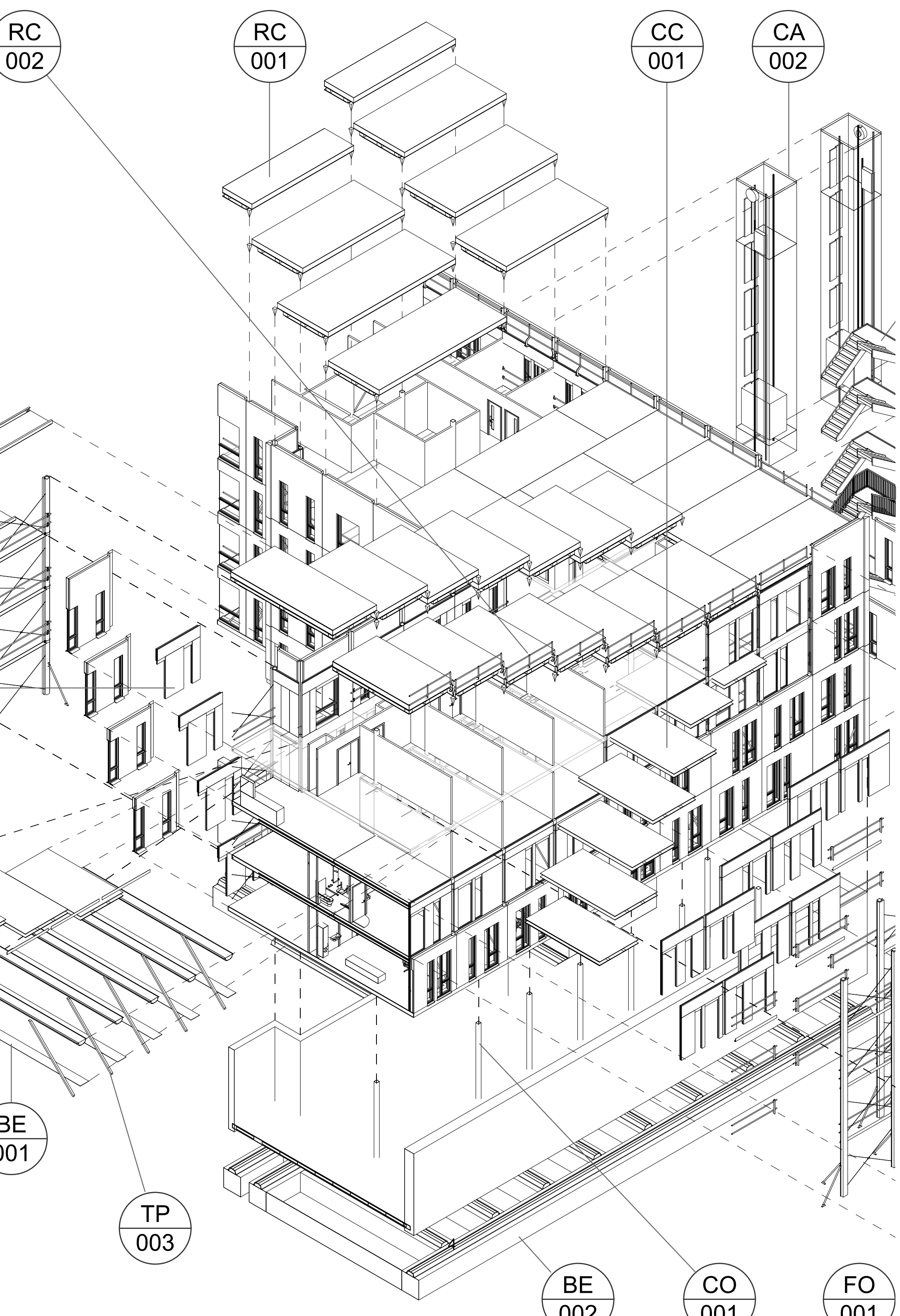
Delivery Platforms for Government Assets

Creating a marketplace for manufactured spaces



Bryden Wood

CONSTRUCTION INNOVATION HUB



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Acknowledgements

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Introduction + context

Introduction

Government will use the scale of its construction portfolio to help transform the market for creating high performing assets which improve the service for users, citizens and society and build a highly skilled and productive workforce.

It will improve the performance of assets towards international benchmarks, delivering enhanced quality, lower carbon and increased whole life value.

It will develop advanced manufacturing capability, products and services in the UK that could be exported globally.

A marketplace for manufactured spaces

Government spends around £10 billion per annum buying buildings and more on maintaining and operating its existing stock - across schools, hospitals, prisons, offices and social housing. However, the multiplicity of departments, agencies and arms-length bodies that specify, procure and operate these facilities means that there are a wide range of solutions deployed to solve similar problems.

In addition, government buys its buildings from a construction industry that is fragmented, wasteful, unpredictable and unproductive.

At the simplest level, government buildings are made up of a series of spaces with different functions and customised layouts, and physical systems that create different boundaries between spaces, with, external appearances and scale.*

However, currently we don't always ask for these in the right way and we often ask the wrong people to do things for us.

* For example, a typical secondary school is made up of a series of 55m² classrooms, plus common facilities (assembly hall, staff room, canteen etc.) The size is dependent on the number of pupils, but the function is broadly similar.

This document sets out the opportunities to create a new paradigm by adopting the same principles which have transformed the automotive and aerospace industries.

The aim is to establish appropriate levels of standardisation in:

- Design of both the 'spaces' and the 'physical systems' that bound them;
- Procurement;
- Manufacture;
- Assembly.

This strategy builds on the increasingly wide acceptance that a 'Design for Manufacture and Assembly' (DfMA) approach in construction yields significant benefits in terms of time and cost savings, while increasing productivity, quality and safety (the 'context' section of this document refers to a number of recent publications containing supporting evidence and advocating the adoption of such an approach).

This document describes the strategic adoption of DfMA in a coordinated and consistent way across the Government estate, setting out:

- The benefits of DfMA;
- The briefing and design process that would facilitate the adoption of standardised solutions;
- The characteristics that a standardised set of components (or 'Platforms') would need to possess;
- The methodology for assembly of assets that would maximise the benefits of an industrialised approach.

Strategic aims

In order to reduce cost or programme, typical value engineering strategies are in fact exercises in reducing specification or compromising the design vision. Other cost reduction exercises focus on the supply chain, where savings of a few per cent may be achieved by squeezing suppliers.

The scale of Government procurement in buildings and infrastructure warrants a more informed strategy by truly understanding value and seeking to:

- Design solutions that delivers the maximum functionality for the minimum whole life cost;
- Develop standard, repeatable solutions that increase quality and certainty of delivery;
- Engage the supply chain in a way that facilitates continual improvement rather than constant reinvention;
- Protect supplier profit and overhead as these are positive aspects that support the wider economy and ensure that the project is seen as attractive to potential suppliers in a highly competitive market;
- Focus the time and effort of designers on the bespoke elements of projects while optimising the use of digital tools and standardisation to automate the production of repetitious information which is often resource-intensive but adds little value;
- Streamline the delivery process to create a high volume of quality information while deploying creative skill where it is most valuable; this could reduce or redistribute design fees while still providing profitable and creatively challenging work;
- Focus on reducing that proportion of the construction cost and programme that has no residual value but is related to risk, rework, and waste during the construction process.

The overall aim would be to improve productivity across the design, delivery and maintenance of the government estate by:

- Adopting best practice in design, procurement, manufacture, assembly and operation;
- Reducing rework and duplication of effort;
- Minimising waste and risk.

Rigorously seeking to find the most efficient way of delivering a project inevitably reduces the resources required (whether this is measured in carbon, cost, time, waste or labour) while increasing positive aspects (health and safety, certainty, quality, morale, reputation and competitiveness).

The approach therefore seeks to:

- Ensure maximum integration of design disciplines;
- Reduce duplication of effort;
- Drive down total costs;
- Engage with the supply chain in a planned and timely fashion drawing on expertise and innovation where it adds value;
- Facilitate waste reduction through strategic and collaborative procurement using common components, material and construction processes;
- Blend highly standardised, mass customisable and bespoke elements together to create solutions that are finely tuned to suit the context;
- Optimise the use of traditional, modular, flat pack and system build elements where they add the most value e.g. to maximise off-site labour where appropriate and improve the efficiency of in-situ construction;
- Facilitate deconstruction and flexibility through the creation of standard components which can be readily adapted to future changes in policy, regulations etc. (through interchanging elements, re-configuring or extending facilities) and eventually disassembled.

Identifying opportunities - methodology

One of the key principles set out above is to leverage benefits across government spend by using standard, repeatable processes and designs. Therefore a key part of the strategy will be to establish where standardisation adds the most value i.e. where the time and effort in optimising something is justified by its overall value to the delivery of multiple assets.

It is anticipated that a relatively small number of repeatable elements (at a range of scales from components to entire assets) could deliver a significant proportion of government need. Optimising these repeatable solutions therefore has enormous benefits.

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 site-wide standardisation at the level of the building may be beneficial, in other cases standardisation at the level of a room type might be more appropriate, and this approach will continue down to typical connections or interfaces.

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

- Rationalisation;
- Standardisation;
- Optimisation.

Rationalisation

By reviewing previous and proposed solutions, a range of analytical tools will be applied to group similar elements. These can then can be tested with a view to ascertaining 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.

Standardisation

The rationalisation process will yield a number of 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.

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.

Optimisation

Further benefits may be realised 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 optimising the use of materials (specification, thickness etc.) to meet the requirements for robustness and durability without being overspecified.

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

Problem statement - what is wrong with 'construction'?

Analysis by a central government department on projects carried out under their construction framework shows that of the construction sum of a typical project, only about half ends up as residual value in the final product. The remainder is spent on:

- Risk inherent in the design and construction method;
- Fees for the various designers involved;
- Profit and overheads for the various parties involved.

Project performance analysis found that the most significant causes (accounting for ~30% of delays and cost increases) are:

- Poor productivity;
- Operational stoppage;
- Labour shortage;
- Lack of materials;
- Lack of design information.

These (and many other issues) could be significantly reduced by the adoption of manufacturing 'platforms' and methodologies (i.e. both products and processes). Specific strategies are listed on pages 34 and 35 under 'Benefits Case for a DfMA approach'.

Opposite: Reasons for project delays causing additional cost on central government department framework projects.

* Causes that will be reduced or eliminated through the proposed Delivery Platforms approach - see pages 34 and 35 for more detail.

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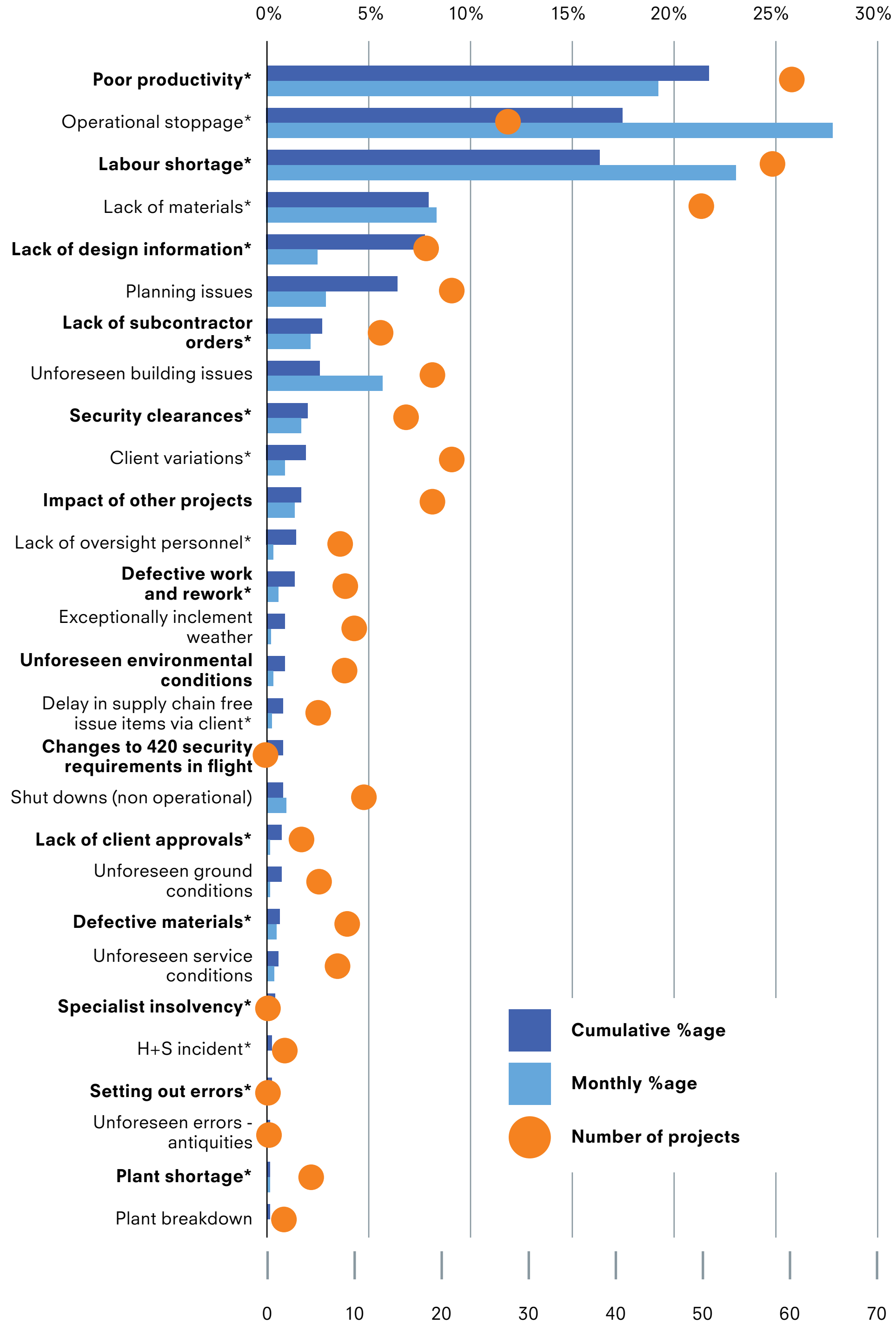
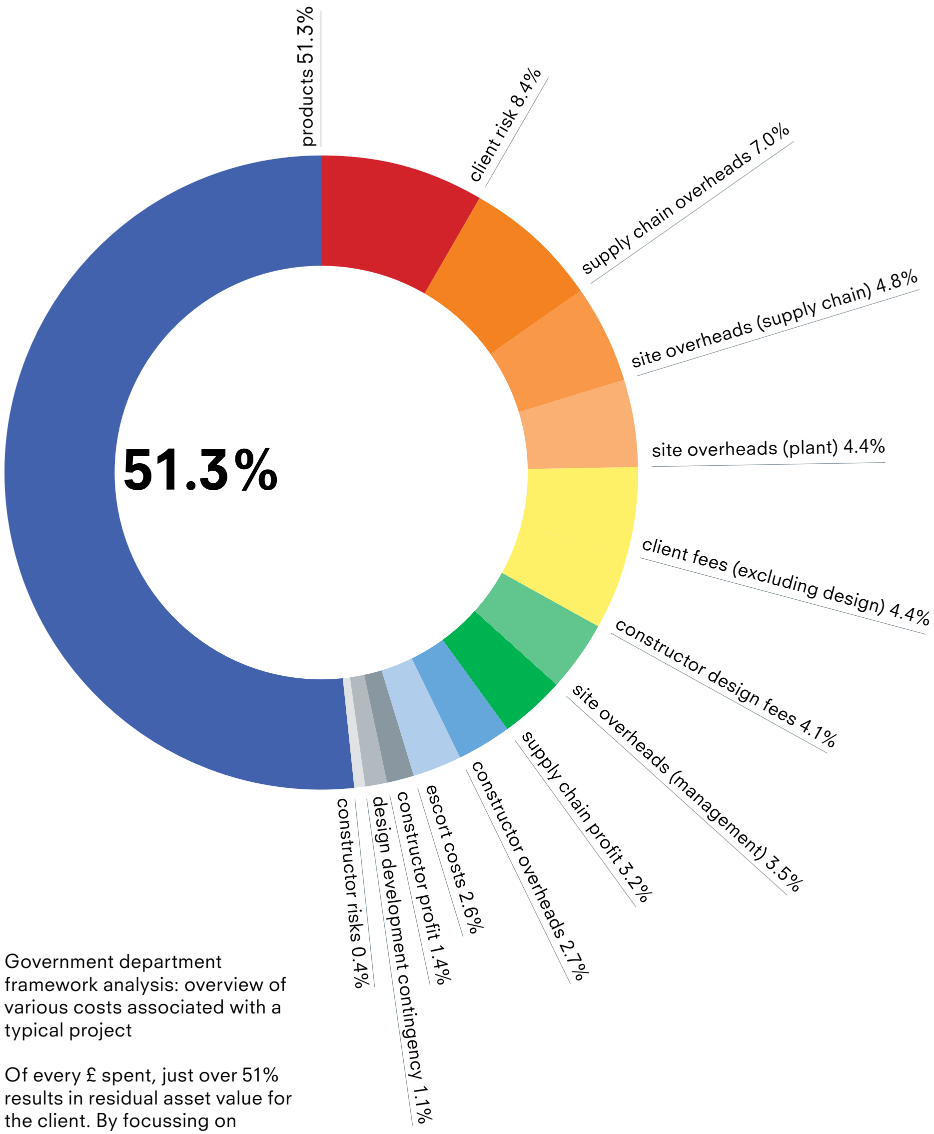


Problem statement cont'd



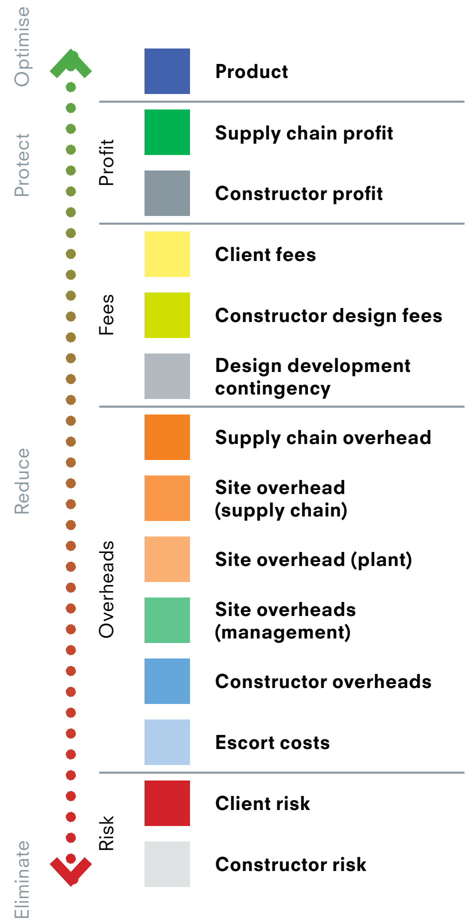
Government department framework analysis: overview of various costs associated with a typical project

Of every £ spent, just over 51% results in residual asset value for the client. By focussing on scheme optimisation, both the material cost (i.e. the cost of the asset) and the associated sources of waste can be significantly reduced.

Cost breakdown across government department framework, ranged in descending order of %age of capital cost

- **Product**
- **Client risk**
- **Supply chain overhead**
- **Site overhead (supply chain)**
- **Site overhead (plant)**
- **Client fees**
- **Constructor design fees**
- **Site overheads (management)**
- **Supply chain profit**
- **Constructor overheads**
- **Escort costs**
- **Constructor profit**
- **Design development contingency**
- **Constructor risk**

Cost breakdown of elements grouped by type



Context - Government targets + aspirations

10 pillars (ones in bold are most relevant to this document)

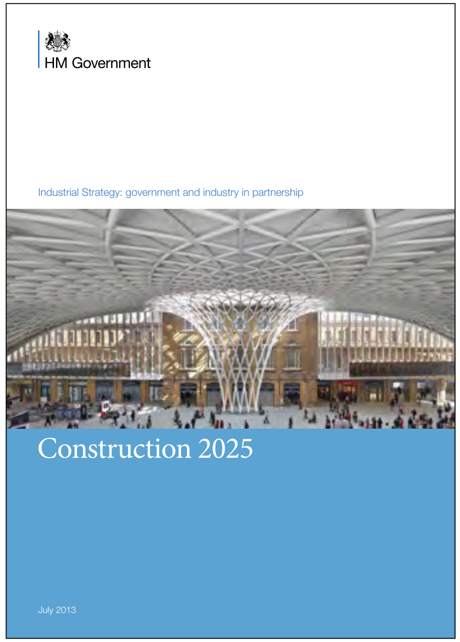
- Investing in science, research and innovation;
- **Developing skills;**
- **Upgrading infrastructure;**
- Supporting businesses to start and grow;
- **Improving procurement**;
- Encouraging trade and inward investment;
- Delivering affordable energy and clean growth;
- **Cultivating world-leading sectors;**
- **Driving growth across the whole country;**
- Creating the right institutions to bring together sectors and places.

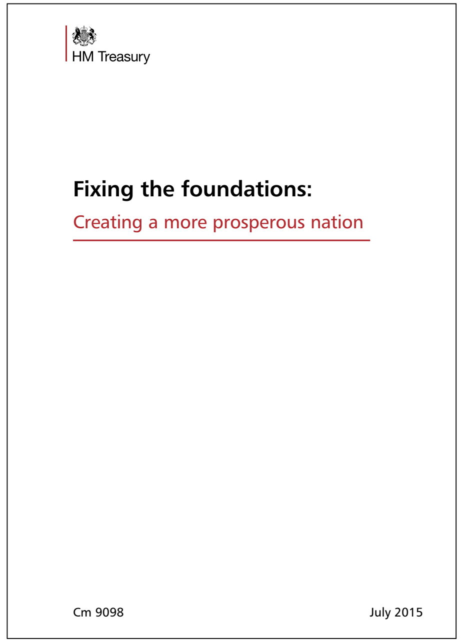
- A 33% reduction in both the initial cost of construction and the whole life cost of assets;
- A 50% reduction in the overall time from inception to completion for new build and refurbished assets;
- A 50% reduction in greenhouse gas emissions in the built environment;
- A 50% reduction in the trade gap between total exports and total imports for construction products and materials.

The Government's framework for raising productivity is built around two pillars:

- Encouraging long-term investment in economic capital, including infrastructure, skills and knowledge;
- Promoting a dynamic economy that encourages innovation and helps resources flow to their most productive use.

Apprenticeships are a key part of some of the most successful skills systems across the world. In many countries they offer young people in particular a high quality training route where they develop skills tailored to a particular sector or industry and earn while they learn.





Context - Further supporting publications cont'd

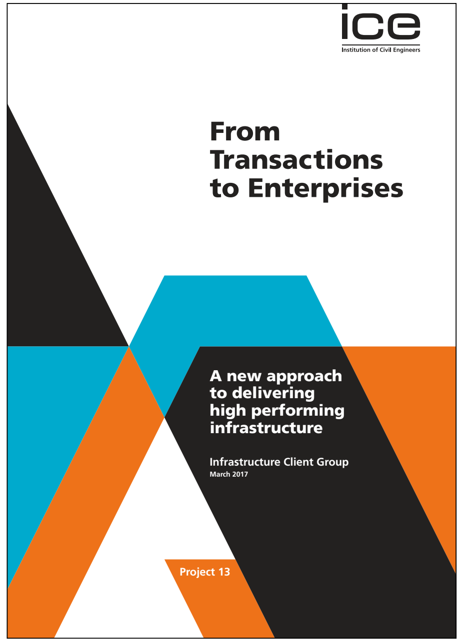
Britain needs high performing infrastructure... yet the model we use to deliver and operate much of our infrastructure is broken.

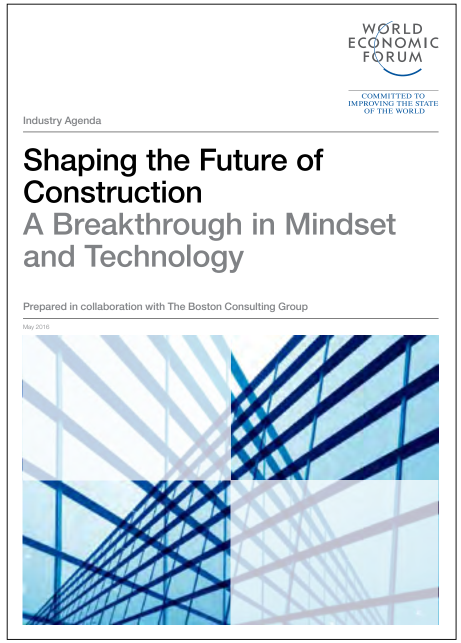
Features of a new approach include:

1. Governance
   - Owner's definition of value
   - Long-term relationships with suppliers
   - Performance measurement
2. Organisation
   - Coalition of suppliers
   - Aligned commercial interests
   - Effective organisation
3. Integration
   - Effective teamwork
   - Production management
   - Health, safety and well being
4. Capable Owner
5. Digital Transformation

Future best practice includes:

- Standardized, modularized and prefabricated components;
- Digital technologies and big data along the value chain;
- Front-loaded and cost-conscious design and project planning;
- Strategic workforce planning, smart hiring, enhanced retention;
- Mutual consent on standards across the industry;
- Cross-industry collaboration along the value chain;
- Actively managed and staged project pipelines with reliable funding;





Context - Further supporting publications cont'd

- Construction-related spending accounts for 13% of the world's GDP but the sector's annual productivity growth has only increased 1% over the past 20 years;
- $1.6 trillion of additional value added could be created through higher productivity meeting half the world's infrastructure need;
- 5–10x productivity boost possible for some parts of the industry by moving to a manufacturing-style system.

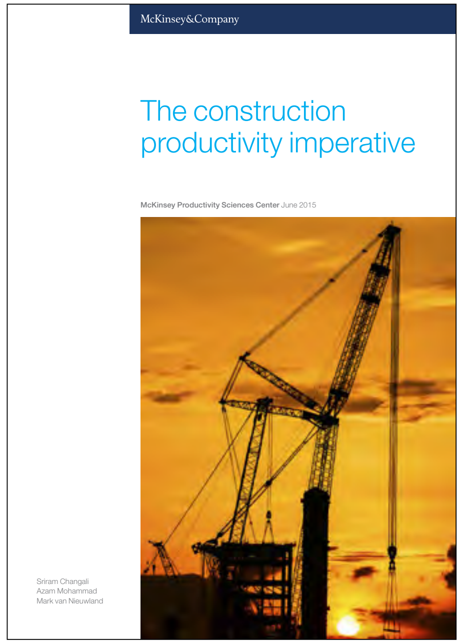
Action in 7 areas can boost sector productivity by 50 - 60%:

- Reshape regulation;
- Rewire contracts;
- Rethink design;
- Improve procurement and supply chain;
- Improve on site execution;
- Infuse technology and innovation;
- Re-skill workers.

- 98% of mega projects suffer cost overruns of more than 30%;
- The average cost increase is 80% of original value;
- 77% are at least 40% late;
- The average slippage is 20 months behind original schedule.

To counter this and improve productivity:

- Think modular design and standardisation;
- Use prefabrication and pre-assembly methods;
- Build only what is needed (design to value);
- Maintain a life-cycle perspective;
- Strengthen scenario planning;
- Optimise around site constraints;
- Optimize engineering processes and choices;
- Focus on quality;
- Minimise waste.



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Context - Further supporting publications cont'd

'KPMG's Independent report evidences that off-site construction offers an alternative to the construction status-quo by promising transformative improvements across the asset life cycle in time, cost, quality and health and safety. But most importantly, off-site construction offers predictability.'

- Standardisation and the introduction of industry quality standards have been critical success factors in automotive, aerospace, defence and medical appliance sectors, significantly reducing cost, timing and improving quality and competitiveness;
- Standardisation and quality should similarly be given centre stage in the construction sector;
- To achieve this there needs to be industry recognition of the need to change - and a desire to change;
- The construction sector needs to mobilise itself via an action group to create an industry quality standard;
- The introduction of a quality standard will facilitate component standardisation, promote collaboration and ensure common planning and procurement practices.

mtc
Manufacturing Technology Centre

DISCOVERY PROJECT

Advanced Product Quality Planning

A Quality Oriented Approach to Construction

Kate Harper

April 2017

Discovery Advocate:
Neil Rawlinson
Discovery Sponsor:
Susan Hone-Brookes

DRAFT Page 1

- 20%–60% reduction in construction programme time;
- Greater programme certainty;
- 20%–40% reduction in construction costs;
- 70%+ reduction in onsite labour, with subsequent improvements in health and safety;
- Reduced need for skilled labour on site;
- Better construction quality;
- Better environmental outcomes, including reduced waste;
- Fewer queries from site.

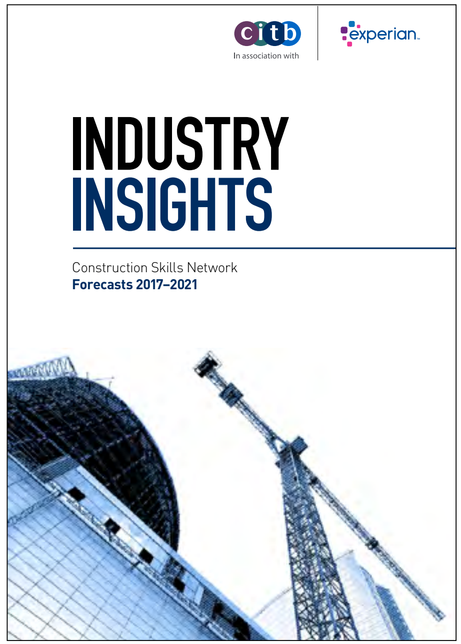
Context - Further supporting publications

‘Critical symptoms of failure and poor performance’ in the industry include:

- Low productivity;
- Low predictability
- A lack of collaboration and improvement culture;
- A lack of R+D and investment in innovation.

- The ambition to grow and upscale the adoption of an offsite approach is underpinned by drivers including:
    - Skills shortages in the construction sector and capacity of offsite to address issues faced in the sector, notably low productivity and inefficiency;
    - The ‘digitalisation’ of the construction sector;
    - Emerging new technologies and a focus on ‘smart’ construction and greater automation in the future.
- Offsite offers economies of scale for the healthcare, hospitality, retail, leisure and education sectors;
- Future opportunities for upscaling offsite may come from the likes of large-scale infrastructure projects;
- Offsite construction may be more appealing as a career option for new entrants to the construction sector;
- Most existing training doesn’t cover specific offsite skills because of its generic nature.

- The construction industry continues to experience short-term skills issues and growing skills needs in the medium term;
- Well-planned and properly funded training programmes are crucial to the continuing success of our sector.



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Benefits case for a DfMA approach

What is DfMA?

DfMA is an approach which allows designers to maximise value for clients, maintain control over the delivery of their designs and facilitate the adoption of emerging methods, materials and technologies in construction best practice. It is important to stress that DfMA is a design activity driven by an understanding of a client's requirements.

DfMA encompasses a wide spectrum of tools and technologies but the underlying driver is to break the relationship that traditionally exists between time, cost and quality in the construction industry by reducing or eliminating waste or any activity that does not add value to the client, designer or supply chain. A number of typical benefits are summarised here.

It is important to mention that where reference is made to adopting a standardised or manufacturing approach that does not necessarily mean use of standard, manufactured elements; it may simply mean benefiting from some of the approaches that the manufacturing industry takes to logistics, just in time delivery, standardised interfaces, design rationalisation and optimisation in seeking to achieve high rates of productivity etc.

Common manifestations of DfMA include the use of prefabrication and off-site manufacture in the construction phase; this includes modular or volumetric units, flat pack or panelised systems and component based construction systems.

Benefits include:

Quality

- Applying factory quality assurance and testing procedures, reduces on-site commissioning and defect rectification;
- This can result in an improvement of up to 70% in reworking and snagging;
- The MTC recommends adoption of the Advanced Product Quality Planning (APQP) methodology proven over more than 30 years to increase competitiveness, save both time and money, reduce waste, manage risk and ensure customer satisfaction. The APQP methodology also ensures that designs are fit for purpose, that non-conforming product does not reach the client-site and that the safety and reliability of the finished product are not compromised.

cont'd

Various DfMA solutions developed in a range of sectors and materials in response to client-specific drivers

Programme

- Taking items off the critical path reduces time on site;
- Fewer deliveries, trades and activities to plan increases certainty in the programme;
- Installation and assembly (as opposed to construction) sequences are more capable of precise execution;
- Lack of design information typically accounts for up to 8% of delays on site in traditional construction; this is mitigated substantially by DfMA.

What is DfMA? cont'd

Labour

- Poor productivity and manpower shortage account for up to 37% of delays on site. A DfMA approach reduces hours on site and increases productivity of those hours;
- The productivity of factory staff is 80% relative to 20% productivity of on-site workers. Staff based on site typically cost up to twice as much as factory personnel.

Health + safety

- By limiting the number of hours on site, adverse consequences are reduced resulting in an 80% reduction in incidents;
- Reduced traffic movements to and from sites leads to improved neighbourhood road safety - up to 20% reduction in road accident data within 0.5km of site;
- The adoption of these methods can only assist neighbourhood consultation and reduce disturbance due to construction.

Waste

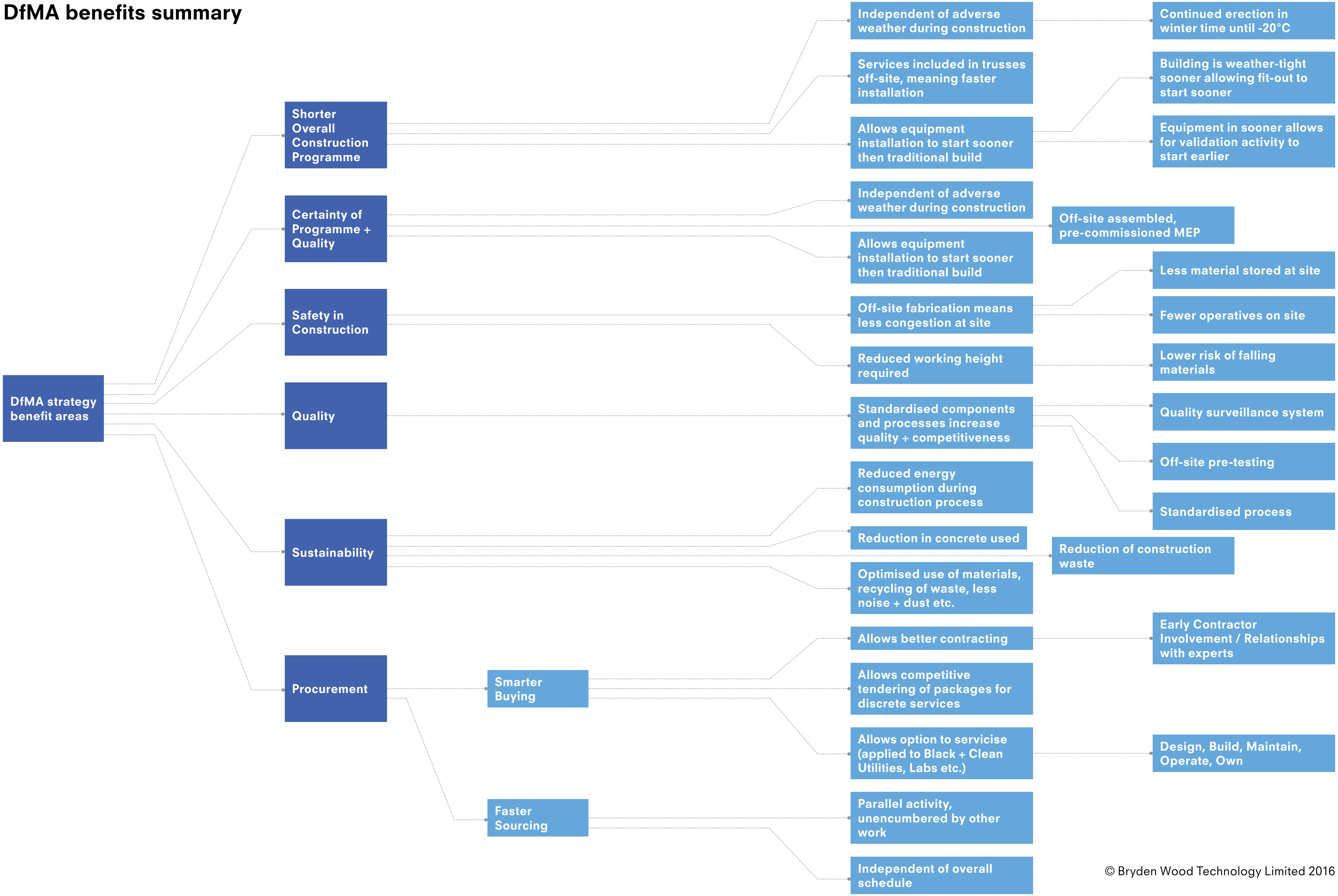
- DfMA components allows waste reduction through better stock control;
- Research data suggests DfMA reduces site waste by 70 - 90%.

Environmental gains

- Fewer traffic movements to / from site reduces neighbourhood pollution / congestion by up to 20%;
- Reduced site labour results in up to 50% saving in renting, heating and lighting of temporary site accommodation;
- Improved performance-in-use of environmental controls (better assembly and factory-based commissioning) results in up to 30% reduction in carbon dioxide.

*Sources are:
Waste and Resources Action Programme
BuildOffsite
Government capital framework analysis
Major UK Tier 1 contractor

DfMA benefits summary



Example projects - Hybrid solutions

- Rapid installation on site if connections and interfaces are pre-planned;
- Requires more work than pre-finished volumetric solutions;
- Requires fit-out and finishing work to take place on site;
- Panelised solutions mean that areas are less protected than in fully volumetric systems so programme activities cannot be overlapped to the same extent.

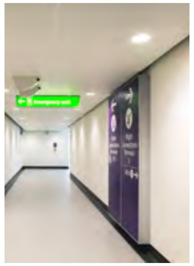
- Requires fewer operatives on site compared to traditional;
- Can reduce the level of skill required on site;
- Requires more logistical control than volumetric as there are more units to control;
- Introduces more operations on site e.g. more crane lifts than pre-finished volumetric;
- Can use low skilled operatives to assemble the units;
- Allows a wide supply chain by splitting elements into more components.

- Logistically efficient as they can be stacked or packed for transport;
- Significant reductions in waste.

- Lower cost than traditional due to speed efficiencies when used efficiently.


Circle Hospital, Reading

- 20% reduction in programme
- 28% reduction in cost
- 79% of components were standardised




Heathrow T3 Temporary FCC

- 38% reduction in overall programme
- 75% of work taken off-site
- 28% reduction in cost vs. traditional


GlaxoSmithKline 'Factory in a Box'

- 60% reduction in programme
- 75% reduction in labour
- Cost neutral (achieves world class standards for the cost of traditional construction in Africa)


EcoCanopy Children's Centres

- 90% of work taken off-site
- 50% reduction in overall programme
- 40% reduction in cost vs. traditional
- 3% waste created (vs. ~30% for traditional) of which 90% is recycled
- Low embodied carbon

Example projects - Modular solutions

- Extremely rapid installation on site;
- Can be pre-commissioned to reduce the handover period;
- Requires long lead in for factory production.

- Requires significantly fewer operatives on site;
- Can significantly reduce the level of skill required on site;
- Can use low skilled operatives to manufacture the units if design is sufficiently complete.

- They are often over engineered i.e. to be stiff enough for transport and lifting requires more structure than is required in their permanent location;
- They are logistically challenging as they are effectively 'empty boxes' and are less efficient in transportation terms than smaller components which can be more densely packed;
- Significant reductions in waste.

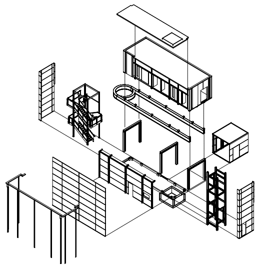
- Can be more expensive than a traditional solution;
- Additional cost must be countered by creating gains in speed, reduction in waste etc.


Heathrow + Gatwick Pier segregation

- 50% reduction in overall programme
- 36% reduction in cost vs. traditional
- 80% of work taken off-site

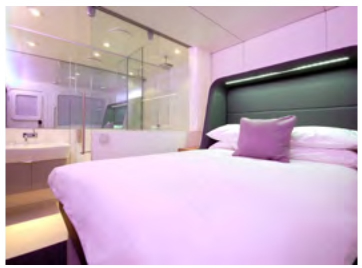

Optimum Switch data centres

- 30% reduction in overall programme
- 40% of work taken off-site
- 30% reduction in cost vs. traditional




Heathrow Terminal 5C Nodes

- 87% reduction in overall programme
- 65% of work taken off-site
- 25% reduction in cost vs. traditional




'Yotel' hotel pods, various airports

- 25% reduction in overall programme
- 60% of work taken off-site
- 40% reduction in cost vs. traditional

Specific challenges + mitigating strategies

PPI Reasons for Change as referenced on page 9 - 'Problem statement' and the mitigating strategy that a manufacturing-led 'Platform' approach would facilitate.

PPI Reason for Change	Mitigating strategy / benefits case
Poor productivity	▪ Productivity of factory staff is typically ~85% relative to ~60% productivity of on-site workers. ▪ By utilising higher levels of factory-like conditions, overall productivity will rise; ▪ Site based operatives will be engaged in 'assembly' rather than 'construction' tasks, creating factory-like conditions on site.
Operational stoppage	▪ Implementation of DfMA strategies allows more precise planning and execution of tasks; ▪ Taking items off critical path reduces site time; ▪ Fewer deliveries, trades and activities to plan increases certainty in the programme; ▪ Installation and assembly (as opposed to construction) sequences are more capable of precise execution.
Labour shortage	▪ Staff based on site typically cost up to twice as much as factory personnel; ▪ DfMA design facilitates the use of local, low skilled but highly productive operatives.
Lack of materials	▪ Pre-manufactured elements limit the amount of bulk or raw material required on site; ▪ Where material is required, it can be managed with the same logistical accuracy as the manufactured elements i.e. pre-cut or pre-kitted in a consolidation centre and delivered with the DfMA components. This increases productivity on site and reduces waste material.
Lack of design information	▪ Manufactured elements arrive at site having been pre-tested and quality controlled, and require no additional design information; ▪ Interfaces and installation techniques can be simplified to use snap fit or plug and play connections; ▪ Installation techniques and H+S advice can be standardised and documented for point of work posters and tool box talks for consistency; ▪ Visual method statements and standard operating procedures can be linked to QR codes or RFID tags on specific components so they are always delivered with the appropriate information and documentation.
Lack of subcontractor orders	▪ Programme wide data analysis and visualisation facilitates supply chain engagement, factory planning and smoothing of demand; ▪ Simplified design of components and the ability to deliver these using a wide and resilient supply chain reduces stress on individual suppliers.
Security clearances	▪ Fewer numbers operatives on site reduces the need for time and management related to security clearances; ▪ Quality assurance processes at the point of manufacture can include security checks; ▪ Reduced programme and on-site personnel means reduced management and site preliminaries.

PPI Reason for Change	Mitigating strategy / benefits case
Lack of escorts	▪ Reduced numbers of operatives on site reduce the need for time and management related to escorts.
Defective work and rework	▪ Applying quality assurance processes and procedures to the manufacture, testing and pre-commissioning of DfMA elements will dramatically reduce instances of defective elements reaching site; ▪ This can result in an improvement of up to 70% in reworking and snagging; ▪ Limiting works on site inherently reduces the amount of damage by following trades; ▪ Use of pre-kitted parts and standard operating procedures at the point of work significantly reduces reliance on trades and workmanship; ▪ Research data suggests DfMA reduces site waste by 70 - 90%.
Delay in free issue items via client	▪ As 'lack of subcontractor orders' on the left.
Lack of client approvals	▪ As 'client variations' above.
Defective materials	▪ DfMA components allow waste reduction through better stock control.
Specialist insolvency	▪ As 'defective work and rework' above.
H+S incident	▪ By limiting the number of hours on site, adverse consequences are reduced resulting in an 80% reduction in incidents; ▪ DfMA can significantly reduce the need for work at height (falls are the leading cause of serious injuries, accounting for 48% of H+S incidents on construction sites); ▪ Reduced traffic movements to and from sites leads to improved neighbourhood road safety - up to 20% reduction in road accident data within 0.5km of site.
Setting out errors	▪ DfMA elements arrive quality assured for dimensional accuracy and tolerance; ▪ Simplified interfaces reduce reliance on workmanship for accuracy; ▪ Connections can be self jigging such that they will automatically align with other components, or include some form of final adjustment.
Plant shortage	▪ Accuracy regarding e.g. duration of specific tasks will be achieved through virtual and physical prototyping to improve logistics planning; ▪ Programme wide data analysis of planned and actual tasks will allow responsive logistics models and agile planning tools; ▪ Use of standard operating procedures and lower numbers of personnel on site will reduce instances of unplanned activity.

Platform development

Project vs. Programme thinking

As outlined earlier, the scale of government procurement allows significant value to be created through the adoption of programme wide approaches rather than considering a series of unrelated, single projects.

In a traditional, one off project, each asset is modelled, and information for design, tender and construction created individually. The design team can only afford to describe the proposed solution to a certain level of detail, which is then developed by the contractor in conjunction with their supply chain. Typically the degree of repetition at project level is low and only warrants highly detailed analysis of a few key areas.

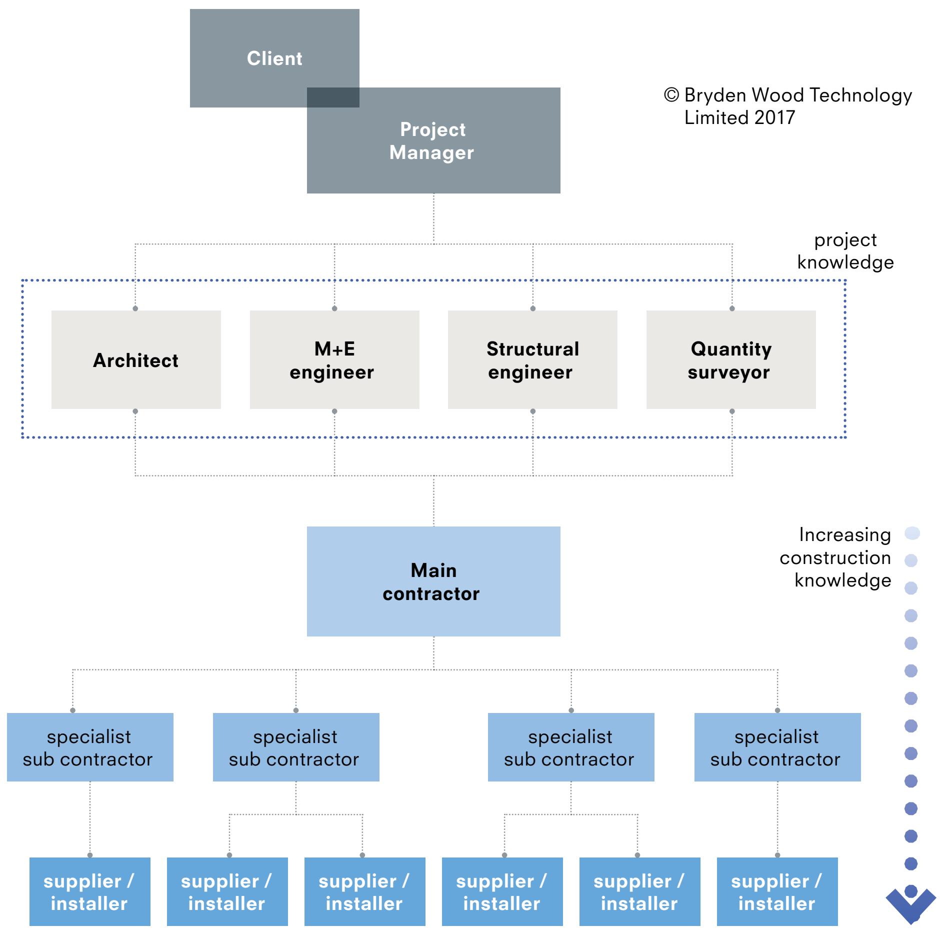
The fact that the design development (project knowledge) often takes place in isolation from the supply chain is a significant source of missed opportunities to optimise the design and leverage best in class construction knowledge.

In addition, most of the construction knowledge sits within the supply chain (see diagram, right) which may be fragmented and have little opportunity to collaborate. This is a significant source of rework and duplication of effort.

As a result, any benefits that are generated by innovation generally remain within the supply chain and are not passed on to the client for wider use. Any knowledge that is gained through the project cannot typically be captured, disseminated and improved upon to the benefit of other projects.

cont'd

Traditional procurement

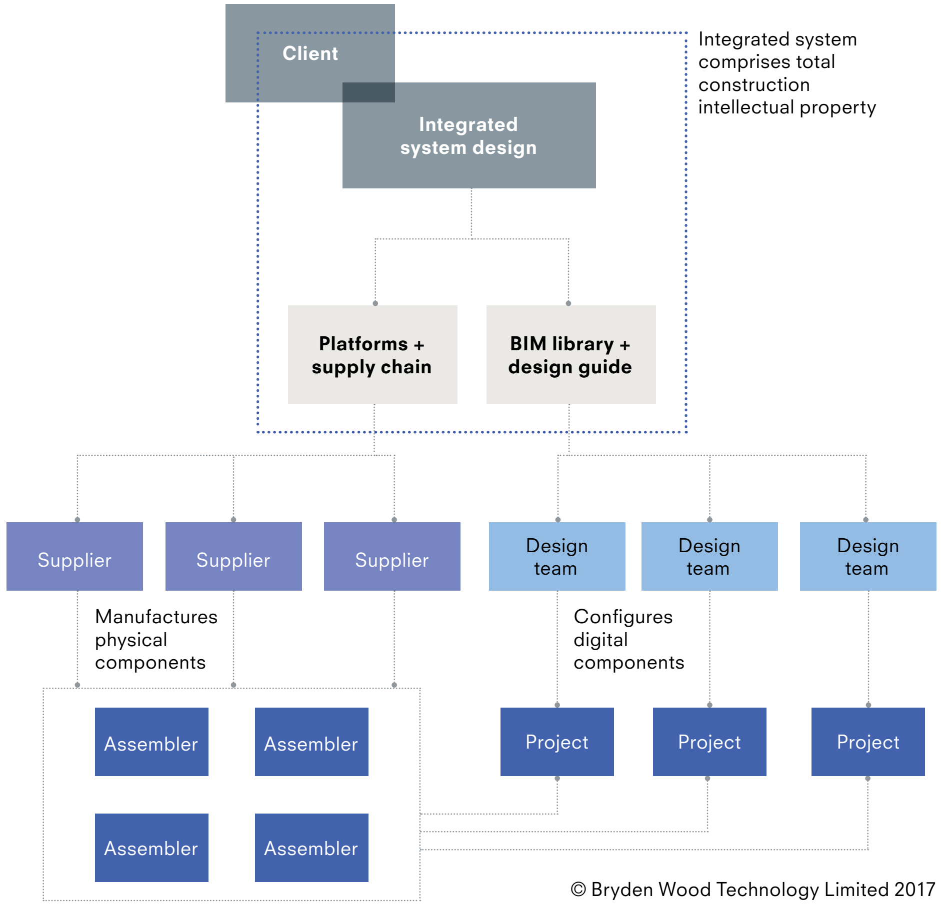


Project vs. Programme thinking cont'd

Considerable value can be therefore be generated through creation of a suite of standardised solutions and repeatable elements that are simply configured differently for different sites and project requirements.

Developing components for a large scale deployment, where knowledge is captured and retained for further collaborative refinement, would facilitate continual improvement (as is common in the automotive and aerospace industries) as opposed to constant reinvention (as is common in traditional construction).

Potential procurement route for an integrated programme-wide solution

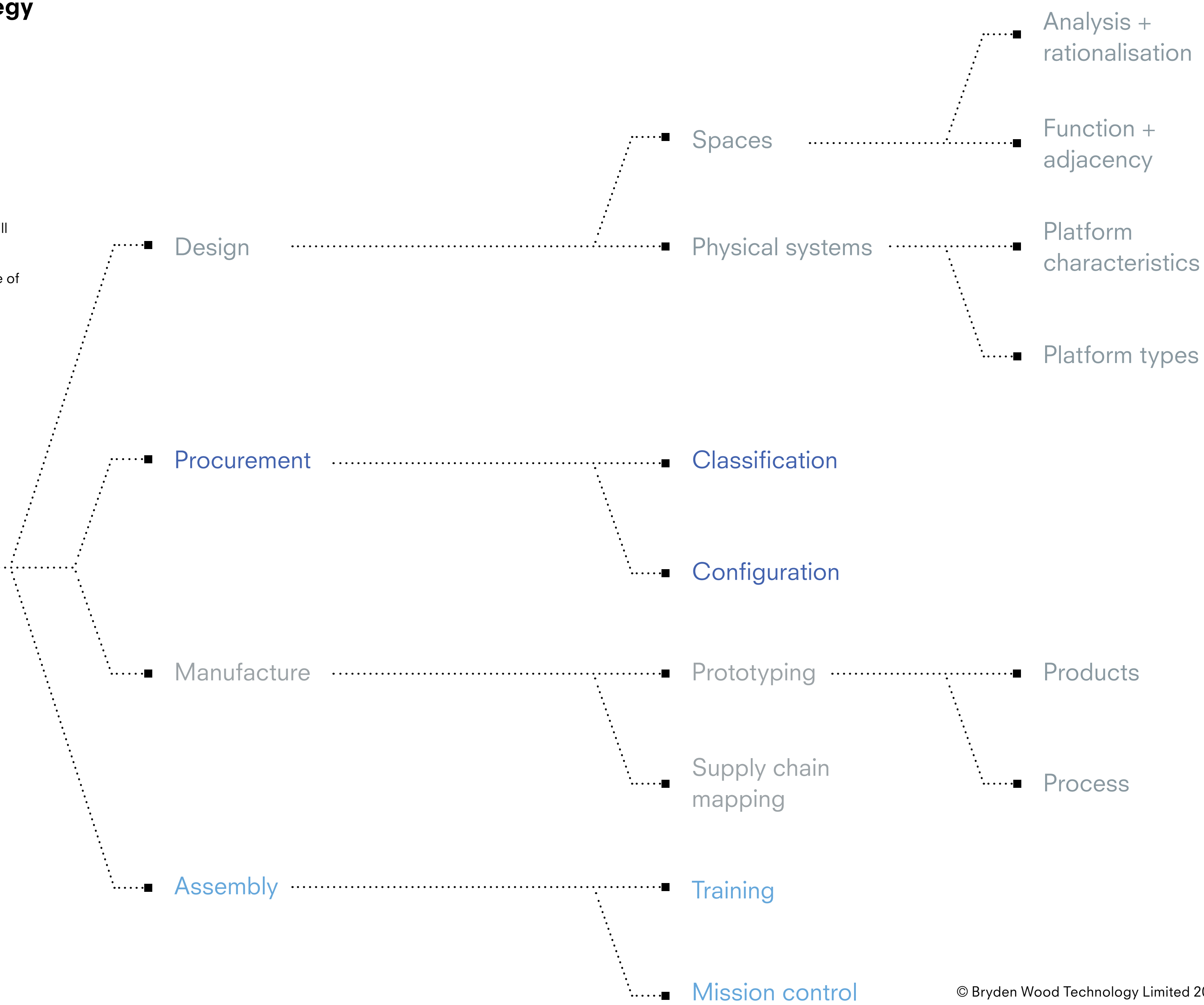


The elements of the strategy

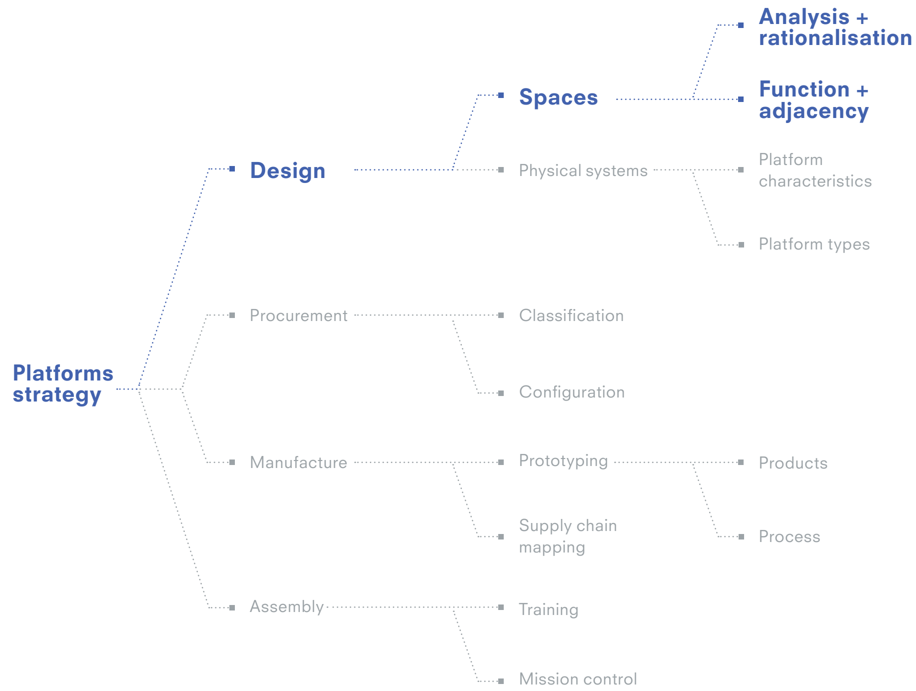
The productivity gains available through the adoption of platforms will be achieved (but will require appropriate levels of standardisation) throughout the project life cycle.
The remainder of the document sets out some of the key aspects of:

- Design
- Procurement
- Manufacture
- Assembly

Platforms strategy



Spaces


Platforms strategy
Design
Spaces
Analysis + rationalisation
Function + adjacency
Physical systems
Platform characteristics
Platform types
Procurement
Classification
Configuration
Manufacture
Prototyping
Products
Process
Supply chain mapping
Assembly
Training
Mission control

The importance of 'spaces'

It is necessary to be able to describe projects at a range of levels of scale, from entire facilities down to individual components and products.

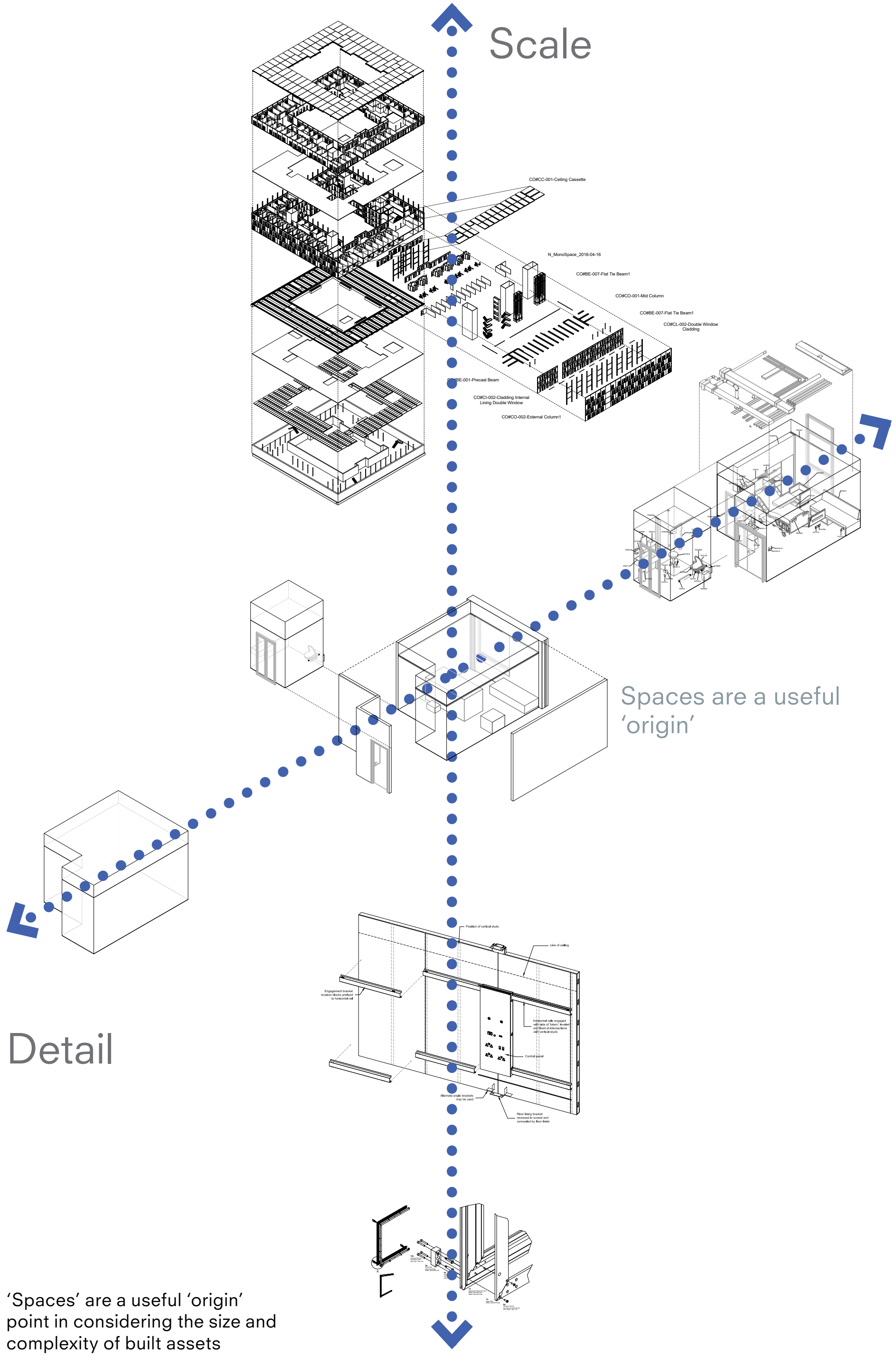
One other important factor is the ability to move between levels of detail, from very high level descriptions of facilities to highly comprehensive information.

Spaces form a useful 'origin' since the majority of human activity takes place within a physical space and it is generally very easy for people to conceptualise and visualise at this scale.

Building functions are also typically described by the spaces they contain. The activities and processes that take place within a facility are governed by the characteristics of their spaces in terms of:

- Dimensions (clear span, clear height);
- Number of storeys (how many spaces can be reasonably stacked on top of each other);
- Density / type of structural load that can be applied (dictating amount of storage / equipment etc. that can be placed in a space);
- Availability or density of mechanical and electrical services such as heating, cooling, lighting, power etc.
- Specialised requirements for processes or equipment relating to the specific asset use;
- Specialised functional needs in terms of e.g. security.

In creating standard solutions, then, the use of human-scale spaces as a starting point is a useful way of engaging stakeholders.



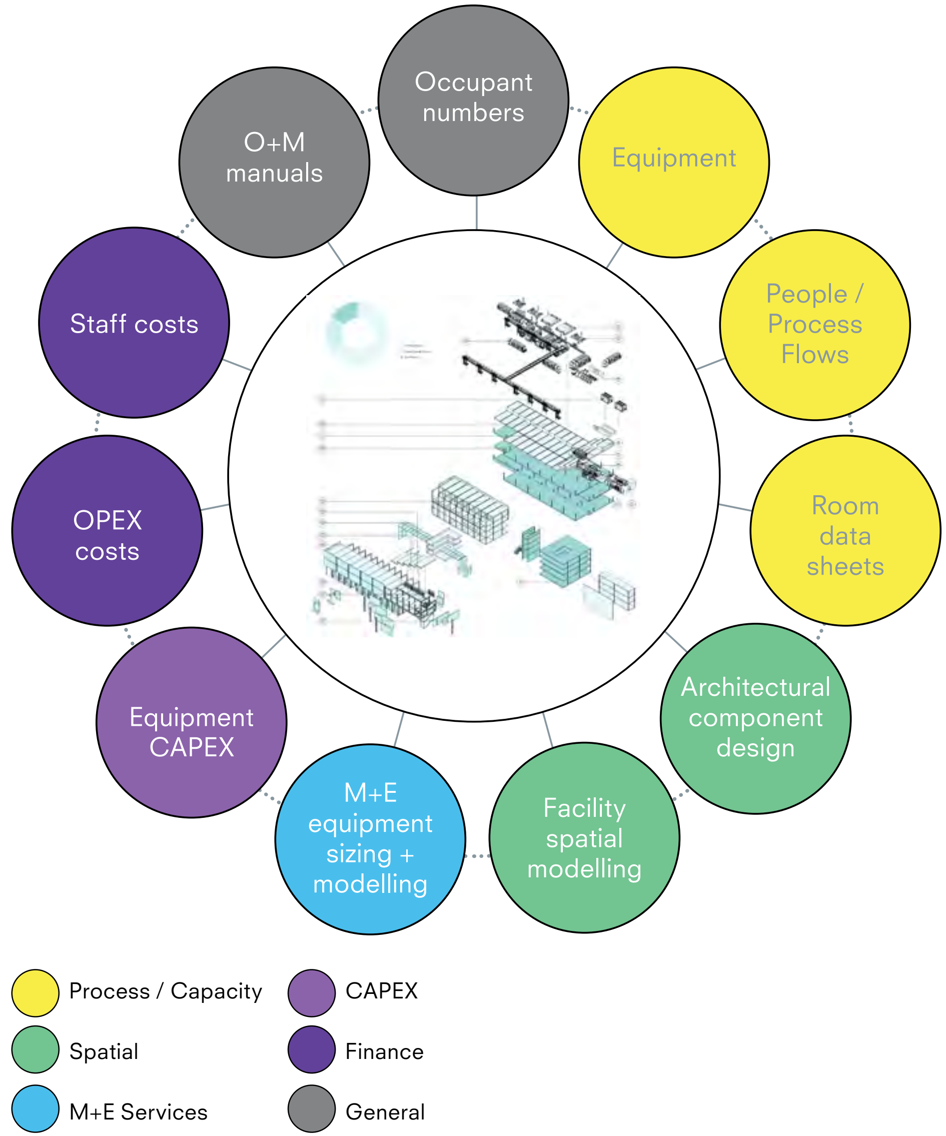
'Spaces' are a useful 'origin' point in considering the size and complexity of built assets

Stakeholder perspectives

The initial need for spaces, and their functional requirements, can generally be identified through schedules of accommodation and technical standards generated on previous projects.

The initial spatial needs can be interrogated, refined and more precisely articulated through a variety of stakeholder perspectives to describe every aspect of how a space needs to function, the people, processes and activities it needs to accommodate etc.

The room properties (from, for instance, standard room data sheets) can then be captured and enriched (if required) with input from key stakeholders representing a number of operational and functional specialisms.



Analysis of spaces

A sensible starting point of the standardisation process would be to analyse the spaces delivered over a range of previous, representative projects within a sector.

Using schedules of accommodation to identify unique room types, their areas and number of times and in which buildings they occur would allow an analytical approach to be taken to understand the degree of commonality and variation between the different space types in terms of:

- Size + frequency;
- Complexity (e.g. whether the proposed use of the space requires a high intensity of power, data, MEP etc. or whether the space itself is relatively simple and the proposed use is simply dictated by the furniture and equipment that is placed in the room).

This analysis will look for patterns in e.g.:

- Distribution of the different room areas and within which typology they occur to develop a reduced number of common room sizes but with an increase in the frequency of each;
- Analysis of the most highly repeated and complex (high value) room types where the benefits of an industrialised approach will have the most impact.

Size + frequency

The design of the high frequency rooms should be standardised as much as possible in order to increase repeatability.

Where there are rooms of a similar size which occur with low frequency, there could be an opportunity to rationalise these rooms to a common area. This would result in certain rooms becoming larger whilst others becoming smaller. It must be ensured that these rationalised rooms remain functional with their revised areas.

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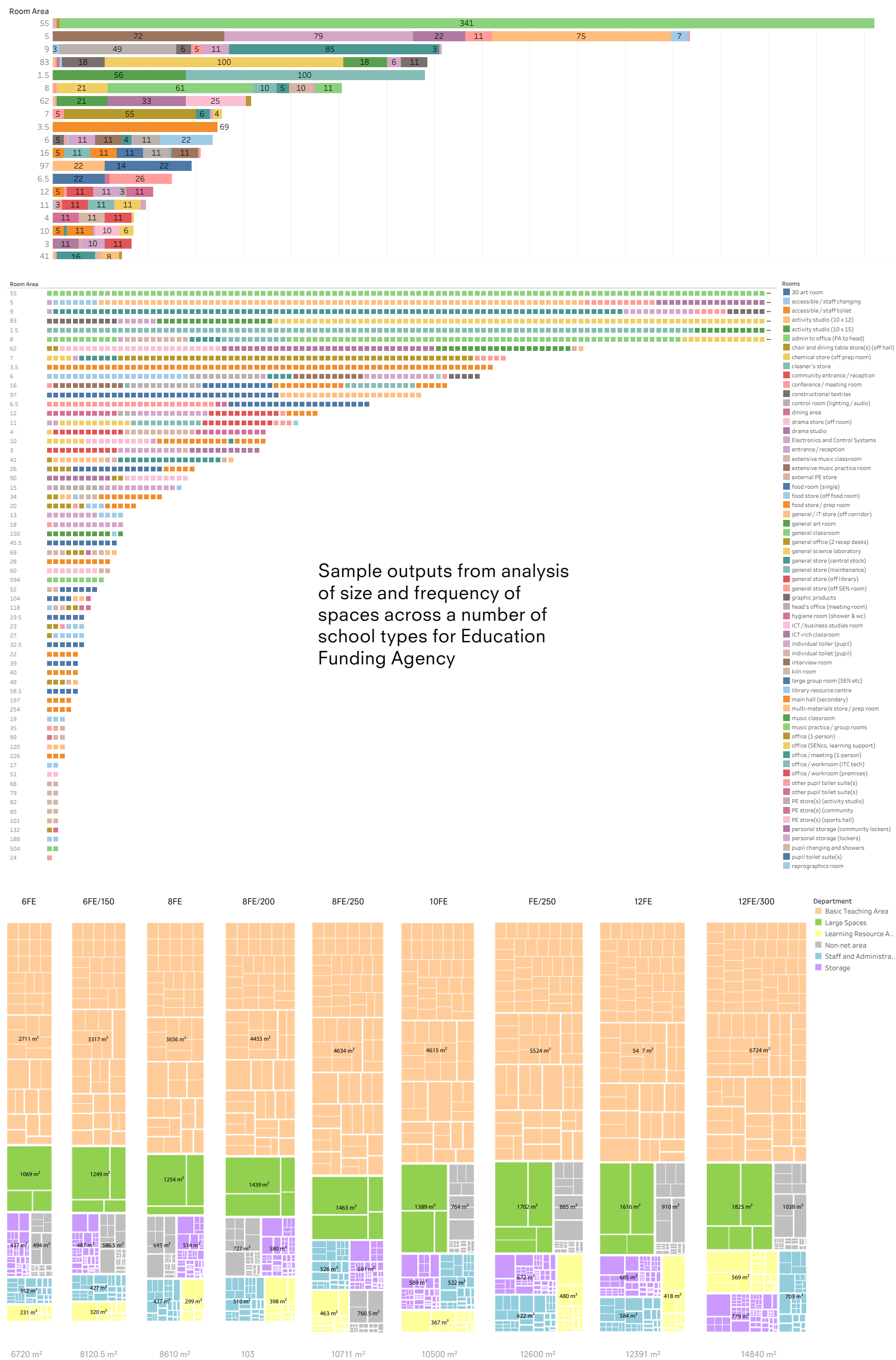


Sample outputs from analysis of size and frequency of spaces across a number of school types for Education Funding Agency

Analysis of spaces cont'd

It will therefore be possible to rationalise the number of space types into a smaller (and therefore more manageable) number of types with common properties, a higher degree of standardisation in the fit-out and operational stages, and also offer the ability to re-purpose rooms of one type to another type with similar properties.

In this way, it should be possible to allow for over-provision of space (i.e. providing generous room sizes) or MEP (providing future proofing and future flexibility) at zero cost or reduced cost by achieving higher levels of standardisation and therefore leveraging the benefits of industrialisation.

Complexity

Factors that will be used to judge the relative complexity of space types will include the requirement for the provision (and density) of mechanical and electrical services.

By aggregating the MEP requirements from the rationalised space types, it will be possible to generate high level requirements for mechanical and electrical plant, including schedules for:

- Estimate of total anticipated building electrical load (KVA) - load estimate
- Estimate of total anticipated building generator load (KVA) - load estimate
- Estimate of total HVAC loadings (m3/s) - load estimate
- Estimate of total cooling plant loading (KW) - load estimate
- List of recommended electrical rooms, sizes based on adjacency diagrams
- List of recommended IT / Data rooms, sizes based on adjacency diagrams

This will facilitate the testing of high level strategies, primary system selection etc. as well as providing a benchmark for testing design development and potential opportunities against.

Sample outputs from analysis of complexity of spaces across a number of school types for Education Funding Agency

Room intelligence

Mechanical properties

AHU No.
Boiler Power
Cold Water Requirements
Domestic Hot + Cold Water no. of connections
Drainage List Quantity
Drainage Requirements
Extract ACH
Extract Air Flow Rate
Heating/Cooling System Type
Hot Water Requirements
Primary Cooling Load
Primary Heating Load
Primary Heating/Cooling Type
RO Water Requirements
Sanitary Waste
Secondary Cooling Load
Secondary Heating Load
Secondary Heating / Cooling Type
Softened Water Requirements
Special Waste
Supply ACH
Supply Air Flow Rate

Electrical properties

Electrical System Clinic Category
Equipment Load
Fire Alarm
Lighting Illuminance
Lighting Lamp Source
Lighting Working Plane
Nurse Call
Power Total Space
True Power
Number and type of electrical / data outlets per room

Specialist requirements

These would vary by sector and project. However, in a healthcare context, these would include medical gasses e.g.
Oxygen
Medical air
Surgical air
Oxygen/Nitrous oxide mix
Nitrous oxide
Carbon dioxide
Helium/Oxygen mix
Nitrogen
Medical Vacuum
Anaesthetic Gas Scavenging

Grouping of spaces to create a brief

Once the spaces have been identified and rationalised, they can be arranged into idealised adjacencies and flows.

Once all senior stakeholders have identified exactly what the functional organisation is that is required to meet their needs, a diagram can be developed using the information about spatial requirements that is contained within the library of space types.

This would allow the creation of a detailed whole facility spatial diagram that can be reviewed and validated by all relevant stakeholders.

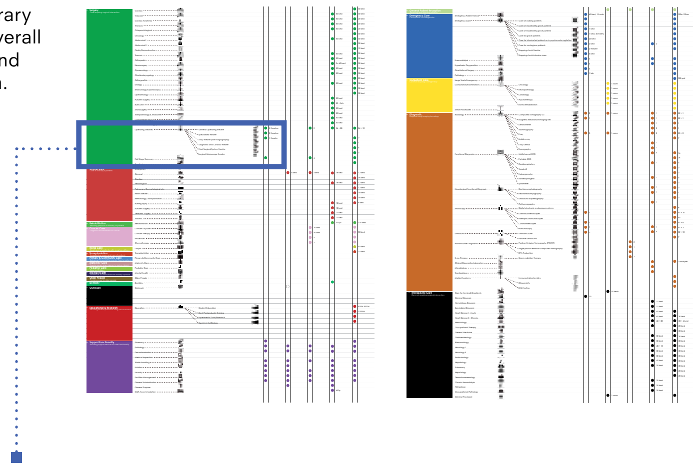
This diagram is then loaded with all the detailed general and technical requirements for each room.

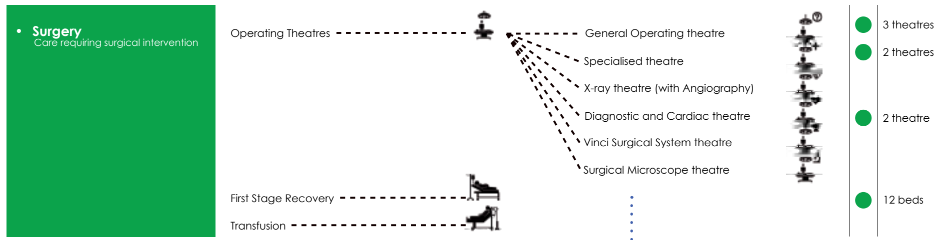
This information becomes the brief for the building and building system design.

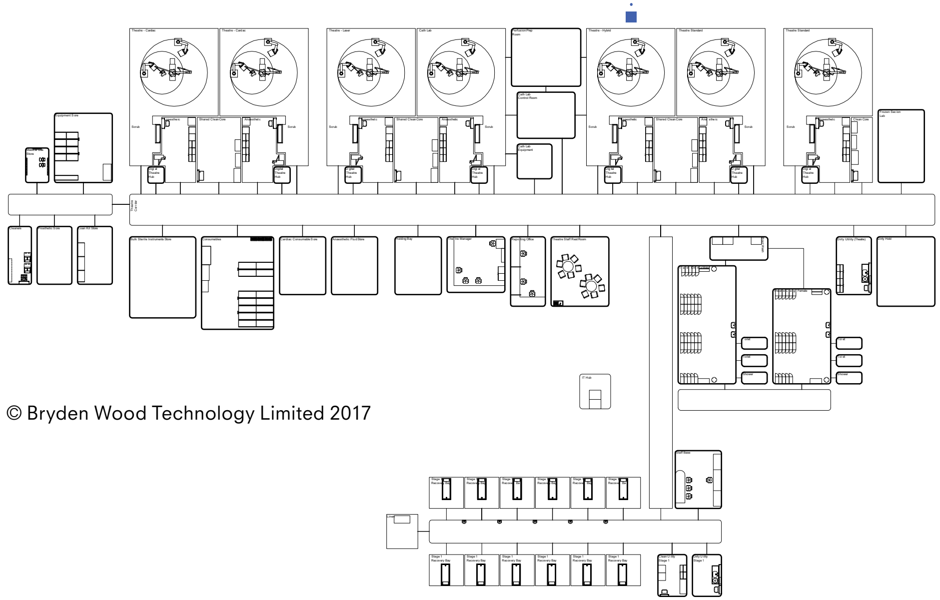
A number of these diagrams already exist for flows in courts and prisons and could be expanded to include healthcare, schools etc. Benefits include:

- A very user friendly interface with an early stage Building Information Model (BIM), ready for the application of subsequent layers of data e.g. cost, room data sheets etc.;
- Actual requirements can be interrogated and understood (rather than assumed or discussed based on geometric / physical constraints);
- Highly targeted stakeholder engagement, feedback and approval;
- Diagrams can be filtered to show a number of different critical requirements for specific stakeholders e.g.
    - user (pupil, patient etc.) / staff / visitor / operational flows;
    - security and access;
    - facilities management;
- Schedules of accommodation (SoA) are generated directly from the diagrams.

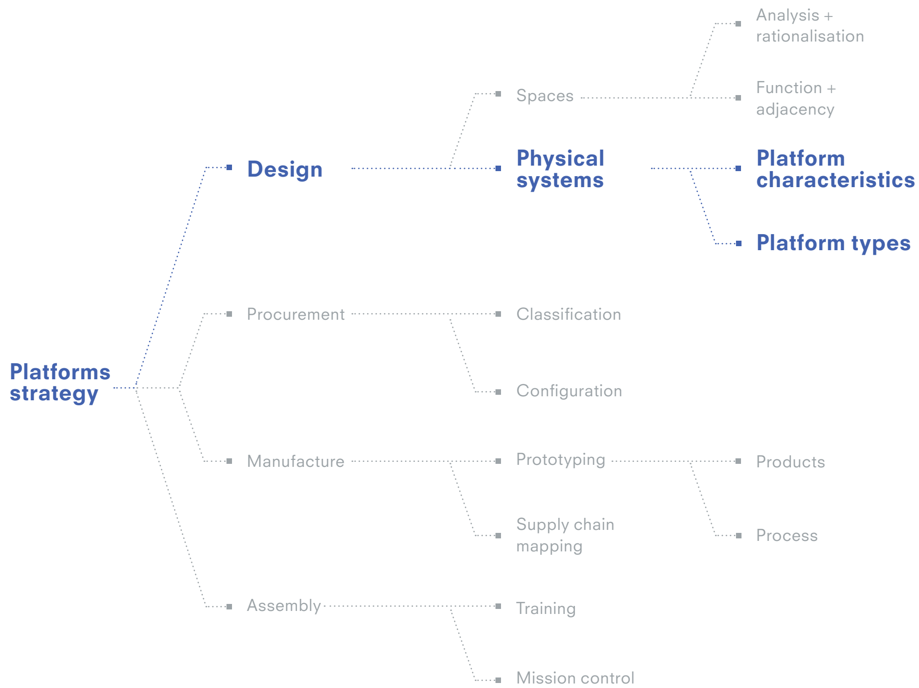
Excerpt from functional library for healthcare facilities - overall library, theatres example and supporting spatial diagram.







Physical systems



Current state + barriers to improvement

As has been set out earlier in this document, the adoption of a 'platform' approach requires standardisation of both the product and process.

However, there are a number of other aspects that should be considered in developing a definition of a successful 'platform'. These are:

- Proportion of pre-manufactured value;
- Proportion of project(s) delivered using modern methods of construction.

The diagram on the right sets out how these factors are related.

- Traditional construction is characterised by bespoke solutions, being delivered by a bespoke process. The adoption of modern methods of construction and creation of value off-site is low. As a result efficiency is low and this is the least productive (but most common) form of construction;
- 'Componentised' delivery uses standard solutions but the way they are deployed is not controlled. An example would be a project that uses standard room data sheets, BIM library objects or sub-assemblies, but delivered within the context of a largely traditional one off project; the efficiency in adopting the standardised components has little impact on the project overall;
- Volumetric solutions are standardised in terms of design, manufacture and delivery and as a result may be significantly more efficient than traditional. However, the level of customisation tends to be very low; setting up even a relatively unsophisticated manufacturing facility requires significant investment which is amortised through the delivery of units and dictates as much standardisation as possible. An automotive example would be the Model T Ford, which dramatically lowered the cost of a car but was famously available in 'any colour, as long as it is black.' To increase customisation requires more sophisticated tools, with higher investment, and greater unit numbers to amortise the cost;
- Manufactured solutions would use standardised processes to deliver bespoke solutions. Continuing the automotive analogy, this would be comparable to today's highly sophisticated 'build to order' manufacturing plants and models such as Ford Transit which have an estimated thirteen million combinations.

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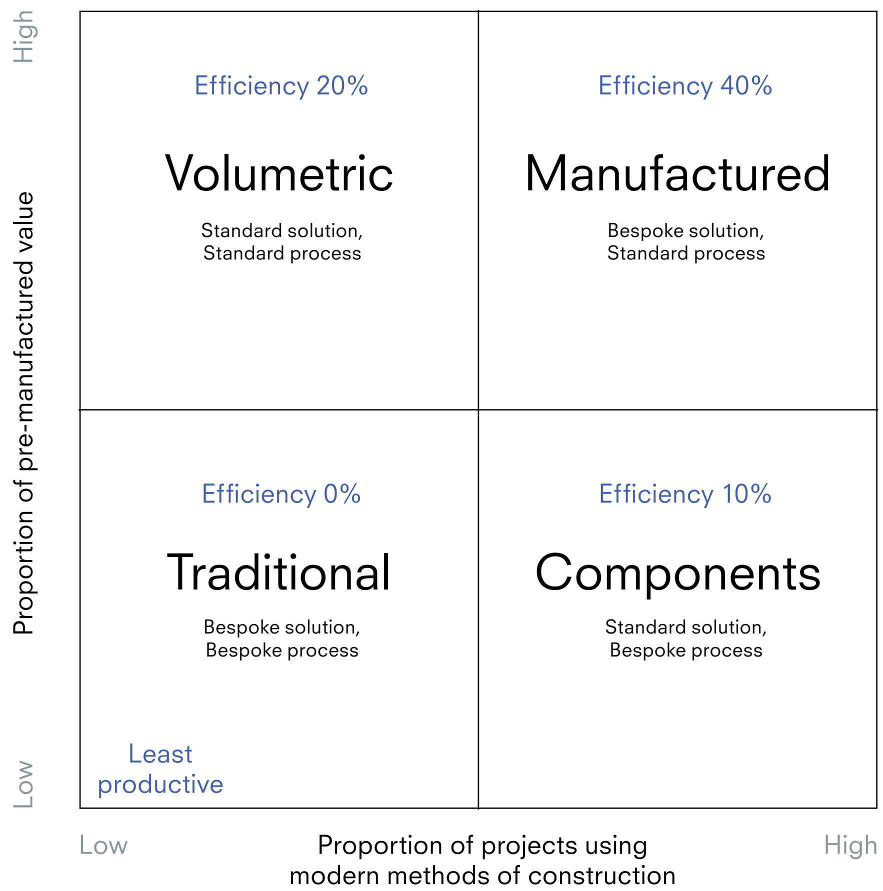


Current state + barriers to improvement cont'd

There is a 'market failure' barrier to achieving truly manufactured solutions, the reasons for which cannot be breached by any single programme of works. Only by coordinating government investment into a limited number of consistent platforms can enough critical mass be achieved to develop the solutions that are needed.

Additionally, to reap the benefits of manufactured solutions, all elements within the supply chain need to be standardised, working to the same rules, procedures and techniques. One simple way to explain the standardisation requirement of manufacturing is to use a football analogy where on the winning team everyone:

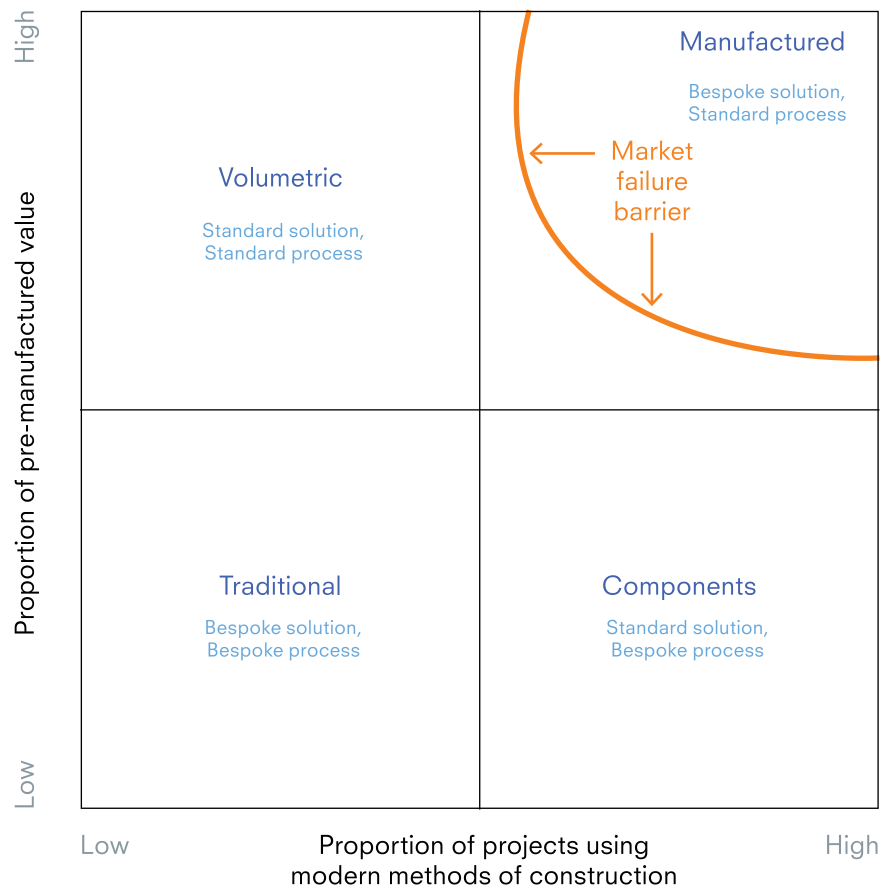
1. Has the same knowledge + rules;
2. Plays on the same pitch and with the same ball;
3. Sees everything that happens;
4. Gets informed about risks and issues;
5. Follows the progress of the game.

Meanwhile, on the losing team everyone:

1. Has different knowledge + rules;
2. Plays on different pitches;
3. Sees only their game/ball;
4. Is not informed about risks and issues;
5. Only cares about how many times he / she has kicked a ball.

Again, in an automotive context, in the 1980s and 1990s, the 'Big Three' US car manufacturers (Ford, General Motors and Chrysler) were forced to collaborate in creating a level of industry standardisation in order to counter the threat posed by Japanese competition. Toyota had successfully implemented Total Quality Management which allowed them to significantly penetrate US markets due to better quality products, shorter cycle times and lower costs. As a result, the automotive industry (and later Aerospace) introduced industry quality standards including Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP) to their supply chains.*

Today, the construction industry faces a similar threat from China, Germany and Sweden who have successfully adopted manufacturing methods, focussing on both standardisation and quality to produce highly competitive volumetric and manufactured products.



* This is described in more detail in the MTC's 'APQP Discovery Project' document 'A Quality Oriented Approach to Construction' (K. Harper, April 2017).

Platform characteristics

The space analysis and data-enrichment described in the previous section will yield a wide range of spaces required across the government estate.

However, within this large number of types and levels of complexity the characteristics that define spaces and indeed entire assets will, for the vast majority, sit within some well defined ranges.

Understanding these characteristics, and the ranges within which most buildings sit, will provide some valuable insights into what type of platforms might be most useful.

It is hypothesised that a small number of platform types would be able to create the complete range of space types that would be needed by the government estate (and also the majority of private sector). This section will explore what their chief characteristics would be.

Physical dimensions

The physical dimensions of any space will have two primary factors:

- Clear span
- Clear height

The diagram on the right shows the location of a number of common space types in a number of sectors. Note there is a large cluster towards the bottom left (relatively small spans, and clear heights) with a few building types requiring significantly larger clear heights and spans.

Building height

The total number of storeys is another key factor, again with a limited range.

- Large span spaces tend to be 1 - 2 storeys;

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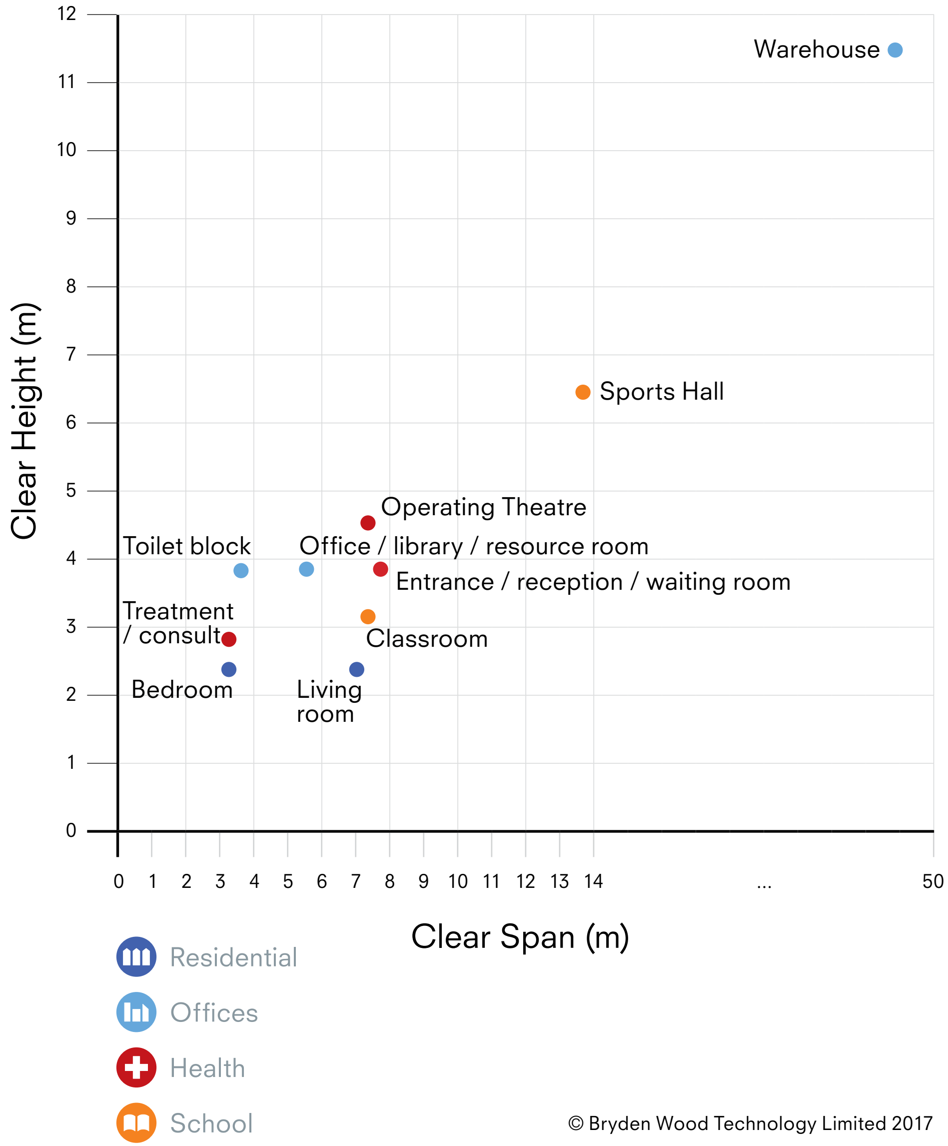


- Small scale domestic buildings and school / prison buildings tend to be 1 - 4 storeys;
- Mid-rise office / domestic sits within 5 - 15 storeys
- High-rise office / domestic will generally be 16 - 25 storeys; while of course there are numerous buildings that are taller they make up a relatively low proportion of all buildings and may not warrant a 'platform'.

Level of complexity

The space type analysis will suggest an overall complexity of the asset type, from heavily serviced buildings with high operational and maintenance costs to simple buildings with relatively straightforward provision in terms of heating / cooling, lighting power distribution etc.

Level of repeatability

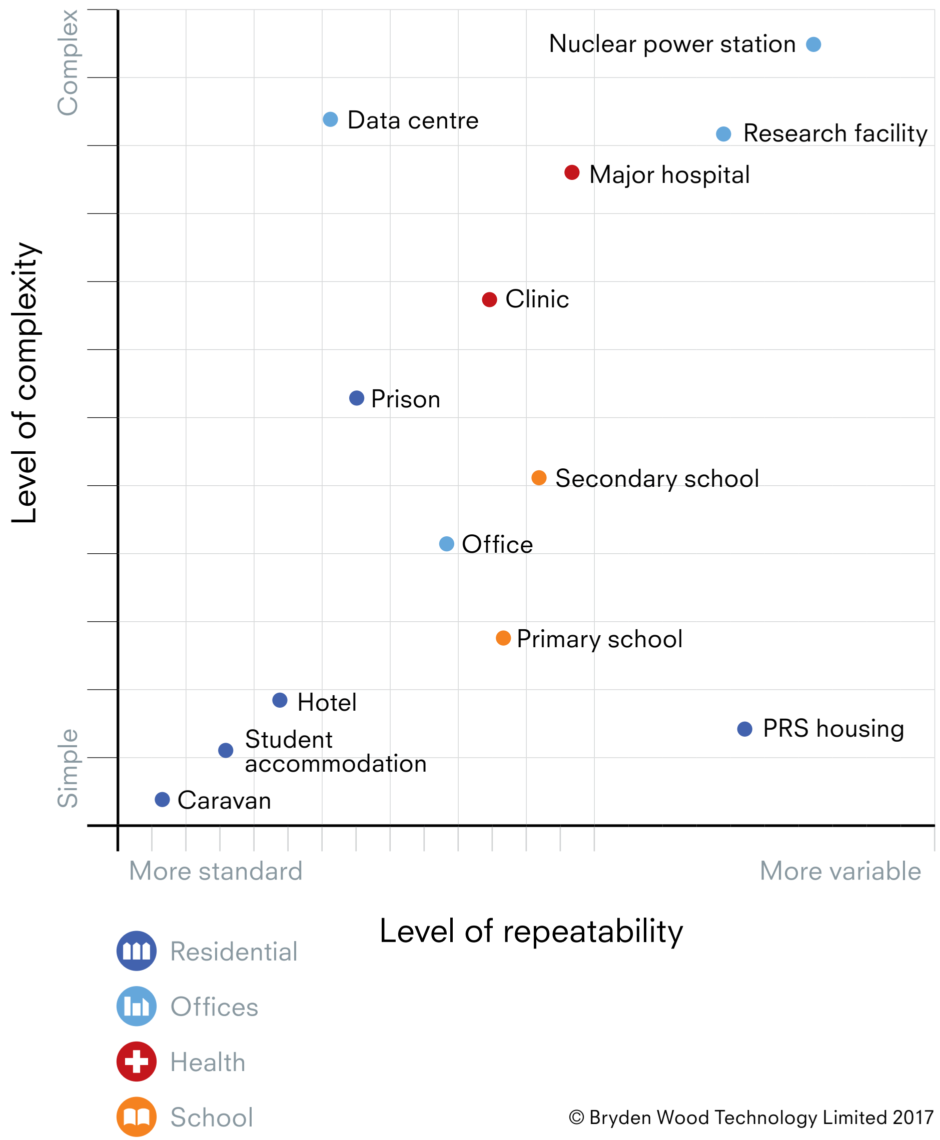
This would describe the overall degree of variation between the types of space or groupings of spaces within a particular building.

A typical housing scheme, for instance will have a mix of unit types from small flats to large apartments, with a different layout on different floors and is therefore highly variable.

By contrast, student accommodation is highly standardised with little meaningful variation between the majority of spaces and floors.

Number of buildings

While the creation of platforms should extend beyond any single programme, the need for a high number of very similar or even identical buildings (e.g. the ESFA priority schools programme or house blocks for the MOJ prison estates programme) will warrant a particular focus as the amount of repetition will have a multiplier effect in leveraging the benefits of standardisation.



Mass customisation

Mass Customisation is a manufacturing technique that combines the flexibility and personalisation of custom-made products with the low unit costs associated with mass production.

As described above, automotive manufacturing is an example of a successful implementation of this approach; computer manufacturing is another. Both of these sectors are characterised by the capability of the suppliers to provide customers with a personally configured product, with seemingly limitless possibilities of configuration. Neither party suffers significant additional cost or inconvenience for incurring such choice. In fact, the opposite is true.

In order to provide solutions that are fine tuned to specific localised needs and contexts, the creation of delivery platforms should accommodate sufficient levels of mass customisation.

In order to achieve these outcomes, consideration will be given to a number of scales;

- Product assemblies - Market testing to find popular or typical product configurations, as well as the likely appetite for variation and deviation from these baselines. The requirement for product assemblies will be created by the spatial design work streams and a more detailed analysis of the make up of the existing and planned government estate according to the characteristics described above;
- Sub-assemblies - Comprehensive understanding of relationships between component parts, such as their interoperability as of part of larger assemblies. This includes the details of the specific assembly processes that are required;
- Component parts – Identification of a parts library, that can populate the sub-assemblies and combine to deliver the performance requirements of the product assemblies. This includes detailed knowledge of parts such as performance, costs and availability.

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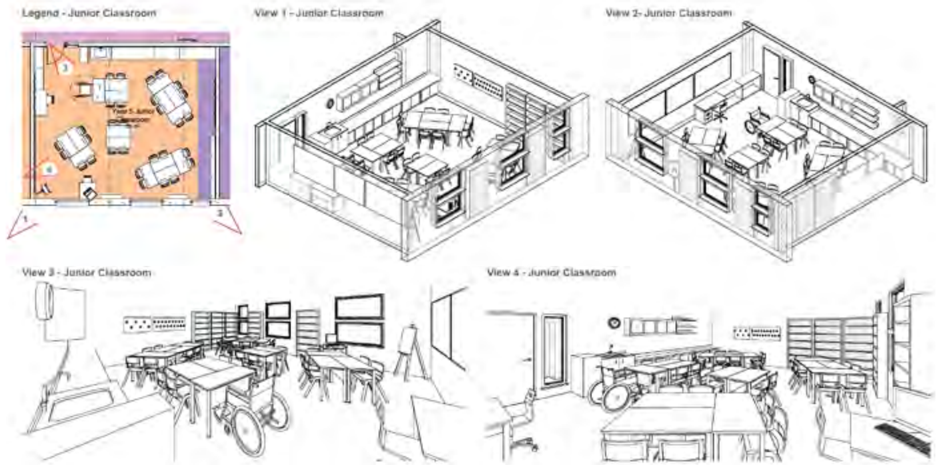
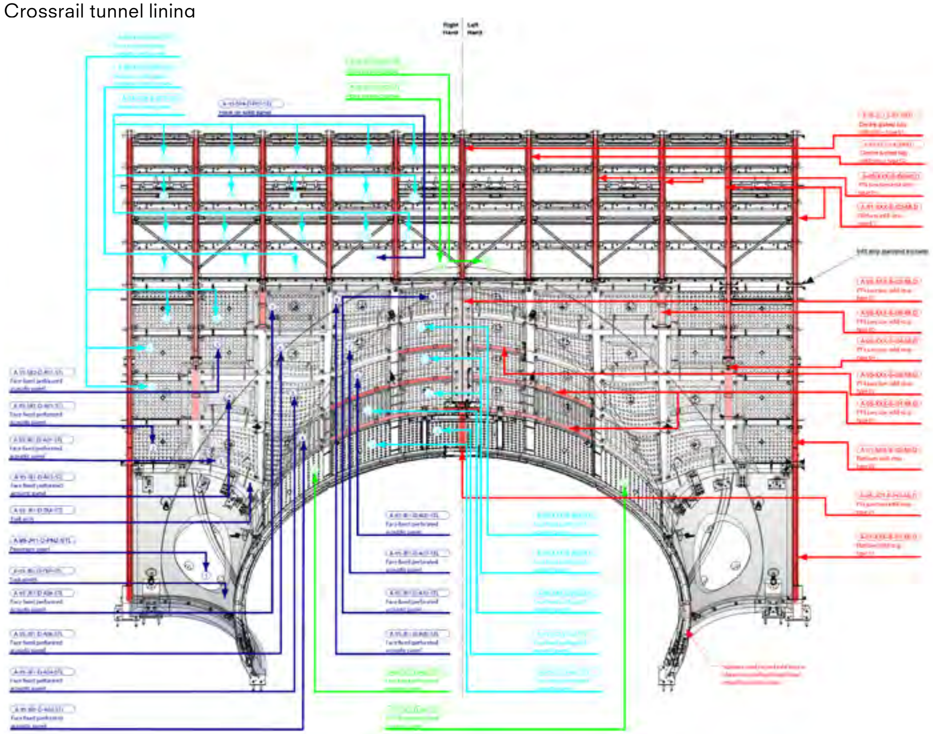


'Product assemblies' example - EFA Component Design for Primary Schools

'Sub-assemblies' example - Crossrail tunnel lining



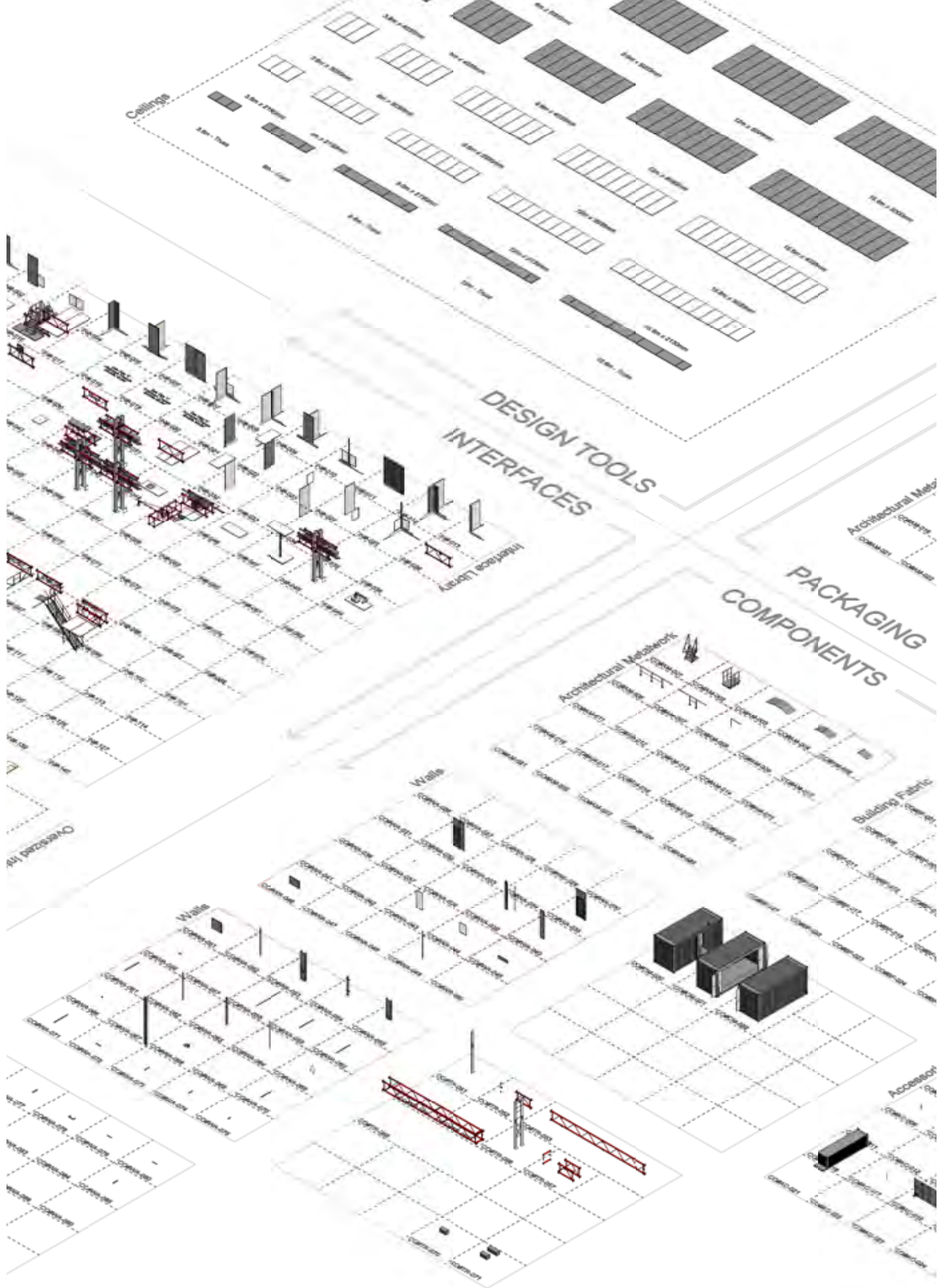
Mass customisation cont’d

This strategy will apply the thinking that underpins existing, successful models of mass customisation to the building design and construction industry and will take on each of these three work strands in order to determine and document;

- Product assemblies – Identification and documentation of the functional typologies of spaces, departments and facilities that define publicly procured built assets across the most high value sectors. This work strand will provide briefing and guidance for the further work necessary to standardise and optimise spatial configurations across typologies;
- Sub-assemblies – Identification of common constructional and operational Sub-Assemblies that can serve multiple typologies. This will include architectural, structural and MEP systems. This workstream will provide briefing and guidance for the further work necessary to standardise and optimise sub-assemblies to suit the Product Assemblies;
- Component parts – Identification and documentation of common component parts that can serve multiple Sub Assemblies. This work strand will provide briefing and guidance for the further work necessary to create a standardised ‘parts library’, including the means of cataloguing criteria for verification and validation required for maintaining it.

Each of these three strands will be underpinned by the use of BIM Level 2 standards, and in particular the use of Uniclass 2015 as a classification system to capture facilities, spaces, systems and products (this is described in more detail in the next section).

‘Components’ example - excerpt from the virtual warehouse of components for GlaxoSmithKline’s ‘Factory in a Box’ system



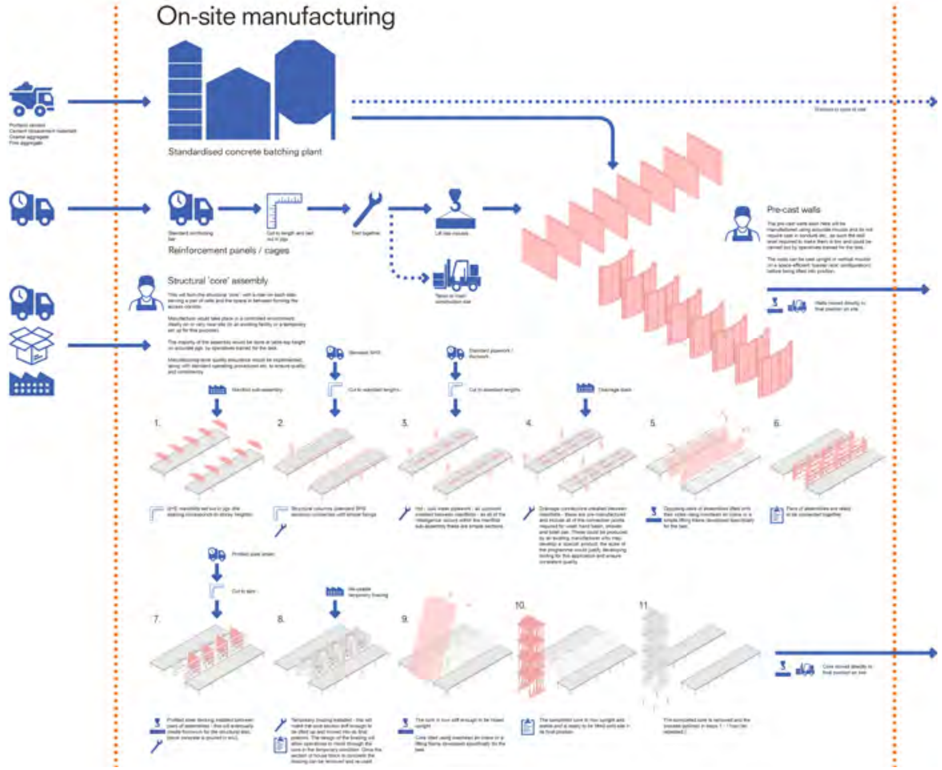
Lowering barriers to entry

Work to date on developing the DfMA solutions for the MOJ Prison Estates Transformation Programme shows that in order to be able to deploy DfMA at scale, the component design should have a low barrier to entry to existing supply chains i.e. manufacturing the components should work with existing skills, processes and tools.

Platforms should therefore be made up from components with the following characteristics:

- Highly repeatable and can be manufactured at scale by a wide supply chain;
- Requires 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);
- Could be manufactured and assembled using local, semi-skilled labour (following standard training in relevant tasks) to facilitate the creation of apprenticeships and expansion of manufacturing skillsets;
- Require minimum materials handling and processing (which inevitably introduces waste and non-value adding activity);
- Uses materials that are widely available in the UK;
- Could be developed with MTC to optimise manufacturing processes (including adoption of some level of automation if appropriate and desirable);

Excerpt from MOJ PETP value stream mapping exercise for component creation using upskilled local labour



Platform types - initial proposal

Based on the considerations above, it is possible to hypothesise three platform types that might be appropriate for the majority of the space and asset types within the government estate. Broadly speaking these might be:

1. A highly flexible and versatile system that would be highly customisable but with the following characteristic 'upper limits':
    - Spanning capability up to 11m;
    - Variable structural loading capacity (depending on span) up to 5kN/m²;
    - Storey height up to 4m;
    - Building height up to 14 storeys;
    - Ability to work with a range of levels of interior fit out / mechanical and electrical services etc.
2. A 'domestic scale' system for mid to high rise housing (assuming that Government investment is more likely to be in mid- to high-rise housing than low rise, low density)
    - Spanning capability up to 8m;
    - Loading capacity up to 2kN/m²;
    - Storey height up to 4m;
    - Building height up to 25 storeys;
    - Ability to work with a range of levels of domestic interior fit out / mechanical and electrical services etc.
3. A 'large spaces' system for buildings such as sports halls, storage / warehouse / distribution facilities etc.
    - Spanning capability up to 50m
    - Loading capacity on ground floor slab, with mezzanine floor up to 5kN/m²;
    - Clear height up to 12m
    - Building height up to 1 storeys
    - Ability to work with a range of levels of domestic interior fit out / mechanical and electrical services etc.

The diagram on this page shows how the platforms might map onto the two characteristics graphs.

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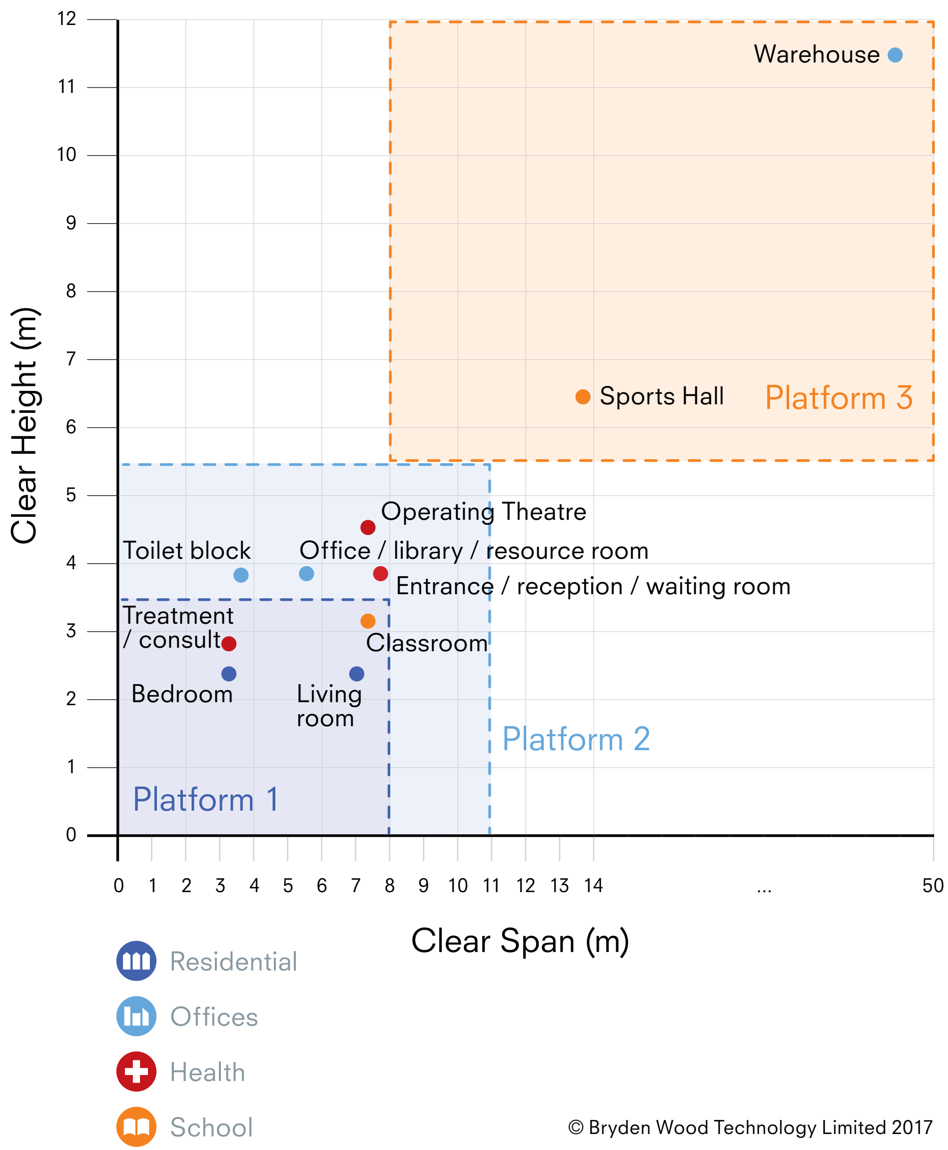
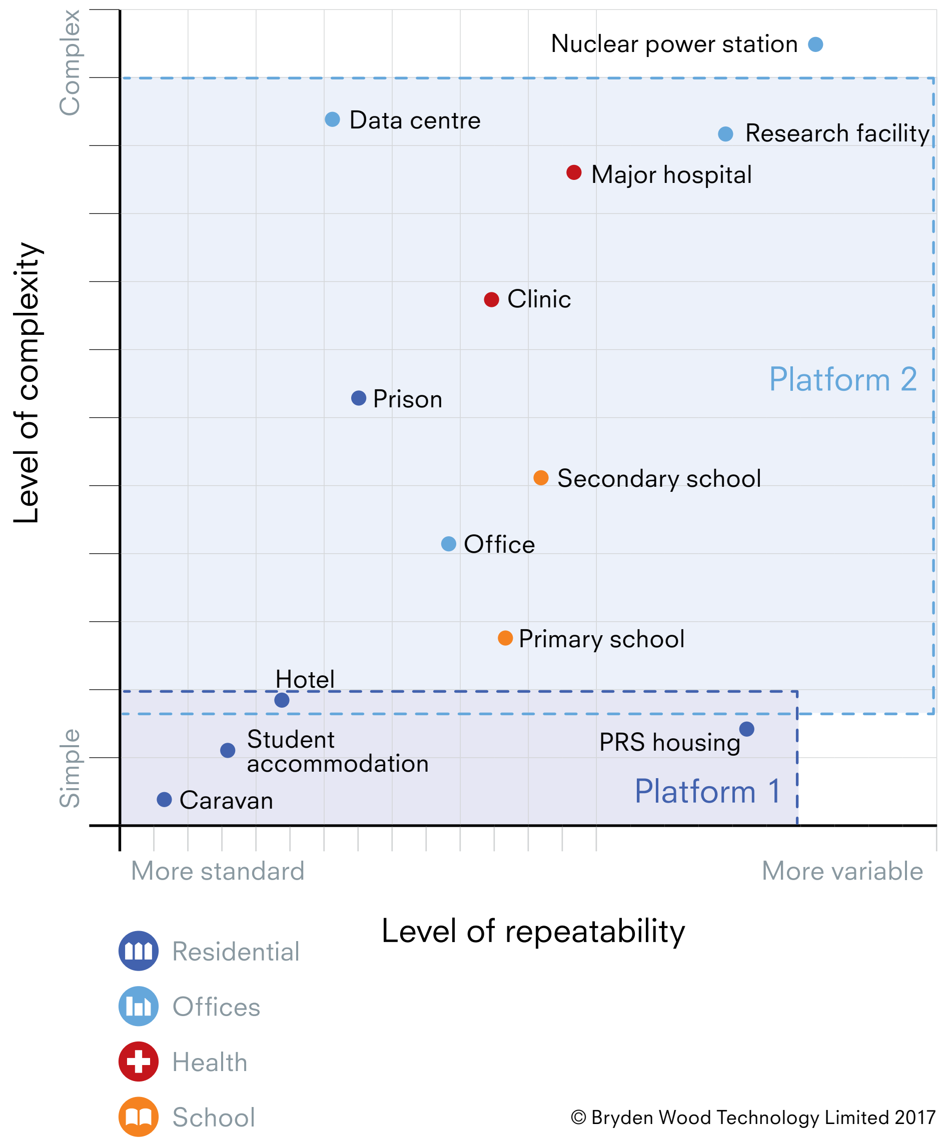
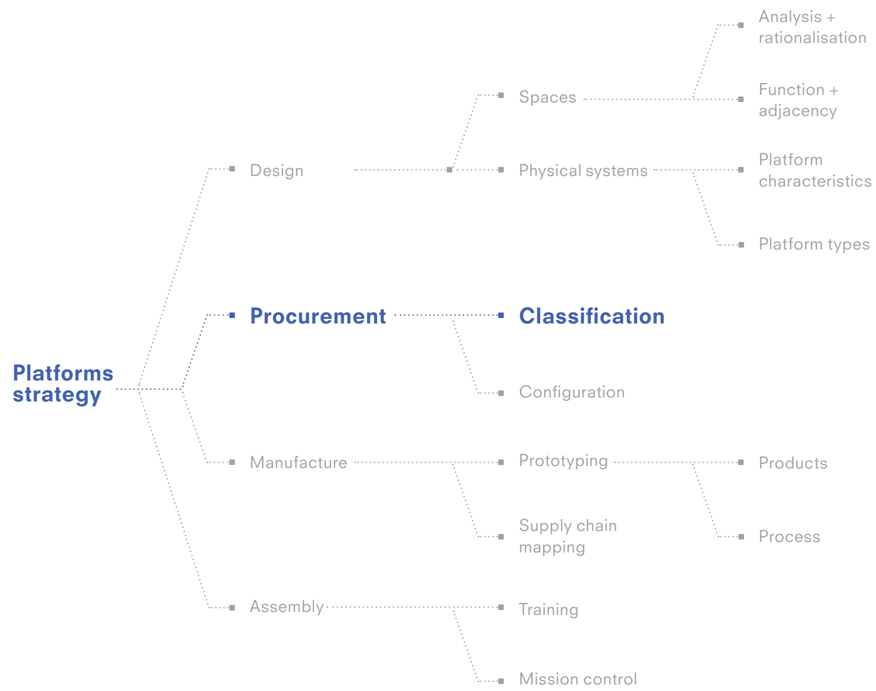


Platform types - initial proposal cont'd

This early stage assessment shows that there are very few building types that would not be adequately serviced using these few platform types.



Classification



Uniclass classification system

One key element of standardisation is the ability to have a common frame of reference for describing buildings, spaces, systems and components.

Uniclass 2015 is a unified classification system for the construction industry, divided into a set of tables which can be used to categorise information for costing, briefing, etc. as well as when preparing specifications or other production documents.

The adoption of Uniclass will be critical for linking the ‘spaces’ and ‘physical systems’ described in earlier systems - Uniclass provides the common thread that can link every scale of the physical elements with the functional and spatial requirements of a facility.

These tables are also suitable for buildings and other assets in use, and maintaining asset management and facilities management information.

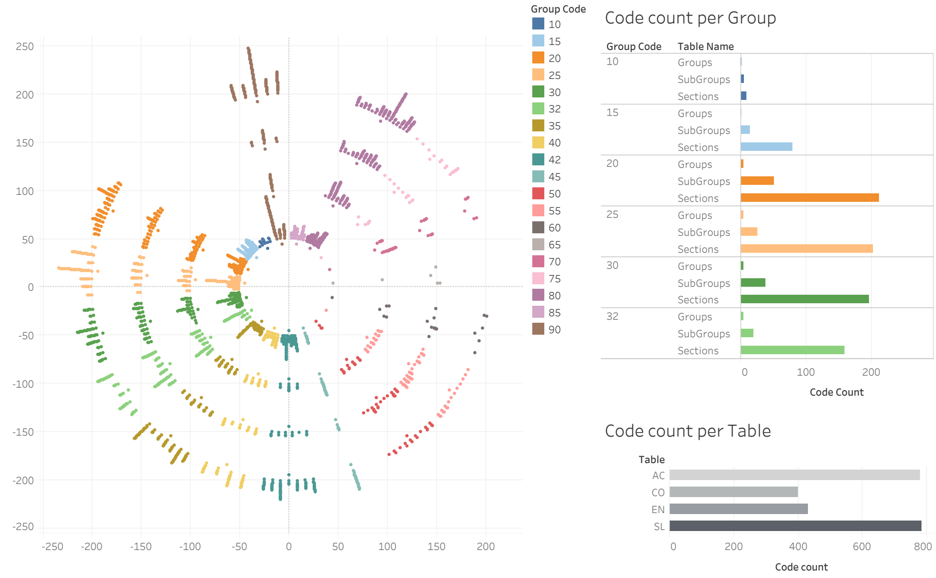
The tables are:

- Ac - Activities
- Co - Complexes
- En - Entities
- SL - Spaces/ locations
- EF - Elements/ functions
- Ss - Systems
- Pr - Products

- CA - Construction aids
- FI - Form of information
- PM - Project management

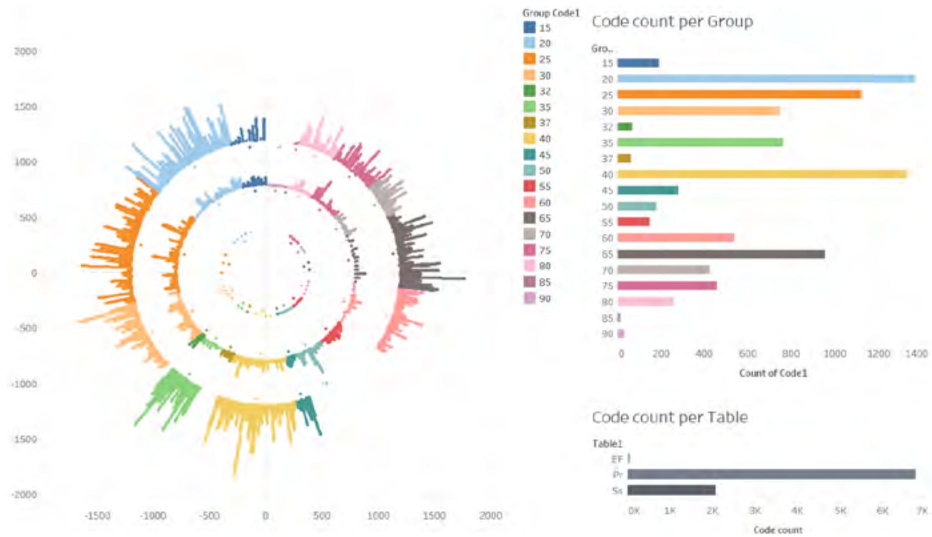
The example on the following pages uses a healthcare facility to show how Uniclass works at a range of scales from an entire facility down to the individual products.

The last three tables listed above also provide classifications specific to the delivery phase of the project.



Above:
Data visualisation for activities, complexes, entities and spaces tables

Below:
Data visualisation for elements, systems and products tables



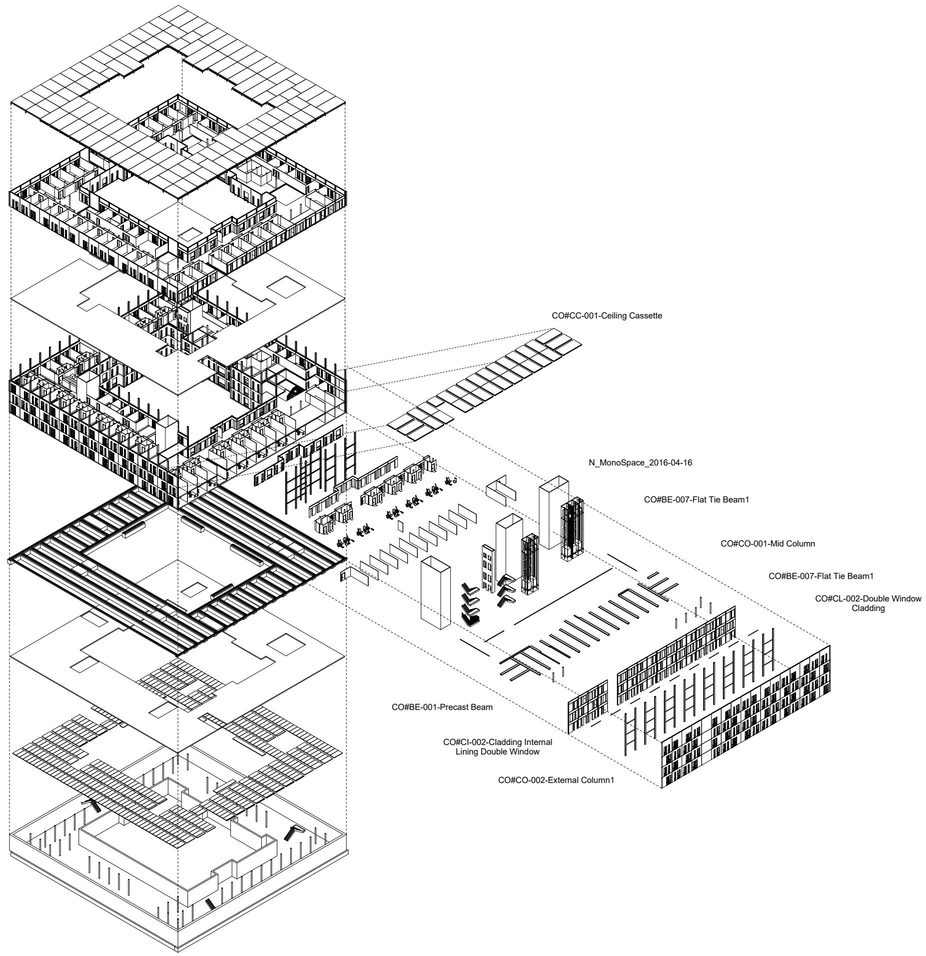
Uniclass classification - at Facility level

Ac -	**Activities**
Ac_25_30	Scientific + laboratory activities
Ac_25_90	Worship activities
Ac_35	Medical, health, welfare + sanitary activities
Ac_35_10	Medical activities
Ac_35_10_08	Birthing
Ac_35_10_10	Burns treating
Ac_35_10_15	Consulting
Ac_35_10_31	First aiding
Ac_35_10_36	Hearing testing
Ac_35_10_39	Hydrotherapy
Ac_35_10_42	Intensive caring
Ac_35_10_43	Isolation caring
Ac_35_10_51	Medical scanning
Ac_35_10_53	Midwifery
Ac_35_10_57	Nursing
Ac_35_10_58	Occupational therapy
Ac_35_10_59	Operating
Ac_35_10_64	Pharmaceutical dispensing
Ac_35_10_65	Phototherapy
Ac_35_10_66	Physiotherapy
Ac_35_10_70	Radiography
Ac_35_10_71	Radiotherapy
Ac_35_10_74	Rehabilitating
Ac_35_10_76	Screening
Ac_35_50	Welfare activities
Ac_35_50_21	Day care
Ac_35_50_42	Infant caring
Ac_35_60	Food management activities
Ac_35_60_16	Cooking
Ac_35_60_30	Food preparation
Ac_35_60_31	Food serving

Co	**Complexes**
Co_35	Medical, health, welfare and sanitary complexes
Co_35_10	Medical complexes
Co_35_10_37	Hospital complexes
En -	**Entities**
En_35	Medical, health, welfare + sanitary entities
En_35_10	Medical entities
En_35_10_10	Medical buildings
SL -	**Spaces / locations**
SL_35	Medical, health, welfare and sanitary spaces
SL_35_10	Medical spaces

EF -	**Elements / functions**
Ss -	**Systems**
Pr -	**Products**

Healthcare example showing whole facility.



Uniclass classification - at Room level

Healthcare example showing bedroom + en suite bathroom.

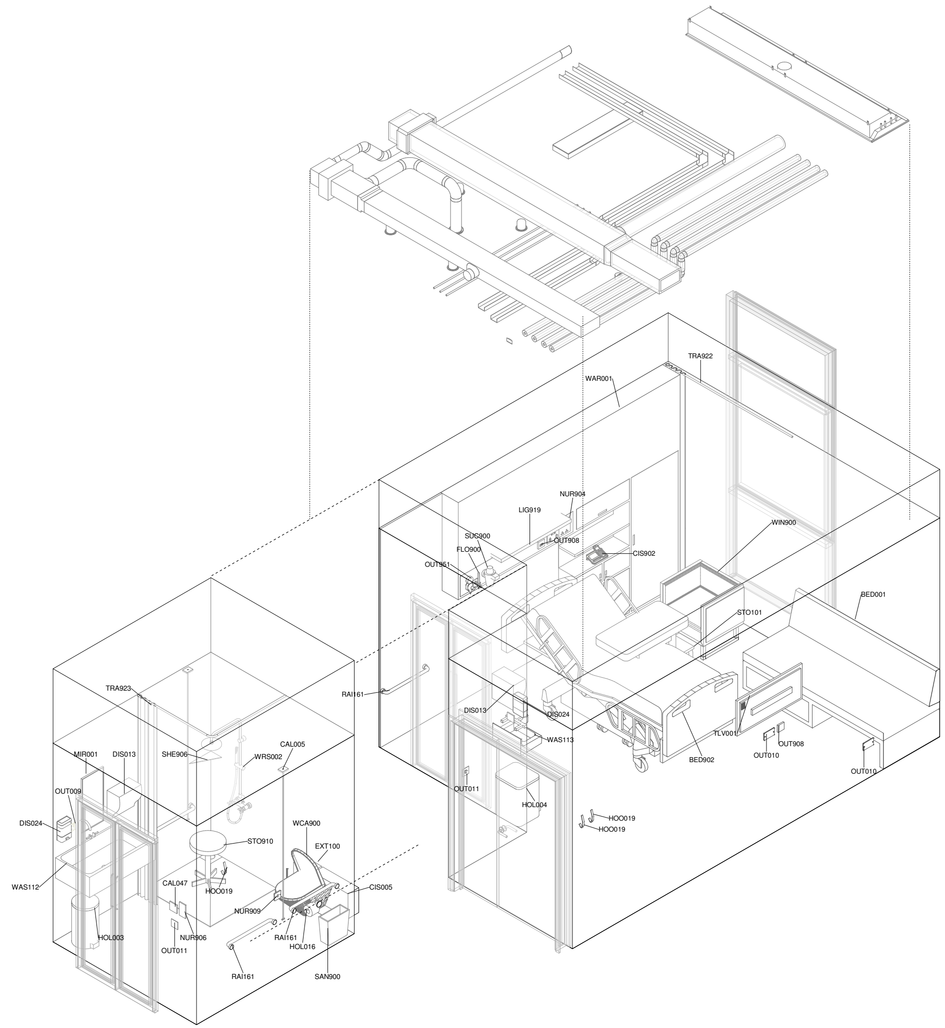
Ac -	**Activities**
Ac_35	Medical, health, welfare and sanitary activities
Ac_35_10	Medical activities
Ac_35_10_57	Nursing
Ac_35_60_31	Food serving
Ac_45_10_79	Sleeping
Ac_35_80	Sanitary activities
Ac_35_80_07	Bathing
Ac_35_80_80	Showering

SL -	**Spaces/ locations**
SL_35	Medical, health, welfare and sanitary spaces
SL_35_10	Medical spaces
SL_35_10_53	Medical treatment spaces
SL_35_10_96	Wards
SL_45_10_09	Bedrooms

EF -	**Elements / functions**
EF_25	Wall and barrier elements
EF_25_10	Walls
EF_25_30	Doors and windows
EF_30_20	Floors
EF_55	Piped supply functions
EF_55_05	Gas extraction and treatment
EF_55_20	Gas supply
EF_55_70	Water supply
EF_60	Heating, cooling and refrigeration functions
EF_60_40	Space heating and cooling
EF_65	Ventilation and air conditioning functions
EF_65_40	Ventilation
EF_65_80	Air conditioning
EF_70	Electrical power and lighting functions
EF_70_30	Electricity distribution and transmission
EF_70_80	Lighting
EF_75	Communications, security, safety and protection functions
EF_75_10	Communication
EF_75_30	Signalling
EF_75_40	Security
EF_75_50	Safety and protection

Ss -	**Systems**
Ss_25	Wall and barrier systems
Ss_25_10	Framed wall systems
Ss_25_10_30	Framed partition systems
Ss_25_10_30_35	Gypsum board partition systems

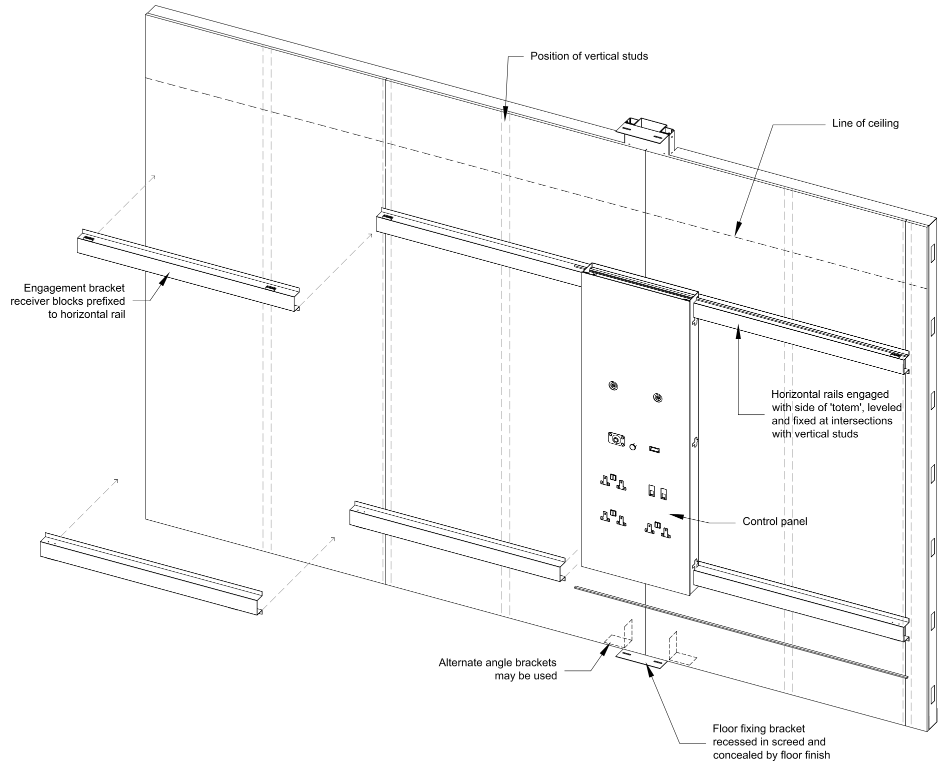
Pr -	**Products**



Uniclass classification - at Fixtures + fittings level

Ss -	**Systems**
Ss_25_25	Wall lining systems
Ss_25_25_45	Lining and casing systems
Ss_25_25_45_25	Duct and wall panel lining systems
Ss_25_25_45_90	Timber board wall lining systems
Ss_40_50	Medical, health and welfare FF+E systems
Ss_40_50_50	Medical and health FF+E systems
Ss_40_50_50_37	Hospital ward FF+E systems
Ss_55_20_51	Medical gas supply systems
Ss_55_20_51_03	Medical anaesthetic gas scavenging systems
Ss_55_20_51_27	Medical entonox supply systems
Ss_55_20_51_36	Medical helium/ oxygen mixture supply systems
Ss_55_20_51_56	Medical nitrous oxide supply systems
Ss_55_20_51_57	Medical nitrous oxide/ oxygen mixture supply systems
Ss_55_20_51_59	Medical oxygen supply systems
Ss_70	Electrical systems
Ss_70_30_80	Small power systems
Ss_70_30_80_45	Low-voltage small power systems with prefabricated wiring
Ss_70_80	Lighting systems
Ss_70_80_33	General space lighting systems
Ss_70_80_33_33	General lighting systems with prefabricated wiring
Ss_75	Communications, security, safety, control and protection systems
Ss_75_10	Communications systems
Ss_75_10_21	Data distribution and telecommunications systems
Ss_75_10_21_21	Data distribution systems
Ss_75_10_21_88	Telecommunications systems
Ss_75_50	Communication, safety and protection systems
Ss_75_50_11	Call and alarm systems
Ss_75_50_11_57	Nurse call systems
Pr -	**Products**

Healthcare example showing a wall panel incorporating medical gas outlets and power / data sockets.



Uniclass classification - at Component level

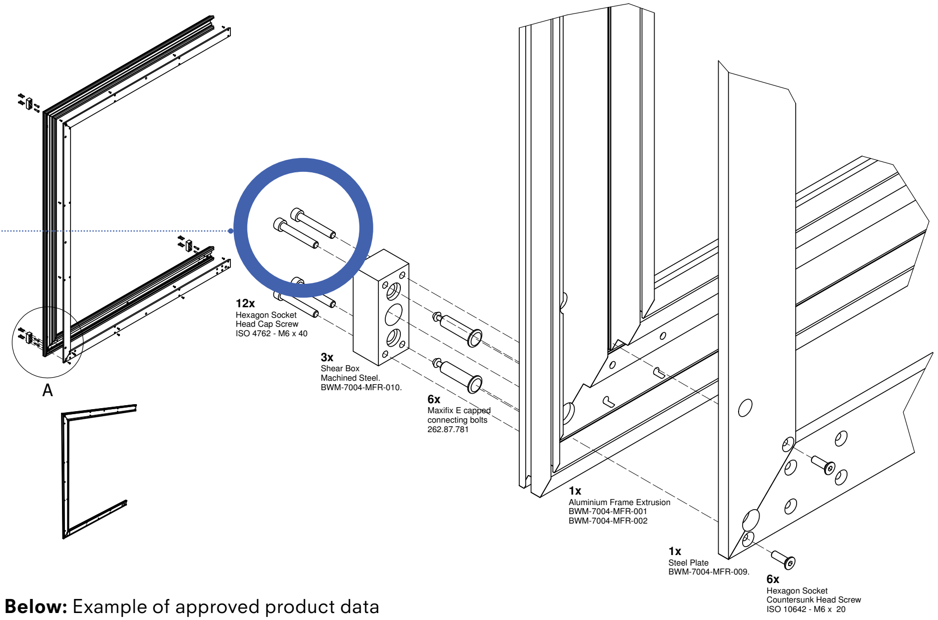
Pr -	**Products**
Pr_20	Structure and general products
Pr_20_29	Fastener products
Pr_20_29_76	Screws
Pr_20_29_76_81	Socket screws

At this level the components can be linked to individual manufacturers' data. This is described in more detail in 'Product Data Definition - A technical specification for defining and sharing structured digital construction product information' (S. Thompson, April 2016).

LEXiCON, hosted by the Construction Products Association (CPA), will implement the methodology set out in the Product Data Definition document and facilitate the capture of the following information relating to products:

- Essential Requirements for the Harmonised European Standards (hENs);
- Requirements from other Standards (e.g. relevant ISO, EN or BS standards other than those captured above);
- Industry recognised documents;
- Mandated requirements for a specific sector or application e.g. NRM for Chartered Surveyors;
- Non-mandated but recognised within a specific sector e.g. CIBSE Guide M;
- Industry agreed and recognised e.g. identified by a professional institute, trade association or cross-industry group;
- User-defined additional terms proposed for approval and wider adoption.

Healthcare example showing individual components making up the wall panel.



Below: Example of approved product data template from 'Product Data Definition' http://bim-level2.org/globalassets/pdfs/product-data-definition_v2.pdf

Template Reference 1234
Classification Pr_20_76_52_16_Carbon steel hot finished hollow sections
Description Hot finished structural hollow sections - example
Template Author Me
Template Status Approved

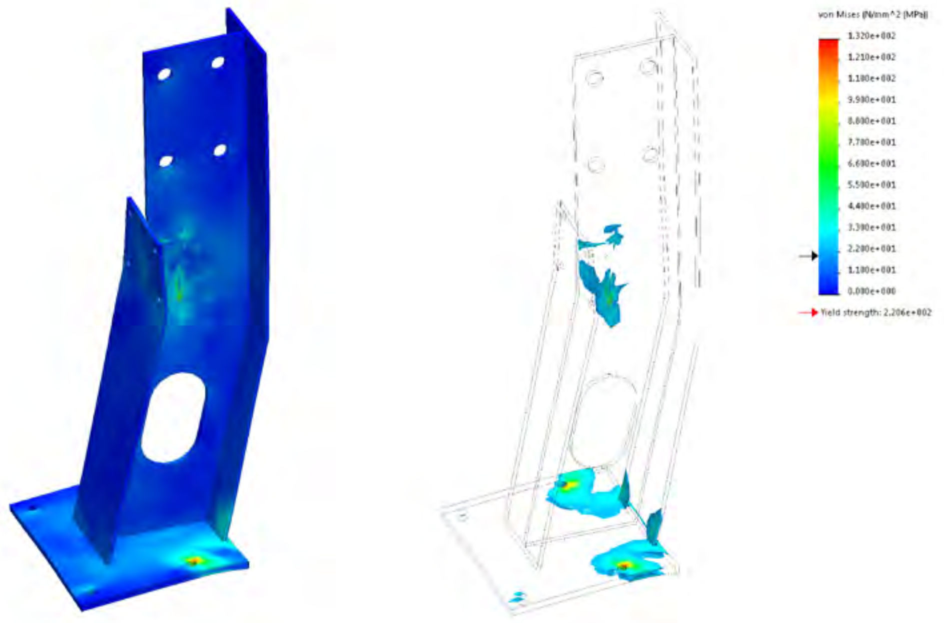
Template Revision 1
Template Revision Date 2016-04-12
Completion Revision 1
Completion Revision Date 2016-04-12
Relevant Authority A N Other

Parameter	Value	Units	Description	Measure	Responsibility	Completed by	Unique identifier	Information Sets
Tolerances		mm	Tolerances on dimensions and shape for hot finished structural hollow sections	Length	Manufacturer		[illegible]	[illegible]
Elongation		%	Elongation in accordance with Tables A.3 and B.3 of BS EN 10210-1: 2006	Ratio	Manufacturer		[illegible]	[illegible]
Tensile strength		N/mm2	Tensile strength in accordance with Tables A.3 and B.3 of BS EN 10210-1: 2006	Force	Manufacturer		[illegible]	[illegible]
Yield strength		N/mm2	Yield strength in accordance with Tables A.3 and B.3 of BS EN 10210-1: 2006	Force	Manufacturer		[illegible]	[illegible]
Impact strength		N/mm2	Impact strength in accordance with Tables A.3 and B.3 of BS EN 10210-1: 2006	Force	Manufacturer		[illegible]	[illegible]
Weldability			CEV value specified, in accordance with Tables A.2 and B.2 of BS EN 10210-1: 2006		Manufacturer		[illegible]	[illegible]
Durability			In accordance with Clause 6.7.2 of BS EN 10210-1: 2006	-	Manufacturer		[illegible]	[illegible]
Outside diameter		mm	Outside diameter D of hollow section	Length	Structural Engineer		[illegible]	[illegible]
External perimeter		mm	External perimeter of square, rectangular or elliptical section	Length	Structural Engineer		[illegible]	[illegible]
Steel grade			Steel name, e.g. S355NH		Structural Engineer		[illegible]	[illegible]
Cross Sectional Area		cm2	Cross sectional area of the section	Area	Structural Engineer		[illegible]	[illegible]
Thickness		mm	Specified thickness	Length	Structural Engineer		[illegible]	[illegible]
Mass		kg/m	Mass per unit length	Mass	Structural Engineer		[illegible]	[illegible]
Second Moment of Area		cm4	Second Moment of Area	Moment of inertia	Structural Engineer		[illegible]	[illegible]
Radius of Gyration		cm	Radius of Gyration	Length	Structural Engineer		[illegible]	[illegible]
Elastic Section Modulus		cm3	Elastic Section Modulus	Section Modulus	Structural Engineer		[illegible]	[illegible]
Plastic Section Modulus		cm3	Plastic Section Modulus	Section Modulus	Structural Engineer		[illegible]	[illegible]
Torsional Inertia Constant		cm4	Torsional Inertia Constant	Moment of inertia	Structural Engineer		[illegible]	[illegible]
Torsional Modulus Constant		cm3	Torsional Modulus Constant	-	Structural Engineer		[illegible]	[illegible]
Width		mm	Specified side dimension of a square hollow section. Specified dimension of the shorter side of a rectangular hollow section. Specified outside dimension of an elliptical section on its minor axis	Length	Structural Engineer		[illegible]	[illegible]
Height		mm	Specified dimension of the longer side of a rectangular hollow section. Specified outside dimension of an	Length	Structural Engineer		[illegible]	[illegible]

Level of detail below Uniclass

Mechanical properties of individual components.

Below Uniclass the level of information relates to the material properties of individual components.



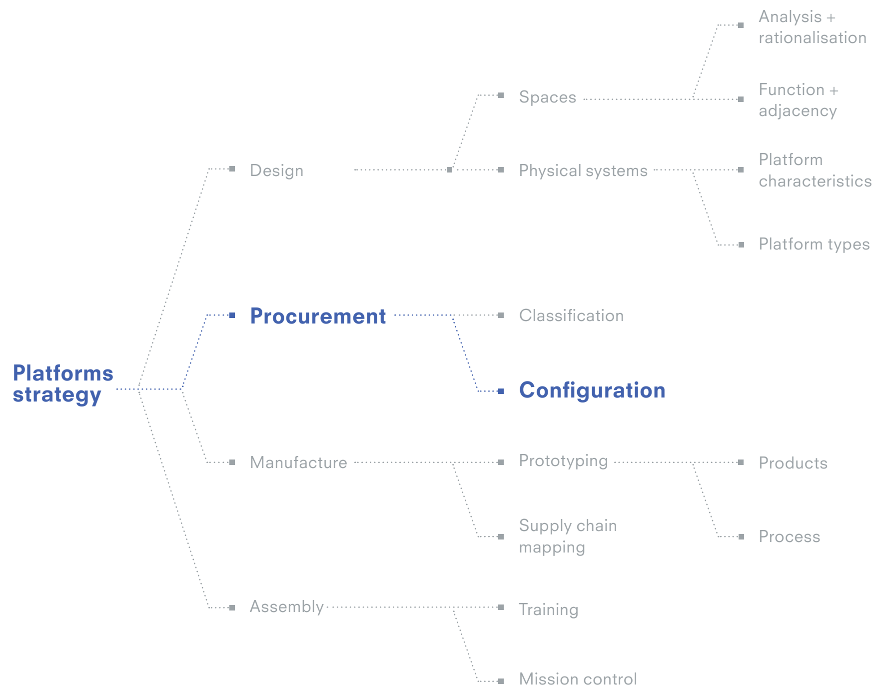
DESIGNATIONS (▼) EN [N°]	AISI/ASTM	DENSITY at 20°C [kg/dm³]	MODULUS OF ELASTICITY at 20°C [GPa]	MEAN COEFFICIENT OF THERMAL EXPANSION [10⁻⁶xK⁻¹] 20°C ÷ 200°C	20°C ÷ 400°C	THERMAL CONDUCTIVITY at 20°C [W/(mxK)]	SPECIFIC HEAT at 20°C [J/(kgxK)]	ELECTRICAL RESISTIVITY at 20°C [(Ωxmm²)/m]
1.4372 [I]	201	7,8	200	15,7 [a]	17,5 [b]	15	500 [e]	0,70
1.4373 [I]	202	7,8	200	17,5 [f]	18,4 [b]	15	503 [d]	0,70
1.4371 [I]		7,8	200	17,5	18,5	15	500	0,70
1.4597 [I]		7,8	200	16,5	17,0	15	500	0,73
1.4369 [I]		7,9	190	17,0	18,5	15	500	0,70
1.4310 [I]	301	7,9	200	17,0	18,0	15	500	0,73
1.4319 [I]		7,9	200	16,5	17,5	15	500	0,73
1.4318 [I]	301LN (301L)	7,9	200	16,5	17,5	15	500	0,73
	302 [h]	8,06	193	17,2 [a]	17,8 [b]	16.3 [c]	503	0,72
1.4305 [I]	303	7,9	200	16,5	17,5	15	500	0,73
1.4301 [I]	304	7,9	200	16,5	17,5	15	500	0,73
1.4311 [I]	304LN	7,9	200	16,5	17,5	15	500	0,73
1.4948 [IV]	304H	7,9	200	16,9	17,8	17	450	0,71
1.4307 [I]	304L	7,9	200	16,5	18,0	15	500	0,73

Uniclass classification - in Delivery phase

Ss -	**Systems**
Ss_15_95	Temporary works systems
Ss_15_95_15	Temporary preparatory works systems
Ss_15_95_25	Temporary wall and barrier works systems

CA -	**Construction aids**
CA_20_10_20	Mobile working towers
CA_20_30_30	Guardrails
CA_20_30_30_35	Guardboards
CA_20_30_30_36	Handrails
CA_20_30_30_41	Intermediate guardrails
CA_20_30_30_89	Toe boards
CA_20_30_80	Work platforms
CA_20_30_80_01	Adjustable platforms

Configuration



Simplifying what we buy and how we buy it

We need to move away from bespoke design and construction and move to standardised, highly productive manufactured solutions.

This can be delivered through a 3 step process:

1. Design and procure in an hour;
2. Manufacture and assemble in days;
3. Benchmark portfolio performance over years.

Step 1 - Design + procure in an hour

Digital configurator

A digital configurator is a database of standard components and elements, with customisable options specific to the building type.

For example: Ikea use a similar tool for their kitchens with a range of user-customisable options (worktops, appliances, doors, handles) based on standard mass-manufactured carcasses that are scalable to suit kitchen size and layout.

BMW allow prospective customers to specify a number of options - colours, trim, engine options etc. - based on a range of standard model chassis.

The intelligent algorithm within the configurator will offer the relevant options consistent with the building type.

For example, choosing 'school' will limit the room, types - the spaces - to those relevant to a school.

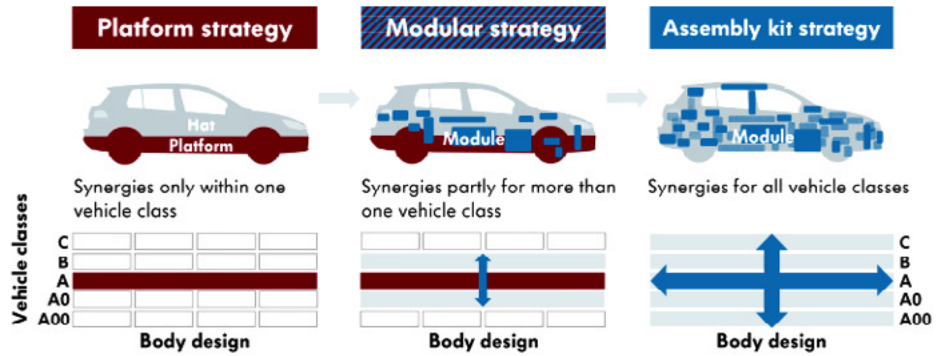
The boundary wall, window and door options for a school classroom differ from those for a High Security prison.

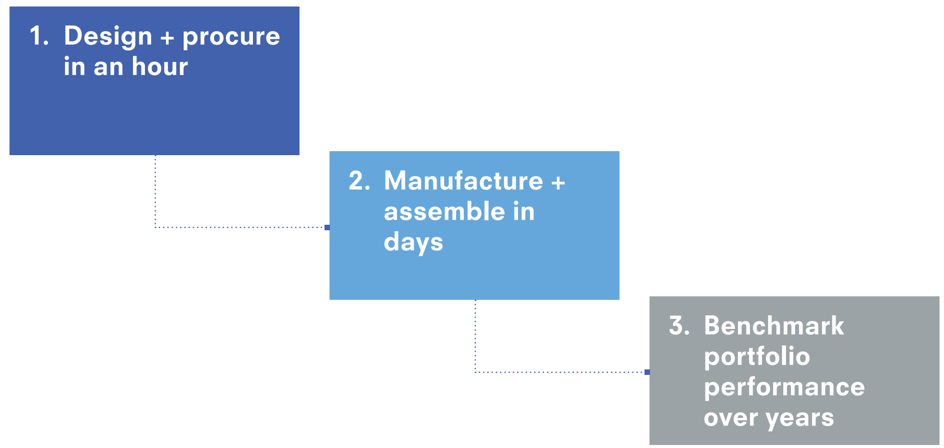
The algorithm will allow the building to be configured based on the size (number of pupils, patients, workers, prisoners etc.) and the footprint (linear, T-shaped etc.), and will include ancillary facilities (staff rooms, canteens etc.) relevant to the building type.

cont'd

VW group's platform sharing architecture.

Source: DS Raikkonen http://www.f1technical.net/forum/viewtopic.php?t=12881





Virtual marketplace

The virtual marketplace is the key customer interface in which the digital configurator sits.

The digital configurator is embedded in a virtual marketplace and from the algorithm can produce the basic design pre-options, together with a nominal 'Base Price'.

Within the marketplace, the client can add their options. They can choose the external cladding type based on a number of architectural options, the floor and wall finishes etc. All of these options, much like a BMW configurator - will show how they add to the Base Price.

When configuration is complete, the client can 'add to basket' and then shop for more, or proceed to Check Out.

Check out

Checking out launches the procurement process. At this stage, the client knows his 'should cost' for his scheme with options. How the market can and will supply this depends on their operational model.

At a simple level, the options could range from 'Manufacture and Assemble', to 'Finance, Manufacture, Assemble and Operate'.

The market place - of approved suppliers and products - then offers to provide the service requested.

The agreed supplier then moves to Step 2.

Step 2 - Manufacture and assemble in days

With the scope agreed, the procurement route chosen and the supplier selected, the digital configurator will electronically generate the component lists which will be fed to the factory facilities for production.
In parallel, traditional site preparation can commence - earthworks, foundations etc., so the site is ready to receive the components.

In addition to the manufactured components, connections, building services etc., required for the structure, the configurator can generate the plant and equipment needed for assembly and temporary site logistics - messing, offices etc. - again drawn from standard, re-usable units appropriate to the location and scale of the facility.

Step 3 - Benchmark portfolio performance over years

Data will be collected from in service performance to ensure outputs and outcomes are delivered across the estate.

Data can inform strategic interventions for maintenance and operational effectiveness and be used to ensure appropriate strategic spares are held to service the needs of the estate.

Output from the data and benchmarking will be used to refine and optimise the designs and methodologies and to inform decisions taken at the front end of new projects.

Data analysis + visualisation

Building Information Modelling (BIM) is, fundamentally, a collaborative way of working that is powered by digital technology.

By optimising the use of the existing governmental department BIM libraries, enhanced with components specific to the early platform developments, there will be a huge amount of cross-programme data available through site-specific models uploaded to the Common Data Environment (CDE).

Data visualisation allows a range of data sources to be brought together to inform strategic planning and decision making. These visualisation techniques work at a variety of scales, so certain techniques allow whole project analysis, while others allow the optimisation of individual components or assembly processes.

By creating highly detailed data sets (dealing in, for instance, numbers of individual components and activities rather than square metres of floor area) the level of transparency and control is dramatically increased.

Aggregating data from multiple sites into a single, project-wide view gives a level of insight that is rarely available to clients.

For instance, visualising interaction between various work-faces so that knock on effects of delays in one area can be better understood, facilitates:

- A more holistic view of project-wide progress;
- Strategic prioritisation and optimisation of work faces / packages;
- Smoothing of cash flow or labour;
- Smoothing demand for individual components through just in time delivery, reducing stress on the supply chain, enhancing their productivity and therefore lowering price;
- Optimisation of resources by understanding how operatives and plant can be shared.

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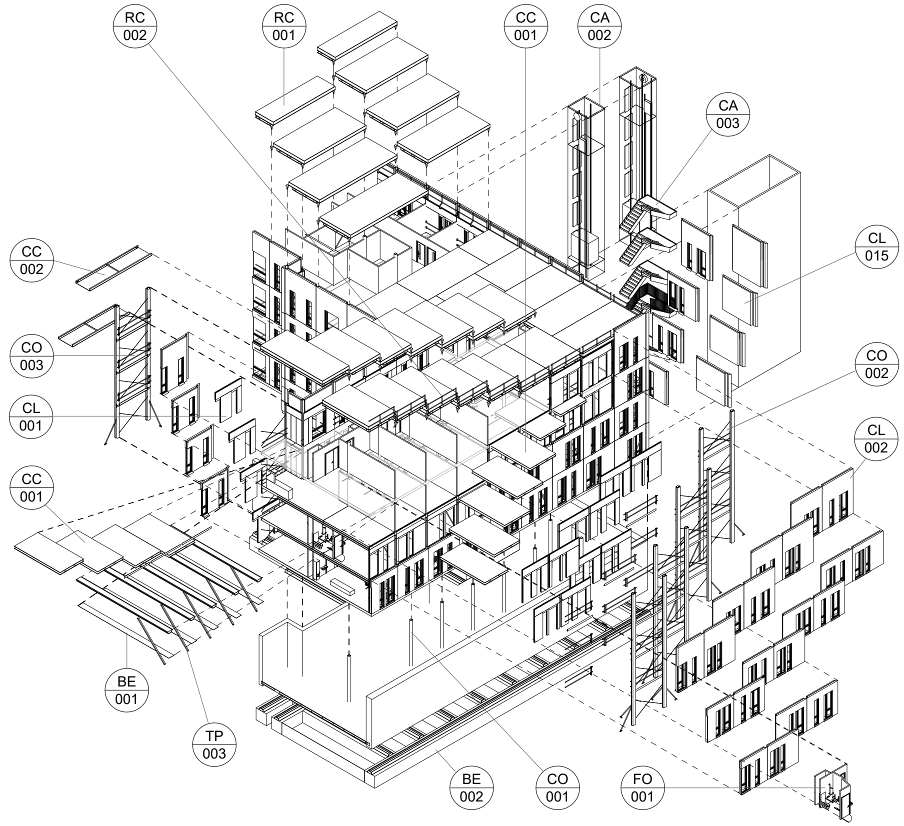
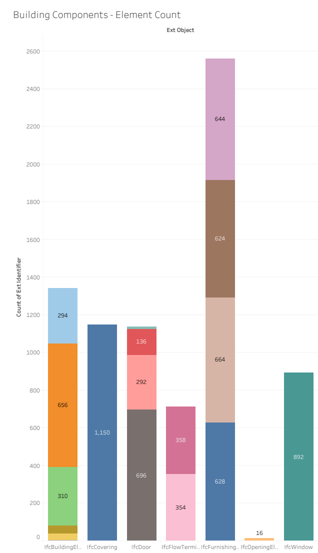
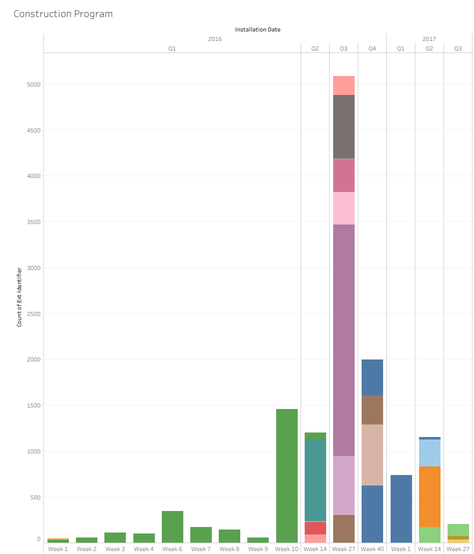
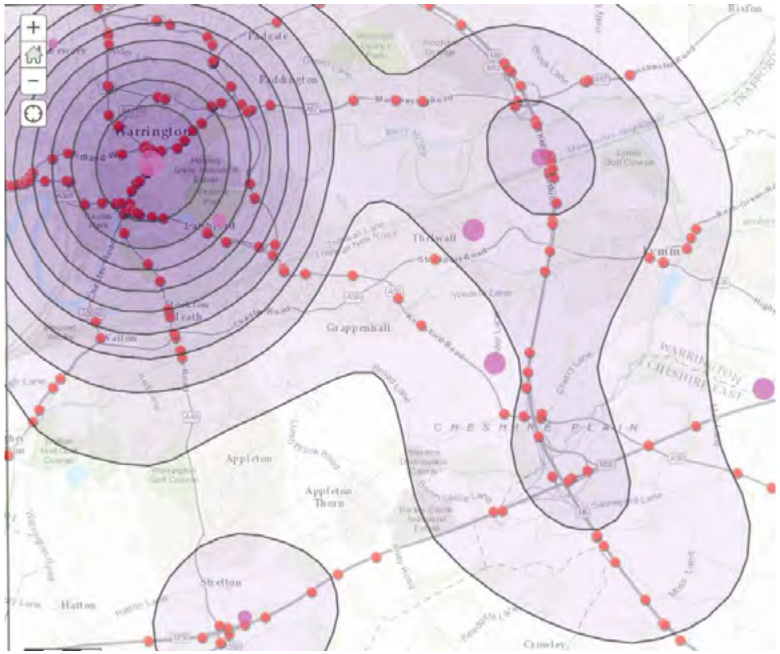


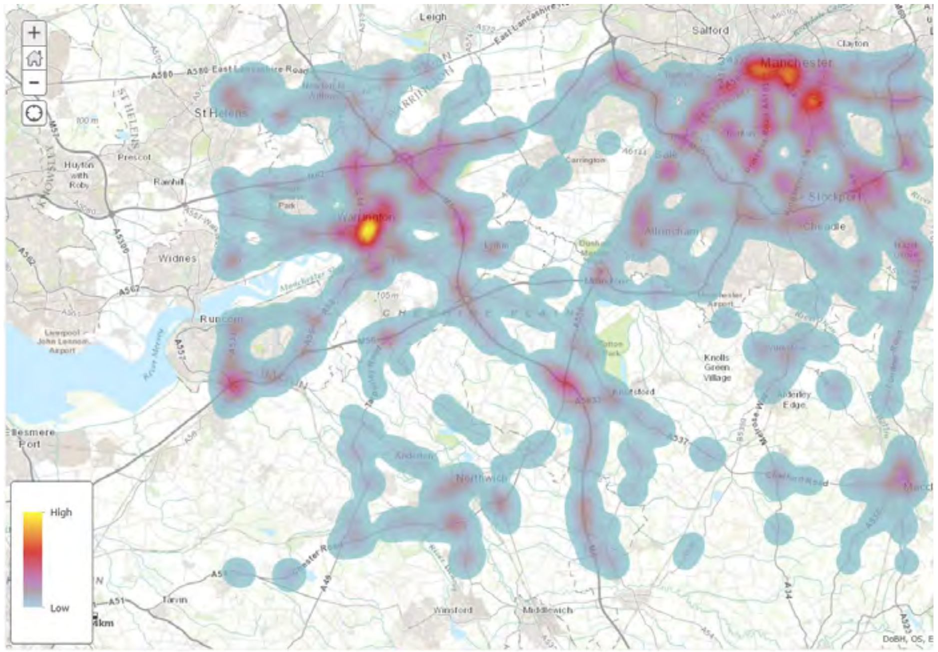




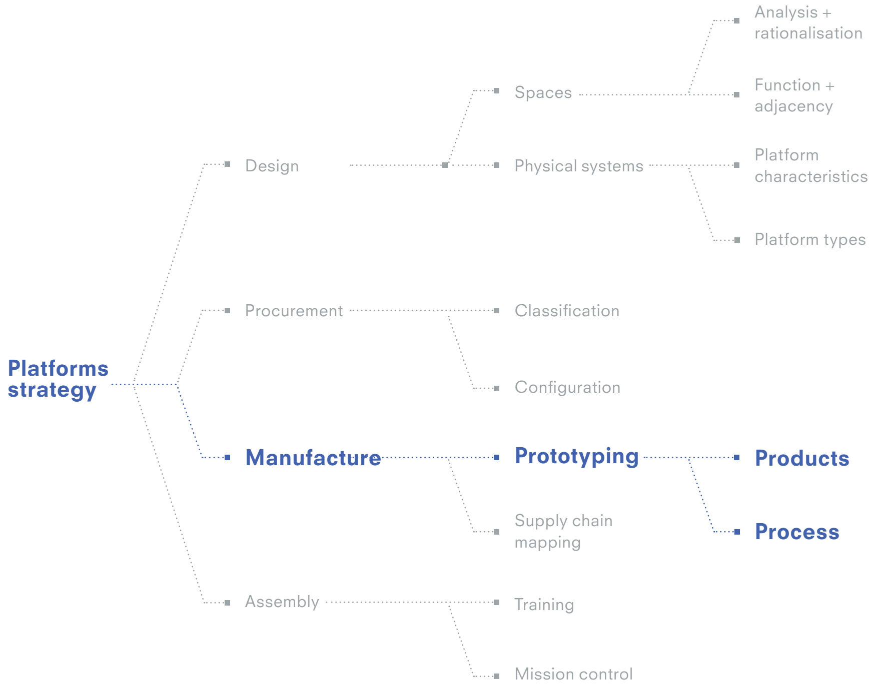
Other example uses include:

- Colour filtering of models to create heat maps showing the intensity of trade overlap, cost per hour of installation etc.
- Allowing multiple stakeholder views to be combined, addressed and prioritised;
- Allowing the interdependency between a range of factors that impact productivity to be understood;
- Providing a single point of entry to a wide range of digital content.





Prototyping



Prototyping

Analysis and experience to date suggest that many major programmes could be delivered using a limited number of relatively simple components, developed in such a way that they can be procured at low cost but consistent quality from a wide supply chain.

Once the repeatable elements have been identified and described, the BIM library objects can be used collaboratively by the project team to establish an installation sequence that is much more like factory assembly than traditional construction, creating the potential for:

- Standardising working;
- Capturing and incrementally improving upon of best in class methodologies;
- Using a non-traditional workforce specifically trained in installing the proposed solution.

For certain critical and highly repeated elements the benefits of refining and perfecting them are enormous; any improvements that are made as a result of this process will be multiplied across the programme. Any issues that arise through failure to prototype will conversely appear numerous times.

In the development of industrialised products, the purpose of a prototype is:

- Testing and trialling a new design;
- Testing and optimising installation or construction sequences;
- Identifying any opportunities to refine and improve the proposed design, installation etc. before commencing large scale manufacture.

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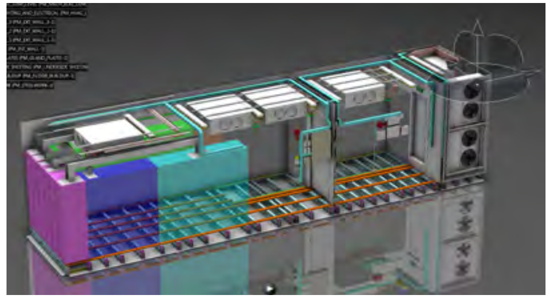
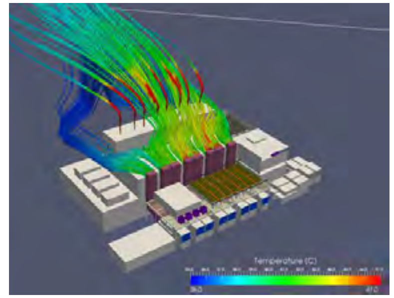
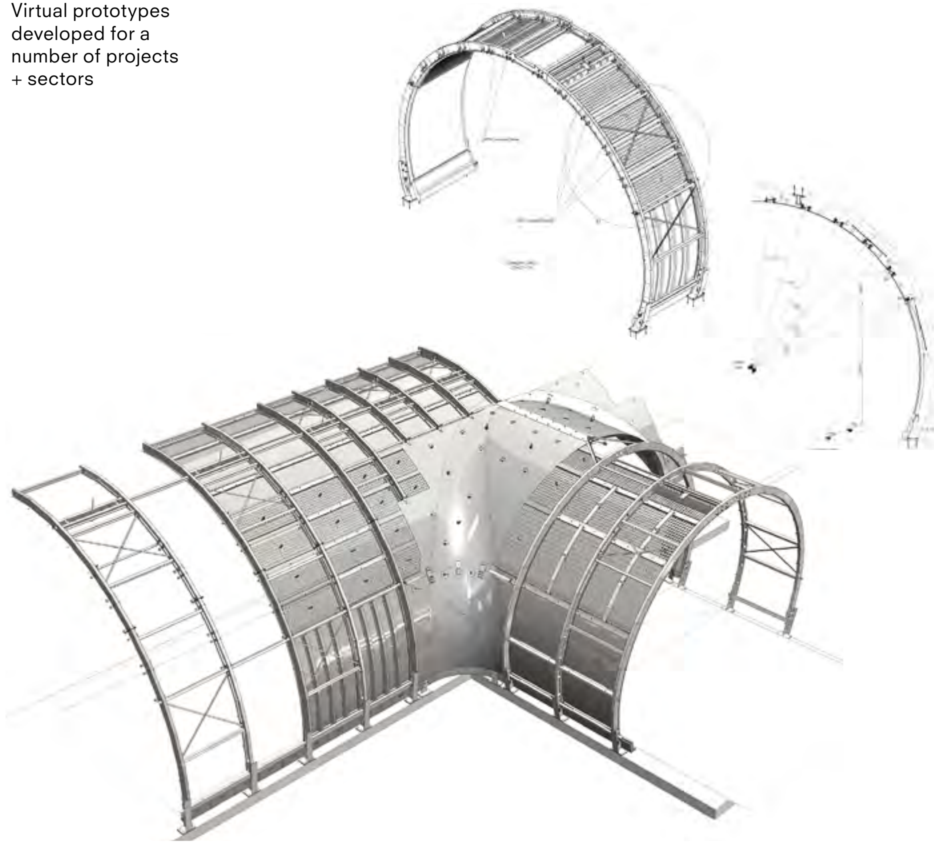




Virtual prototypes developed for a number of projects + sectors



The ultimate aim is risk reduction, by learning as much as possible from the prototype in a controlled environment, off the project critical path, to inform the development of the production run of the system or element.

There are varying degrees of prototype, which provide differing levels of feedback and learning but have commensurate levels of time and cost associated with them, including:

- Digital (virtual) prototypes;
- Physical prototypes.

Virtual prototypes

These are developed in sophisticated software packages that allow a wide range of analysis to be carried out without ever producing a physical element. Product design software allows the digital components to have 'real' properties such as density to allow analysis including:

- Mass and centre of gravity (for e.g. craneage studies);
- Failure modes and effects analysis (FMEA);
- Computational fluid dynamics.

The result is an holistic virtual build that can be iteratively used to refine the solution by:

- Developing a model of a sample section of the initial industrial design concept;
- Developing the model to include construction sequence, program, supply chain and resulting cost modelling;
- Filtering the model to determine quantities, program, site labour histograms etc.;
- Assessing the outcomes of the virtual build against local benchmark norms for cost and against aesthetic and quality issues;
- Considering modifications to the components on the component deployment and assembly techniques in response.

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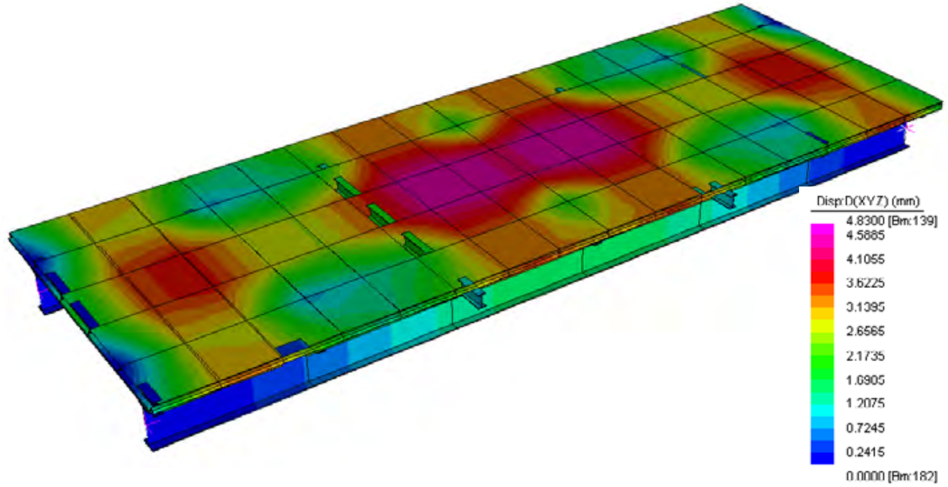
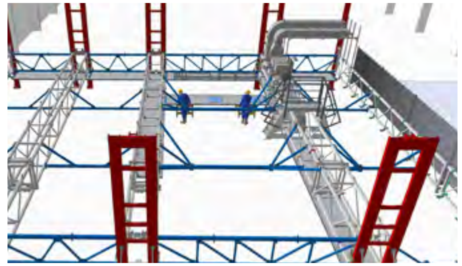
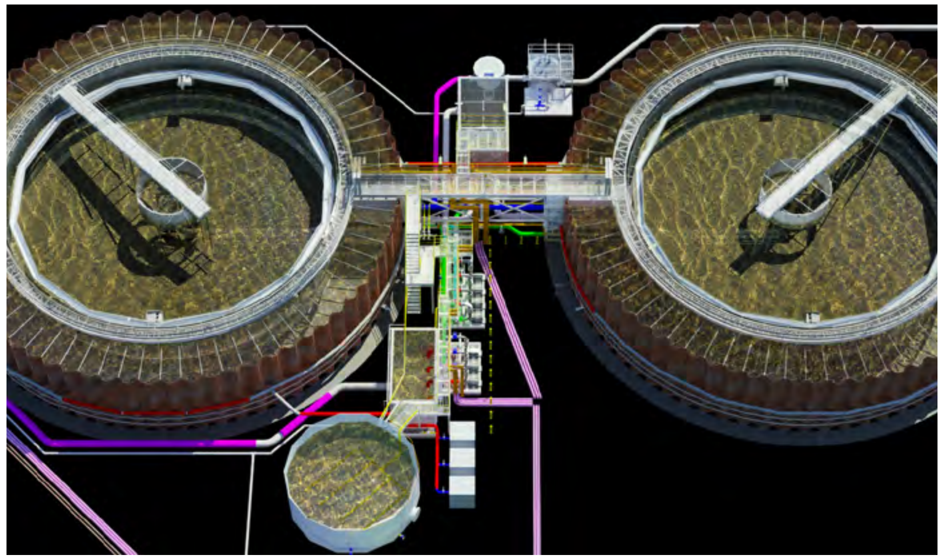






Prototyping cont'd

Physical prototype

This is a full or partial section of an element or assembly, usually at full scale and using the final proposed materials. A prototype can be used to test the physical characteristics of an element or system, including installation. Prototypes are typically created for learning purposes only, not for deploying in a live environment. Significant issues may be identified in the creation of a prototype.

The benefits of creating physical prototypes are particularly high for the transformation roll-out project - before embarking on a process of building 8,000 prisoner spaces, a relatively small prototype could be used to:

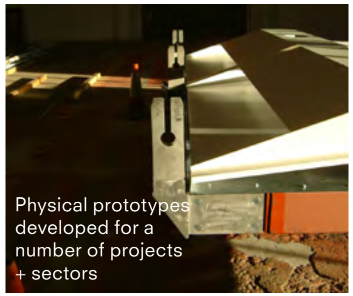
- Demonstrate the delivery system in practice;
- Optimise the assembly sequence and create installation / health + safety guides;
- Provide detailed data regarding assembly to inform construction programmes, logistics planning etc. with a relatively high degree of certainty (compared to current efforts which are necessarily based on assumptions);
- Provide training for assembly crews, crane operatives etc.

The benefits will include:

- Better, more targeted engagement of suppliers as the required end product will be extremely well understood and defined;
- More objective assessment of suppliers as the quality of their products can be measured against a known standard;
- Greater consistency across the two buildings - labour teams will be able to work on any plot as the methods of construction will be identical;
- Assembly teams can be trained using the prototype before going on site, so productivity on site will be high from day 1 (no learning curve on actual buildings)
- Greater opportunity for measuring progress on site, creating feedback loops and driving continual improvement.






Physical prototypes developed for a number of projects + sectors


Process prototyping

Process prototypes are well established in other industries such as aerospace, manufacturing or defence. Those sectors rely on virtual prototypes to verify and validate processes prior the physical commission of the equipment. The virtual process prototype allows:

- Rapid testing of different manufacturing sequences under a full scale production scenario;
- Optimum utilisation of resources, material and equipment;
- Elimination of physical collisions with structure;
- Identification and mitigation of potential process capability issues (i.e. time, cost and quality);
- Reduction of installation and commissioning time;
- Validation of robotic paths and programmable logic controller programs;
- Identification and mitigation of ergonomic and health and safety issues;
- Quicker natural interpretation for better informed decisions;
- Replacement of expensive full scale prototypes;
- Operator training;
- Optimization of design for manufacture and assembly (Design for 'x');
- Bespoke tooling, jigs and fixtures can be identified.

Companies in those industries have benefited from using virtual prototypes to optimise their manufacturing processes before the physical installation and achieving, in some cases, significant figures:

- Reduction of 25% on annual operational costs;
- Reduction of 80% on capital equipment;
- Increase utilisation of resources by 20%;
- De-risked strategy through simulation techniques;
- Part count reduced by 30%;
- Assembly cycle time reduced by 27%;
- Variable volume and product assembly process;
- Reduced facility commissioning time.

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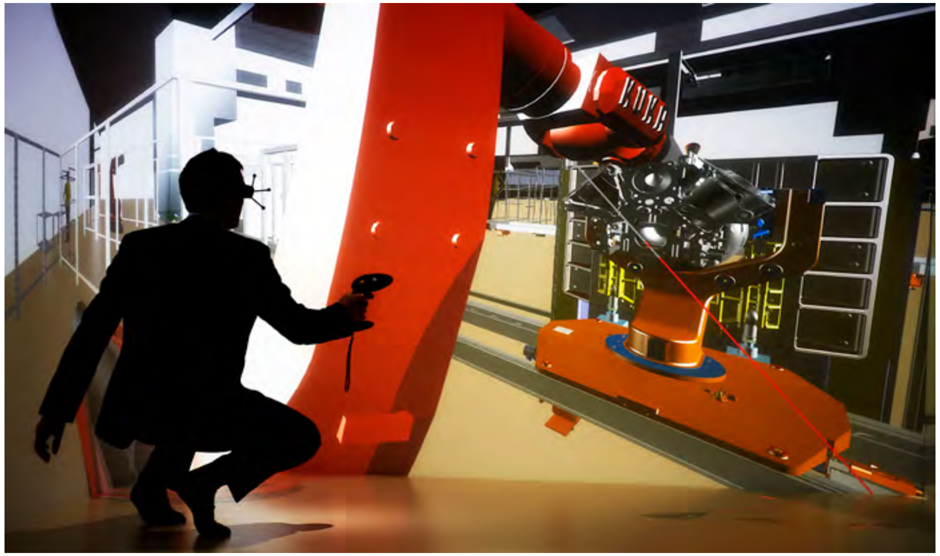
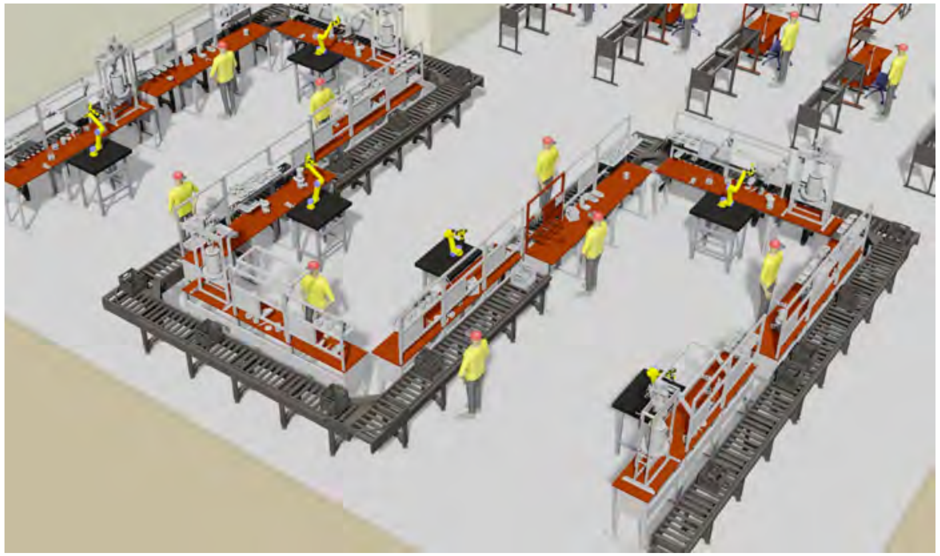


Virtual prototype within the immersive CAVE (Cave Automatic Virtual Environment) at The Manufacturing Technology Centre (MTC) in Coventry

Production line virtual prototype (courtesy of The Manufacturing Technology Centre)



Process prototyping cont'd

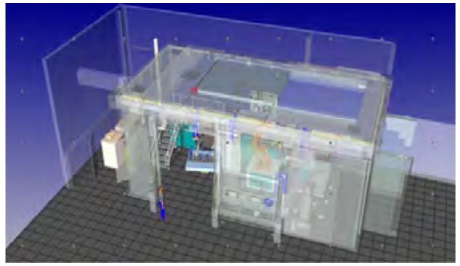
Companies also run pilot processes after the virtual prototype validation in order to test and trial, within a controlled production environment, the future manufacturing process. This enables companies to:

- Identify potential capability issues and mitigate them prior to escalating to full production;
- Test and debug different line configurations or set ups without having to disrupt other production areas;
- Optimise the manufacturing line prior to full scale-production.

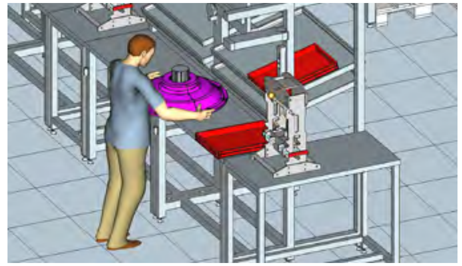
Virtual prototype testing production line configuration

View inside the MTC CAVE

All images on this page courtesy of The Manufacturing Technology Centre

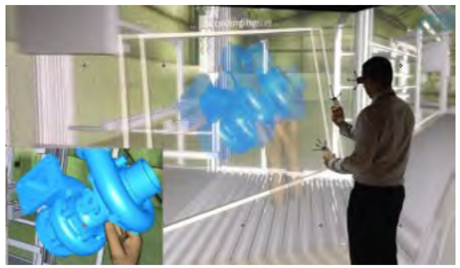


Virtual prototype of a laser welding cell

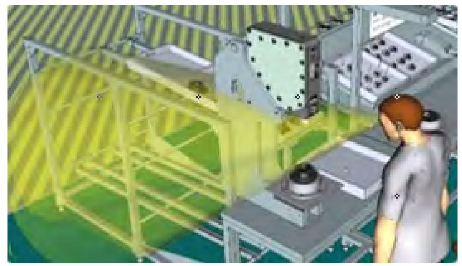


Process simulation

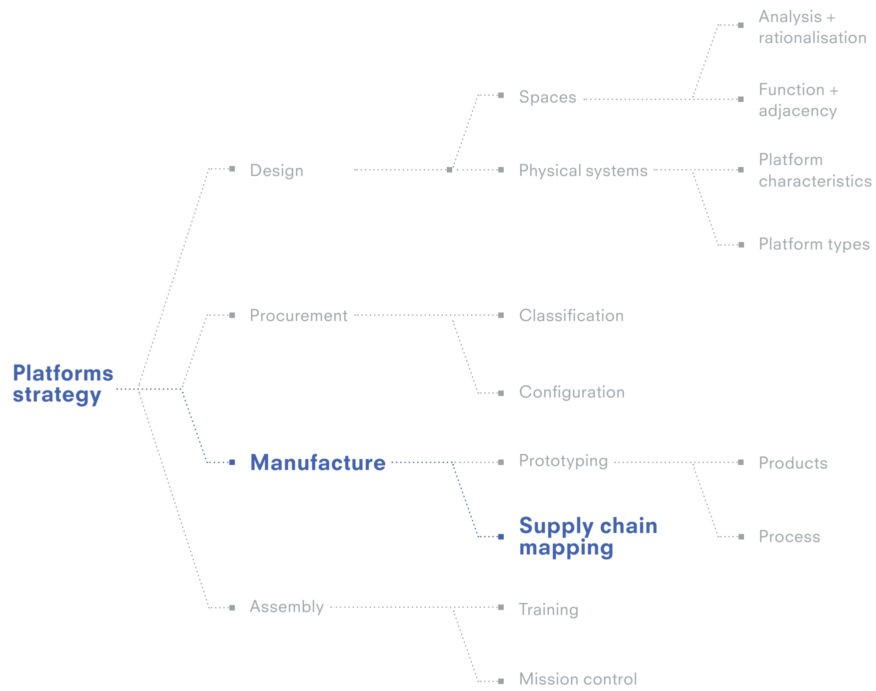
Assessment of worker's visibility using a virtual prototype



Engineering review of a component using Virtual Reality



Supply chain mapping



Supply chain mapping

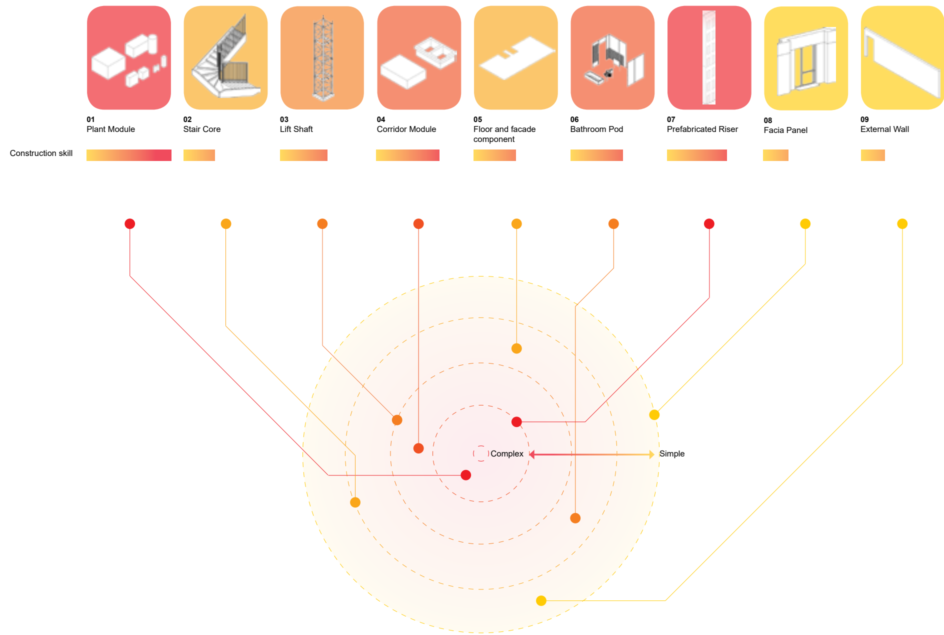
The use of an industrialised approach allows the supply chain to be treated very differently than in traditional construction. For instance, manufactured products are often made many thousands of miles away from their point of use; value is created where operatives are low cost and abundant. This is further enhanced by ensuring that manufactured products can be assembled by low skilled personnel, making the supply chain as wide (and therefore as competitive) as possible; this may extend to non-construction companies.

The diagrams on the right are a typical output of an assessment of the components required to create a roll out programme. This assessment could be developed specifically for the transformation project at the next stage (as part of the standardisation and optimisation exercise).

In particular, the ability to develop components using low skilled labour could facilitate the use of prisoner population manufacturing capability, or e.g. using the workforce in Scotland who traditionally work in the oil + gas sector.

Once the design analysis is complete, it will be necessary to start identifying supply chain partners for the delivery of the scheme. This assessment may be far-ranging and will consider components in terms of:

- Size;
- Weight;
- Complexity.



Component assessment - potential for using low skilled operatives

cont'd

Supply chain mapping cont’d

The design of the repeatable elements can then be refined in line with supply chain capability and capacity. By working with and designing ‘towards’ a supply chain the benefits of their existing skills can be optimised, with benefits to cost and quality.

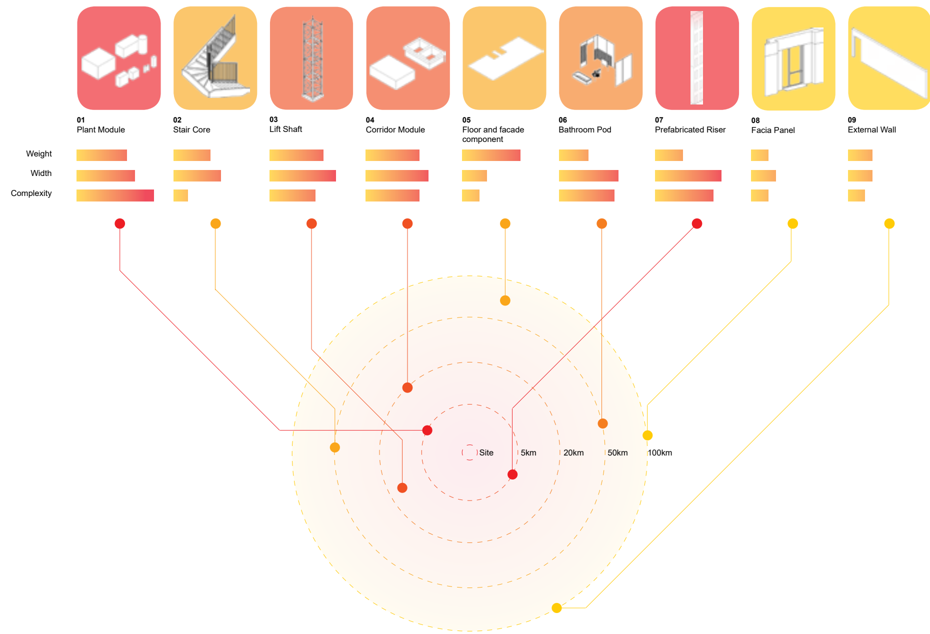
Outcomes should include:

- Extremely wide, and therefore resilient, supply chain for all major components with good regional coverage for all sites (e.g. value mapping shows percentage of overall value to be delivered within known km radius of sites) to maintain commercial advantage while minimising transport and logistics costs;
- Ability to utilise a number of small companies rather than rely on large, ‘single source’ suppliers;
- Ability to manufacture complex components where specialised skills exist, but use local labour for final ‘on site’ assembly.

By working with, where appropriate, supply chain partners the components can be developed to a ‘fit-for-fabrication or manufacture’ stage.

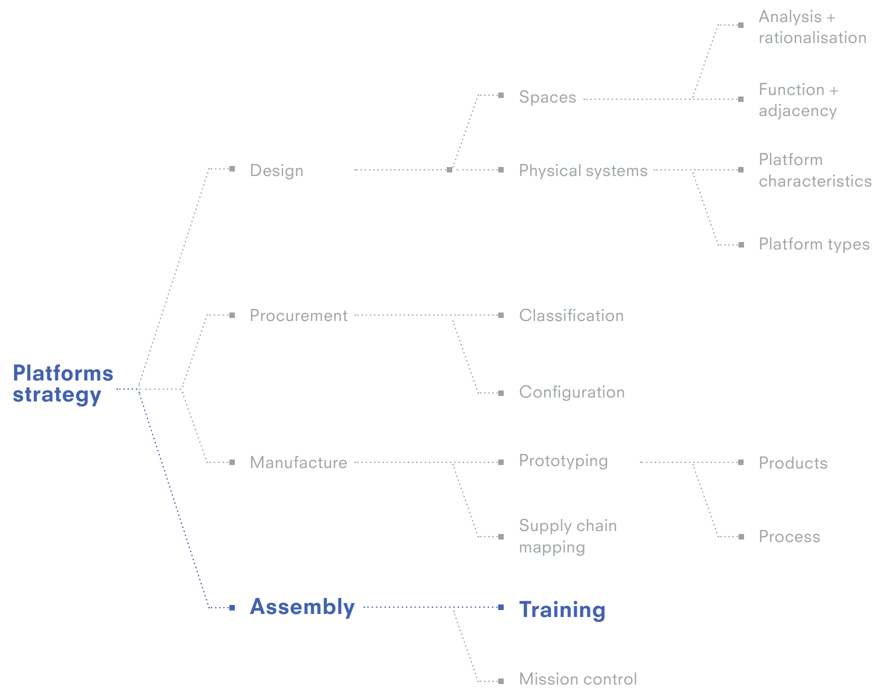
With input from the MTC to drive enhanced manufacture processes, benefits could include:

- Trade contractor drawings virtually eliminated - where possible all coordination takes place using aggregated models;
- Clashes are detected and resolved within the digital environment well before fabrication commences;
- All interfaces fully resolved digitally;
- Fabrication models are used for the ‘virtual building’ exercises described later in this document;
- Impacts of proposed changes assessed using updated models to provide clearly understood and objective metrics;
- ‘As built’ models readily assembled from the fabrication models;
- The aggregated models are ready to be populated with O+M / FM data.



Component assessment - potential for creating value remotely from site

Training


Platforms strategy
Design
Procurement
Manufacture
Assembly
Spaces
Physical systems
Classification
Configuration
Prototyping
Supply chain mapping
Training
Mission control
Analysis + rationalisation
Function + adjacency
Platform characteristics
Platform types
Products
Process

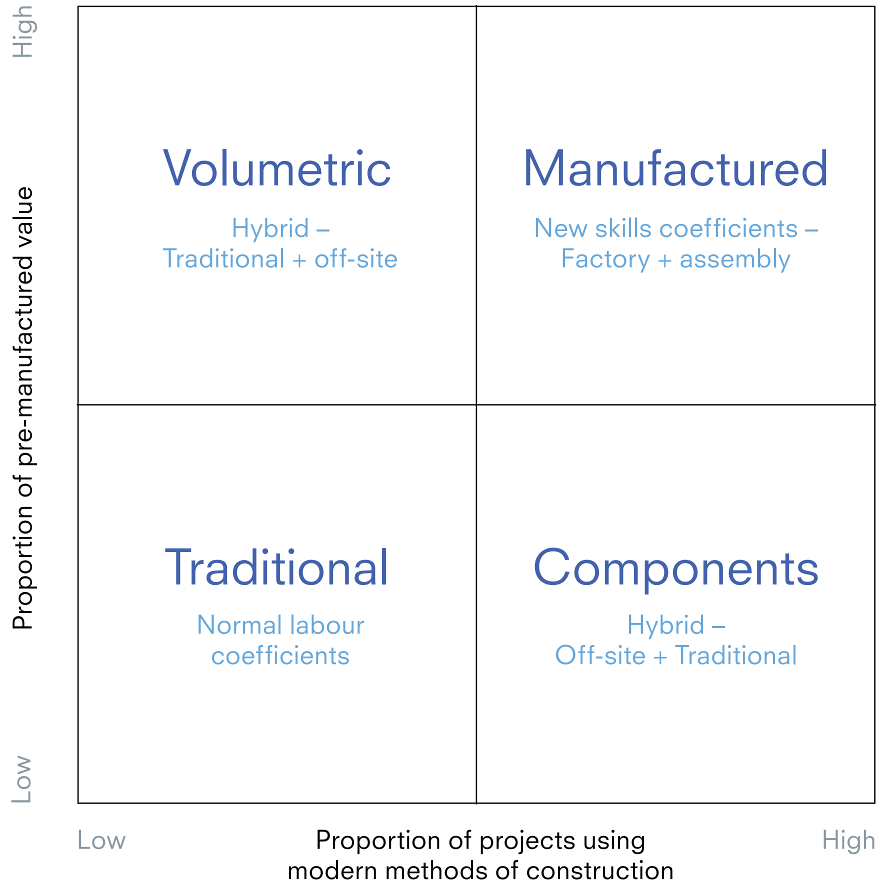
Skills scenarios

Adopting a platform strategy will necessitate a significant growth in manufacturing skills, requiring new apprenticeships and training regimes.

The matrix on the right references the characteristics that were described earlier, showing the skills requirements for each.

While componentised and volumetric solutions require a hybrid of traditional and off-site skills, a manufactured solution will require factory-based and assembly skills, plus better logistics planning etc.

Some of the methodologies for delivering platform based solutions are considered on the pages that follow.

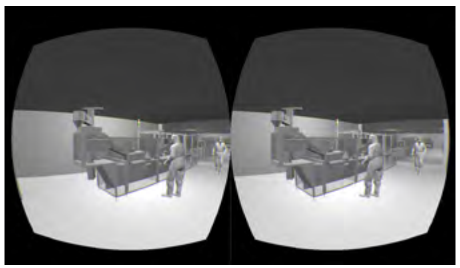


Advanced construction training

Another step in ensuring high productivity and safety on site is using all of the technology that is available for the training of operatives. Virtual prototypes can be used to train operatives in the assembly of components, sub-assemblies and entire projects in a very safe and low-cost environment before they are allowed to enter the relatively higher-risk live environment of a site. Installation sequences can be tested and optimised so that time on site is not spent working out problems.

There are a range of tools and outputs to do this, including:

- 'Ikea' style diagrams;
- Animations;
- Training guides;
- Immersive / virtual reality training programmes;
- Daily 'tool box talks' using the BIM models ahead of a work shift on site to talk operatives through the work ahead, point out particular health and safety issues and ensure everyone is clear on the tasks;
- Visual method statements accessed via QR codes attached to the physical components at point of work.



Oculus Rift goggles used for virtual induction

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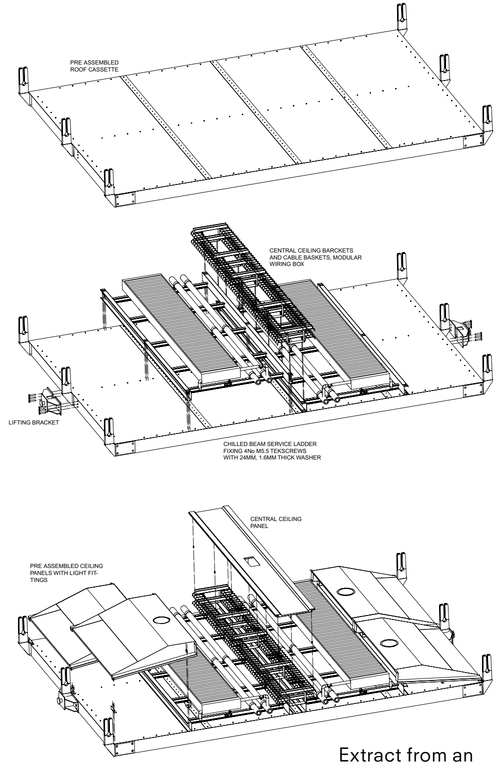
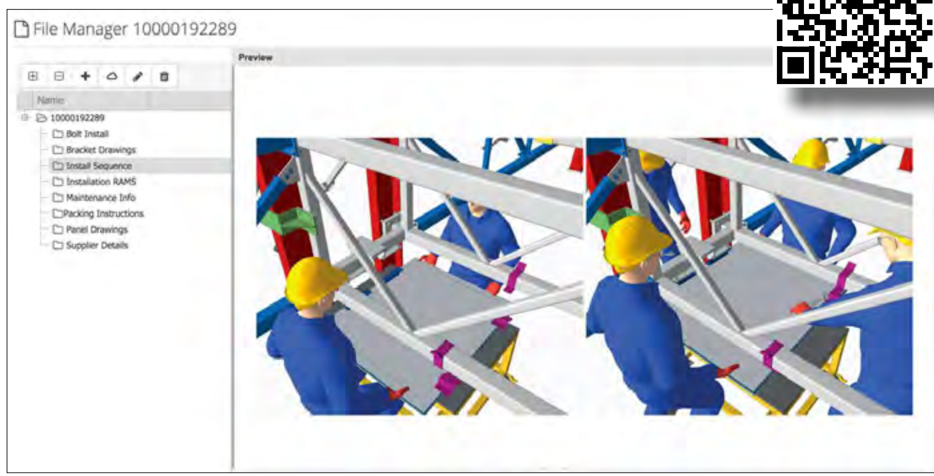


Extract from an assembly guide



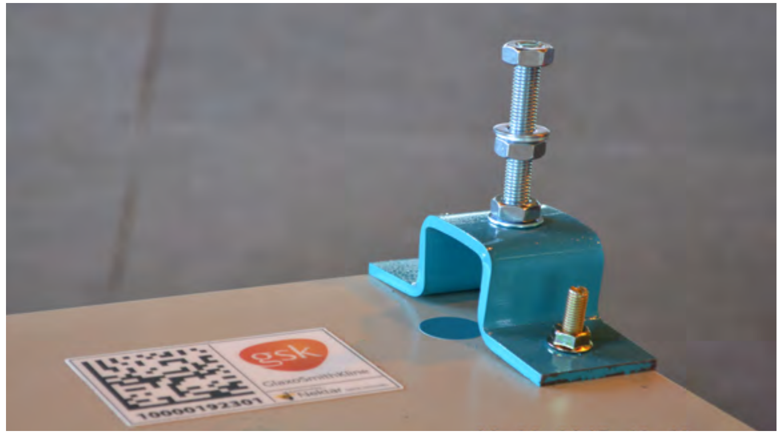
As well as increasing the productivity of operatives, these methods offer the possibility of using low skilled operatives to deliver high quality buildings.

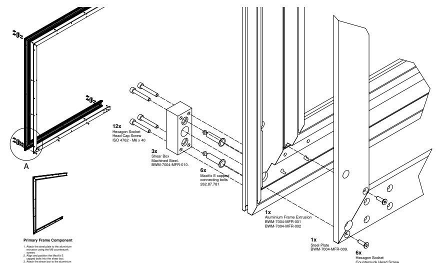
Bryden Wood has many years of experience in using unskilled labour to create quite complex projects. For the Heathrow and Gatwick Pier segregation modules the initial projects were assembled using traditional site based personnel, relocated to a factory. However, as the installation sequences became optimised and better documented, we were able to take unemployed people with no previous experience and train them to assemble these modules. The result for the client was a labour cost that was reduced by 75%.

For the GlaxoSmithKline (GSK) ‘Factory in a Box’ Bryden Wood has have successfully used non-construction operatives (ex-Army servicemen) to deliver the project. During the assembly process 17% of the operational hours were expended on briefing, training etc. but the project was delivered with a 60% programme saving and a 75% reduction in workforce.

These training programmes can be extended beyond construction operatives (how to build a facility) to staff (how to work in and operate the facility). For example, for GSK Bryden Wood has developed a virtual induction – operatives ‘walk’ through the model, select appropriate personal protective equipment (PPE) and answer questions on safety before they can enter their ‘work area’.

By ensuring that the correct information is available directly when required, there will be significant benefits in terms of operative safety and productivity.





Top: Component colour coding and QR coding for GSK ‘Factory in a Box’

Middle: Screen shot from training video

Right: Structural system - training manual

Use of low-skilled / upskilled labour

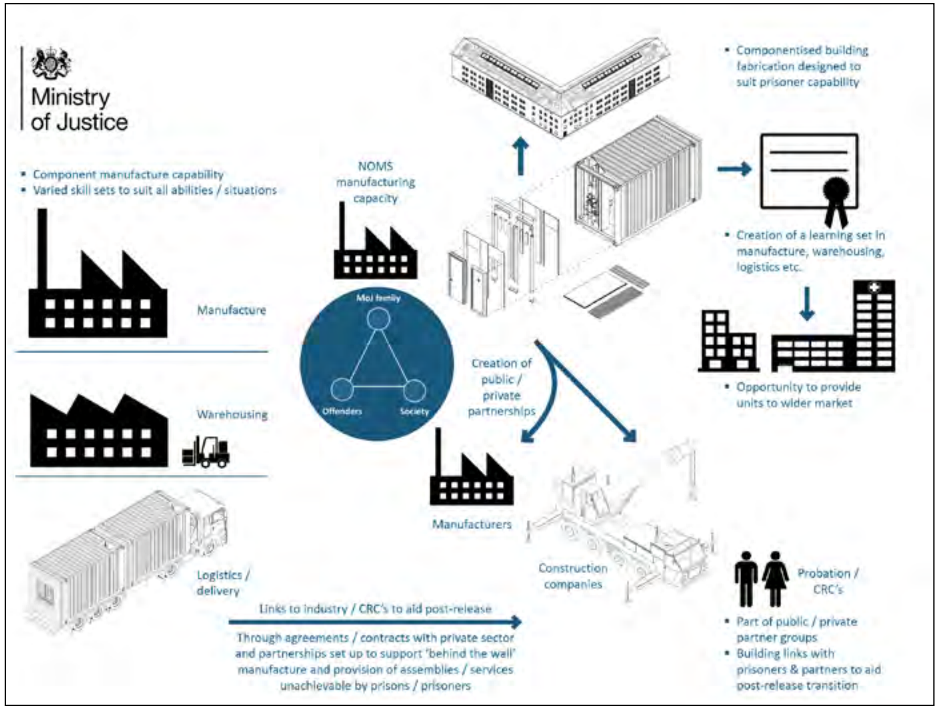
The use of a platform approach allows the supply chain to be treated very differently than in traditional construction. For instance, manufactured products are often made in locations far removed from their point of use; value is created where operatives are low cost and abundant. This is further enhanced by ensuring that manufactured products can be assembled by low skilled personnel.

This could certainly facilitate the use of apprentices as described in HM Treasury's report 'Fixing the Foundations'.

This approach could also make use of lower skilled, local labour on individual site, to carry out standardised tasks alongside more skilled operatives.

Major programmes in particular offer the potential for using e.g. existing or enhanced manufacturing capability within the prisoner population (Prison Industries); the delivery system could be designed to use simple but highly repeated components that could be made by very low skilled operatives.

This thinking was explored more fully in the 'Industrial Modular Accommodation Concept' in January 2015. This report included a solution that was designed in such a way that it could be delivered using either external supply chain, or using prisoner population manufacturing capability.



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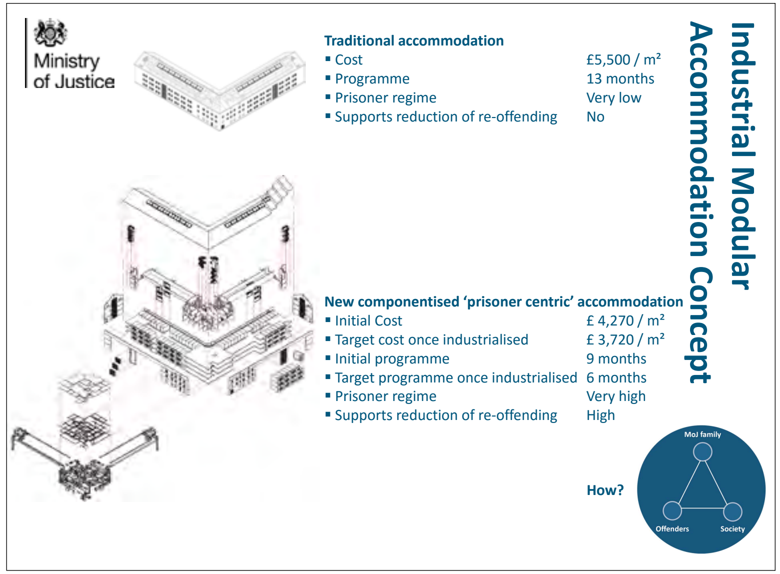
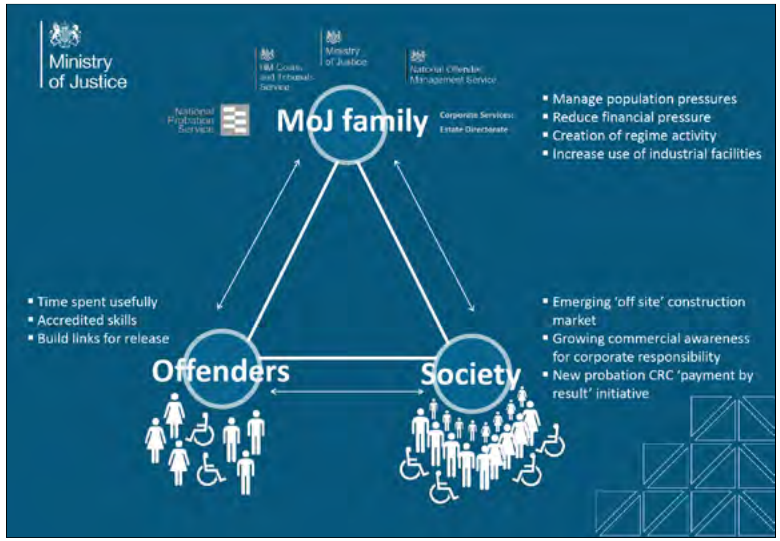
Comparing a costed solution for a 180 person house block delivered using the modular design against benchmark data for a range of schemes delivered traditionally demonstrated:

- A cost reduction of 17% - 22% if delivered using external supply chain;
- A cost reduction of 30% to 32% when prisoner population labour was factored in;
- A programme saving of 30% for the first prison;
- Programme savings of 50% once the installation of the repeatable elements was practised, optimised and standardised.

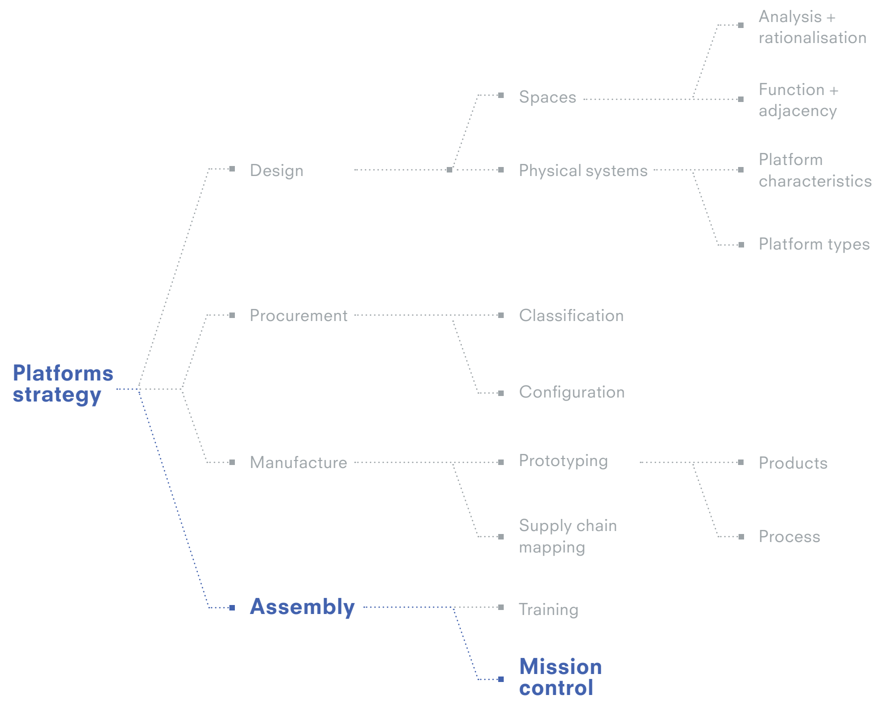
While this was a major improvement, the greatest benefit was in the impact that this would have on re-offending rates; in using prisoner population labour the proposal was to provide inmates with a range of accredited skills in manufacturing, logistics and warehousing that could be used on release. This would reduce re-offending and probation costs, while also addressing the skills shortage in construction and supporting the growing market for off-site construction. The same workforce could also could be deployed in the delivery of other public sector needs e.g. schools and hospitals.

The transformation programme could be designed in such a way that this proof of concept becomes a reality.





Mission control



Detailed construction + logistics planning

As the installation of the DfMA or off-site elements becomes increasingly efficient, their interaction with other systems will become critical i.e. the programme benefits that off-site brings will be lost if the remainder of the construction process cannot keep up.

It will therefore be important to optimise and rehearse the site assembly sequence to ensure that the full benefits are leveraged.

The PPI Reasons for Change included in the introduction showed that the most significant causes of low productivity are:

- Operational stoppage;
- Labour shortage;
- Lack of materials;
- Lack of design information.

As a result, site installation must be highly productive and well planned to leverage the full benefits of DfMA.

The advanced use of BIM generates highly accurate (in some cases fabrication quality) representations of the final building. This will allow virtual build exercises which will be used to optimise assembly sequence, test health and safety aspects and create highly detailed assembly manuals and installation programmes.

Activities

Include install time (i.e. 'when') and duration ('how long') as attributes in the models to enable the following:

- Linking the programme to the model so that the build sequence can be shown in a clear visual manner;
- Testing construction sequences and scenarios;
- Assessing and improving health + safety impacts.

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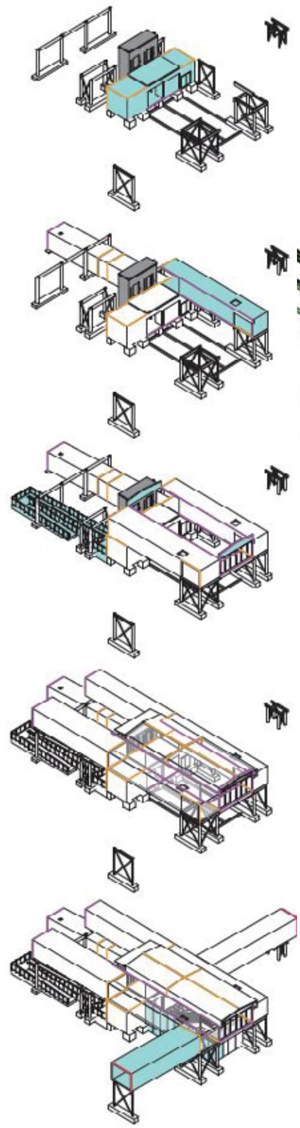
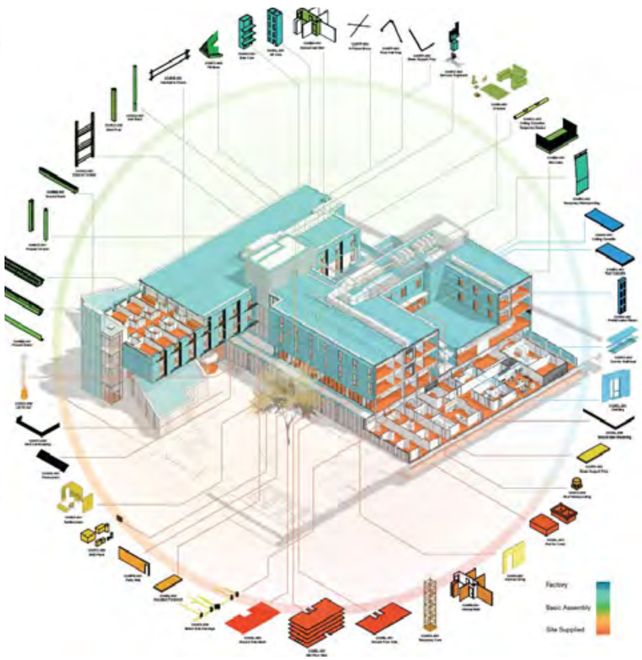




Interface and collaborate with Tier delivery partners regarding:

- Planning logistics (placement of cranes and hoists, delivery of materials vs. programme etc.);
- Planning and optimising temporary works;
- Progress reporting from site, planned vs. actual progress, time slice reports etc.

Outcome - Pre-construction

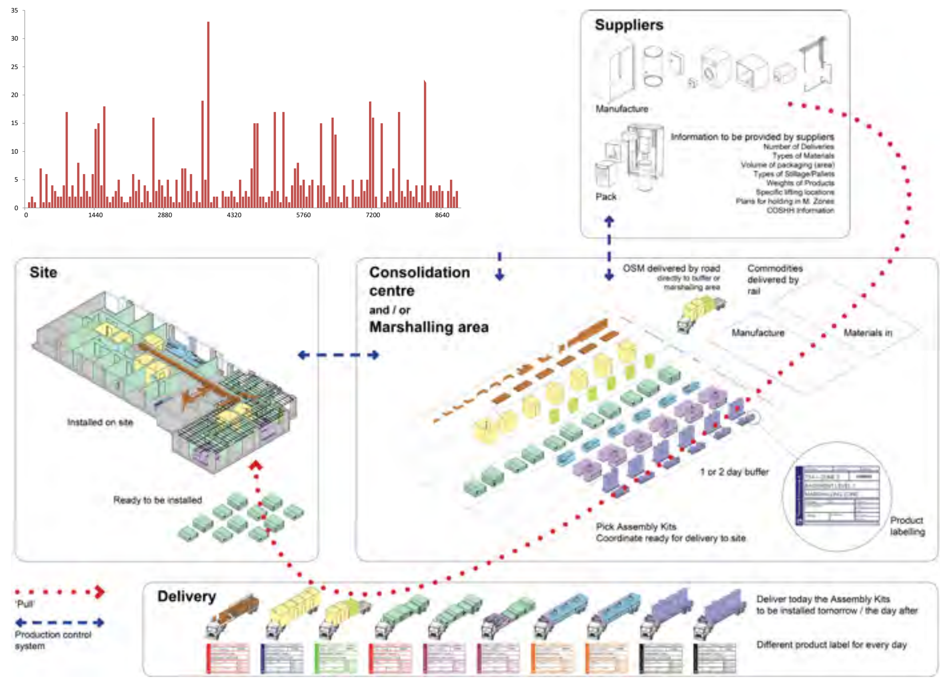
- Programme and construction sequence tested virtually to create optimised programme;
- Critical path identified and protected;
- Logistics plans tested for difficult parts of the programme;
- Health and safety reviews carried out for complicated build sequences;
- Temporary works erection and removal tested against permanent works.

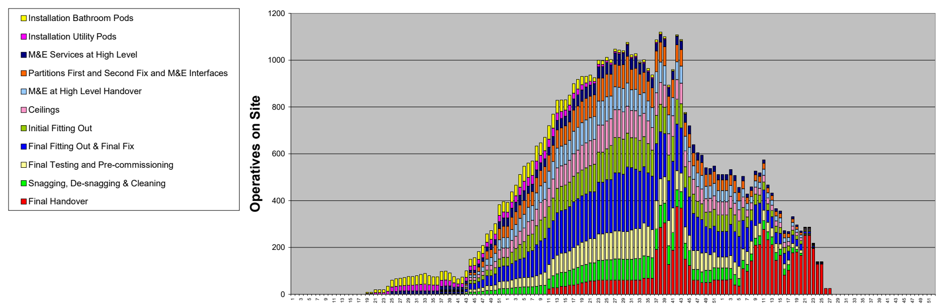
Outcome - Construction phase

- Construction status fed back to the models for visual reporting;
- Feedback loops in place to identify activities which are creating a barrier to timely delivery;
- Accurate reporting and mitigation strategies for Early Warning Notices etc.
- Accurate forecasting for impacts of change.

Outcome - Handover

- Plan commissioning activities, based on which systems are interlinked and must be tested in a particular sequence etc.
- Optimise handover schedule;
- Review phased handover scenarios - testing which areas can be made fully functioning and safe for the client to commence fit out or occupation.





Mission control room

The previous sections have shown how data can be captured and processed from the smallest scale (individual materials) to the largest (nationwide geographic information systems).

The use of highly standardised BIM libraries, enhanced with data gathered through the virtual and physical prototyping stages, will create a rich information benchmark that can be analysed as described in earlier sections.

The use of standardised solutions at the scale and geographic diversity of the government estate, combined with open and collaborative ways of working, offers the chance to take this further and create an exemplar project controls system for the BIM-enabled industry.

By combining all of the available data sets, bridging the traditional boundaries (physical and imagined) between 'the site' and 'the factory' a data flow would link manufacturing centres to the construction zone.

High quality, accurate data would be received from a range of existing sources including:

- Operatives - activity recording using GPS enabled smart phones with custom apps;
- Vehicles - GPS tracking for all construction vehicles, recording all delivery journeys as well as on site activity;
- Mesh-network enabled CCTV monitoring systems using balloons;
- Drone technology for image and video capture;
- Digital weather stations / sensors monitoring air and ground conditions;
- Photogrammetry / laser scanning for site topography;
- Live traffic reporting;
- Weather satellite data and services.

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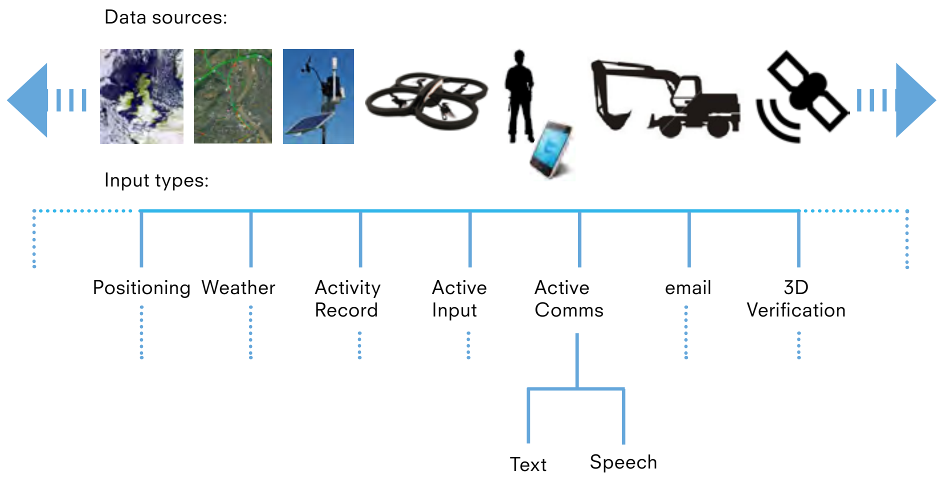


Data collection categories:

Active
- Participants send info about activity
- Detailed but less robust

Passive
- Participants activity is monitored
- Less detailed but more robust

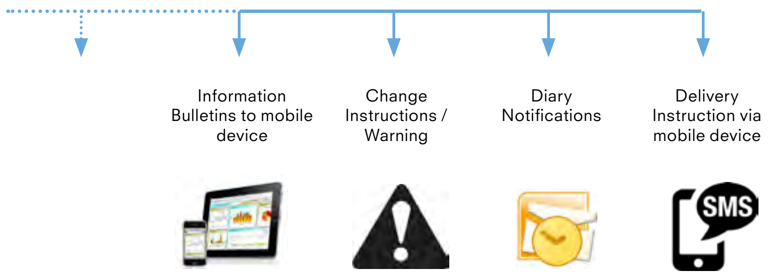
Mission control will use the data capture and analysis to provide targeted communications to the project team and operatives across the site including:

- Better project planning prior to construction through detailed scenario studies;
- Data-rich, visual feedback to assist project planning decision making;
- Accurate benchmarking of carbon footprint before construction and using it as a driver for project planning;
- Simulation of unusual/ extreme events, their potential impacts and possible mitigation;
- Familiarisation of the monitoring system that will be used during construction;
- Long range forecasts for factory production with long lead time;
- Weekly plans with detailed activity schedules;
- Daily updates to site operatives for optimum deployment of workforce;
- Hourly updates with weather warnings;
- Real time redirection of deliveries to avoid traffic or to hold points to ease congestion at site entrances.

This would be used for more agile and responsive project controls, linking suppliers, logistics and sites in a highly organised network.

Integrating live reporting from subcontractors and suppliers would facilitate:

- Higher productivity;
- Better levelling of supplier workload;
- Just in time delivery;
- Fewer on site movements;
- Reduced waste.



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