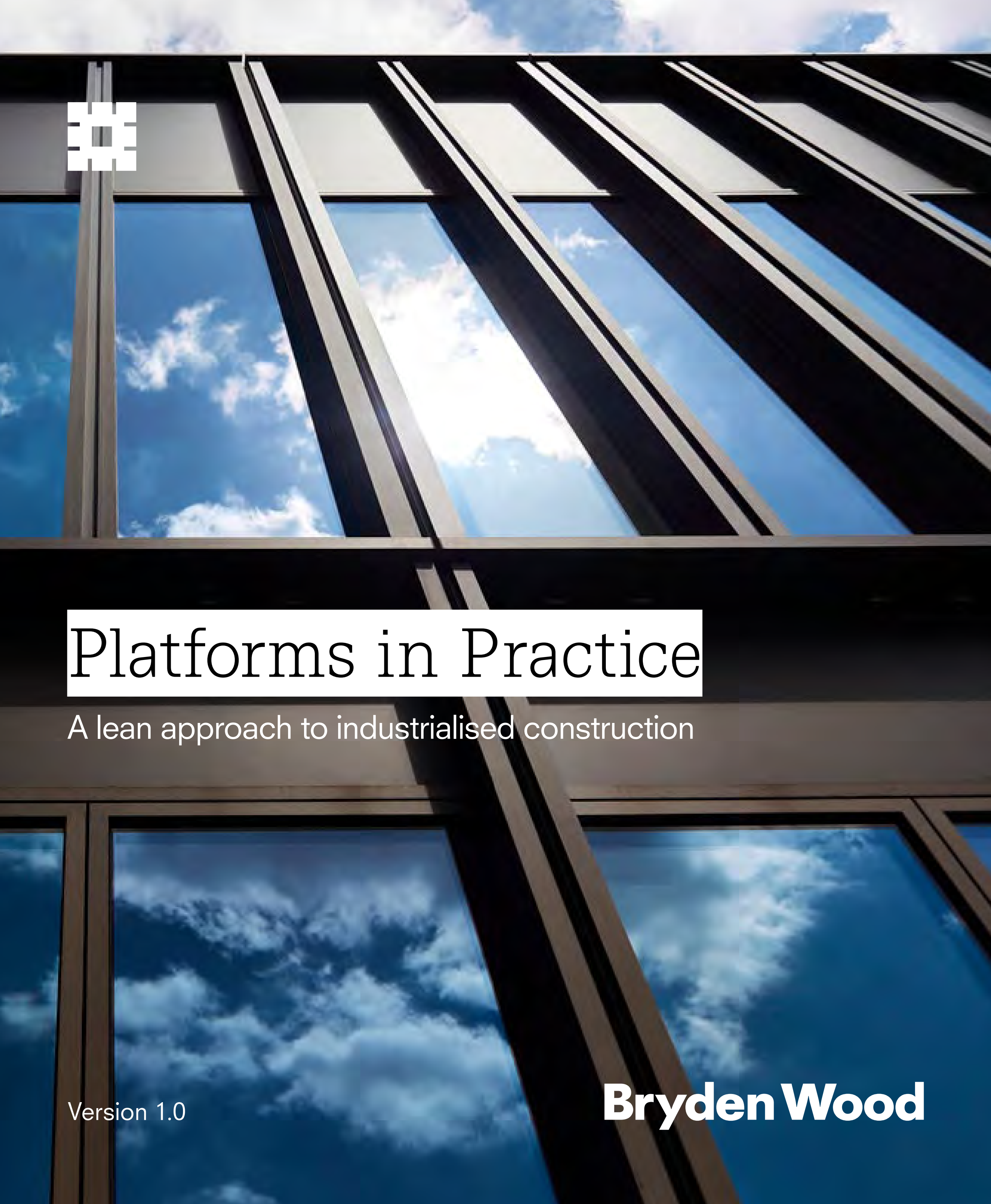

Platforms in Practice

A lean approach to industrialised construction

Version 1.0

Bryden Wood

Links to videos, documents + apps are indicated by

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How to use this document

Over the last few years, much has been published on the potential opportunities and benefits of adopting platform approaches to construction.

This document is intended to be a detailed worked example that demonstrates how **platform theory** has been translated into **platform practice**.

It is written as a series of sections that can be read together, or navigated using the interactive contents page to quickly access the most useful or relevant section.

It is broadly split into four topics:

1. The origins

An outline of the journey that started with a single UK government department and expanded into a cross-sector initiative, and how industry-wide challenges were used to identify the need for a highly effective superstructure solution. Plus, the analysis and logic that led to the creation of Platform II.

2. The application

A practical guide that sets out the technical detail on: key components, capabilities and benefits that have been proven for Platform II.

3. The Forge - the world's first example

A real-world example of how Platform II has been used to deliver The Forge, a commercial office project in London for Landsec, one of the UK's largest real estate companies. This project is the UK's first commercial development to be designed in line with UK Green Building Council's net zero carbon buildings framework, allowing the sustainability benefits of platforms to be demonstrated.

The Forge construction process was also subject to detailed productivity analysis by the University of Cambridge. This demonstrates the step change that is available through the adoption of a platform approach.

4. Alignment

While Platform II was developed in advance of the formation of the Construction Innovation Hub, this section outlines how Platform II aligns with the Hub's rules and principles regarding platform approaches.

Click on any topic to go straight to that section

Click on any topic to go straight to that section

Image opposite: Completed floorplate at The Forge
Source: Han Teh, GSixtySix.

Context

Definition of 'Platforms'

A Platform approach to Design for Manufacture and Assembly (P-DfMA) identifies features such as floor heights and structural spans that are shared across different types of buildings (e.g. schools, apartments and healthcare facilities) to reveal the kit of standardised parts that can be used to deliver assets across multiple sectors. These parts are readily available from existing suppliers and can be assembled easily and intuitively, in countless ways, to sustainably create a huge range of spaces.

Using these repeatable, cross-sector components creates the economies of scale that have allowed the manufacturing sector to continually drive down time and cost while increasing safety, productivity and quality.

This approach also allows the application of automation - both in the manufacture of individual components, and in the assembly processes that create whole assets on-site. It is this automation that has the potential to transform the productivity of the sector, as we have seen across so many other industries.

Background

The concept of platforms, common in manufacturing sectors, and how they might be applied in construction, was first set out in Bryden Wood's 2017 publication 'Delivery Platforms for Government Assets: Creating a Marketplace for Manufactured Spaces' (referred to simply as 'Delivery Platforms' for the remainder of this document). This arose from a programme of works that was being developed for the Ministry of Justice (MOJ), which demonstrated the power of thinking across sector boundaries.

This idea was then embraced by the UK government's Infrastructure and Projects Authority (IPA) and became a key feature of a series of policy and strategy documents that followed, including the Construction Playbook, and the Construction Innovation Hub's (CIH) Product Platform Rulebook, which described it as:

> "A seminal book that brought into close focus the opportunity and benefits of applying a platform approach to the scale and scope of the UK government construction portfolio. Pioneering in its vision, this text gave clear definition and assignment of title to a strategy which has, in instances, been successfully applied within the construction industry."

Product Platform Rulebook

Download 'Delivery Platforms for Government Assets' here

Platform II summary

Delivery Platforms identified three potential superstructure platforms that would deliver the majority of public sector assets (broadly Platform I - small span, Platform II - mid-span and Platform III - large span).

Of these, Platform II is the one with the most potential for mainstream and widespread application.

Platform II is a product platform: it is a system for the main structure of a wide range of buildings (for instance, schools, hospitals, prisons, commercial and residential) with a common mid-span range (6m - 9m).

The system can deliver this variety of buildings with a limited set of components (e.g standardised steel columns, standardised connection brackets and optimised in-situ concrete floor) with clear interfaces that allow other systems to complement it to deliver the full building.

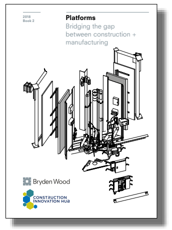
The components of this system are conceived such that they optimise the construction process of the buildings while doing so with a minimum of standardised components. This makes it possible to create pipelines for large quantities of these standardised components (scale of quantities of components for the relevant scale of the different types of buildings) and significantly increases the benefits of using this product platform industry wide.

A key aspect of Platform II is that it is designed as a 'carrier frame' to enable a range of complementary products to be developed and to maximise productivity in their installation. This has already been demonstrated through the manufacture of mechanical, electrical and plumbing (MEP) cassettes and façades.

Platform timeline

Delivery Platforms for government assets

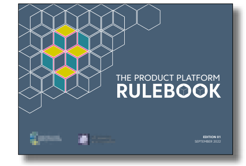
Platforms: Bridging the gap between construction + manufacturing



Platform Design Programme 'Defining the Need'

Transforming Infrastructure Performance: Roadmap to 2030 (TIP2): Focus Area 3

Product Platform Rulebook

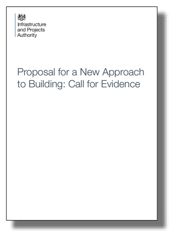


2017 2018 2019 2020 2021 2022 2023

Autumn Statement

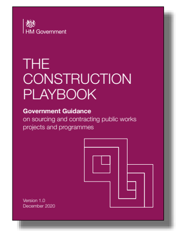
"The government will use its purchasing power to drive adoption of modern methods of construction…"

Transforming Infrastructure Performance



Proposal for a New Approach to Building

"We will use a set of digitally designed components across multiple types of built asset… a single component could be used as part of a school, hospital, prison building or station."



The Construction Playbook

"We will procure projects based on product platforms comprising of standardised and interoperable components and assemblies, the requirements for which will be part of a digital component catalogue."

The Value of Platforms in Construction

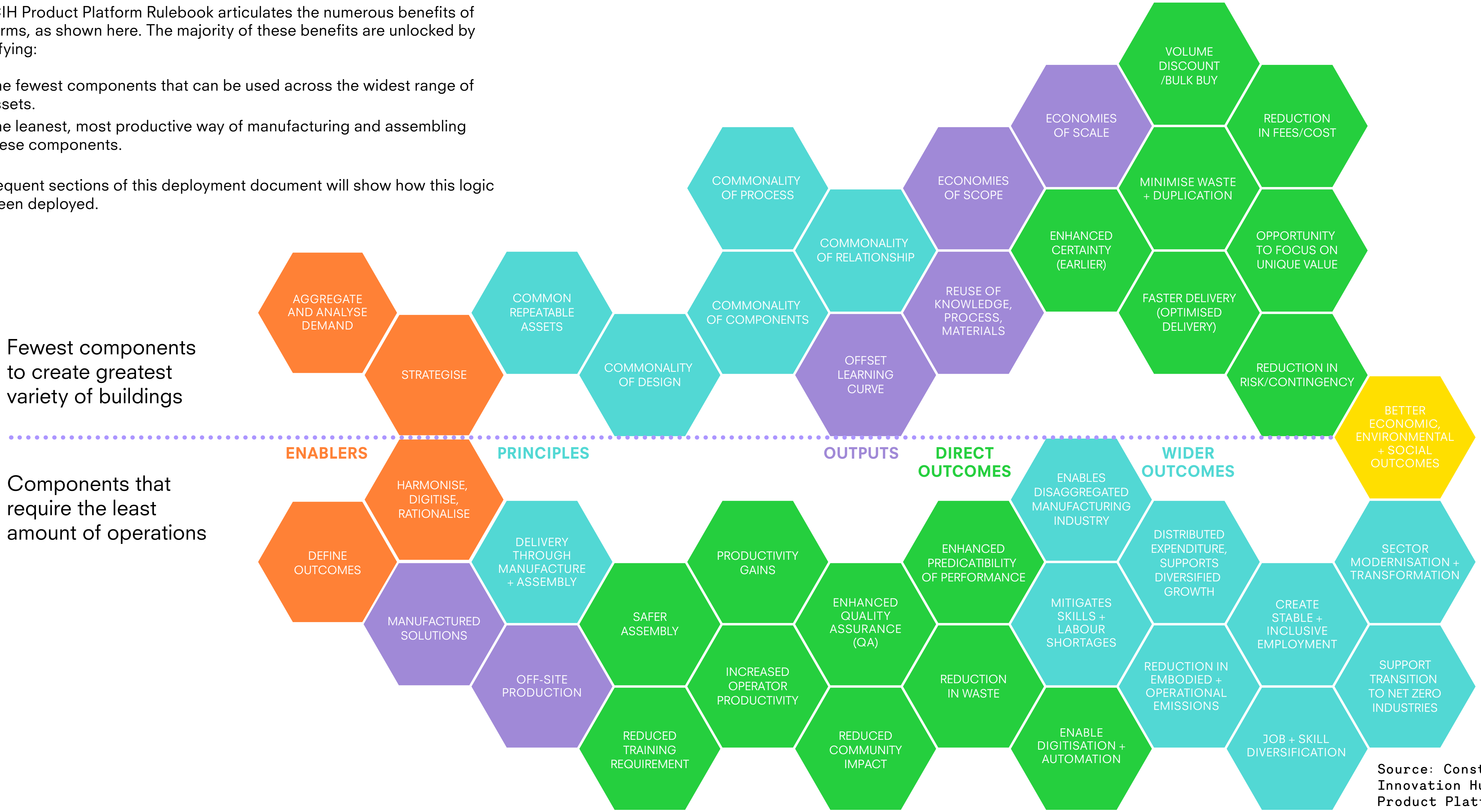
Clicking on any of the icons will link to the document or website.

Benefits of platforms

The CIH Product Platform Rulebook articulates the numerous benefits of platforms, as shown here. The majority of these benefits are unlocked by identifying:

- The fewest components that can be used across the widest range of assets.
- The leanest, most productive way of manufacturing and assembling these components.

Subsequent sections of this deployment document will show how this logic has been deployed.



Source: Construction Innovation Hub Product Platform Rulebook.

Maximising the benefits of platforms

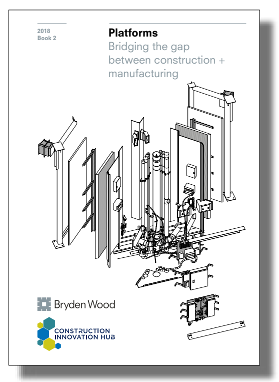
The benefits of platforms could be maximised by a 'network effect', whereby large numbers of suppliers adopt the same solution and benefit from economies of scale and standardisation.

It is for this reason that the original contract with the MOJ (that led to the creation of construction platforms) allowed them to re-use the platforms for any purpose.

Rather than every organisation developing their own platform, if they came together to adopt and refine a small number of platforms, the industry would have the opportunity to create the economies of scale that the manufacturing sector employs.

A good example in the construction sector is scaffolding - standard, interoperable components and processes are used widely across the industry across projects of all scales and all sectors.

Download 'Platforms: Bridging the gap between construction and manufacturing' here



"Making platforms open source would engage the full reach of the industry, giving designers and suppliers, on even the smallest projects, access to the same best in class innovation and supply chains that are used for high-profile major infrastructure. The enabler would be a digital marketplace which would allow everyone from the smallest to the largest organisations to create a highly effective supply chain network."

Platforms: Bridging the gap between construction and manufacturing
Bryden Wood, 2018

Origins

Defining the value of Platform II

The origin of ‘platforms’: Ministry of Justice

The MOJ’s Prison Estate Transformation Programme (PETP) was a £1.2 billion programme to create 10,000 ‘new for old’ prison places across six sites.

Bryden Wood was initially engaged in 2016 with a brief comprising three value drivers:

- Develop a new type of prison with a focus on rehabilitation.
- Create standardised designs that enshrined these rehabilitative principles and could be rolled out across multiple sites;
- Design the facilities to facilitate the adoption of Design for Manufacture and Assembly (DfMA) in their procurement and delivery.

This image shows HMP Five Wells, the first of the new prisons to adopt the repeatable designs developed under PETP.

Read more about the PETP programme

Transforming Prisons, Transforming Futures

MOJ - HMP Five Wells

Value drivers

PETP was predicated on a key programmatic value driver: rehabilitation and the impact that this has on the lives of prisoners, their families and society as a whole. This guided every aspect of the stakeholder engagement and design process.

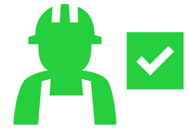
This preceded a more general shift in industry thinking whereby increasing 'value' is preferential to simply reducing 'cost'. The TIP 2 vision includes achieving better social outcomes, as outlined in the Construction Playbook. Projects and programmes must now identify and be led by a set of value drivers.

The value drivers at the programme level will always be widely variable and programme-specific. For example, PETP was focused on rehabilitation, while the New Hospitals Programme (NHP) is delivering high-quality and sustainable healthcare.

However, while the value drivers that a client, programme or asset seek to deliver may be highly variable at the level of platforms or DfMA kits of parts, the value drivers are associated with the design and delivery of components themselves, not their application to specific projects. As they are common across projects and programmes.

This facilitates the platform approach, as it means that the same components can be used across multiple programmes (and, for instance, no programme will ever want lower safety or productivity.)

Platform drivers for all sectors, programmes + projects



Safety
Drive to zero incidents

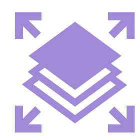
Productivity
Radically improve efficiency of site labour

Quality
Drive to manufactured quality

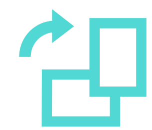
Programme
Reduced construction time to meet expectations

Cost
Drive to budget + below

Carbon
Drive to net zero carbon



Flexibility
Asset + sector variation

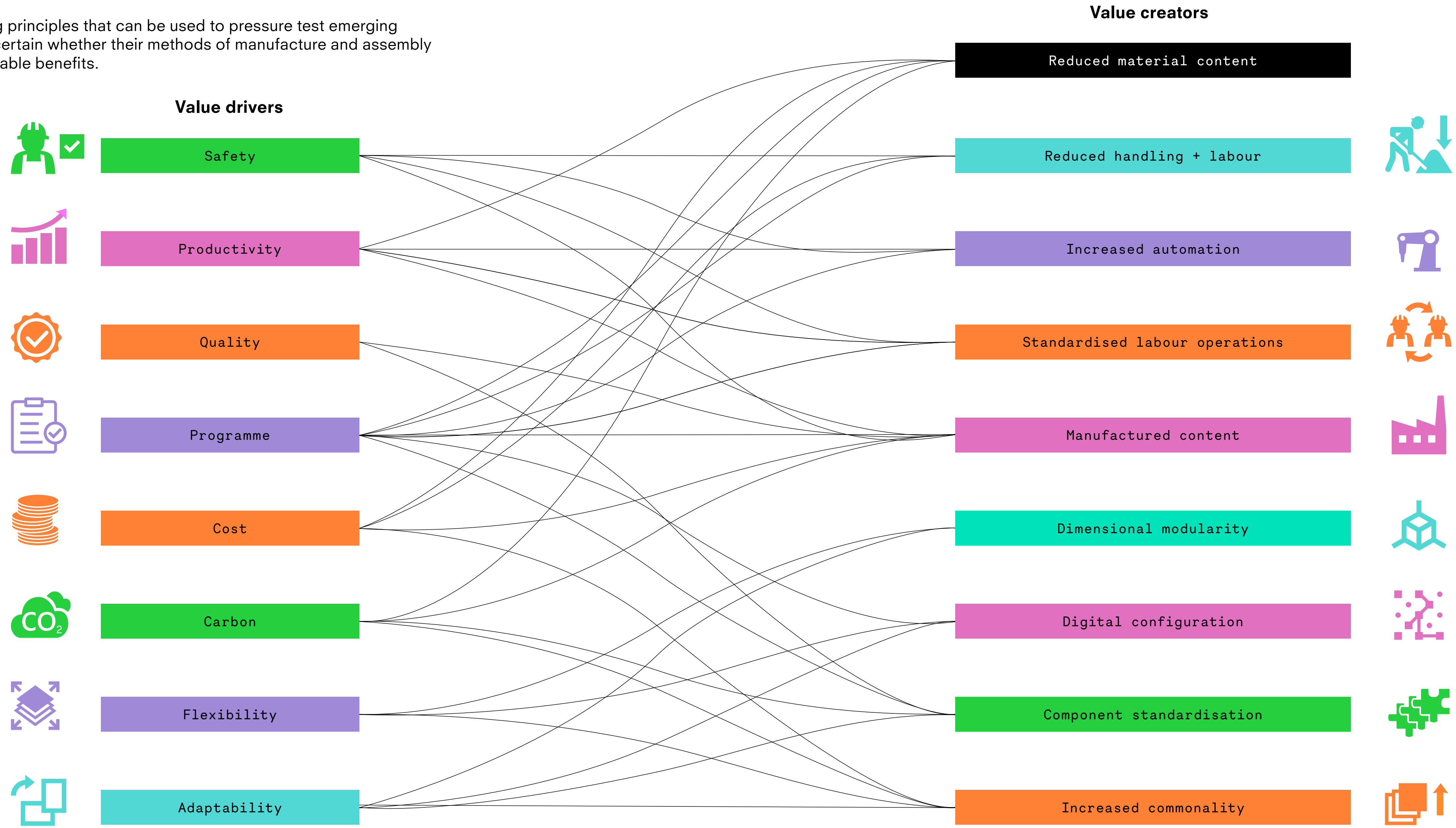


Adaptability
Support change in evolving assets

Value creators

Value drivers are achieved through a series of strategic ‘value creators’.

These are guiding principles that can be used to pressure test emerging solutions and ascertain whether their methods of manufacture and assembly are providing suitable benefits.



Developing a DfMA strategy

Preceding a platform approach, an analysis was carried out across the wide range of assets that form part of the PETP estate to ascertain what types of DfMA might be most appropriate.

This considered dimensions, MEP strategy and functional vs 'support' spaces.

Dimensions

The best way to ensure opportunities for commonality and repetition (which amplify the benefits of DfMA) is to develop a strictly rational dimensioning strategy in terms of grids and sub-grids, floor-to-floor heights, etc. In parallel, it is best to simplify geometry where possible.

MEP strategy

Mechanical and electrical systems make up a significant proportion of the construction and operational costs of any facility. The MEP strategy, including the placement of plant and the associated distribution of services, has a huge impact on floor-to-floor heights and, therefore, overall building volume and running costs, as well as ease of operation, maintenance and future flexibility.

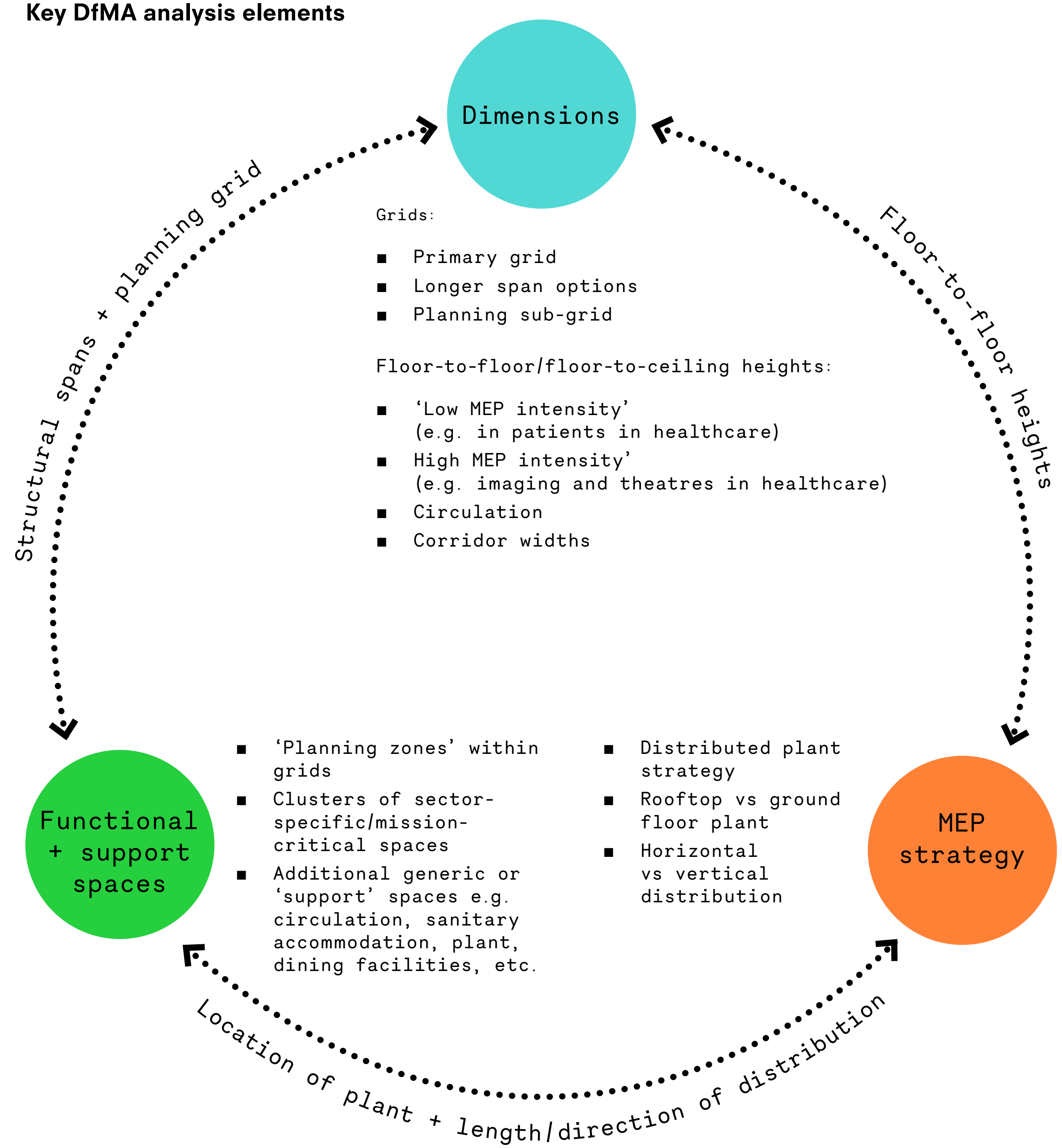
Functional + support spaces

Within any asset, there will be key 'functional' spaces that are critical to the asset's purpose (e.g. teaching spaces in a school, clinical spaces in a hospital). However, there will typically also be a large number of spaces that are generic or support spaces, for instance, circulation, sanitary accommodation, storage, plant areas and dining facilities. The relative balance of these and the variability in their technical requirements (which could be very large in a hospital but relatively limited in a school), will inform the types of DfMA solutions that are applicable.

As the diagram shows, all of these aspects are linked:

- Developing structural grids must facilitate ease of planning and support a range of space types and needs.
- MEP strategy and floor-to-floor heights are strongly linked, as described above. For example, in a healthcare facility, the proximity of, plant areas to the clinical functions they serve drives dimensions of e.g. ductwork and the potential need for cross-overs. These have a significant impact on MEP distribution zones and floor-to-floor heights.

Key DfMA analysis elements



Identifying key physical elements + technical performance

Analysis of the three key strategic elements reveals the major groupings of elements that form the DfMA 'kit of parts':

- Superstructure
- Façade
- MEP
- Fit-out

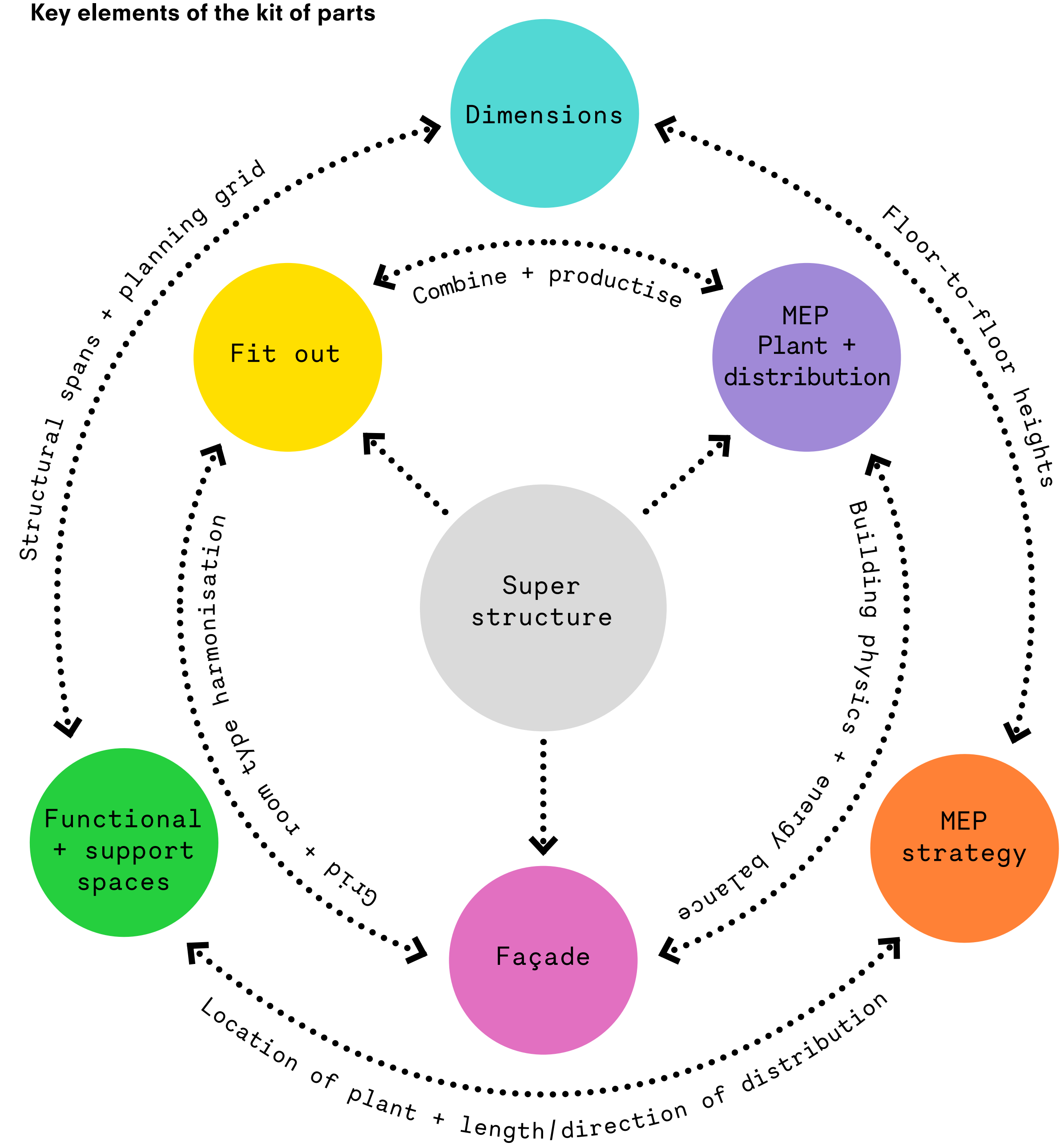
These vary in importance from a DfMA perspective. While the superstructure is often a relatively small proportion of the cost, it is absolutely critical in maximising the benefits of DfMA. The reason for this is that creating a very highly dimensionally accurate superstructure 'unlocks' existing, but underutilised capabilities in the other supply chains:

- Supply chains for unitised façades, prefabricated MEP, etc. are quite mature.
- Issues occur at the interface between the manufactured parts and the 'traditional' parts, i.e. ±5mm prefabricated part meets ±60mm traditional superstructure.
- Thus, following trades are often fixing the 'tolerance' issues created by the previous trade.
- For instance, up to 40% of façade installation cost is the on-site surveying, brackets, shims, mastic, etc. to fill this gap.

A lean and accurate 'carrier frame' with fixing points and interfaces pre-considered will, therefore, facilitate latent benefits in the other pre-existing solutions, without needing to design everything, akin to the automotive industry where the car chassis already includes setting out and fixing points for body, power train and interior.

This is the purpose of Platform II - to provide a fast, accurate, low-carbon superstructure that will enable high levels of productivity not just in its delivery, but also in the complementary elements that follow.

Key elements of the kit of parts



"The greatest scale [of benefit] is enabled by harmonising features of the superstructure (such as structural grids, beams, columns, connectors and slabs) across sectors. Key aspects of assets (such as façade and fit-out) can all be incorporated into the approach, and a repeatable grid and common dimensions make these easier to design and install. Mechanical, electrical and plumbing systems can be designed and prefabricated to fit into platform carrier frame superstructures."

Transforming Infrastructure Performance: Roadmap to 2030

Image opposite: Integrated superstructure MEP + façade at The Forge
Source: Han Teh, GSixtySix

Analysing typologies

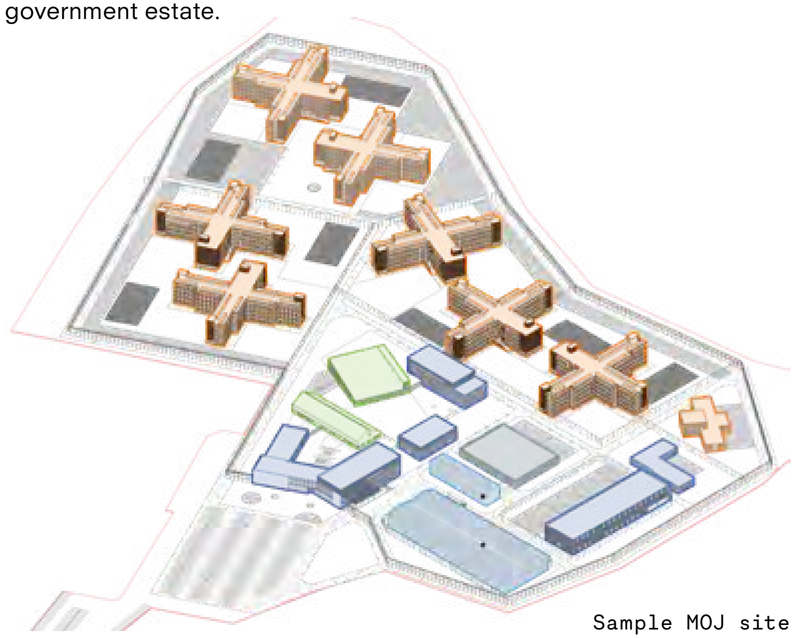
Undertaking the analysis across PETP showed that house blocks are the most prevalent, representing over 65% of the total programme. This suggested a very optimised, repeatable design for these since the 'pipeline' for this asset type alone was so large.

However, while house blocks are the key asset type for the MOJ estate, there are numerous other 'supporting' assets providing education, healthcare, administration, training and exercise.

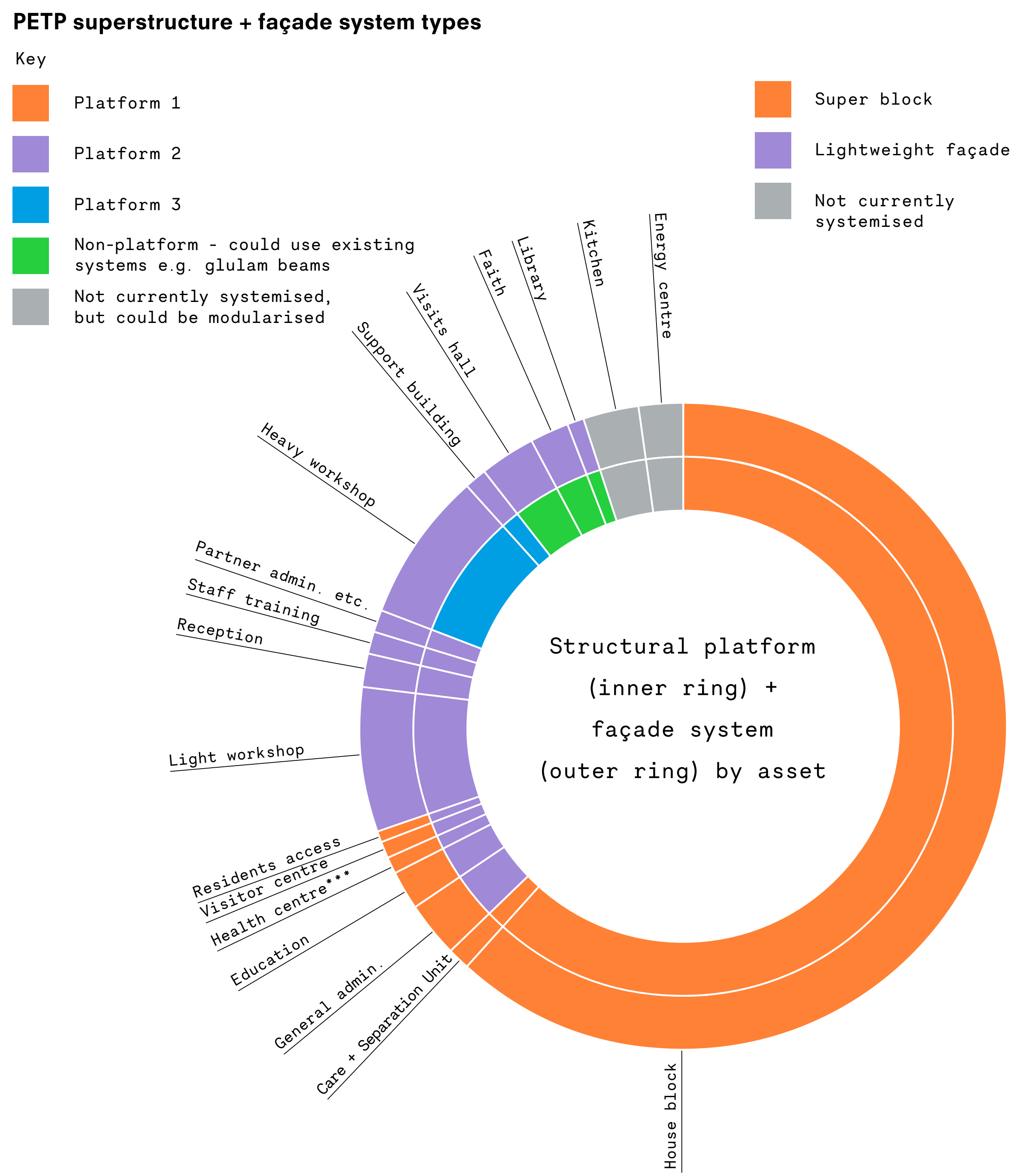
It became apparent that if DfMA solutions were developed that would assist in the delivery of PETP, some of these would also be of use to wider government. For example, a DfMA solution for teaching spaces would have greater value to the Department for Education (DfE) who has a far larger portfolio.

In addition, it was found that a range of asset types presented similar technical and performance characteristics. This offered the opportunity to 'group' certain asset types and spaces across sectors and develop DfMA solutions that would then have a wide application across multiple government departments and clients.

From this thinking the idea of cross-sector 'platforms' emerged. The next challenge was to identify which common, repeatable components would create the most value across the government estate.



Sample MOJ site



Identifying cross-sector commonalities

The MOJ work showed a high prominence of cellular, repeatable accommodation (house blocks) which is typologically very similar in room size, layout and function to student accommodation and Single Living Accommodation for the MOD.

This typology (highly repeatable single person accommodation with a small structural span) therefore justified a very highly optimised solution - one that only creates single rooms but does so very effectively.

However, many of the other assets had similar technical requirements, regardless of use. For example:

- Typically floor-to-floor heights are generally based on the size of people.
- At a person-sized floor natural light can penetrate over 8 m into a floor plate.
- This limits depths of many room types to a structural span of over 8 m.

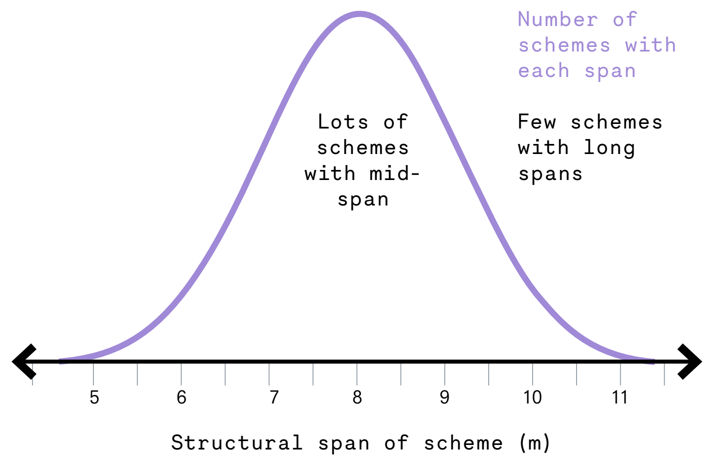
This is why hospital wards, classrooms, apartments, etc. have similar spans – they are governed by the size of people, not by sector.

As a result, it was hypothesised that there would be a much larger amount of mid-span typologies across wider government departments that had similar spans but more variable functions.

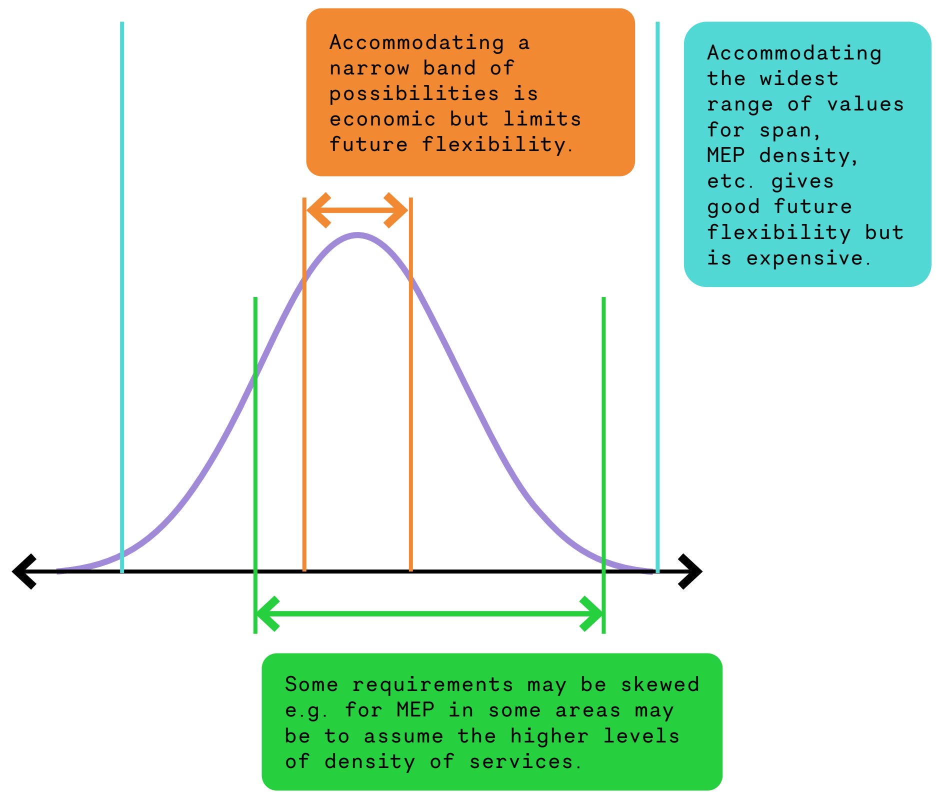
These would require a more flexible kit of parts that allowed for a range of spans (6m up to 9m), storey heights and acoustic/vibration characteristics and would facilitate a range of MEP, envelope and fit-out requirements.

Identifying performance ranges

Distribution curve for technical aspects - in this case structural spans.



Accommodating various ranges of flexibility will have an impact on cost - the goal is to find the 'sweet spot' of sufficient range at a viable cost.



Identifying key platform types

To further this initial hypothesis, more analysis was carried out to consider and group the breadth of space and types forming the public sector estate.

Three structural platform types were proposed from this mapping exercise:

Platform I

For repeatable, cellular accommodation such as prison house blocks, student accommodation and single living accommodation for the defence estate. Facilitating a range of interior fit out and levels of MEP to suit.

Platform II

A mid-span, 'general purpose' platform to suit education, healthcare, large commercial office blocks and multi-occupancy residential typologies (e.g. apartment blocks). Able to be 'tuned' to varying acoustic and vibration criteria, and to support a range of fit-out, MEP and façade types.

Platform III

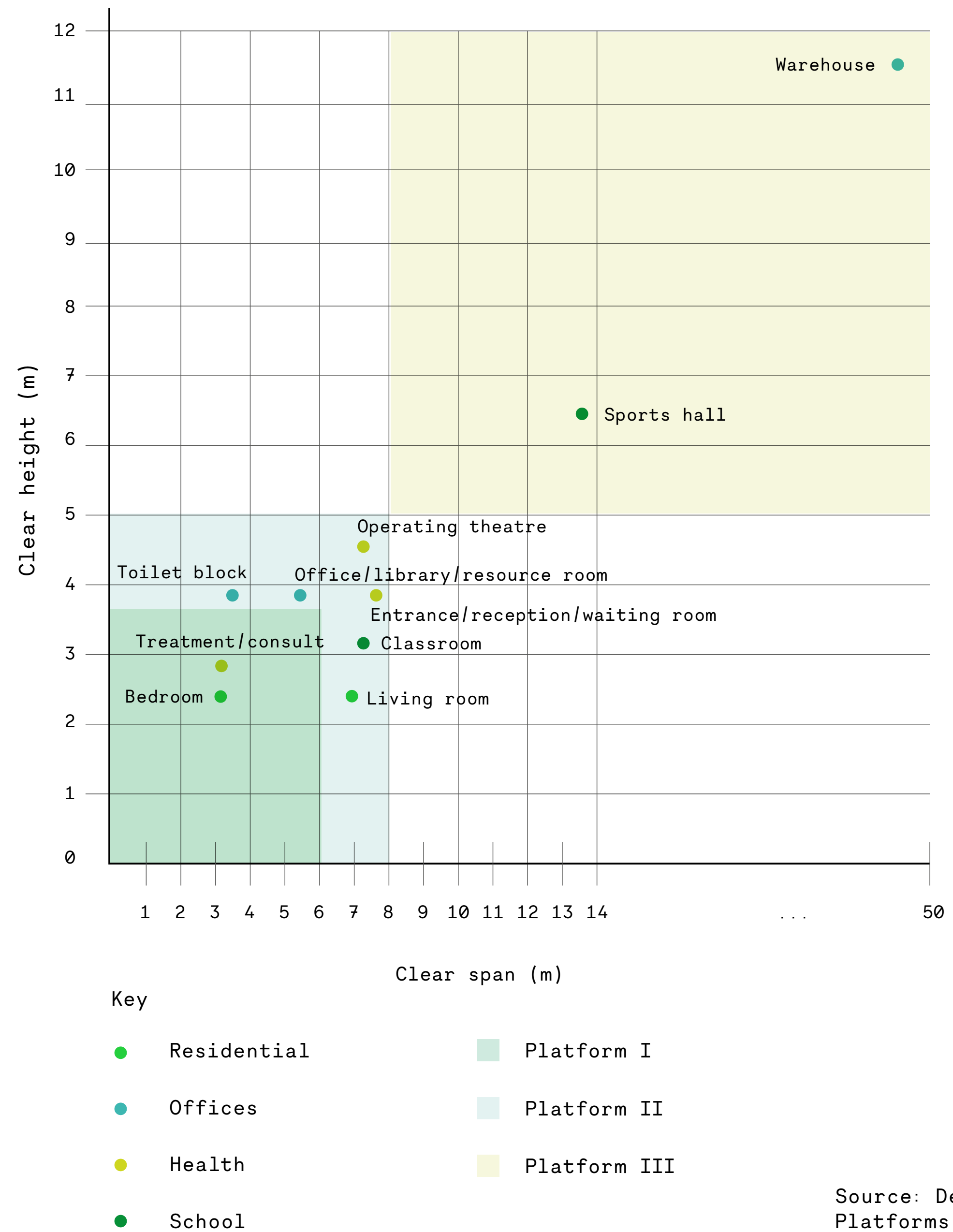
For larger span open spaces such as gymnasia, dining halls and community halls.

Next steps

Platforms I and II were prototyped as part of the MOJ PETP. These demonstrated some of the key principles of platforms, including reduced fabrication, cost-effective of assembly and efficient use of materials.

However, the question remained; "What proportion of government assets would each platform type represent?"

The three platform types that service the government estate



Source: Delivery Platforms for Government Assets

Understanding the opportunity for Platforms I, II + III

To quantify the relative size of the opportunity for the different platform types, it was necessary to analyse space typologies across departments and identify opportunities for standardisation.

However, the traditional focus on 'projects' rather than 'programmes' and the vast array of nomenclature across asset types made cross-comparison impossible.

The importance of a common classification system cannot be overstated, with 'Harmonise, digitise and rationalise demand' being a key policy of the Construction Playbook.

To overcome this, the original 'Delivery Platforms' book proposed a formal analysis of space types using Uniclass as a classification system. This would allow multiple asset types from different sectors to be compared.

"Contracting authorities should seek opportunities to collaborate in order to develop and adopt shared requirements and common standards. This should be done to enable standardised and interoperable components from a variety of suppliers to be used across a range of public works. This will create a more resilient pipeline and drive efficiencies, innovation and productivity in the sector."

"Greater use of platforms will require government to harmonise its technical standards, for example, increasing consistency in the naming of spaces."

Construction Playbook

"Contracting authorities can achieve [numerous] benefits by supporting the development and use of consistent structure, rules and language in standards and specifications to facilitate shared understanding and the use of digital and automated solutions."

Transforming Infrastructure Performance: Roadmap to 2030

Validating the mid-span hypothesis

In 2020, the Construction Innovation Hub undertook a comprehensive study following these principles. They aggregated £50 billion of forward pipeline data for the Department of Health and Social Care (DHSC), Ministry of Housing, Communities and Local Government (MHCLG), MOJ, Ministry of Defence (MOD), and the DfE into a single cross-departmental data set (using Uniclass categorisation of individual space types).

Space types that had different names but performed the same function were grouped. For instance, the Uniclass code for 'toilets' is SL-35_80_89 (see breakdown below). This showed that there are 104 different names for toilets within the public estate.

SL_35_80_89

Table **SL**
Spaces table

Group **35**
Medical, health, welfare and sanitary spaces

Sub group **80**
Sanitary spaces

Object **89**
Toilets

Once the cross-departmental data set was assimilated into a single data set, it was then analysed to identify areas of commonality and difference. The result was a set of space characteristics, which would have the overall greatest applicability to the public sector estate.

The foundations of a platform approach

The results were striking (see the summary page from 'Defining the Need' on the right) and showed that 70% of public sector procurement could be delivered using a mid-span platform solution, confirming the initial hypothesis and providing compelling evidence for the potential of platform adoption.

Read our blog on this topic:

The power of data for 'Defining the Need' - an evidence-based approach

Download 'Defining the Need' here

Key insights

Findings from the Hub's analysis of a £50 billion DfE, DHSC, MOD, MHCLG and MoJ's five-year new build pipeline:

c£35bn

he estimated value of the pipeline that could be delivered with a defined range of mid-span (~8m) platform construction systems, based on geometry alone.

c£13bn

the estimated value of the pipeline that could be delivered with the Hub's Platform Construction System.

104

different names for toilet spaces across the estate. This highlights the need for a common, machine–readable, way of naming spaces to accurately analyse and harmonise future demand.

50%

More than 50 percent of space types across the pipeline are not department specific — hallways, bathrooms and storage areas could be delivered with a standardised platform solution.

38%

of spaces across the new build pipeline will be 'Residential Spaces', presenting a secondary market for the private sector. If the Hub's Platform Construction System demonstrates how it can be used to deliver 'more beautiful, more sustainable, better quality homes in all parts of the country[1]', it could potentially be used to deliver private sector homes, student accommodation, and hotels domestically and internationally.

?

The majority of departmental specifications are open to interpretation. Units can vary across departments — . dB or NR are both used for acoustic performance. Improved standardisation of requirements — not least nomenclature — is needed to unlock the potential for solutions that deliver pan-government.

Trends

0

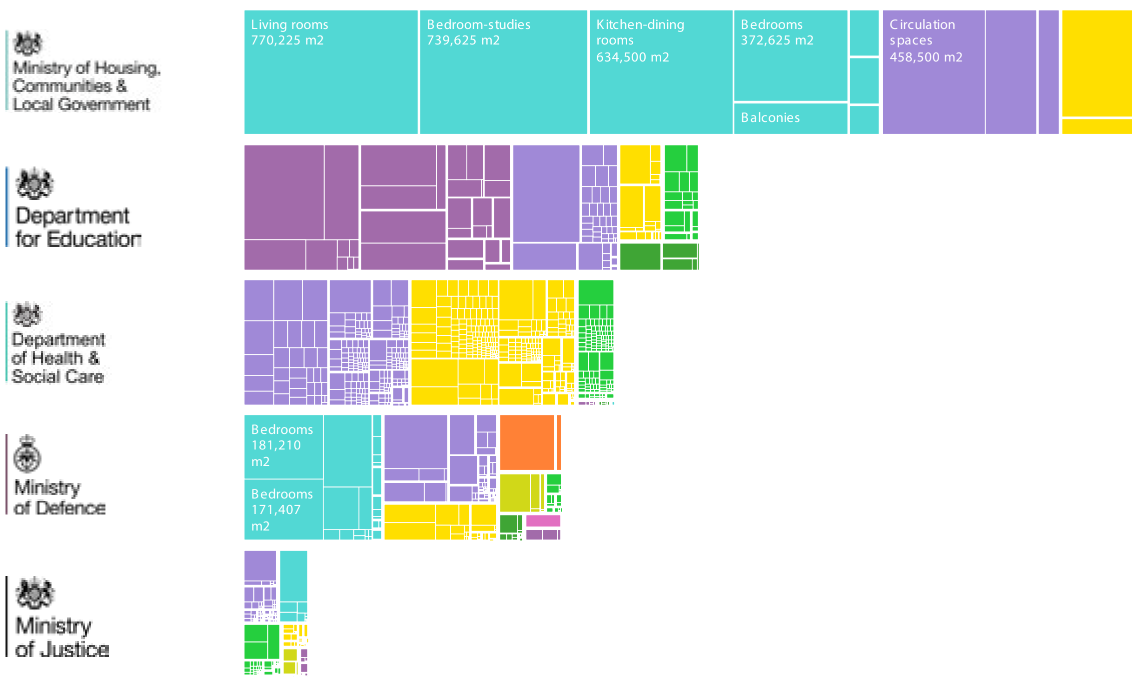
The government is committed to bringing all greenhouse gas emissions to net zero by, or ahead of, 2050. Platform construction systems must understand and minimise their GHG emissions footprint throughout their lifecycles.

Buildings need to be highly adaptive so that they can be reconfigured/repurposed across the required 60–year service life.

Source: Construction Innovation Hub 'Defining the Need' summary report

1 https://www.gov.uk/government/speeches/robert-jenricks-speech-to-chartered-institute-of-housing-cih-2020

Government pipeline by Uniclass space types

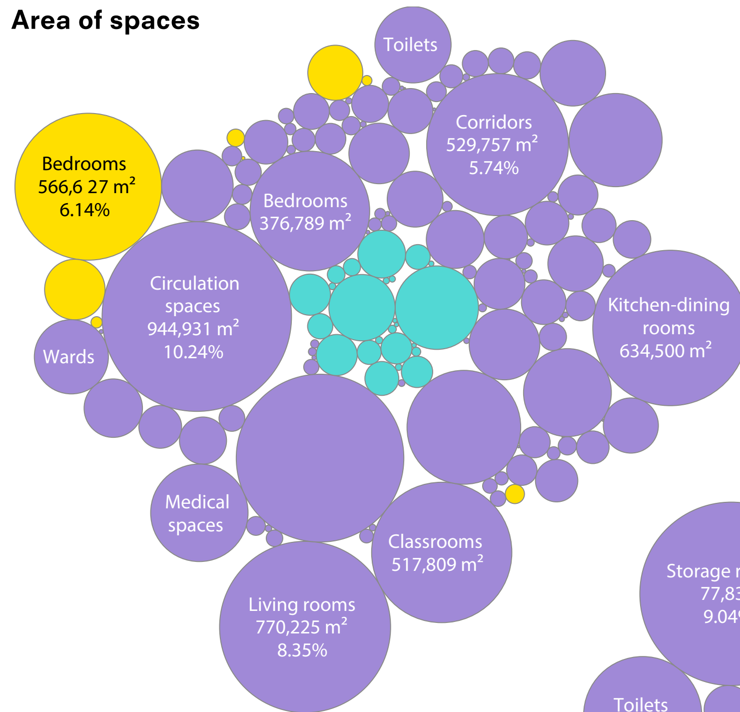


Key

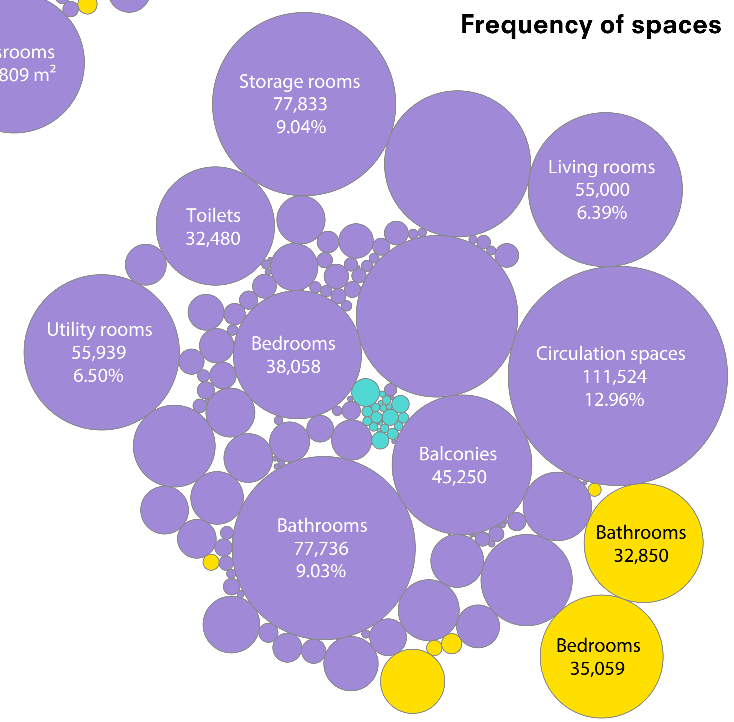
- Administrative, commercial and protective service spaces
- Communications, security, safety and protection spaces
- Cultural, education, scientific and information spaces
- General spaces
- Heating, cooling and refrigeration spaces
- Industrial spaces
- Medical, health, welfare and sanitary spaces
- Recreational spaces
- Residential spaces
- Sport and activity space
- Waste disposal spaces and locations

Space types by span

Area of spaces



Frequency of spaces



Key

- Small-span
- Mid-span
- Large-span

Source: Construction Innovation Hub 'Defining the Need'

Lean design

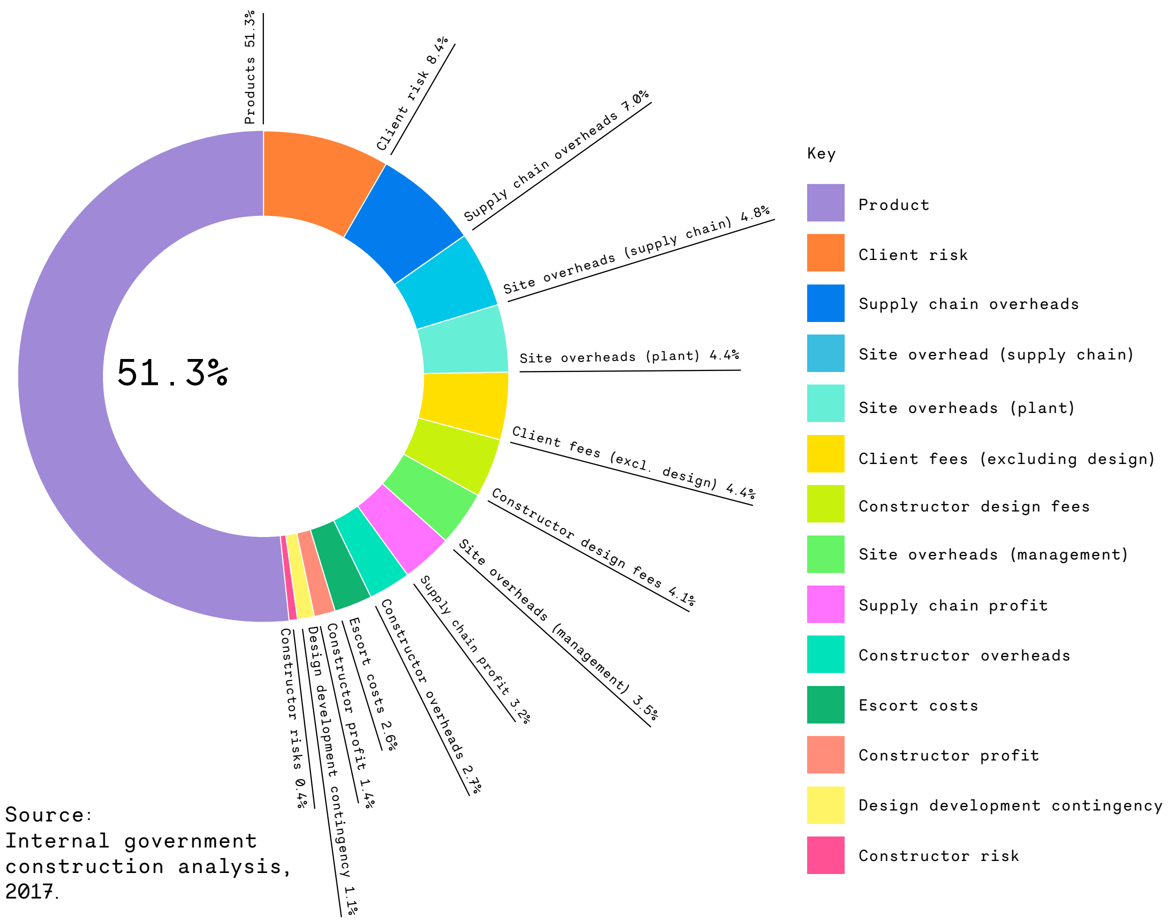
Lean principles: eliminating waste

Numerous studies have highlighted the difference in efficiency and productivity between the construction and manufacturing sectors.

The fundamental strategy that manufacturing has employed to consistently boost productivity and make incremental gains year-on-year is to relentlessly eliminate any non-value-adding activity, and remove waste in all its forms.

This was a critical insight in the development of Platform II. Firstly it should use as little material as possible, and then eliminate as many non-value adding steps as possible in design, configuration, manufacture and assembly.

Government project cost analysis



Source:
Internal government construction analysis, 2017.

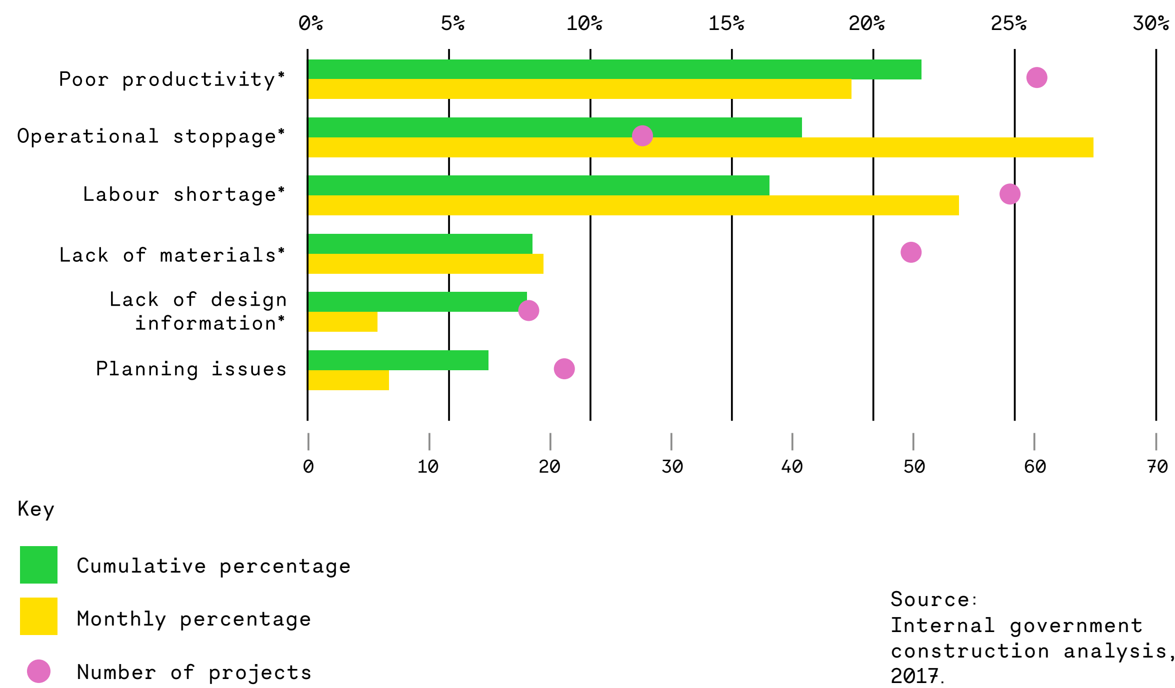
Data from one government department (but believed to be typical across projects) showed that nearly 50% of capital cost is risk, waste and transactional inefficiency in the system.

Meanwhile, project performance analysis found that the most significant causes of project delays and cost increases, accounting for approximately 30%, are:

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

Many of these would be addressed by ensuring that the correct elements are delivered to the right people, at the right time and with the right information.

Reasons for project delays



Source:
Internal government construction analysis, 2017.

Adopting lean principles in platform design

Adopting a lean approach, like manufacturing, provides a set of strategies that should guide the platform design process:

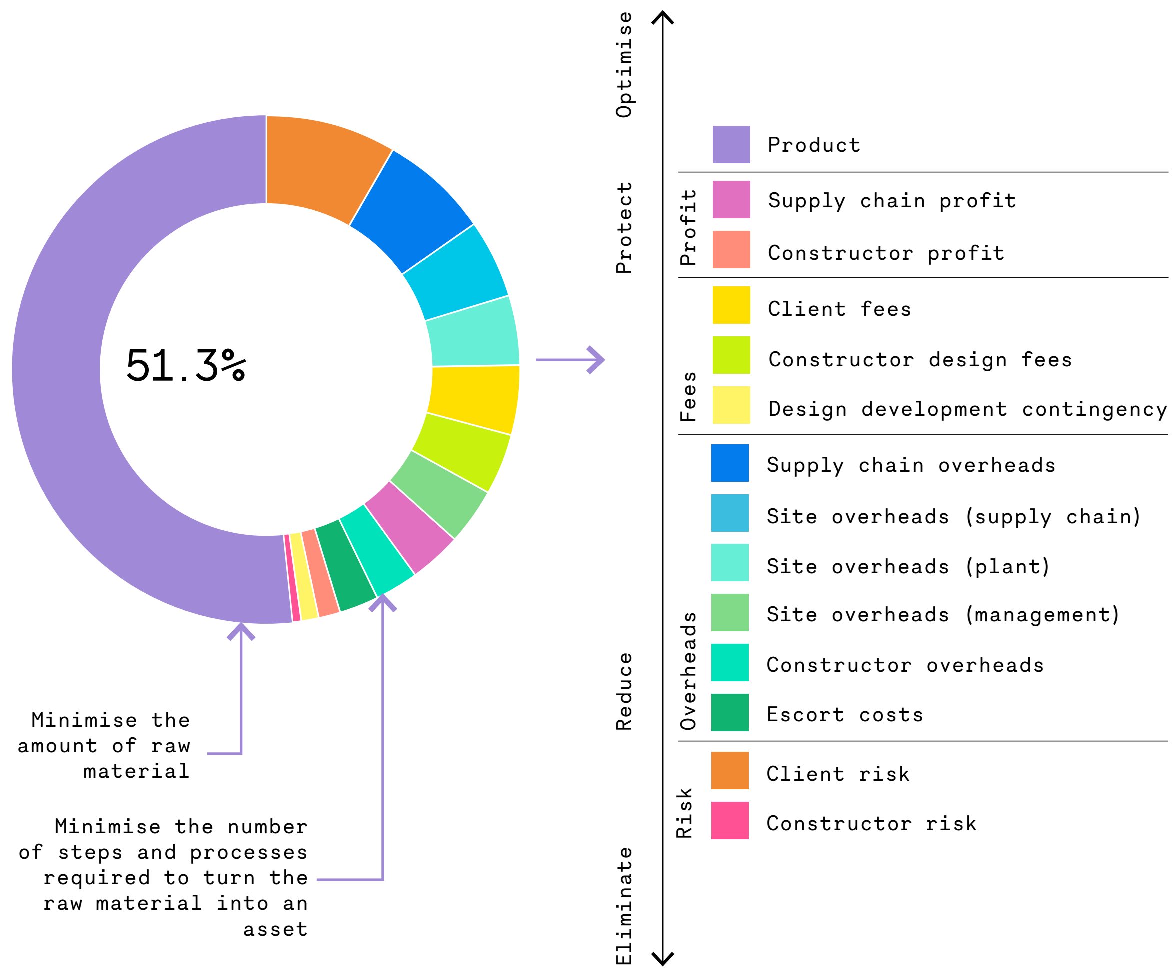
- Use the least amount of material.
- Reduce the effort required to turn raw material into the finished asset by handling and/or moving material:
  - The fewest number of times.
  - Through the least amount of processes.
  - By upskilled and / or highly productive people.
  - By the fewest number of people overall.
- Locate activity where it is best suited, rather than mandating 'on-site' or 'off-site'.
- Deliver materials and elements to site at the right time, in the right sequence and with the correct information.
- Remove transactional cost and commercial friction in the procurement process.

An effective platform solution cannot simply be about components. It should also consider procurement, logistics, manufacture and assembly.

> "The approach enables low levels of waste, with commodities handled the fewest number of times, by the fewest number of people, via the least number of processes."

Transforming Infrastructure Performance: Roadmap to 2030

Minimising waste in project delivery



Source:
Internal government construction analysis, 2017

Applying lean principles: the factory on site

An often-quoted phrase from the UK Government's Autumn Budget Statement 2017 says that major departments would 'adopt a presumption in favour of off site construction' ('off site' is a term often used as a synonym for MMC).

The obvious outcome of this was a drive to focus on solutions that involve a high degree of off site activity. However, the full Budget text begins much more broadly:

> "The government is taking a series of steps to improve the cost effectiveness, productivity and timeliness of infrastructure delivery. The government will use its purchasing power to drive adoption of modern methods of construction, such as off site manufacturing."
>
> Autumn Budget Statement, 2017

This sets out both:

- The problem statement, which is to improve outcomes (time, cost and productivity).
- The means of achieving this, which is to change the process (modern methods of construction), with off-site manufacturing being only one example.

The development of Platform II was, therefore, not guided by a desire to move activity off-site, but rather to boost productivity and reduce time and cost.

The intention was to facilitate factory levels of productivity on-site, without the cost and carbon associated with a remote factory and transport to site, as an elegant way of meeting the desired outcomes. To assist with this, the aim was to reduce the manufacturing and assembly process to a series of simple, productive processes which would create the potential for automation and reduce reliance on skills and workmanship, another key practice which manufacturing has embraced.

> "Factory conditions in the construction stage:
>
> Platform approaches deliver via a series of simple, repeatable, productive activities. This addresses challenges presented by the size of the build and enables predictability in the sequence of work. A mixture of simple human operations, low complexity automation, and lean manufacturing principles can improve health and safety, help to increase productivity and speed of assembly, and address the skills gap.
>
> The approach also enables low levels of waste, with commodities handled the fewest number of times, by the fewest number of people, via the least number of processes. Predicting operative numbers, their positioning on-site, and accurate training and workload schedules is unremarkable in manufacturing. By extending the use of consistent, digital workflows into logistics and labour, similar capabilities can be achieved in construction."
>
> Transforming Infrastructure Performance: Roadmap to 2030

Applying lean principles: reducing reliance on skilled trades

Significant and well-documented challenges faced by the construction industry include the skills gap and an aging demographic.

In response, a key aspiration of Platform II is to create a series of simple components and assembly processes in order to:

- Lower the barrier to entry – allowing existing suppliers to manufacture components without needing significant upfront investment.
- Reduce reliance on workmanship and skilled trades on-site.

It will be seen that the procurement of Platform II components, such as brackets and temporary works, facilitates:

- An extremely wide, and therefore resilient, supply chain for all major components with good regional coverage to maintain a commercial advantage while minimising transport and logistics costs.
- Ability to utilise a number of small companies rather than rely on large, 'single source' suppliers (while using large and well-established partners for commodities such as steel and concrete).
- Procuring components more locally to place investment in regions closer to camps, supporting the local economy.
- Ability to manufacture complex components where specialised skills exist, but use local labour for final 'on-site' assembly.

The assembly processes facilitate:

- Reduced reliance on skilled operatives to diversify the pool of available labour and allow workers to be sourced more locally to site.
- Reduced need for operatives to travel and an increase in the mental wellbeing of operatives (better contact with friends and family).
- Diverse labour pool providing new manufacturing skills and jobs.

Depending on location, sub-assembly processes could take place in a number of locations:

- On-site, whereby bulk deliveries of components are brought to site and put together at the point of use.
- Near site, at a fabrication facility where bulk deliveries of components are taken (via logistics/consolidation hubs) before complete sub-assemblies are taken to site.

Pier segregation product (for Heathrow and Gatwick airports)
- Delivered using unemployed operatives, trained in a facility set up specifically for the purpose.

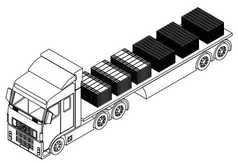
GlaxoSmithKline pharmaceutical facilities
- Delivered using ex-Gurkhas (British Army), trained to assemble components.

Prototypes for the MOJ
- Delivered using serving prisoners in a live prison.
- 73% of the manufacturing and assembly activities could be undertaken by prisoners once they were given training.

"By better enabling a diverse manufacturing and assembly capacity, a wider set of strategic outcomes can be assessed. Examples could include the sourcing of manufacturing supply based on regional capacity and skills, and incentivising investment in local capacity to mitigate the carbon implications associated with sourcing over greater distances."

Transforming Infrastructure Performance: Roadmap to 2030

Prison industries prototyping Platform I: Brick slip panel manufacture



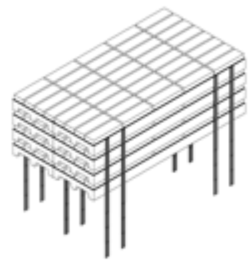
Loose brick slips delivered
Loose gravel boards delivered.

Stainless steel band straps are loosely fitted.

Part 1 of plastic former placed on gravel board.
Two part glue mixed and applied. Levelled to top of former.

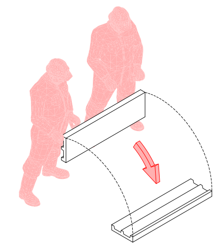
Part 2 of plastic former placed on top and slips placed into grids (4 slips tall, 5 slips long i.e. 20 slips per panel).

Boards and slips pressed together in correct location. Slip grout lines are filled with mortar.



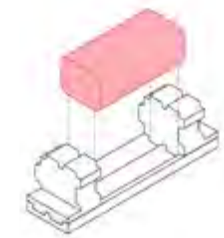
Completed boards stored in racks to cure. Once cured, boards are moved to 'Super block' manufacturing line - see Productive Routine 2.

Prison industries prototyping Platform I: Super block manufacture

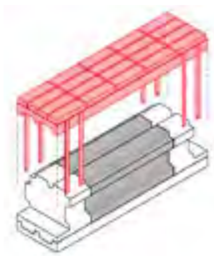


Gravel board laid on its back on production table.

Rigid preformed insulation added.

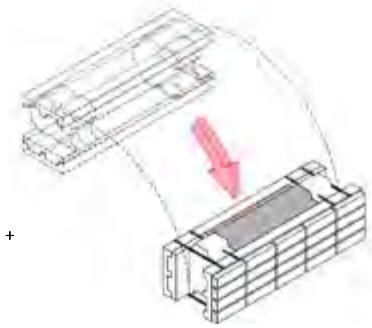


Flexible mineral wool insulation installed bagged to be cut just before assembly.



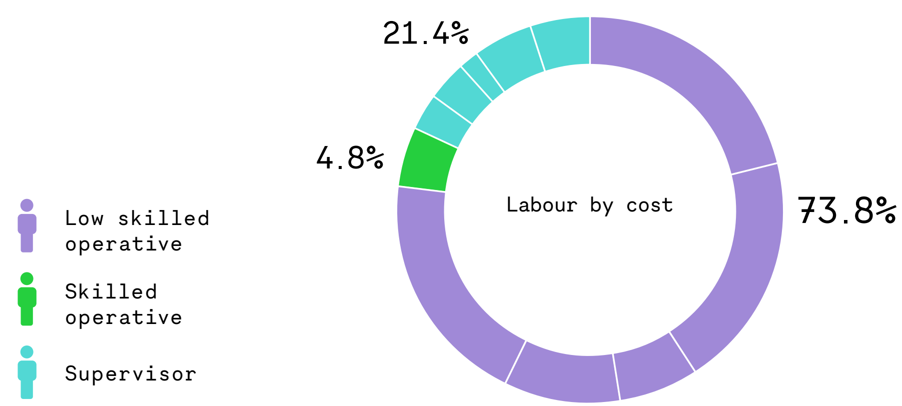
Ready prepared slip-covered gravel board married with partner and strapped.

Special tool used to automatically tighten + secure bands.



Completed block stored dry, then moved to assembly platform when needed. Weight is approximately 45 kg.

Superblock manufacturing process - Labour by cost



Source: Platforms: Bridging the gap between construction + manufacturing.

Platform II material selection

A key lean principle is to optimise the 'product'. So, Platform II uses a mix of materials to leverage their best performance characteristics, with the optimal result found to be a steel and concrete hybrid.

Steel

- Accurate, consistent and can be erected swiftly using simple processes.
- High compressive strength – good in compression, per unit area.
- Relatively lightweight – lots of parts can be moved in a single vehicle movement or lifted in a single tower crane movement.
- Good for columns + connections.

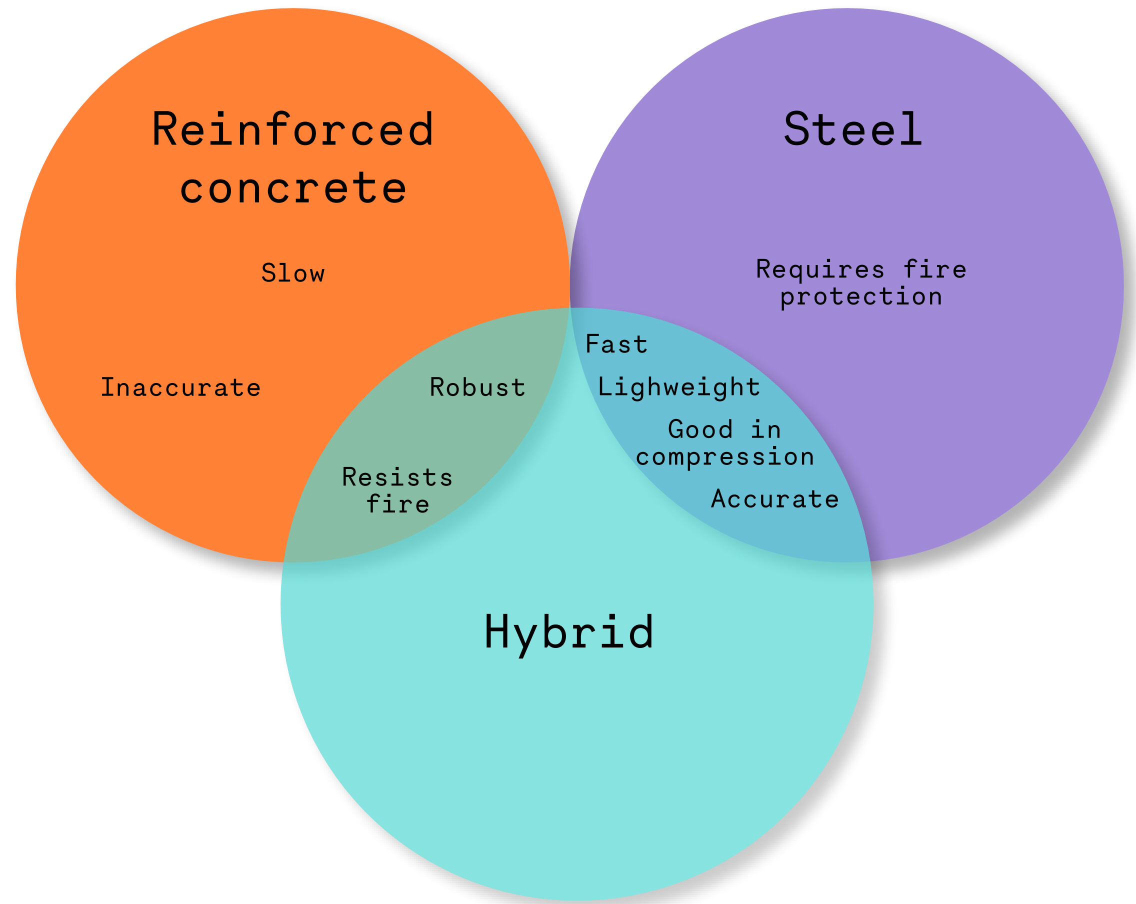
Concrete

- Good for compartmentation, it can meet fire and acoustic separation without additional layers/treatment.
- Mass is good for improve vibration behaviour.
- Good for slabs.

Hybrid

Platform II uses a mix of materials to leverage their best performance characteristics. Therefore it uses steel for columns and connections, and concrete for the slabs.

Lean principles to optimise the product



Applying lean principles to steel elements

Lean principles suggest the use of basic materials with the minimum amount of fabrication where possible.

In a traditional steel frame, only 30–40% of the cost is the material itself, i.e. the 'raw' material cost is multiplied by 2.5–3x through multiple handling and processing. Therefore, the fabrication should be limited where possible to stay as close as possible to commodity cost.

Within the Platform II superstructure, the majority of components use no, very low or low levels of fabrication (these can be thought of as 'dumb' components). These tend to be the large, heavy, commoditised elements including:

- Columns - standard square hollow sections (SHS) are used, since these use the most efficient distribution of material compared to I-beams or other steel sections. They require no 'fabrication' as such; a single hole is simply punched or laser cut in each column.
- Beams made using a standard rolled metal profile (metal coils are passed through a highly efficient, automated rolling process with virtually no waste, no double handling, etc.) as a permanent shutter for concrete.

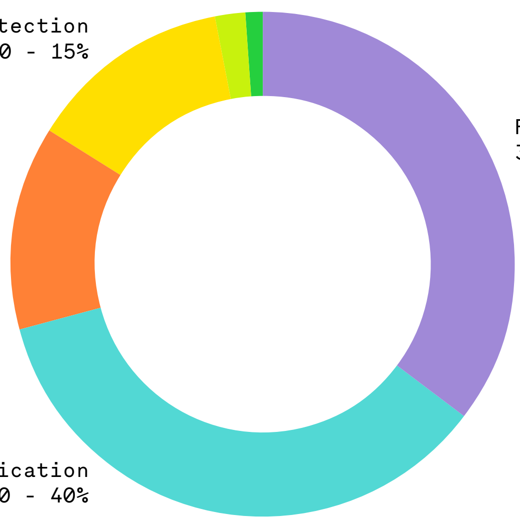
As much 'intelligence' as possible is then placed in the interfaces (e.g. bracketry which is self-locating to control tolerances and is colour-coded to ensure correct application, etc.) The 'intelligent' components are small, manually handleable and accurately mass-produced.

Separating 'dumb' from 'intelligent' components focuses the level of bespoke production on far less tonnage than designs for traditional steel composite or flat slab solutions.

This has significant cost implications - rather than passing the steel through multiple fabrication processes (and incurring significant labour, factory overhead and transportation costs) the residual asset value is very high since the conversion cost is very low.

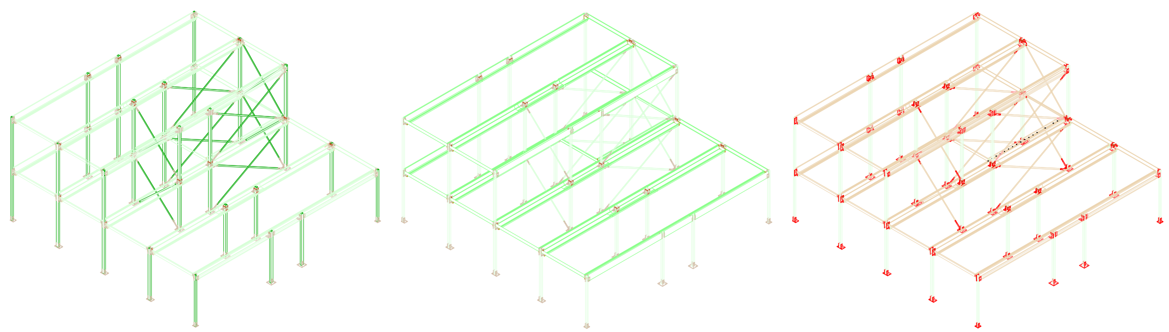
In addition, these intelligent, fungible components can be manufactured by a large number of small fabricators, creating opportunities to engage a local supply chain and to allow Small and medium-sized enterprises (SMEs) to contribute to major infrastructure projects.

Breakdown of costs for a traditional steel frame



Source:
Steel Construction Institute

Levels of fabrication in Platform II steelwork



Elements with no fabrication or very low level of fabrication.

Elements with low level of fabrication (bolted connections to elements).

High level of fabrication (welding and voids with bespoke production) for standard, repeatable connection brackets.

Ease of assembly

In the assembly phase, the use of low fabricated elements and connecting brackets removes the need for skilled trades. Instead of requiring specialist steel erectors, the frame can be bolted together by trained, competent operatives (this has been demonstrated in the prototyping phase).

Brackets are designed in a way that they can only be installed correctly (referred to as 'poka-yoke' in manufacturing) making it impossible for an error to occur or making the error immediately obvious once it has occurred.

In addition, the brackets are colour coded, with each colour relating to a specific condition, e.g. end bay, base of column, etc. Each colour is also linked to a series of standard tasks, such as a number of bolts and settings on the torque wrench.

In this way, the operatives need to match the colour with the type of interface. Quality assurance is visual and straightforward and the system ensures consistency and accuracy. It also ensures very high productivity, as operatives are not engaged in non-value-adding activities such as measuring, cutting, finding tools or materials which can reduce productivity on construction sites.

"Components making up these kits of parts can come from a range of suppliers whilst ensuring consistency of standards and quality.

The products to address the pipeline would be manufactured by a broad and disaggregated supply chain, creating stable and inclusive forms of employment."

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Image opposite: Platform II standard connection brackets Source: Easi Space.

Applying lean principles to concrete slab

Precast concrete

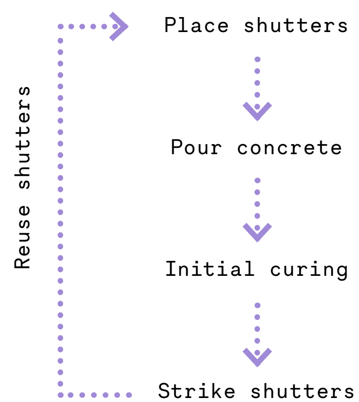
Although concrete is a low-cost commodity, the process of precasting adds numerous additional steps, costs and carbon into the process.

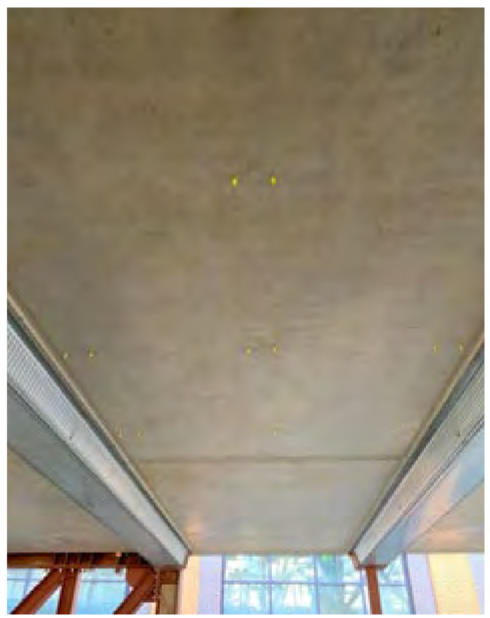
- It increases the cost of the raw material by a factor of 4 – 6.
- It uses tower crane hook time, introducing uncertainty in the process and potentially slowing down the installation since the crane becomes the rate-limiting step, and each lift may take 15 - 20 minutes.
- Requires additional steps on-site - typically it requires at least grouting, and very often a screed topping that may be 50–100mm. These are both wet trades.

Platform II concrete

- Platform II accepts that wet trades are very likely but simply achieves the complete concrete slab in a single step without the need for additional layers or processes.
- It can be pumped in situ eliminating the need for hook time. Large areas can be poured in a single process, so does not require additional layering.
- By using pumped concrete, Platform II gets closer to commodity cost.

Platform II concrete

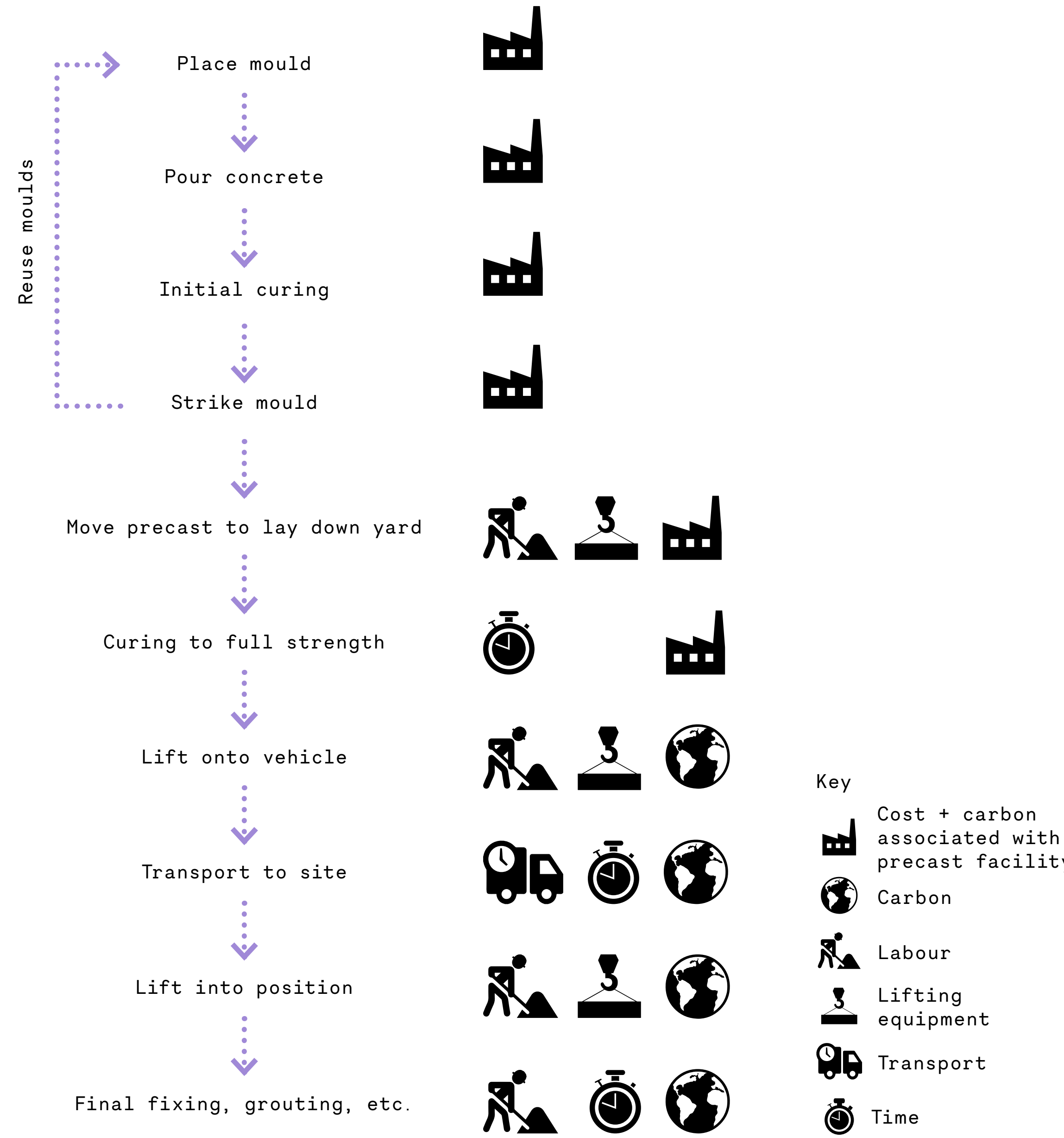




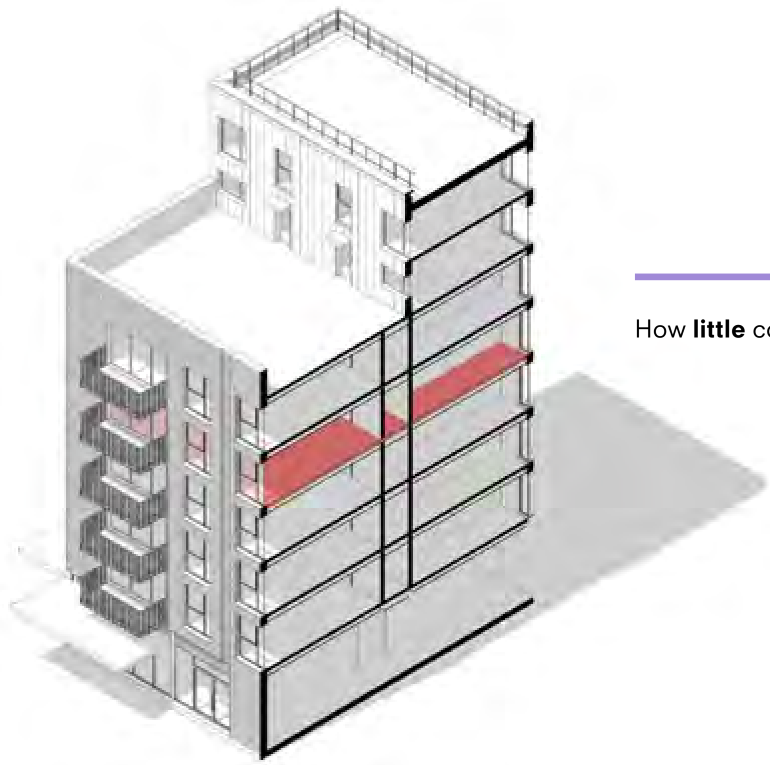
Completed soffit on-site. Note fixing points for MEP cast into slab

Additional cost + carbon associated with precast compared to Platform II

Precast concrete **Additional cost/carbon**



Applying lean principles to slab thickness



How **little** concrete?

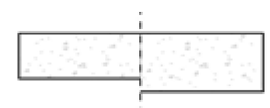
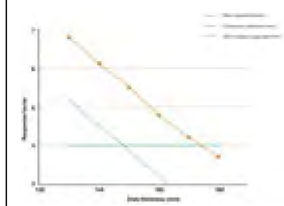
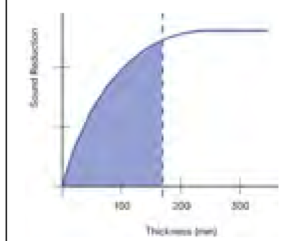
In line with lean principles, it is necessary to use the least amount of concrete possible.

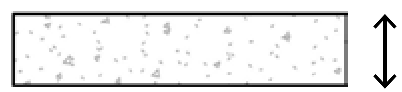
The minimum amount of concrete required for most fire, acoustic and vibration conditions is approximately 140 –160mm. Anything above this is a waste of material, carbon, labour, etc.

A typical flat slab for a residential apartment block may have a slab of 225mm or more, which means that approximately 50% of the material is unnecessary, contributing to excessive cost and carbon.

Following the 'least amount of material' principle, Platform II, therefore, uses a thin slab typically measuring 150mm (although for The Forge, the acoustic and vibration requirements meant that a slab of 140mm could be used).

Defining performance characteristics

Structure	Fire	Vibration	Acoustics
			
Minimum 2,400 kg/m³ for residential	Fire rating	Thickness vs response factor	Thickness vs sound reduction



Depth = 140 –160mm

Enabling a mid span using a thin slab

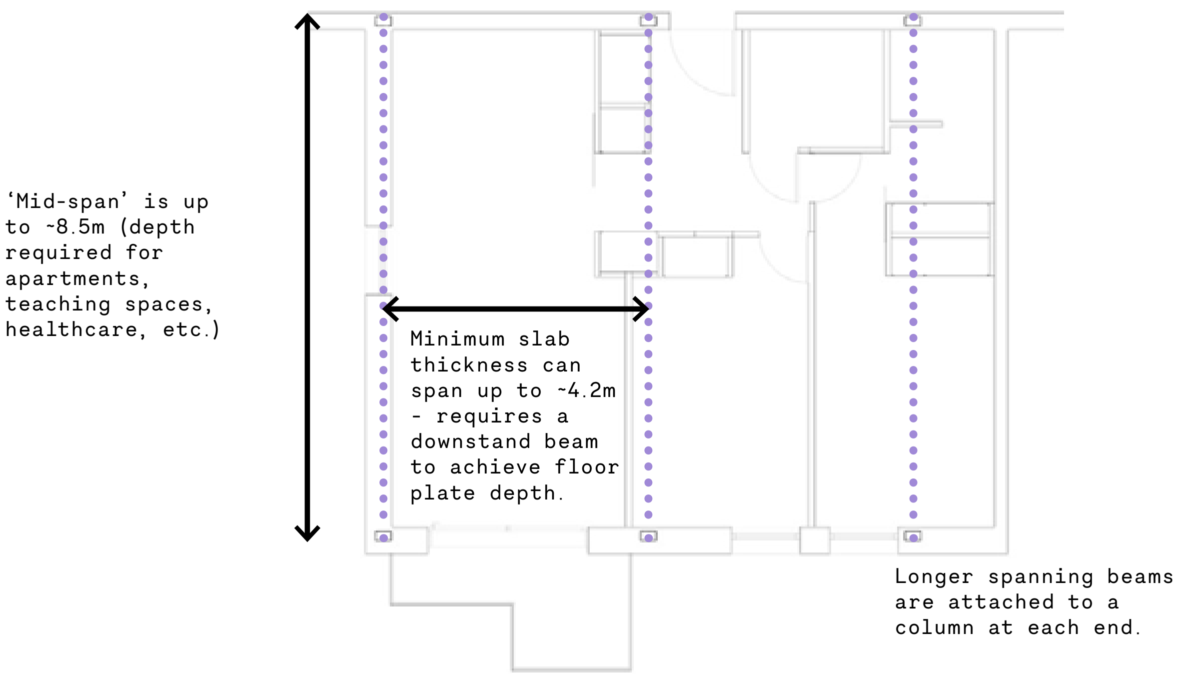
A 140 –160mm slab will only span approximately 4m, which is not sufficient for mid-span applications. Therefore, a longer spanning element, known as a downstand beam, is required to achieve the necessary spans of around 8.5 m.

Ideally, the downstand beam should be made of concrete to maintain material homogeneity and allow structural continuity between the slab and the downstand.

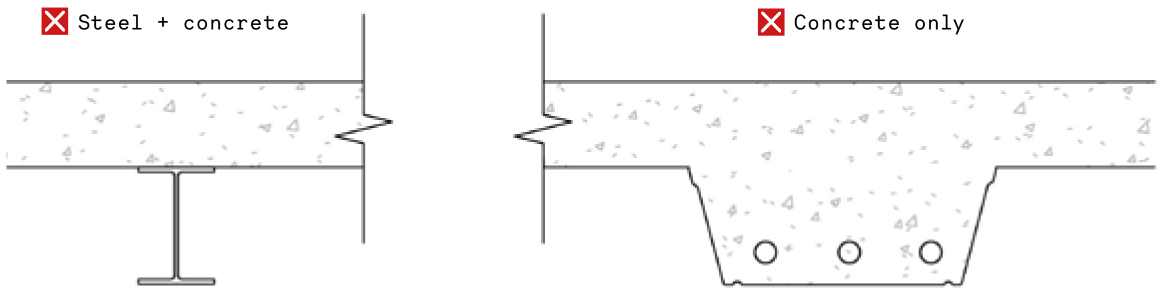
However, creating shuttering for a downstand is usually a labour-intensive activity on-site. A ready-made product already manufactured at scale and commoditised was required to solve this.

ComFlor, a solution for long-span composite decks already manufactured by Tata, was adopted for this purpose. It possesses a suitable profile and is produced at scale using a highly industrialised process, making it very low cost. However, rather than use it in its intended orientation, it is flipped over to form a permanent beam shutter for Platform II.

In the future, it may be worthwhile developing a specific Platform II profile, but the economies of scale achieved by Tata made this an easy first step.



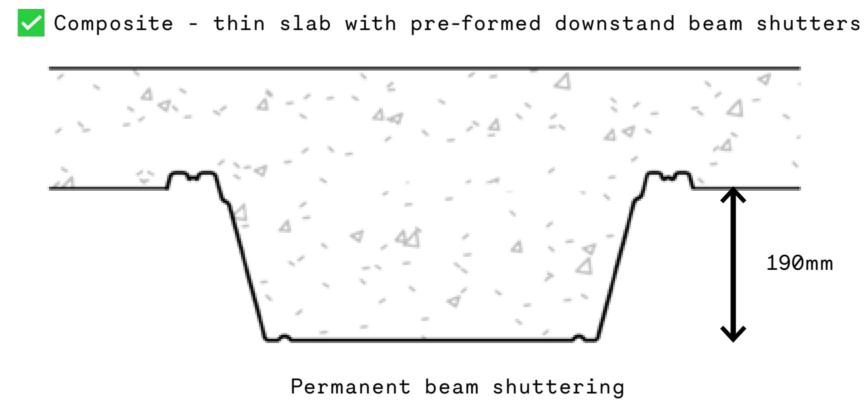
Creating a contiguous slab + downstand with minimum effort



Increased:
- Fabrication + erection cost of steel (see page 52).
- Carbon content.
- Depth of structural build-up.

Precast
- Increased time, cost, + carbon (see pages 56-57).

In-situ
- Increased time + cost associated with labour-intensive shuttering to create thin slab with downstands, OR;
- Increased cost + carbon associated with over-engineered slab (see page 58).



- Minimum material (and therefore cost + carbon).
- Minimum handling + labour (and therefore time + cost).
- Minimum structural build-up, with opportunities to integrate MEP within structural zone.
- Industrialised shutter manufacture ensures consistency + accuracy, and allows interfaces to be designed in.

Permanent shutter

Duct within void

Applying lean principles: steel columns

To take the load from the downstand beams, each one must be supported by a pair of columns, placed at approximately 4m intervals as dictated by the thin slabs.

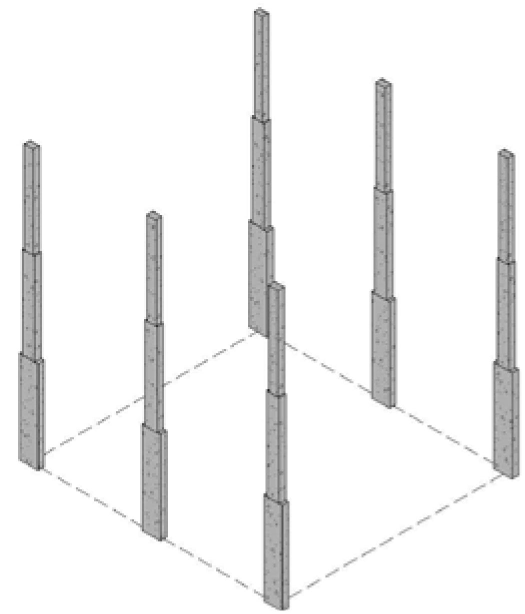
The hybrid superstructure of Platform II uses steel for the columns due to its high compressive strength, resulting in much smaller columns compared to a concrete equivalent.

Because columns are frequent, microcolumns (typically standard 150 x 150 square hollow sections) can be used. These can be built into the façade and internal partitions (especially corridor walls in residential, school and healthcare applications).

The microcolumns use a range of standard sections that have consistent external dimension but a selection of wall thickness. This allows the properties of columns to be adjusted on lower storeys, where there is a greater load by choosing the appropriate section variant. This maintains consistency of external dimensions, as opposed to concrete columns which increase in size down through the building, while also:

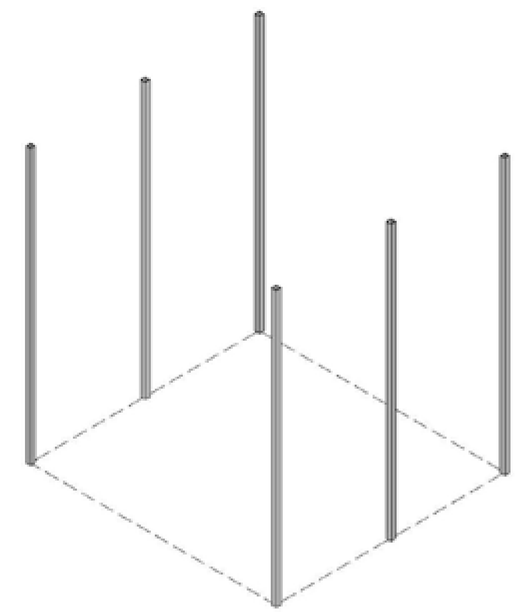
- Reducing impact on net to gross and internal planning, providing flexible floor plates.
- Using the least amount of steel for the supporting function required.
- Providing an inherent level of partial fire protection through encasement in the façade and party walls, which is enhanced with standard proprietary systems or products.

Benefits of steel micro columns vs concrete



Concrete blade columns

- Relatively large.
- Impact on net to gross and floor plate planning.
- Increase in size for lower storeys.



Steel microcolumns

- Small and unobtrusive.
- Improve net to gross and floor plate flexibility.
- Consistent section size.

Application

Platform II components

Common elements + processes

The development process resulted in a suite of common, repeatable elements that form the Platform II kit of parts.

- Permanent elements that form this superstructure.
- Temporary, reusable elements used during the construction process.
- Processes and equipment for lifting and placing components.

However, to truly eliminate waste, it was also necessary to develop methods of manufacture and assembly that would ensure efficient delivery, such as digital configuration and robotic fabrication.

For The Forge, these methods were delivered by our platform ecosystem partners.

Permanent elements

Microcolumns + slab edge beam

Brackets

Permanent beam shutters

Slab (with MEP fixing points cast in)

Temporary elements

Slab shutters

Stillages

Temporary props

Handrails pre-attached to microcolumns

Processes + equipment

Colour coding

Repeatable standardised tasks

Reach stackers

Modified forklifts

Complete suite of Platform II elements

Kit of parts

- Microcolumns.
- Beam/column connection brackets.
- Permanent beam shuttering with rebar cages and temporary works fixing brackets.
- Thin low-carbon concrete slabs with single layer reinforcement.
- MEP fixing points cast in.
- Façade interfaces cast in.

Design processes

- Automated configuration of digital components.
- Data flow into logistics, manufacturing + assembly processes.

Manufacturing processes

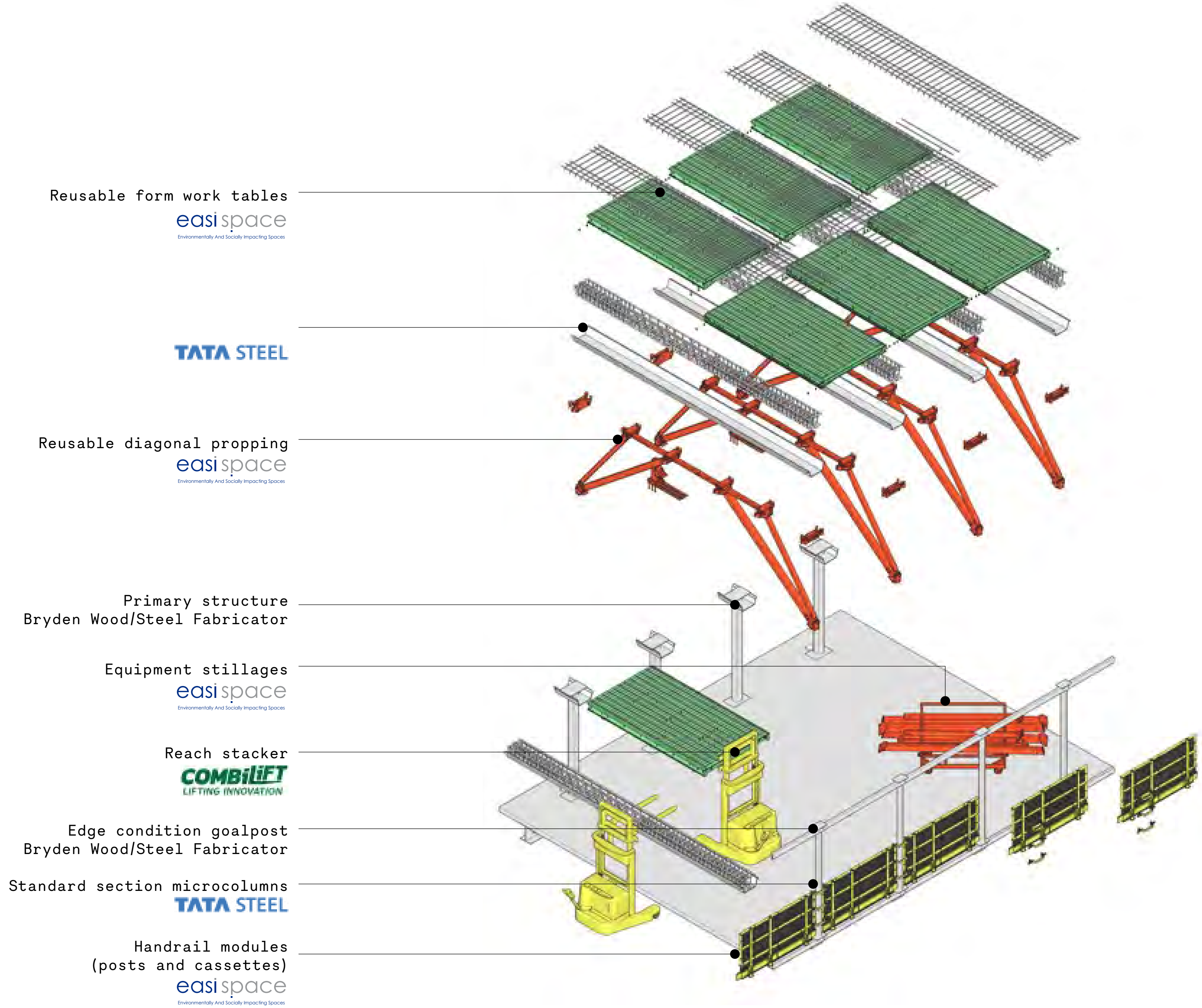
- Robotic cutting and welding of brackets and temporary works.
- Jigging and cutting of columns, beams and permanent beam shutters.

Assembly processes

- Colour coding for QA.
- Microcolumn pre-assembly including temporary handrails.
- Microcolumn lifting and placement.
- Permanent shuttering lifting and placement.
- Slab shuttering lifting and placement.
- Temporary works lifting, placement and striking.
- Temporary works reuse in the next bays/floors.

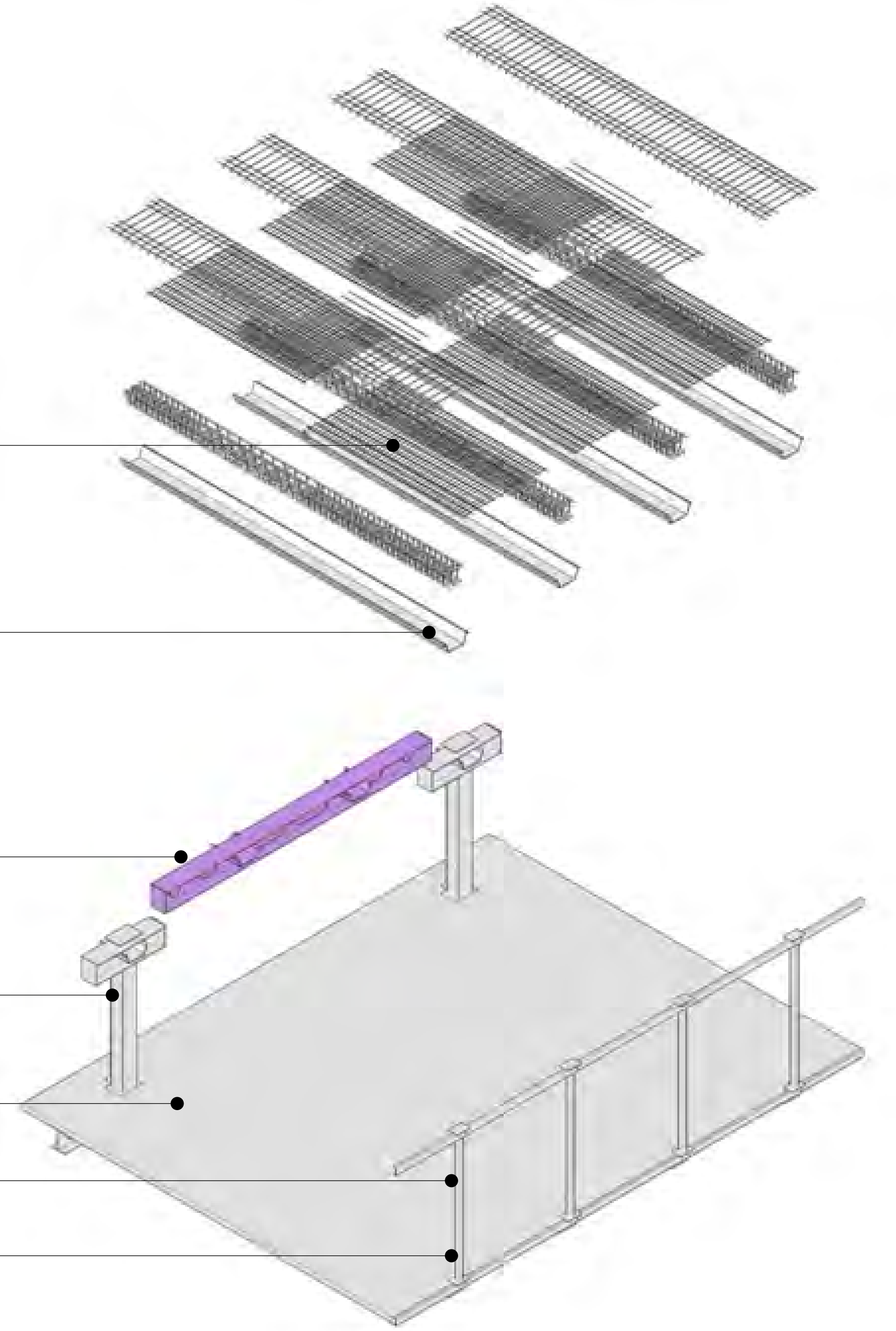
Equipment

- Reach stackers/modified forklifts for lifting permanent shutters, slab shutters and temporary works.
- Stillages for shutters and temporary works.



Permanent elements

- Microcolumns.
- Beam/column connection brackets.
- Permanent beam shuttering with rebar cages and temporary works fixing brackets.
- Thin low-carbon concrete slabs with single layer reinforcement.
- MEP fixing points cast in.
- Façade interfaces cast in.



Temporary elements

Temporary components

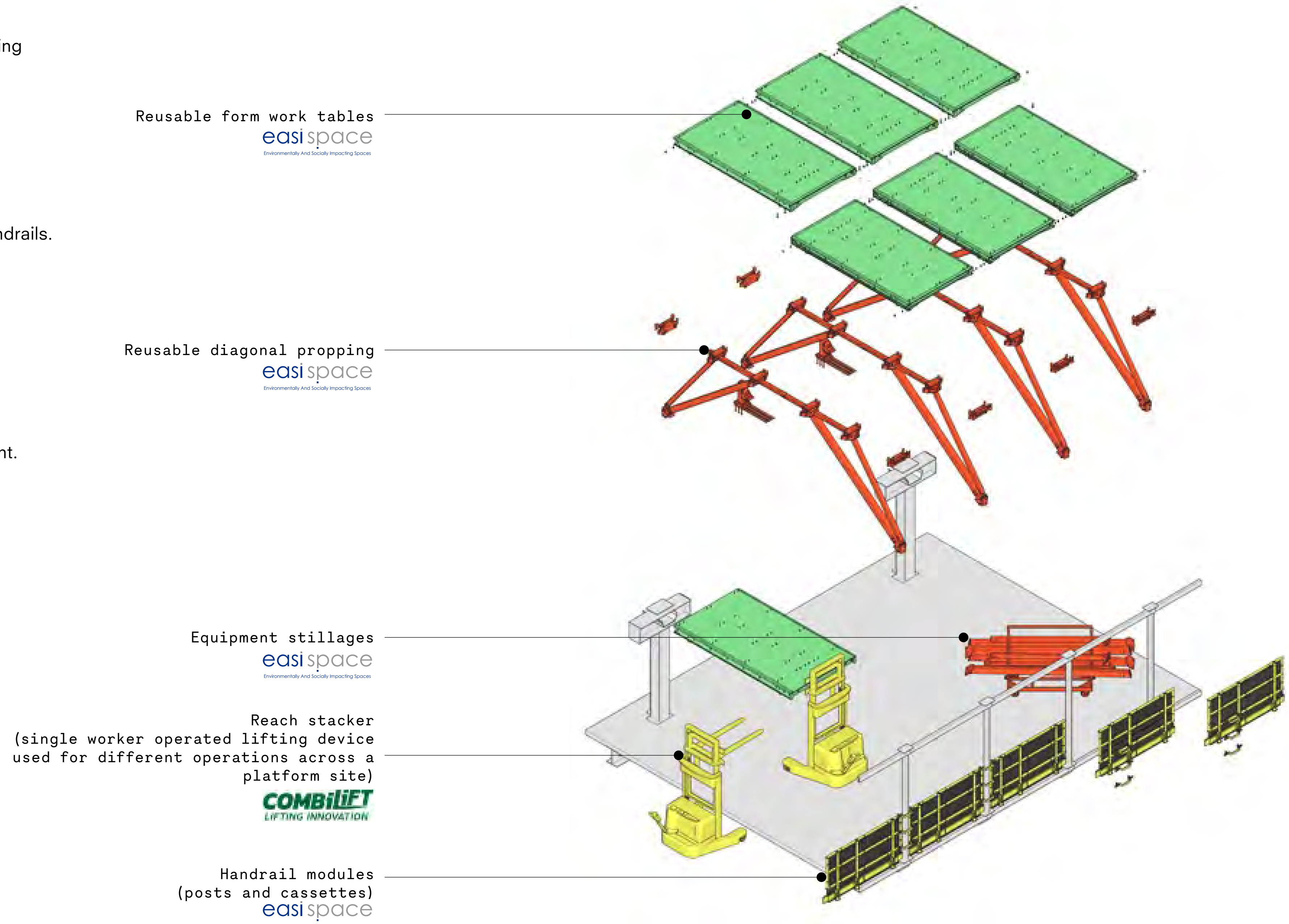
- Reusable formwork tables with pre-installed MEP fixing points.
- Temporary props.
- Temporary handrails.

Assembly processes

- Colour coding for QA.
- Microcolumn pre-assembly, including temporary handrails.
- Microcolumn lifting and placement.
- Permanent shuttering lifting and placement.
- Slab shuttering lifting and placement.
- Temporary works lifting, placement and striking.
- Temporary works reuse in the next bays/floors.

Equipment

- Reach stackers/modified forklifts for lifting permanent. shutters, slab shutters and temporary works.
- Stillages for shutters and temporary works.



"We were really impressed with how Bryden Wood's structural platform combined standard products in new and innovative ways to create such a lean and accurate frame. As a manufacturer working across sectors, it was refreshing to have the same sorts of conversations we usually have in automotive, but in a construction context. We look forward to working on future iterations of the platform and potentially developing new products that will further maximise the benefits already seen."

TATA STEEL

Matthew Teague
Market Engagement Manager
Building Systems UK
Tata Steel

"The platform superstructure allowed us to bring our fabrication and installation expertise to the fore, rather than being buried under a long supply chain. As an SME, we had a fantastic opportunity to partner with Landsec, the UK's largest developer, and contribute real innovation to The Forge, one of the UK's most advanced construction projects. Working alongside Bryden Wood, we were able to pioneer new technologies and techniques in an exciting learning environment. We are now the first people to hold BSI accreditation for robotic welding of structural components and have developed a range of skills which we can bring to other projects using the platform solution."

easi space
Environmentally And Socially Impacting Spaces

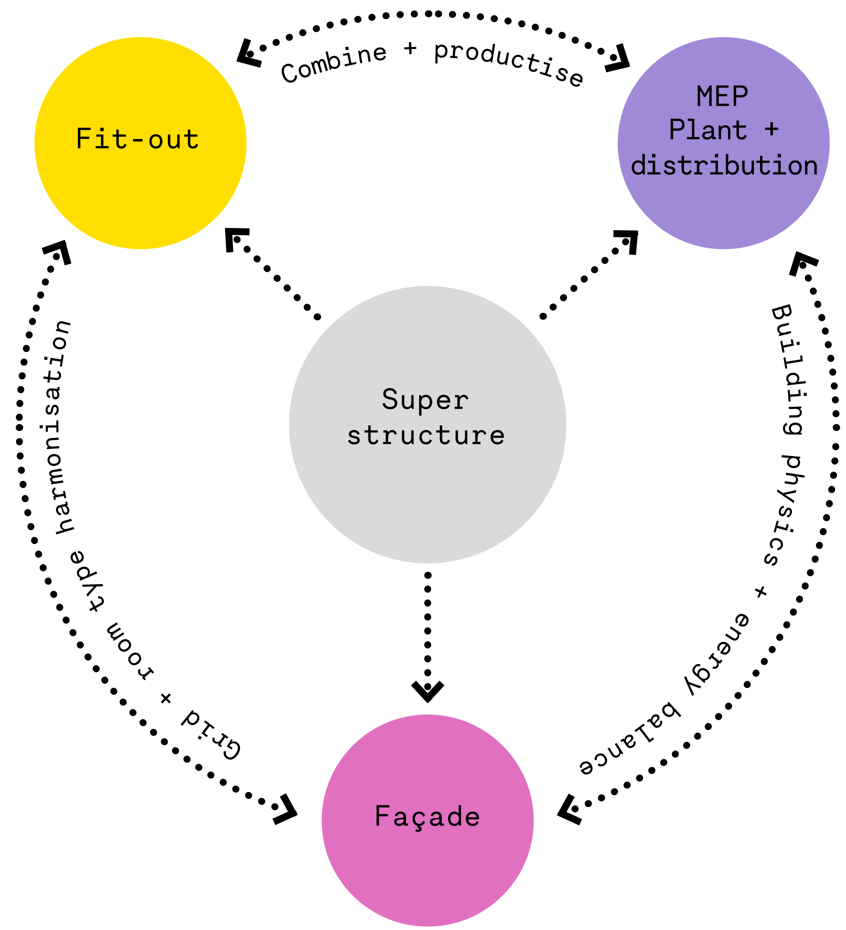
Richard Green
Director
Easi Space

Complementary elements

Platform II acts as a carrier frame, providing a stiff and accurate superstructure that allows suppliers of manufactured façade, MEP and fit-out systems to maximise the benefits of their own solutions.

By creating a high degree of accuracy and allowing interfaces to be pre-designed and delivered along with the superstructure, Platform II unlocks high levels of efficiency and productivity across the supply chain.

A range of complementary elements have already been developed and delivered on The Forge.



Complementary elements developed for Platform II

Permanent elements

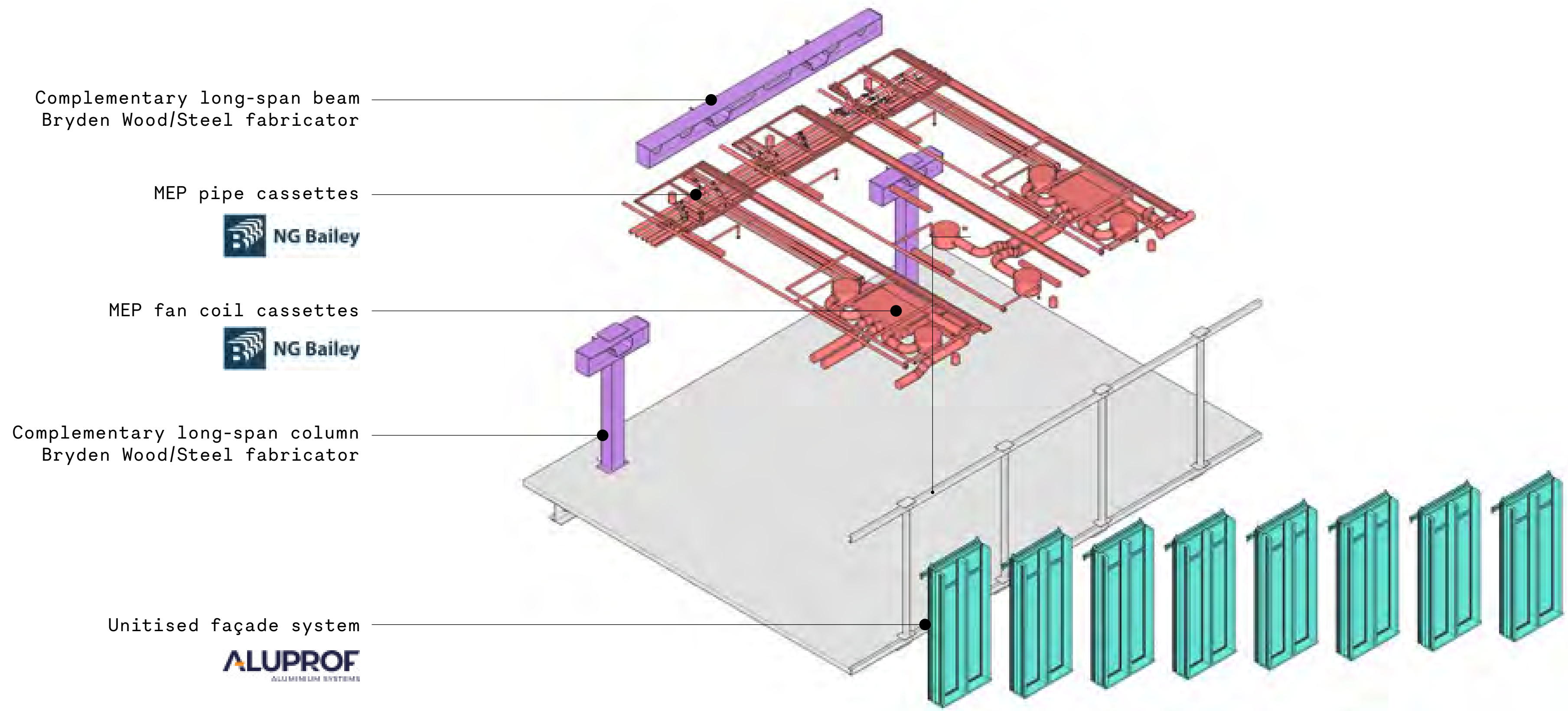
- MEP cassettes by NG Bailey.
- Façade panels by Aluprof.

Manufacturing + assembly processes – MEP cassettes

- Bench top working.
- Cassette stacking for transport and installation.
- Use of reusable spacers as part of MEP stillage systemInstallation using modified forklifts.

Manufacturing + assembly processes – façade

- Installation methodology for safe working behind edge protection.



"Working with Bryden Wood's structural platform enabled us to fully realise the potential of our Bradford facility deploying manufacturing processes. By engaging early and working with the team, we could ensure that the superstructure allowed us to do our best work, maintaining unparalleled levels of speed and productivity from assembly right the way through delivery and installation. The platform created a 'factory on-site' which allowed us to develop, test and perfect new ways of working. We look forward to further refining and innovating as this platform becomes more widely used."

Graeme Brady
Engineering Manager
Offsite Manufacture
NG Bailey

"It was great to be able to work with the Bryden Wood team and visit their prototype, which gave us a rare opportunity to see how the structure was designed to be so accurate and consistent. Developing the façade solution around the structural platform at an early stage, allowed us to really optimise the use of materials and detailing and create the most efficient units for handling in the factory and on-site. It also facilitated incredibly fast installation - on traditional projects up to 40% of installation time is spent on wasteful, unproductive activity. The platform allowed crews to work safely without the need for fall arrest systems – conditions under which they could install finished panels much faster than we've ever seen before."

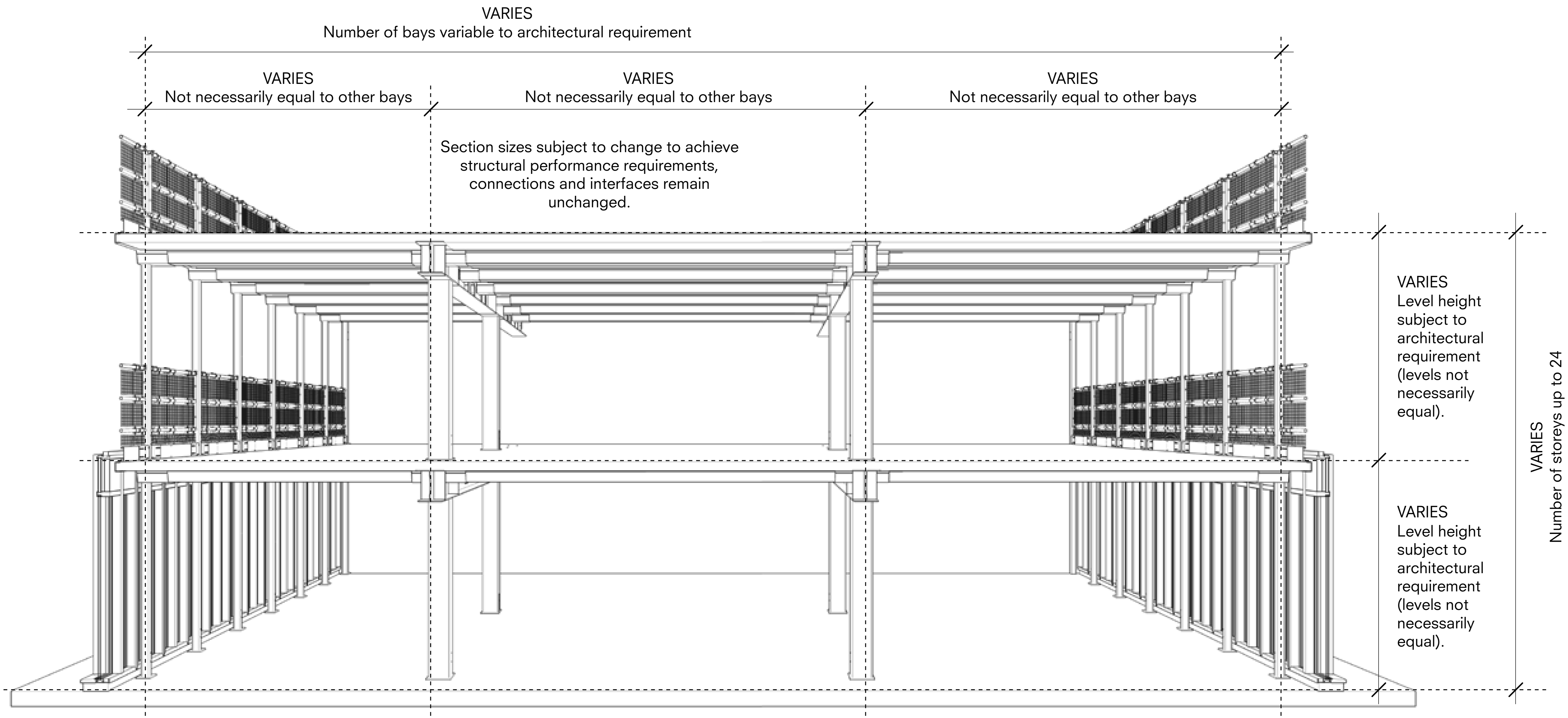
Wojciech Brozyna
Managing Director
Aluprof

Building configuration

Mass customisation opportunities of Platform II

Platform II allows flexibility for clients while still harnessing the benefits of standardisation:

- The column/beam interface + method of assembly are always the same.
- However, column and beam length can vary.



Examples of flexible configuration

"Platforms identify features of assets that could be shared… This approach provides the opportunity to create common 'kits of parts'… Harmonised cross-sector demand for these 'kits of parts' can enable their manufacture in high volume, with configuration allowing delivery of multiple asset types across sectors (e.g. schools, apartments, healthcare facilities).

[Components] can be designed to offer choices in assembly and support the widest range of architectural ambition and intended outcomes."

Transforming Infrastructure Performance: Roadmap to 2030

SINGLE SYSTEM

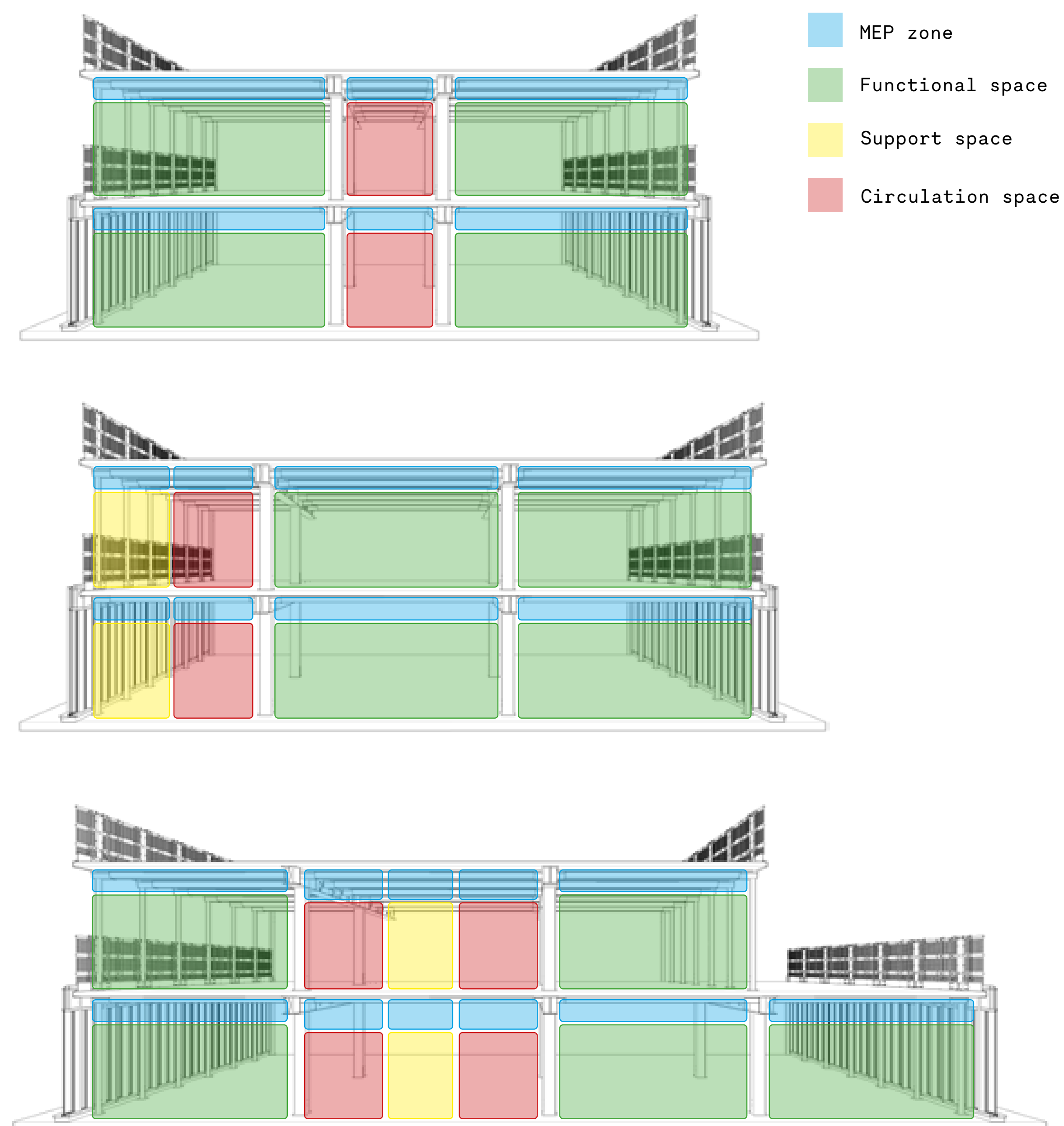
Example - Residential
(e.g. medium rise apartments)

Example - Education
(e.g. teaching block)

Example - Commercial
(e.g. open plan office)

Example - Healthcare
(e.g. hospital)

Sample configurations using Platform II



Structural design process

A series of span tables have been set up to provide quantities for concrete and reinforcement, based on slab performance requirements, including:

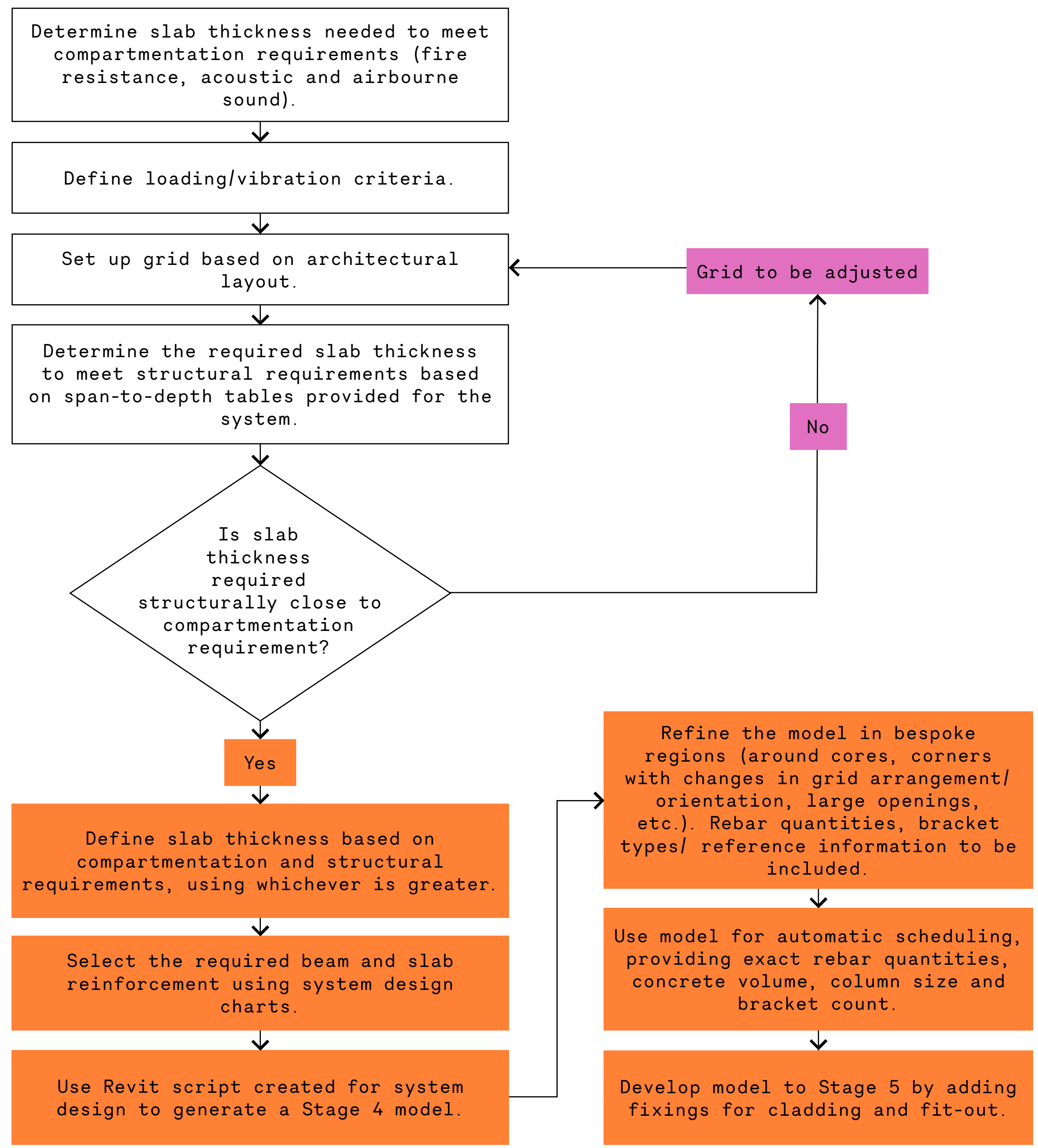
- Fire separation required.
- Acoustic separation required.
- Loading and vibration performance.
- Spans and grids.

This allows a very quick quantification for design development and estimation, without the need to commence from first principles on each project.

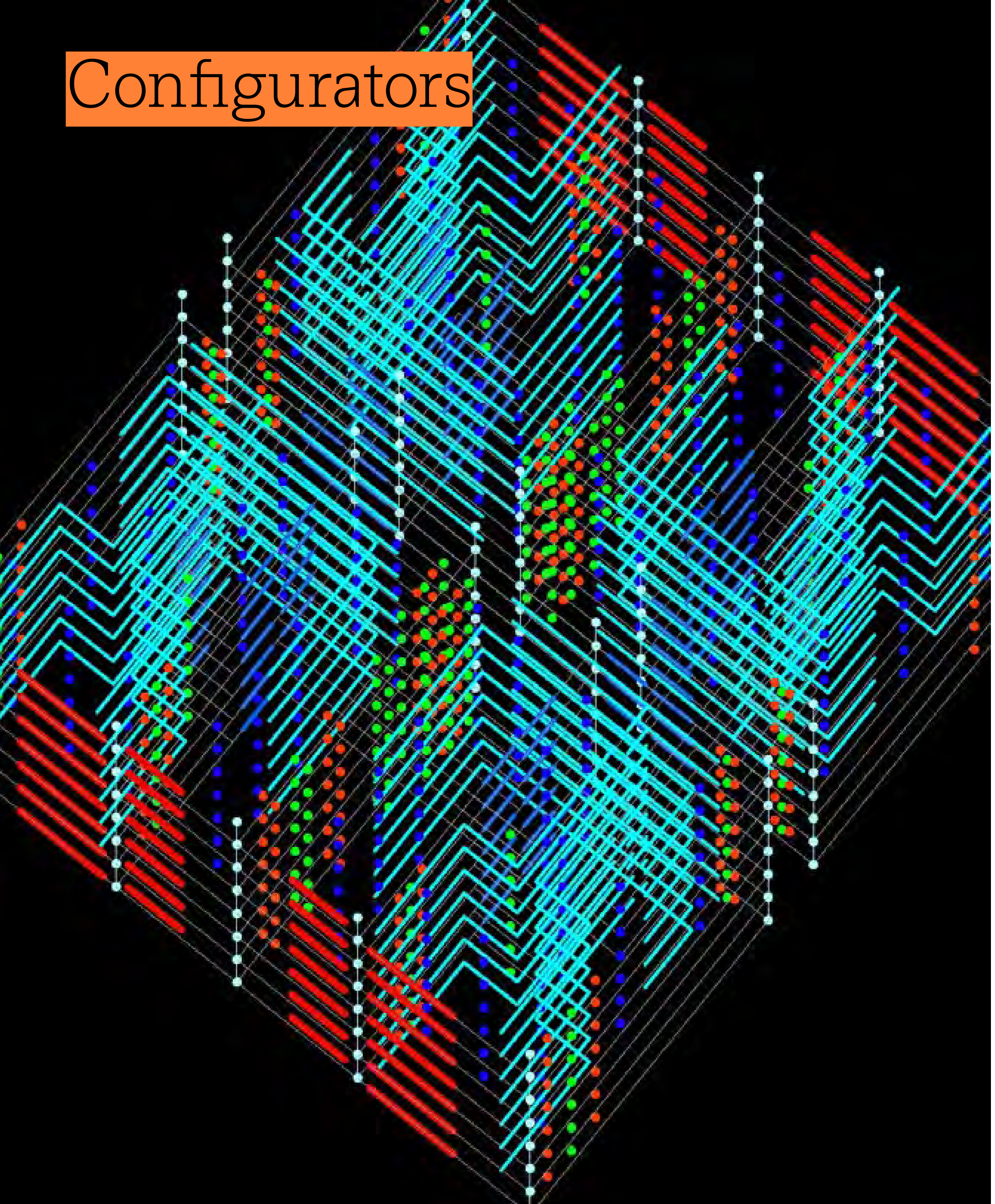
This is currently tabulated, but in future, the underlying rule set and logic will form part of a design configurator.

The flow chart on the right shows the decision-making process for deploying the tables.

Structural design flow chart



Configurators



"Some of the greatest design stage benefits of platforms will be realised through the use of applications referred to here as 'configurators' [citing Bryden Wood's PRiSM as an example]. These configurators marry the rules with component data in the digital catalogue to automate the generation of design, from a schedule of rooms to a digital asset model and could ultimately provide outputs such as a full cost breakdown or a list of approved suppliers. Configurators can result in much faster design and the consideration of a greater range of permutations. They can enable the involvement of local communities and professionals at earlier stages, and they can support the quality assurance process that enables the tracing and recording of critical data from design through to operation."

Transforming Infrastructure
Performance: Roadmap to 2030

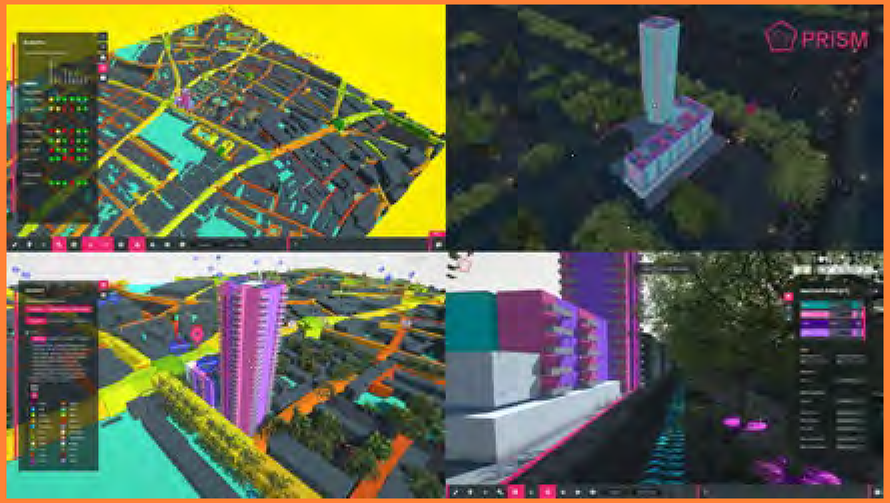
PRiSM

Bryden Wood developed PRiSM, a free-to-use housing design application that is open to all, and designed to help solve the shortfall in affordable homes. It has the potential to transform residential design and construction. PRiSM was developed to bring together central and regional government, funders, developers and manufacturers and drive a step change in productivity and quality in homebuilding. We worked in PRiSM with residential consultancy Cast, supported by the Mayor of London.

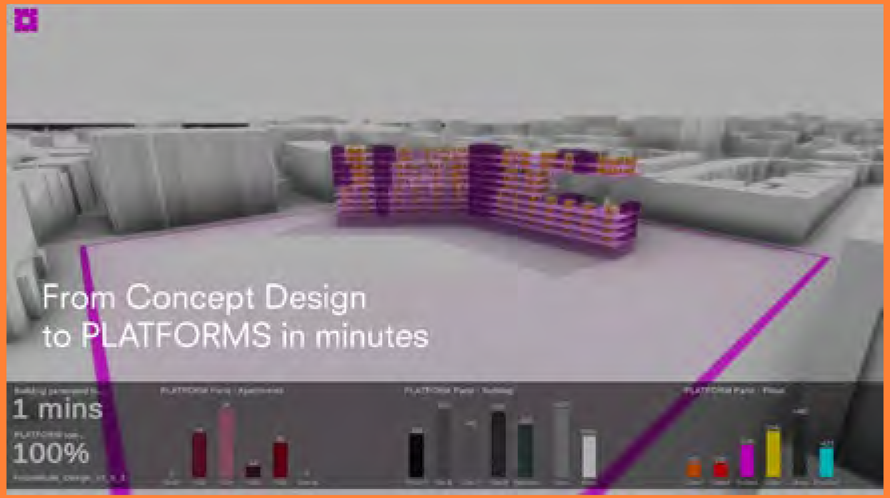
The free, easy-to-use and open-source app combines the Mayor of London's spatial planning rules with Precision Manufactured Housing (PMH) manufacturers' expertise to allow architects, local authority planners and developers to determine quickly the viability of developing a site using a variety of DfMA solutions, including Platform II, using multiple permutations of housing type and size. This accelerates the early design phase and allows designers to focus on the quality of the built environment.

This pioneering app launched in 2019, with a significant new version released in 2020.

Since its launch, Bryden Wood has developed an automated workflow that automatically generates a Building Information Model (BIM) using Platform II components (plus MEP and fit-out elements) directly from the model created in PRiSM. This was showcased at FutureBuild in 2020, with users being able to generate a scheme, and a complete LOD 400 model, from a blank site in under 30 minutes.



Click on the image to go to the PRiSM app



Watch the 'PRiSM to Platforms' workflow here

Assembly

Process

Platform II leverages the standardisation of its components to facilitate manufacture and assembly using a series of standard, highly productive tasks and routines, including automation.

> "Platform approaches deliver via a series of simple, repeatable, productive activities... A mixture of simple human operations, low complexity automation and lean manufacturing principles..."

Transforming Infrastructure Performance: Roadmap to 2030

The system is designed to reduce the delivery programme by 'telescoping' activities and allowing them to overlap. It does this by reducing or removing interdependency of activities, seeking to eliminate the traditional critical path. For instance, the superstructure allows work to start on floors just 24 hours after concrete has been poured, maximising the opportunities for active work faces.

Image opposite:
Temporary works kit for Platform II
Source: Easi Space.

Indicative section showing key assembly processes - superstructure, façade panels and MEP cassettes.

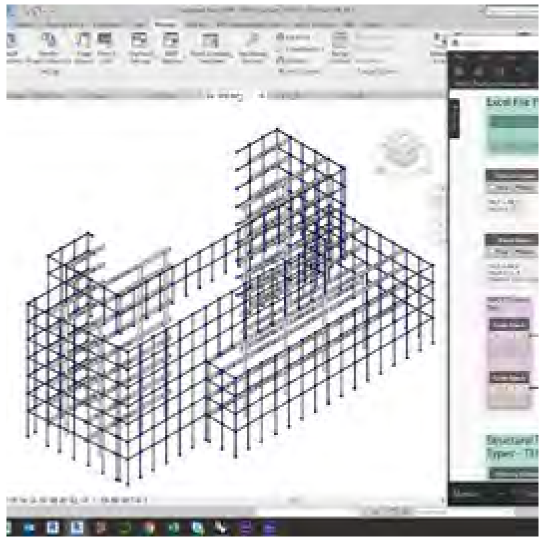
BIM automation

Before manufacture and assembly the configured design is used to drive an automated BIM work flow using a library of digital platform components.

Bryden Wood use a combination of typical construction software (Revit, Tekla) and platform-specific routines (in Grasshopper and Dynamo) to automatically generate a data set describing the position and orientation of every structural component by drawing on a digital library of standard columns, beams, connections and so on.

This data set is then used to:

- Create a complete bill of materials for pricing and procurement.
- Automatically generate the BIM model for coordination with the traditional-build elements, façade and MEP models i.e. the BIM model is one 'view' of the data set, not the other way around.
- Generate QR codes to identify individual components, so teams can track components from the factory through to installation.



Robotic fabrication

Repeatable, standard elements such as the brackets and temporary works are designed to be robotically fabricated directly from the digital library.

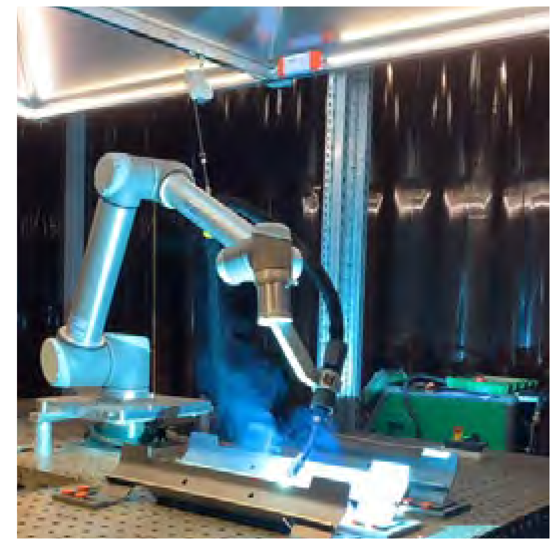
> Digital files from the model can be sent directly to the fabricator.

> This removes the need human for 'interpretation' of drawings, increasing speed, productivity, accuracy and consistency.

> Large numbers of components can be produced by relatively small SME organisations with the right capabilities.

SME Easi-Space worked with the British Standards Institute (BSI) to develop a standard for robotic welding of structural components. The exam and inspections were specifically developed for Easi Space's unit, since this is the first co-working robot to be set up in the UK. The certification to BSI and UKCA standards covers:

- Fabrication of structures and components for structures up to 15 stories high using steel, aluminium and stainless steel.
- Execution Class 2 welding - to be completed to ±0.4mm on steel and ±0.0 on aluminium.
- Certification is for the full factory control procedure including procurement, processing, fabrication, storage, Q&A and delivery with documentation at every stage.



Assembly sequence

1. Inboard columns are installed using mobile crane. The column head detail is already installed, including fixing brackets for long span beams.

2. Perimeter edge micro columns are installed, as ‘goalposts’, including the slab edge condition. Note that temporary handrails and toe boards are also pre-installed, ahead of any operatives working at height.

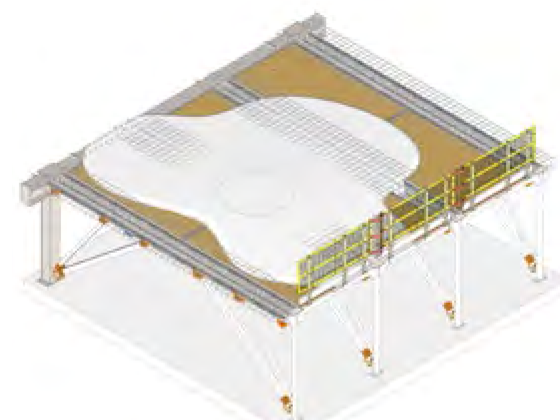
5. Permanent shutters, including rebar cages, are installed using reach stackers. The long-span beams have pre-installed, self-locating ‘shoes’ into which the shutters drop for accurate positioning. Temporary diagonal props are installed; laser cut components ensure accuracy.

6. Slab shutters are lifted into position using reach stackers. Shutters have reinforcement and fixings for MEP pre-installed before lifting. Reinforcement links are installed from a Mobile Elevated Work Platform (MEWP).

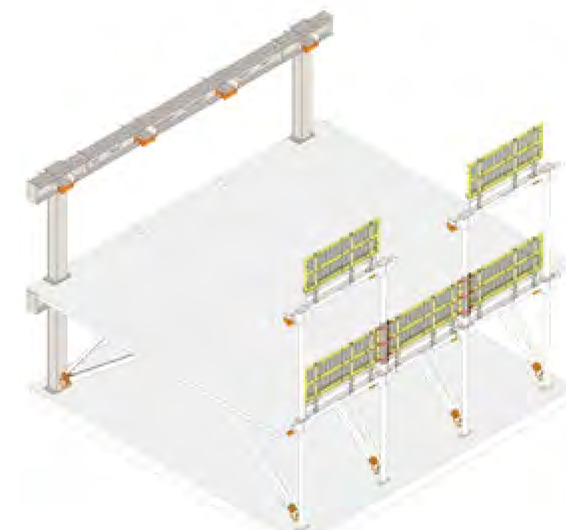
Watch the prototype assembly video here

3. Long span-beam is located using a mobile crane. The standard pattern of service provisions and cross-beam fixings are pre-installed. Operatives work in MEWPs to fix the beam to columns using bolted connections to the column heads.

4. Infills are installed between ‘goal posts’. This includes a ‘cage’ at upper floor microcolumn locations, which aids column positioning while maintaining edge protection.



7. Self-compacting concrete is pumped across the floor plate, creating the slab and filling the beam shutters to create a contiguous diaphragm. MEP fixings are encased in concrete.



8. After 24 hours, slab shutters can be struck and the process commences on the next floor. Pre-installation of edge protection ensures safe working on each of the upper floors.

Steel column installation

Microcolumn installation

Because columns are lightweight, a number of bays can be installed in a single operation in a 'goalpost' arrangement.

These can be located and fixed by a small team working on the floor plate.

Temporary handrails + toe boards

Temporary handrails are installed on the microcolumn 'goal posts' before installation, so they are already in place ahead of any work on the upper floor.

Temporary handrails and toe boards are designed to remain in position while the columns and façade are installed.

- This allows the façade team to work safely without requiring a fall arrest system tied back to the structure, which increases speed and productivity.
- Columns can be installed with the handrails in position (toe boards have a sliding section which opens up in column location) ensuring there is never a need to work on a leading edge without protection.

Microcolumns with temporary handrails installed at The Forge.

Watch the prototype assembly video here

Long-span beam + column 'goalpost'

One of the complementary elements created for The Forge was a long-span steel beam to increase the grid from the 'mid-span' to a 9m grid typical in commercial offices.

The long-span beam was subject to intensive design to minimise the amount of steel required, maximising the number of possible service penetrations. Once optimised, this beam was manufactured at scale, with the same beam used repeatedly. This leveraged economies of scale and assisted with logistics.

Long-span beam in place at The Forge.

Lifting equipment

Tower cranes are inefficient for the delivery of Platform II:

- Each lift can take approximately 20 minutes.
- They can be 'winded off'.

Platform II is designed to reduce reliance on tower cranes, which are used for 'bulk loading' of components onto a floor plate.

'Local' movement and installation are carried out using CombiLift 'reach stackers'. These are not typically used in construction but they are commonly used in storage and distribution warehouses worldwide.

They are used to lift and place permanent shutters, shuttering tables and MEP cassettes. They are the perfect equipment for the assembling of Platform II because they:

- Reduce reliance on tower cranes.
- Allow adjustment of the position of the forks enabling operatives to places the forklift close to the point of use and use finely adjust for forks for accurate positioning of a payload.
- Ensure accurate placement of components.
- Are agile and allow one or two operatives to move and place components efficiently.
- Allow a single operative or pair of operatives to work very productively without working at height.

Reach stacker being used to install shutters at The Forge.

Image opposite:
Reach stacker being tested at the Construction Platforms Research Centre
Source: Easi Space.

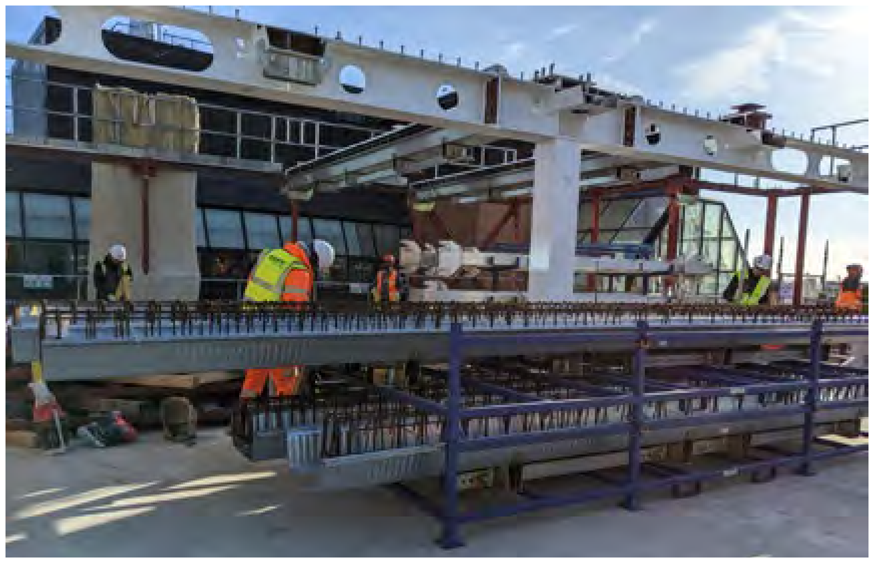
Installation of permanent beam shutters + temporary props

Permanent beam shutters

The ComFlor shutters have the rebar cages pre -installed, then a stack of these assemblies are delivered on a stillage.

The shutters are lifted and placed into position in the pre-designed and installed brackets. A single operative can then move the shutters into position using a reach stacker.

Inspection 'walkways' can also be pre-installed so that operatives are not required to walk across the rebar on-site.



Stillage containing multiple beam shutters with reinforcement cages pre-installed at The Forge.

Temporary props

Concrete is in its 'worst' structural state just after pouring – it has all of its mass but no structural capability. As a result, shuttering is required to hold the concrete beam shutters in place while it cures.

Traditionally, shuttering has to 'back prop' down through multiple floors to reach a floor which is sufficiently cured to support the floors above. This prevents these floors from being active work faces as they have a 'forest' of props.

However, Platform II uses steel columns that are already designed to support the weight of the concrete.

The system, therefore, uses temporary props that take the weight of the concrete back to a column, preventing the need for back propping. These:

- Are easily installed using simple installation processes.
- Are laser cut so they are self-locating and ensure an accurate and level superstructure.
- Provide large openings for moving materials around, freeing up the floor plate as an active work face much sooner (as fast as 24 hours after the concrete is poured).
- Take load the down into the permanent steel structure so do not require back propping down through multiple floors, freeing up floor plates sooner for following trades.
- Enable low embodied carbon solutions. Since they can be left in for longer periods, they facilitate the use of low-carbon concrete, which typically has longer curing times.
- Removes striking of props from the critical path.

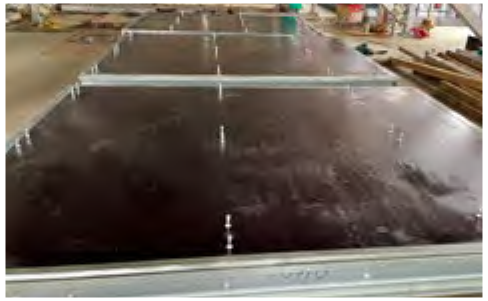
Temporary props in place at The Forge.

Installation of slab shutters + concrete

Slab shutters

Slab shutters are lifted and placed into position in the pre-designed and installed brackets using reach stackers.

- Because the shutter components are laser cut, they are highly accurate and ensure the slabs are square.
- Fixing points for MEP are pre-installed on the shutters, creating a repeatable pattern of accurately positioned fixing points that will be cast into the slab.
- There is an overprovision of fixing points since the same pattern is used in every bay. This standardises the components and processes in the manufacturing and assembly phase, and provides future flexibility for changes to building use or MEP systems.
- Because the slab is thin, it only requires a single layer of rebar, reducing site work.



1. Shutters prior to installation - MEP fixing points are visible.

2. Shutters in place working at height.

3. Stack of shutters being installed using a reach stacker.

Concrete

The concrete chosen for Platform II is low-carbon (40% ground granulated blast-furnace slag [GGBS]) and self compacting:

- It can be pumped from below, eliminating the need for work at height, or above if required.
- The pre-installed handrails and walkways allow the concrete to be safely inspected from above without walking on the rebar.
- 'Converge' sensors are installed in the slab, accurately reporting the strength of concrete and allowing early striking of shutters.

If required, a robotic levelling device can be used, or the final finish can be made traditionally.

Once the concrete has cured (after typically 24 hours, as shown by the sensors), the shutters can be struck and reused further up the building.

4. Completed slab soffit, with MEP fixing points visible.

Cross-sector application

Residential

To understand the requirements of the residential sector, it is helpful to categorise these systematically. The diagram on the right identifies factors which require distinct differences in technical performance, including fire, acoustics and access to natural daylighting. Moving out from the centre, the first key differentiator is:

The presence of a core

- If there is no core, then the asset is a type of house.
- If there is one core, it is a tower.
- If there are multiple cores, it is a multi-occupancy typology.

This makes a crucial difference in all sorts of ways. For example, the fire and acoustic separation required by the floor in an apartment building, separating different households, is more onerous than in a house.

The presence of party walls

A house with no party walls is detached, while a house with party walls is semi-detached or terraced.

The next factors are:

- Number of storeys (which trigger differences in fire strategy at a certain height).
- Number of aspects (needed for larger apartment types).
- Location of circulation (deck access vs central corridor, leading to double- or primarily single-aspect apartments).

Using this categorisation, it may be suggested that houses are more suited to a modular approach as opposed to a platform solution.

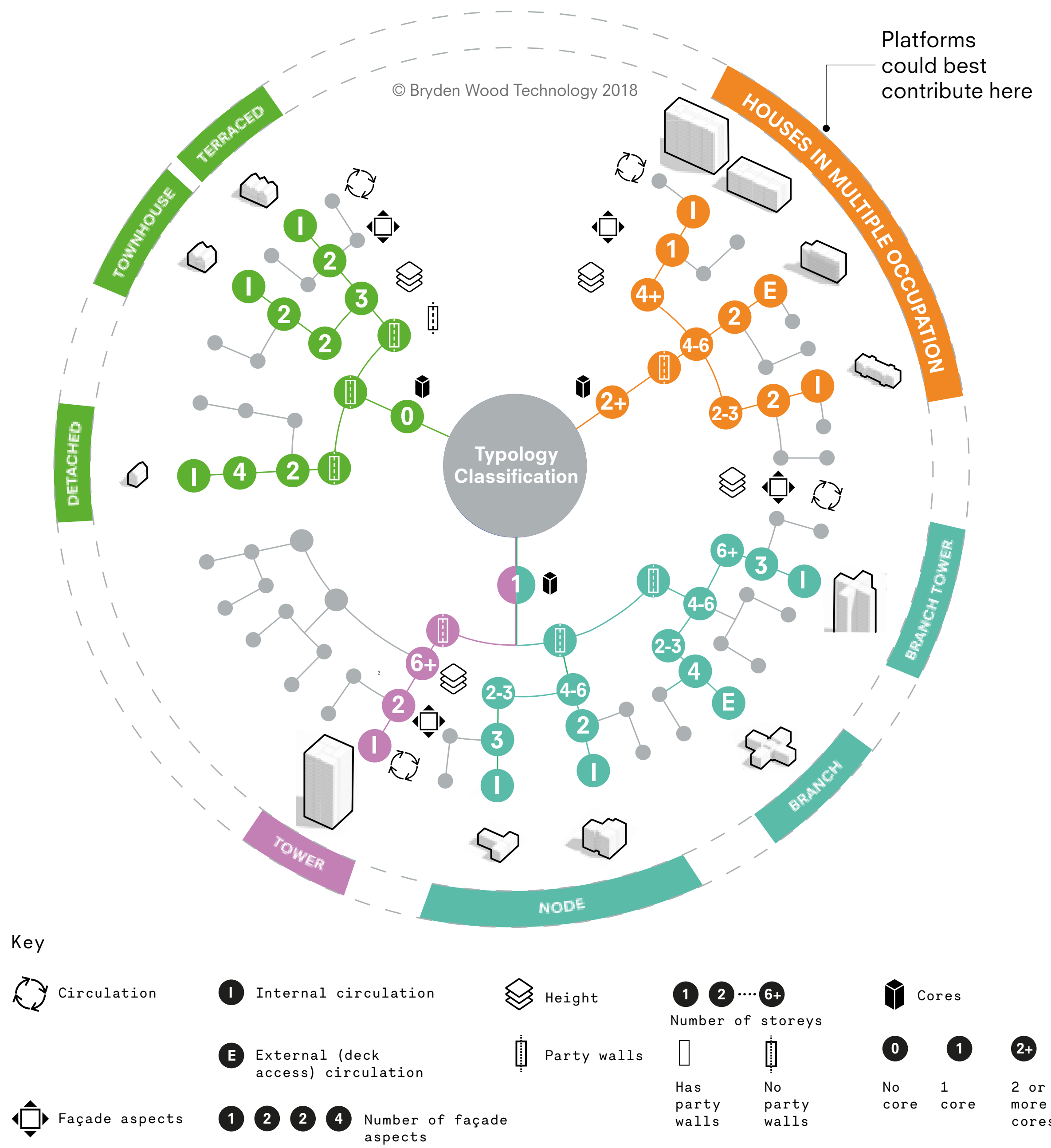
However, a platform solution would be well-suited to multiple occupancy apartment blocks. These often have a central corridor, with flats on either side spanning up to 8m. Typologically, this is not unlike, for example, a teaching block, which will also tend to have a central corridor with an 8m span either side.

In 2020, Bryden Wood used figures published by the UK government, and applied to this categorisation. It estimated the addressable market for the residential application of Platform II to apartment blocks delivered by Housing Associations or Local Authorities to be £1.4 billion in the UK market. Extrapolating this globally and it suggests there is a huge opportunity for the application of this solution.

Read more about platforms and the residential sector

Residential – a complex market that calls for a range of construction solutions

Categorisation of technical factors for residential



Residential: Platform II vs flat slab

A number of residential schemes originally designed as flat slabs have been redesigned using Platform II to undertake an analysis of the material quantity benefits.

This exercise showed that Platform II reduces the quantity of both steel and concrete compared to a traditional concrete frame.

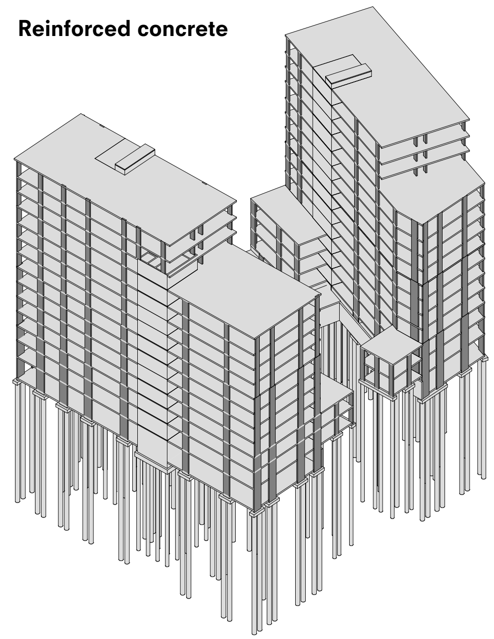
It also demonstrated another key benefit. The microcolumns used in Platform II provide consistency of external column dimension over approximately 12 storeys, while optimising the placement of material and steel. In contrast, concrete columns increase in size for lower storeys.

Over 12 storeys, the next standard section size can be used used, which allows for increased width while maintaining a narrow depth for concealment in façades and party walls.

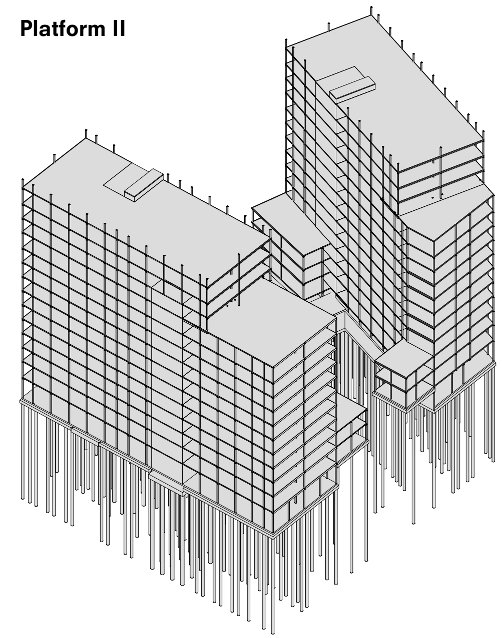
This facilitates open floor plates with freedom of internal planning, both for 'day 1' and for future refurbishment. The layout of large columns does not impinge on or dictate the position of internal walls, since the micro columns are concealed in the façade and corridor walls.

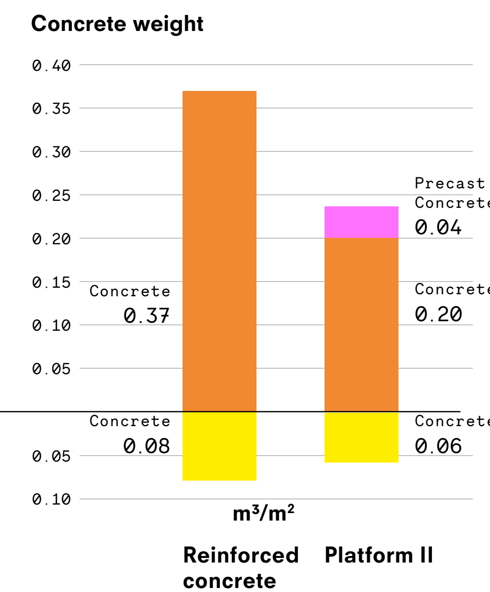
Material comparison for Platform II vs flat slab

Reinforced concrete



Platform II





Residential: Sectional efficiency

By closely integrating the MEP services with the superstructure (using the depth of the downstand to accommodate ducts, cable trays and lighting), Platform II allows very efficient floor-to-floor heights to be achieved, which has obvious advantages:

- Potential for more storeys within a given planning envelope, increasing the profitability or viability of schemes.
- Reduced overall building volume and, therefore, less energy required to heat and cool the building.
- Reduced material use in façade and internal walls.

Downstand

Thin low-carbon slab

A manufactured MEP cassette sits under and is attached to each downstand. This cassette contains all MEP that is usually ceiling mounted:

- MVHR supply and extract duct
- Small power
- Downlighting
- Fire detection and alarm

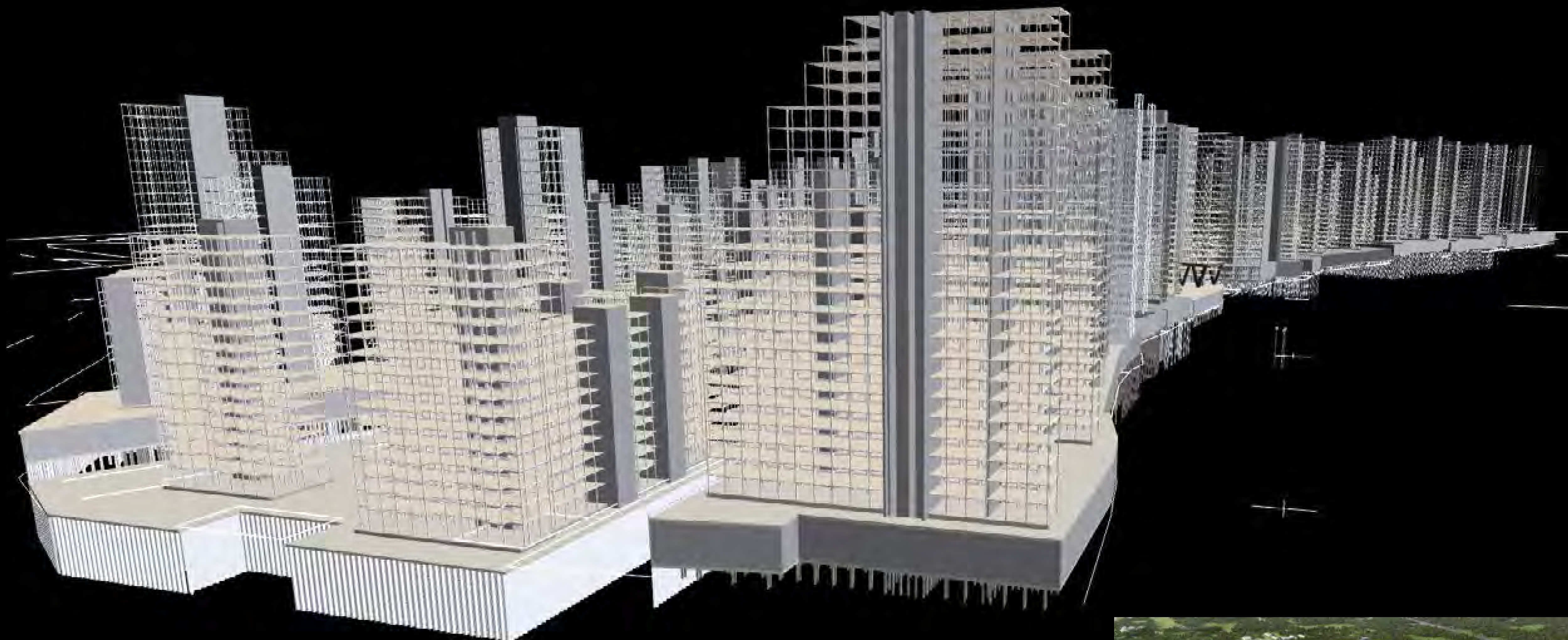
This prevents the need for any work at height or drilling into the slab. The manufactured cassettes can be lifted and attached using standard equipment, as demonstrated on The Forge.

At least one cassette serves every room providing fresh air and lighting.

Since the ceiling assembly would form an element of the kit of parts, it is possible to introduce features such as pelmet lighting at no extra cost. These are relatively expensive to achieve traditionally and are usually associated with higher specification residential projects.

Typical floor-to-ceiling heights (2.65m) could be achieved within very low floor-to-floor heights (2.85m), making schemes highly compact.

Residential at scale



A combined superstructure model for ~15,000 apartments, using the same limited, repeatable kit of Platform II parts in large quantities.

Proposed development with a range of architectural typologies up to 24 storeys.

Education

Platform II has been applied to a number of education schemes, including a DfE 'GenZero' standard teaching block.

The results show that the Platform II design provides a significant reduction in embodied carbon below the LETI 2020 target and, using the worst case calculation values, is on par with the 2030 target.

Embodied carbon calculations for Platform II superstructure

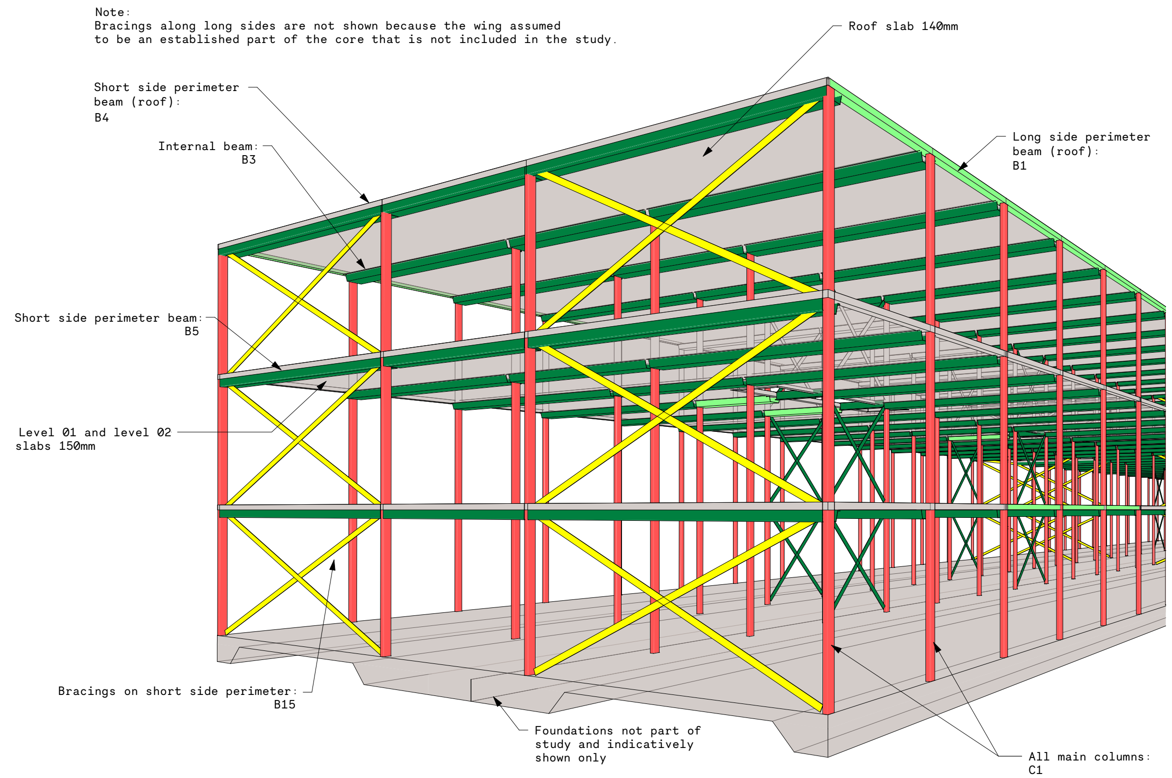
	Methodology 1 A1 - A3 ($kgCO_2e/kg$)	Methodology 2 A1 - A3 ($kgCO_2e/kg$)	Methodologies 1 + 2 A4 ($kgCO_2e/kg$)	Methodologies 1 + 2 A5a (kgCO2e/kg)	Methodologies 1 + 2 A5w ($kgCO_2e/kg$)
Concrete	0.103	0.150	0.005	0.002	007
ComFlor	1.790	2.750	0.096	0.014	0.019
Plate steel	1.790	1.790	0.096	0.014	0.019
Hot rolled steel	1.790	1.790	0.096	0.014	0.019
Reinforcement	1.337	0.647	0.096	0.007	0.077

	Product Stage A1-A5 (tonnes CO_2e)	Product Stage A1-A5 ($kgCO_2e/m^2$)	Weight (kg/m^2)
LETI benchmark 2020	1089.4	180.0	
LETI benchmark 2030	635.5	105.0	
Methodology 1	436.7	80.3	282
Methodology 2	524.5	86.7	282

Methodology 1 uses standard embodied carbon values provided by the DfE.

Methodology 2 uses databases which is more relevant to Platform II. For example Environmental Product Declaration (EPD) for ComFlor permanent shutters, carbon data from the concrete mix trialled in the platform prototypes centre and EPD for rebar with highly recycled content. The assumptions provided by DfE apply to other materials such as hot rolled and plate steel.

Material weights for Platform II applied to education

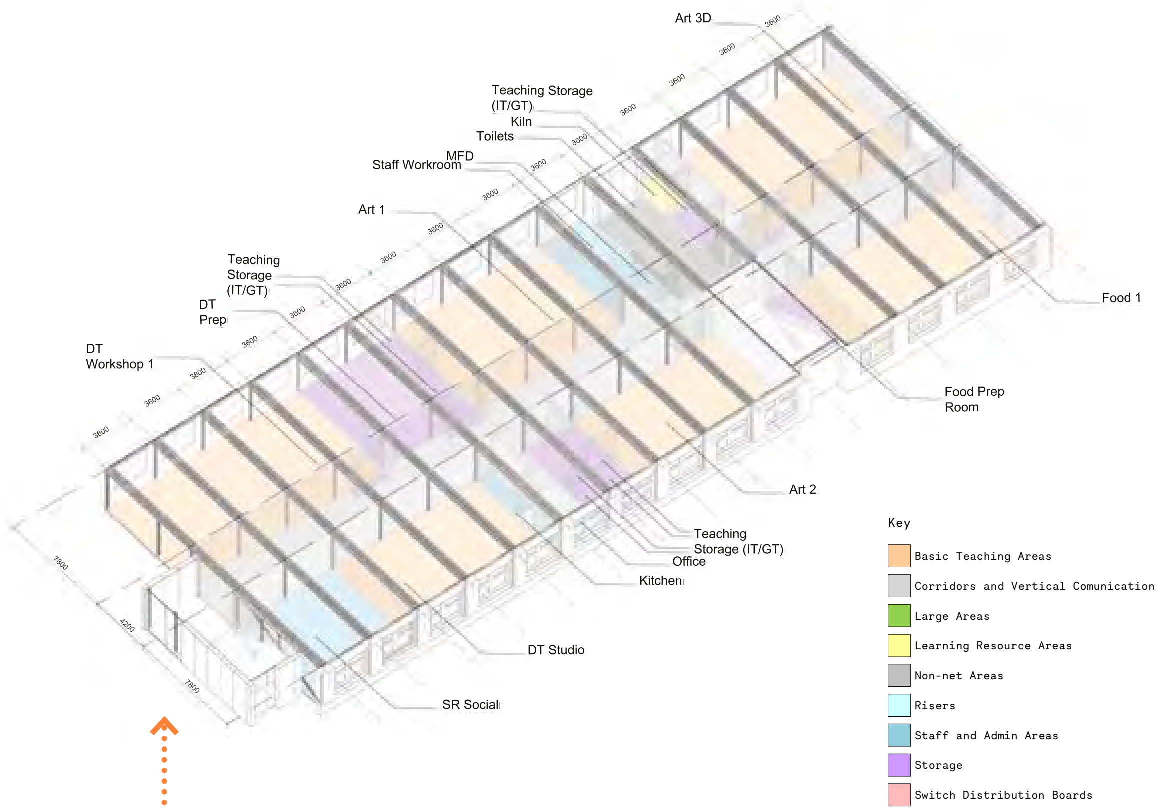


Key

- Weight of element 0-50 kg
- Weight of element 50-100 kg
- Weight of element 100-200 kg
- Weight of element 200-300 kg
- Weight of element 300-600 kg
- Weight of element 600-800 kg
- Weight of element 800-1000 kg

Education: Sample secondary school

Platform II has also been used to develop complete schemes for secondary schools. Given the degree of rationalisation within the existing DfE design standards, it is not surprising that Platform II is ideally suited to this type of social infrastructure.



Platform II applied to secondary education

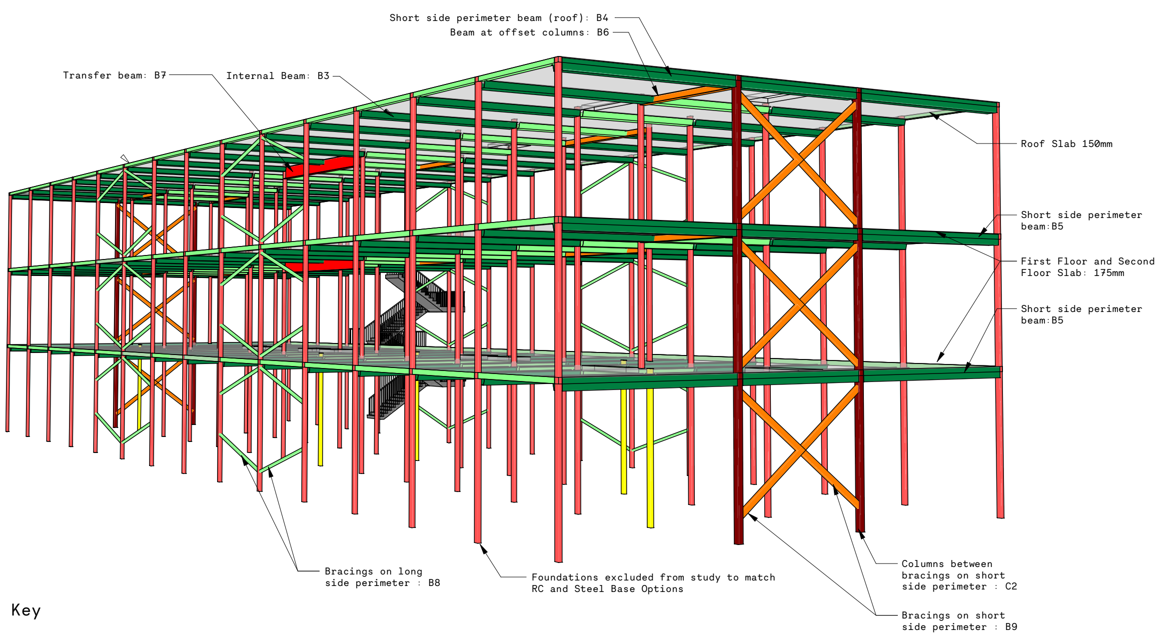
Aerial view of secondary school teaching block.

Courtyard view of secondary school teaching block.

Healthcare

A number of healthcare schemes have been redesigned using Platform II to analyse the material quantity benefits. The breakdown of results on the right shows a reduction in the quantity of both steel and concrete.

Material weights for Platform II applied to healthcare

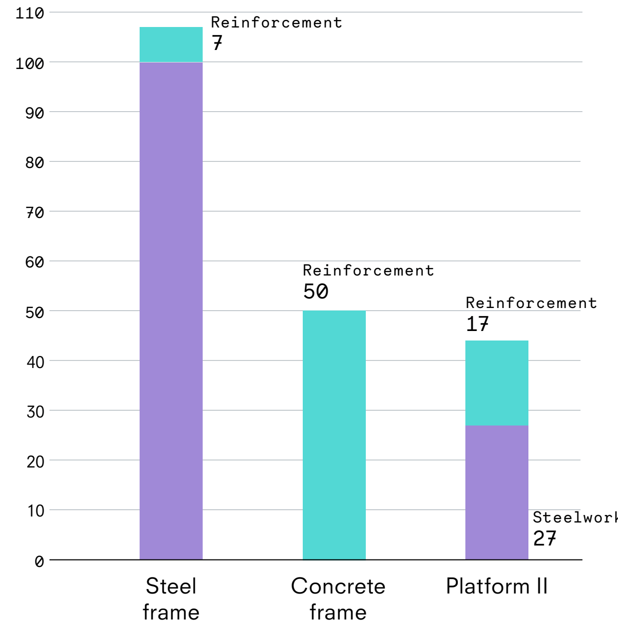


Key

- Weight of element 0-50 kg
- Weight of element 50-100 kg
- Weight of element 100-200 kg
- Weight of element 200-300 kg
- Weight of element 300-600 kg
- Weight of element 600-800 kg
- Weight of element 800-1000 kg

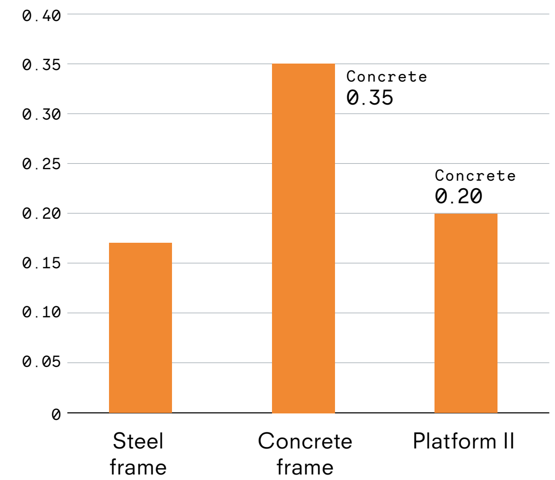
Material weights for Platform II compared to steel frame and concrete frame

Steel weight



Average kg/m²

Concrete weight



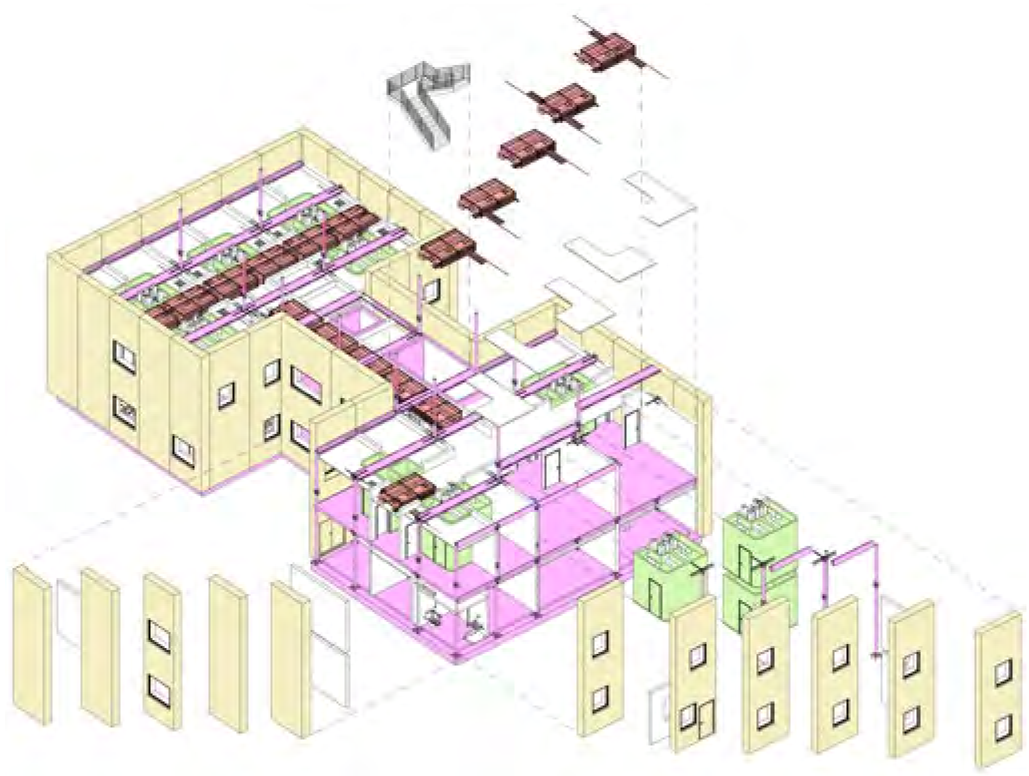
Average m³/m²

Approximate superstructure quantities (all as averaged sum including floors columns and walls per m²)	Steel frame	Concrete frame	Platform II
Steelwork	100 kg/m²	-	27 kg/m²
Reinforcement	7 kg/m²	50 kg/m²	17 kg/m²
Concrete	0.17 m³/m²	0.35 m³/m²	0.20 m³/m²
Other main costs to consider	Fire protection	Shuttering Higher foundation cost	(Reusable shuttering)

Custodial estate

Having initially been developed for multi-function facilities (healthcare, education, offices, etc.) within the MOJ, Platform II has also been used to develop designs for other custodial facilities such as the low-risk estate, demonstrating low embodied carbon in line with MOJ's sustainability aspirations.

Platform II applied to the low risk custodial estate

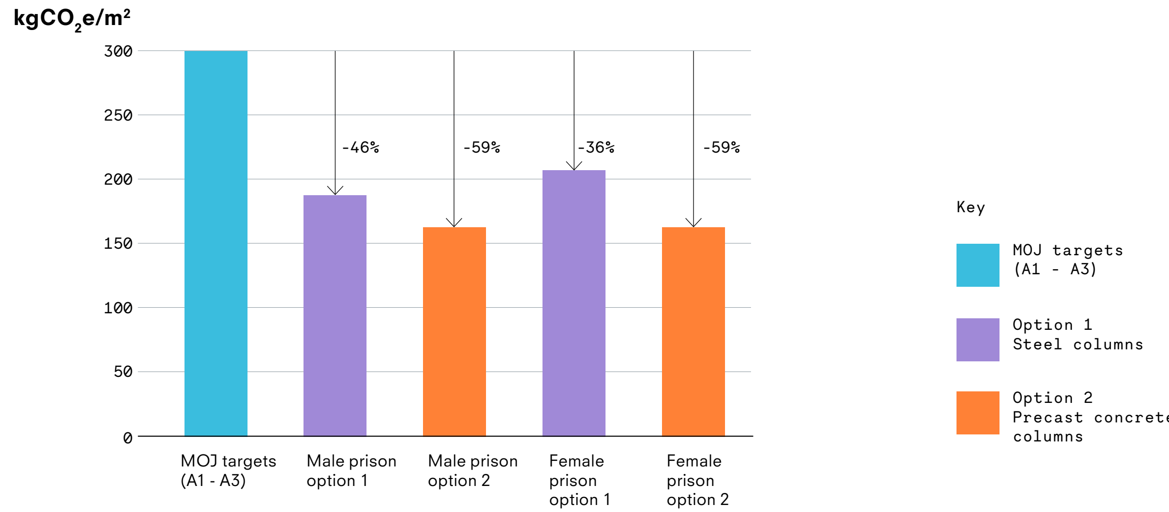


Key

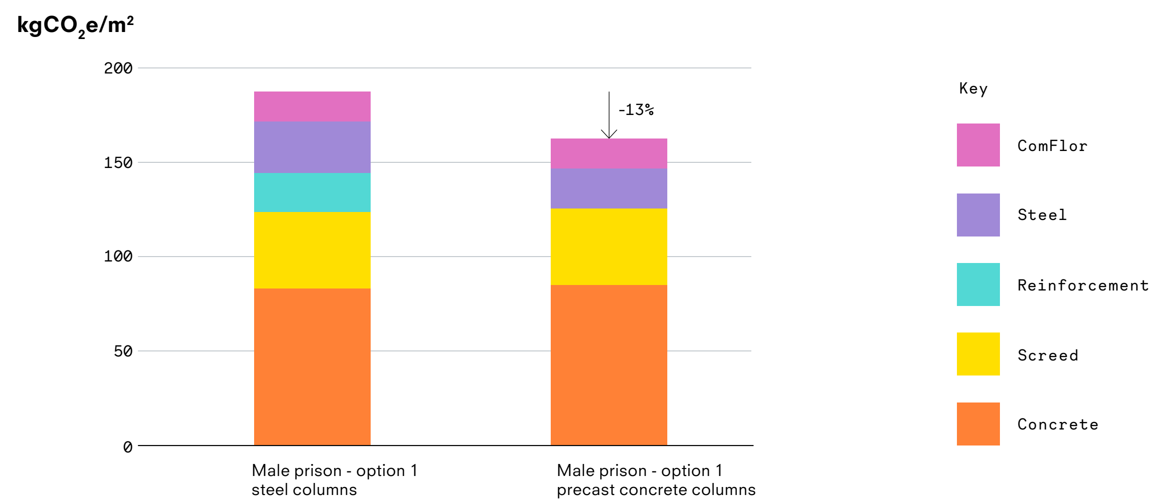
- Structure
- MEP cassettes
- Façade modules
- Bathroom pods

Embodied carbon for Platform II applied to the custodial estate

Total embodied carbon of materials (A1 - A3 stages) for superstructure



Male prison comparison of materials (A1 - A3 stages) for superstructure

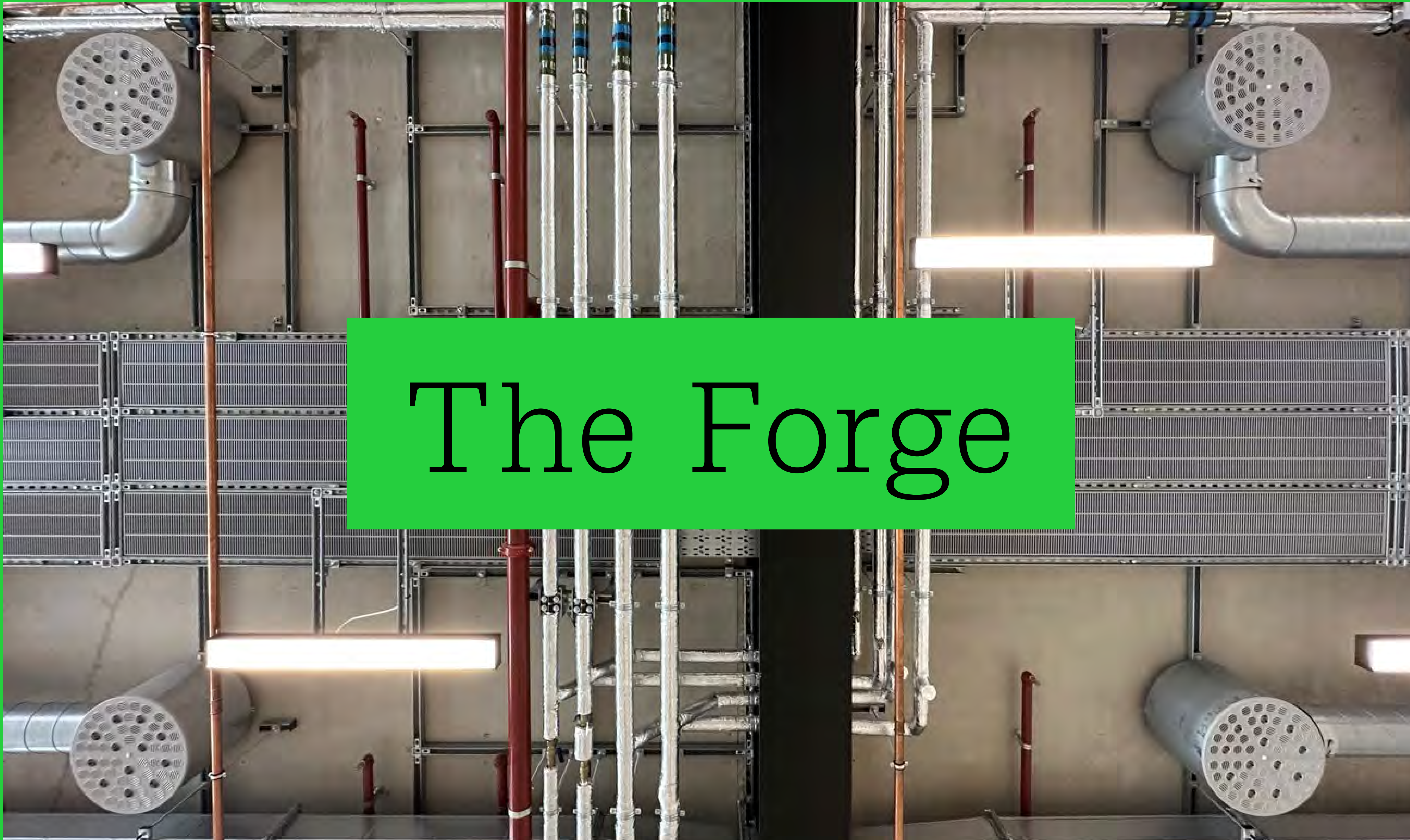


Design: Architectural expression

The standard interfaces at columns and slabs will support a wide range of cladding and balcony types. There is no limit to the architectural expression that Platform II will support. This is true in all sectors.

Identical Platform II superstructure with three alternative cladding options.

The Forge



“As the first client to embrace Platforms, we knew it was experimental. But without P-DfMA, we simply couldn’t have delivered on the sustainability ambitions for this build.

Not only Landsec’s first net-zero commercial development, The Forge is an adaptable workspace that is fit for the future and responds to its local context and community.

Bryden Wood’s superstructure platform delivered an architecturally ambitious and highly location-specific building, alongside the safety, quality, and productivity benefits that a manufactured solution offers.”

Neil Pennell
Head of Design Innovation and Property Solutions
Landsec

Landsec

Completed floorplate at The Forge
Source: Han Teh, GSixtySix.

Introduction

The Forge, at 105 Sumner Street in central London, is the first private sector building completed using the platform approach, from building design to delivery.

The project comprises two new-build commercial office buildings designed and engineered by Bryden Wood for Landsec, one of the UK's largest real estate companies. These buildings are built around a publicly accessible internal courtyard, with a total area of approximately 139,000ft² net internal area (NIA).

The project was completed in March 2023 2023, marking several significant achievements:

- It was the first building to use a platform approach.
- The Forge is the UK's first commercial development to be designed in line with the UK Green Building Council's net zero carbon buildings framework.
- It is one of the pioneering projects of Design for Performance, and is predicted to achieve a 5 star NABERS UK (National Australian Built Environment Rating System) rating.

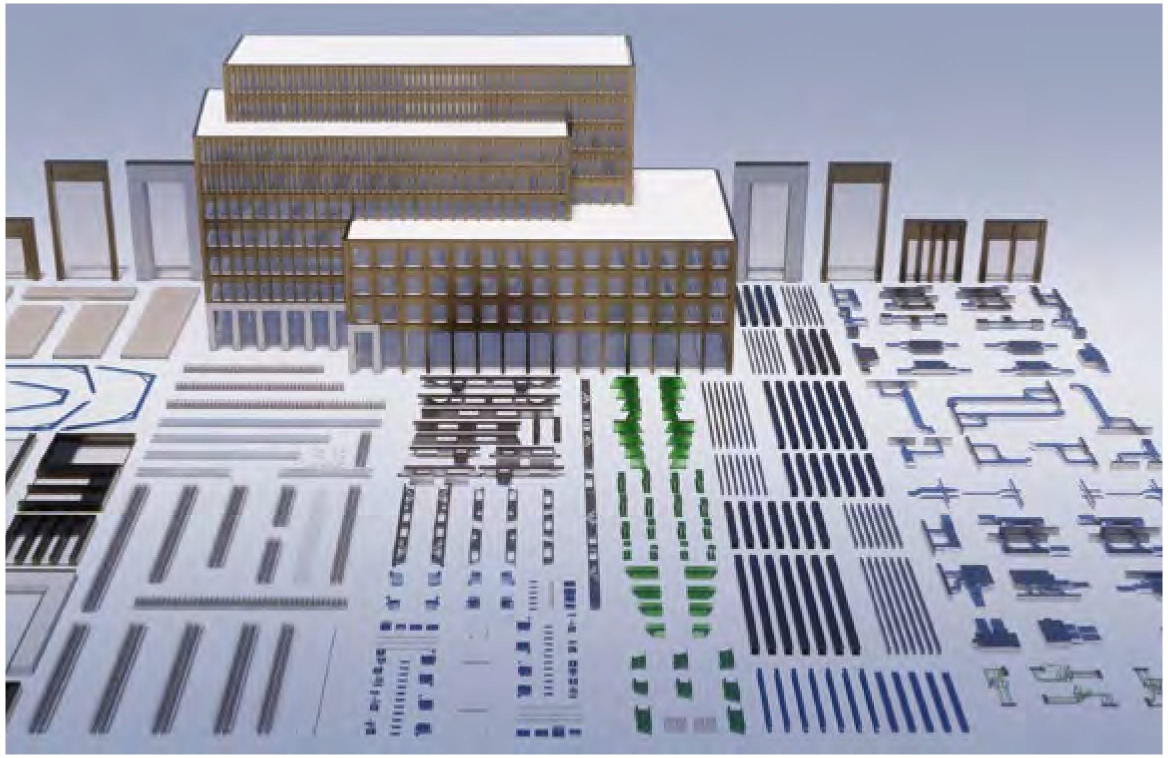
To accomplish a 9m x 9m grid, which is typical of London offices, the building uses common, repeatable components developed for Platform II. This carrier frame then allowed supply chain partners (particularly the M+E and façade) to develop their own complementary elements. These would leverage the accuracy and consistency of the main superstructure to enable more productive ways of working.

The project was awarded funding through the Innovate UK Transforming Construction Challenge fund. Initially, as an R+D project to test automated construction, and then as a demonstrator project to apply the learning from the R+D to a real world-project.

Four key aspects of the platform approach that led to the project's success were:

- Prototyping.
- Digital tools.
- Sustainability benefits.
- Productivity gains.

The Forge 'kit of parts'



"The Forge: Pioneering a platforms approach for more productive and sustainable automated builds... Using a platform approach and BIM technology, the partners created an optimised structural frame that could be precisely manufactured off-site and assembled on-site using an automated assembly process."

Transforming Infrastructure Performance: Roadmap to 2030

Prototyping

"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.

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."

Delivery Platforms for Government Assets

Prototyping at the Construction Platforms Research Centre

To deliver The Forge, a prototype was assembled at the Construction Platforms Research Centre (CPRC) in Ropley, Hampshire. This is a prototyping facility jointly set up by Bryden Wood and Easi Space. The prototype measured 9m (equivalent to one structural bay) wide by 18m (equivalent to two structural bays) long, with one bay being 2 storeys tall.

It was used to test a number of aspects:

- Assembly sequence for ease, productivity and health + safety.
- Timing of activities to understand where improvements could be made and to assess productivity.
- Adoption of semi-automated approaches, such as the use of reach stackers.
- Pouring and setting characteristics of the low-carbon concrete mix.
- Use of 'Converge' sensors in the concrete.
- Ability to reuse shutters and props, and on what cycle time.

The prototype also became an invaluable aid in engaging the supply chain, including NG Bailey and Aluprof.

> Both companies were able to visit the CPRC and test the installation processes for the M+E cassettes and façade.

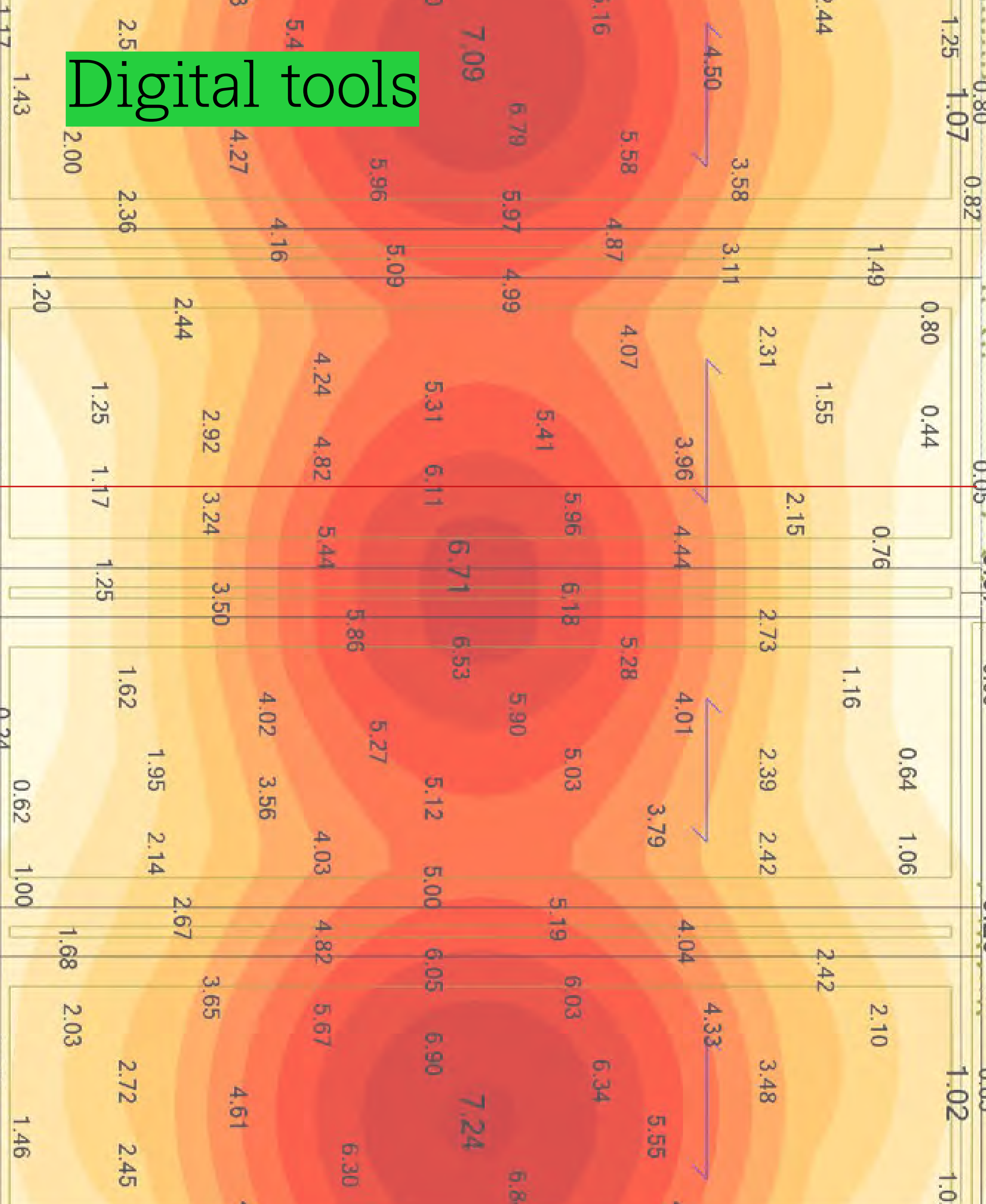
> This allowed design refinements, ensuring maximum productivity once operatives started work in the live site environment.

Aerial view of superstructure prototype.

Installation of prototype M+E cassettes.

Watch the open day video here

Digital tools



"Further embed digital technologies:

While the volume of data relating to UK construction is rapidly increasing, it is often fragmented or not easily accessible. Improving the consistency and quality of data will be transformational in how we can deliver projects and programmes by improving safety, enabling innovation, reducing costs, and supporting more sustainable outcomes."

Construction Playbook

Tools + workflows

A suite of digital tools was used, sourced from existing products available on the market.

Algorithmic design

The Platform II design was digitally-enabled from the outset. The digital library of components includes predefined interfaces and relationships facilitating automated design.

The platform superstructure was not modelled manually. It was generated through specific routines (Grasshopper and Dynamo) that generated a dataset describing the position and orientation of every component. This:

- Created a complete bill of materials for pricing/procurement;
- Automated the generation of BIM models in Revit/Tekla for coordination of the platform elements with the traditional build and other systemised, prefabricated or volumetric elements including:
  - Temporary works kit of parts.
  - Unitised façade panels.
  - On floor M+E cassettes.
  - Rooftop plant rooms and risers.

The same digital library was linked to SolidWorks manufacturing models of the components, facilitating automation and the use of robotics in fabrication.

Leveraged BIM outputs

For the prototype, the BIM model was visualised at the construction site using Trimble's augmented reality SiteVision product, enabling the team to measure and cross-reference the digital components to the physical components. There is further scope to adopt tools such as this on future Platform II applications, e.g. digital 'toolbox talks', accurate progress reporting, and 'guided instructions' for operatives, etc.

For the construction of The Forge, models supplied QR codes to track components from factory to installation, transferring off-site benefits to site. This was used for the temporary works, the ComFlor shutters and the MEP cassettes. In this instance, different systems were used for each; however, in the future a single co-ordinated system should be defined and adopted.

QR codes were used by NG Bailey to document the install timings for the M+E cassettes. The site manager could register the install time of each component using the QR code and upload the information into the system.

The install times could then be collated, reviewed and compared with the benchmark targets that were developed from component installation times recorded during the prototype trial installations. This facilitated more accurate reporting, but also rapid identification of any issues or opportunities to refine the manufacturing or installation processes.

Further digital tools

The following range of tools were used to support the transfer of data from design and manufacture into assembly and monitor progress and quality on-site:

Qflow/Tracker Plus/DataScope
Qflow is an automated data-gathering and AI tool monitoring deliveries and waste transfer from site, proving especially useful for demonstrating compliance with environmental targets. This was linked to other solutions, creating a valuable data ecosystem:

- Tracker Plus collates all the information required for the Building Research Establishment Environmental Assessment Method (BREEAM)assessment process in one location, allowing the project team to review the progress being made in real time. The API enabled information from the site delivery and waste transfer notes to be extracted from Qflow and automatically uploaded into Tracker Plus.
- DataScope was used for booking and managing trade contractor vehicle access to site. An API allowed accurate data relating to deliveries and waste transfers (vehicles, timings and content) to be recorded in DataScope to be accessed by Qflow and, therefore, TrackerPlus.

Disperse.io/Site-Eye
Disperse io is AI 360° photo capture and automated weekly progress tracking system. It reduced risk by enabling speedy, remote review progress and reporting, facilitating decision-making and reducing the need for site visits. The tool also generated reports to enable the team to focus more of their time on the construction sequence planning and coordination. Site-Eye time-lapse cameras were placed at strategic locations on neighbouring buildings, looking back at the site, creating a complete visual record of progress. This was a valuable source of data for the productivity studies, allowing daily counts of numbers of structural elements and façade panels installed.

Converge
Live data from sensors within the concrete pour and predictive software combined to calibrate curing times and strength, informing when the temporary works could be struck and the earliest time machinery and materials could arrive. This optimised floor cycle times based on real-site conditions, not predetermined curing periods.

Sustainability benefits

Lean + flexible design

A key principle of sustainability is to develop solutions that consider whole-life performance, including future uses and adaptations in response to evolving technology and working practices or complete re-purposing.

As well as using a 'kit of parts' in its delivery, the design of The Forge adopted a highly rational dimensional strategy that facilitates ongoing maintenance and refurbishment using standardised and repeatable solutions. It does this by enhancing the commonality of grids and floor heights and adopting, for example, planning grids recommended by the Bristish Council for Offices, allowing a range of existing, standard solutions to be adopted.

- The structure has a grid measuring 9m x 9m, which allows for large open-plan layouts with minimal internal columns, and provides flexibility for cellular rooms, alternative uses and split tenancies in the future.
- Each 9m x 9m bay is made up of three bays of 9m x 3m, providing a highly rational soffit into which M+E cassettes can be inserted.
- The grid is further subdivided using a 1.5-3m wide grid along the façade to further ease intersections with glazing when subdividing large spaces.
- The façade uses standard façade panels of either 3m or 1.5m.
- The slab-to-slab dimensions were rationalised to just two heights: 3.5 and 3.7m. The additional 200mm was required on floors where terraces were provided to accommodate the additional buildup required. Having just two heights assisted in greater standardisation of the unitised façade panels and could be accommodated with a single set of temporary works components.
- Long-span beams were standardised, with a repeatable design that maximised the number and size of penetrations. This facilitated coordination of M+E services but also allows for future adaptation, replacement or reconfiguration. Coordination of these penetrations between the downstand beam locations enabled a much more integrated and reduced-depth services and structural zone.

In the construction phase, the temporary works kit of parts was used repeatedly. Only one set of shutters and two sets of props plus handrails were required and were reused as works progressed. The image on the left shows a set of temporary works brackets ready for reuse. The cost of these can be further amortised across future projects.

Carbon reduction strategies

The platform superstructure then facilitated a very low-carbon solution through a linked series of approaches:

- Least amount of material.
- Lowest carbon material.
- Circularity + reusability.

Least amount of material

In line with 'lean manufacturing' principles, the first step is to reduce the amount of material used. The 9m spanning beams were subject to a huge amount of detail design, including Failure Mode Effects Analysis (FMEA) to understand how little material was required for the beams to function structurally. Material was removed by making holes in the flange and the removed material was recycled. This approach had two major benefits:

> Reduced material use and weight of the components, therefore, also reducing carbon associated with transport and lifting.

> A repeatable series of penetrations which maximised opportunities for M+E services to pass through, facilitating close integration of M+E and structure.

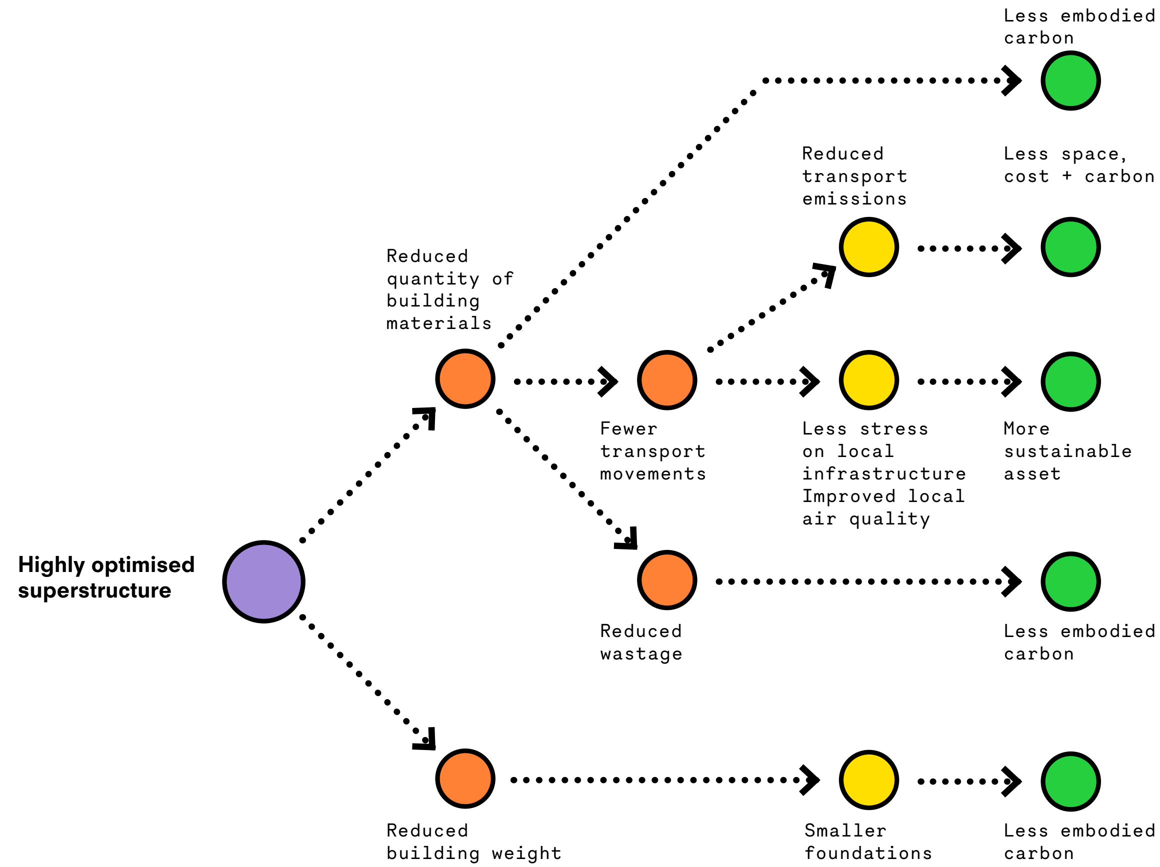
> Over-provision of penetrations provides future-proofing by allowing a different pattern of services to be accommodated in the future depending upon change in use or different patterns of working, delivering on the platform value driver of flexible, adaptable assets.

The overall reduction in steel achieved was 18.4% compared to a traditional solution.

The slab was also designed to be as thin as possible, using downstands in one direction with a very thin (140mm) slab to span between them. This reduced the amount of concrete in the slab by 13% compared to a traditional approach.

Microcolumns were used at the slab edge, with only 3m spans between them, meaning that slab deflections were very small. The need for a cladding support frame was removed since the façade units were able to sit on the slab edge and span between columns.

Embodied carbon benefits of Platform II



Lowest carbon material

British steel was used, reducing transport distance by two-thirds. It also had a high recycled content of 26%.

The temporary shuttering system allowed the concrete to be supported off the steel columns (rather than back propped through lower slabs) without inhibiting movement across the floor plates.

- This allowed lower carbon concrete, which has a longer curing time, to be used.
- For The Forge, 50% GGBS was used within the concrete mix of the substructure and 40% GGBS in the upper floors.
- Concrete was procured within a transport distance of less than 10 km.
- By using a compact kit of parts, transport and logistics could be highly controlled, and there was virtually no waste created on-site.

The design of the unitised aluminium facade called for an anodised finish, but a powder-coated finish was used internally to reduce the embodied carbon level of the final panel manufacture. In addition the aluminium used in the facade has a high recycled content of 65%.

The Forge has demonstrated an embodied carbon intensity of approximately 850 kgCO_{2e}/m^2.

Circularity and reusability

The temporary works components were reusable and recyclable. Across the project, there were only two sets of shutters and three props. These were recycled up the building so each component was used multiple times.

By using reversible bolted connections, the steel columns can be easily removed, and all the steel components within the building are tagged to provide the technical information that enables the steel to be easily reused.

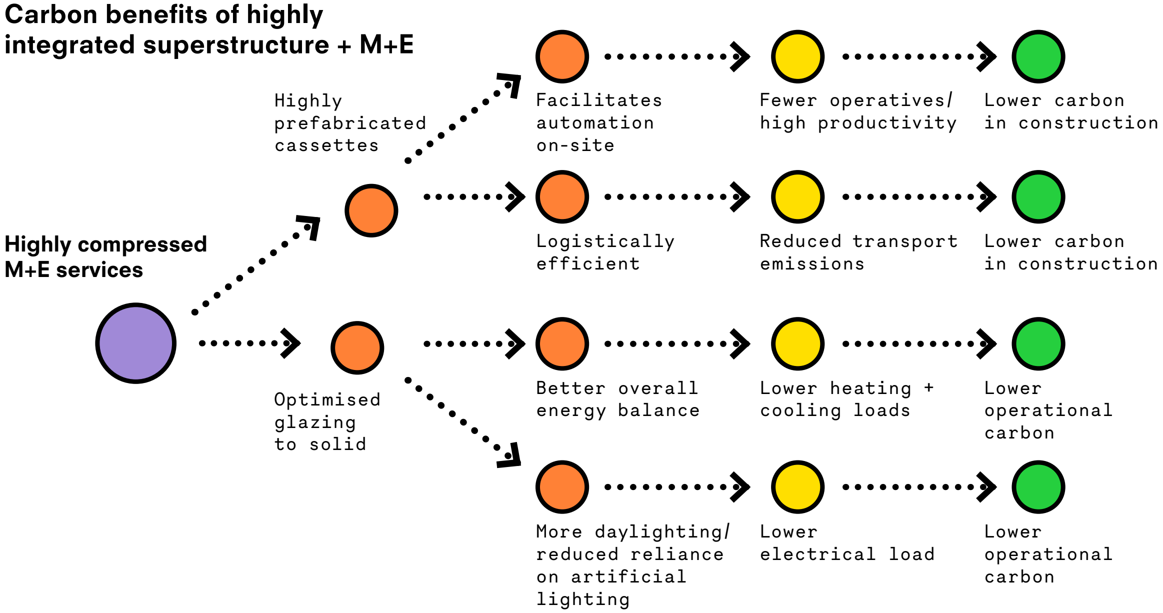
Image opposite:
MEP cassettes awaiting installation at The Forge.

Integration of superstructure + MEP

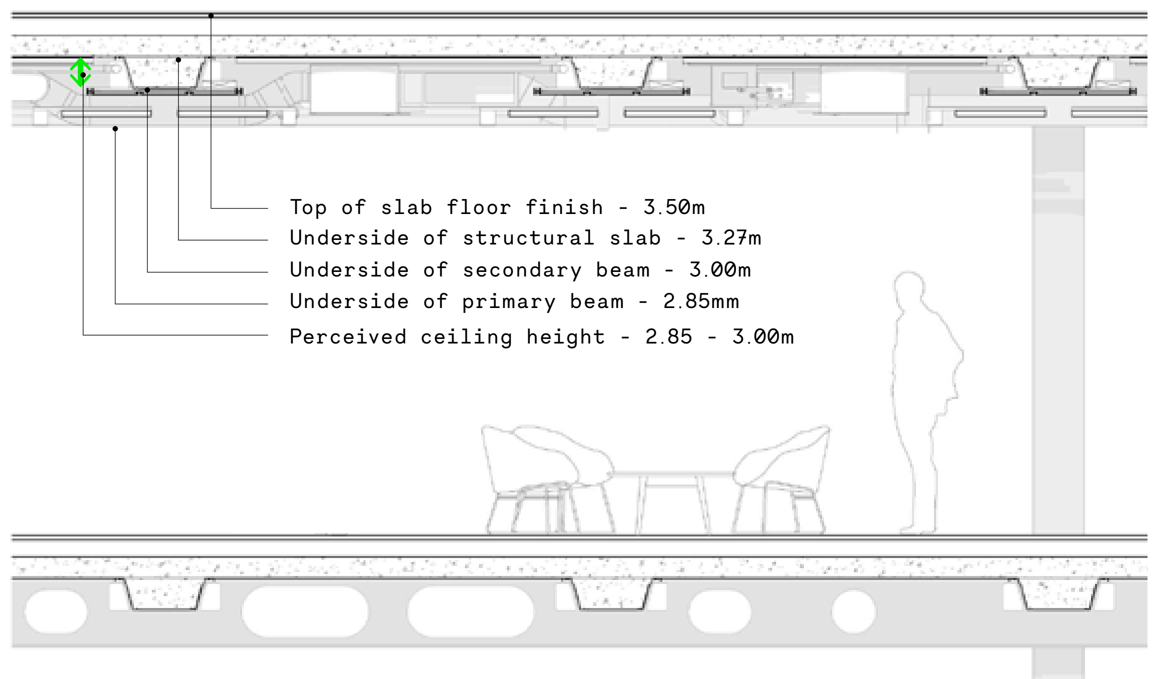
The use of M+E cassettes, designed to interface with the superstructure platform, enabled very close integration of MEP and superstructure. Rather than a traditional large ceiling void or generous structural/services zone, the services installations used the space between the ComFlor shutters to accommodate the larger fan coil cassettes and services crossovers. The more integrated design minimised the slab-to-slab dimension needed to achieve the clear height of 2.75m required by the client brief.

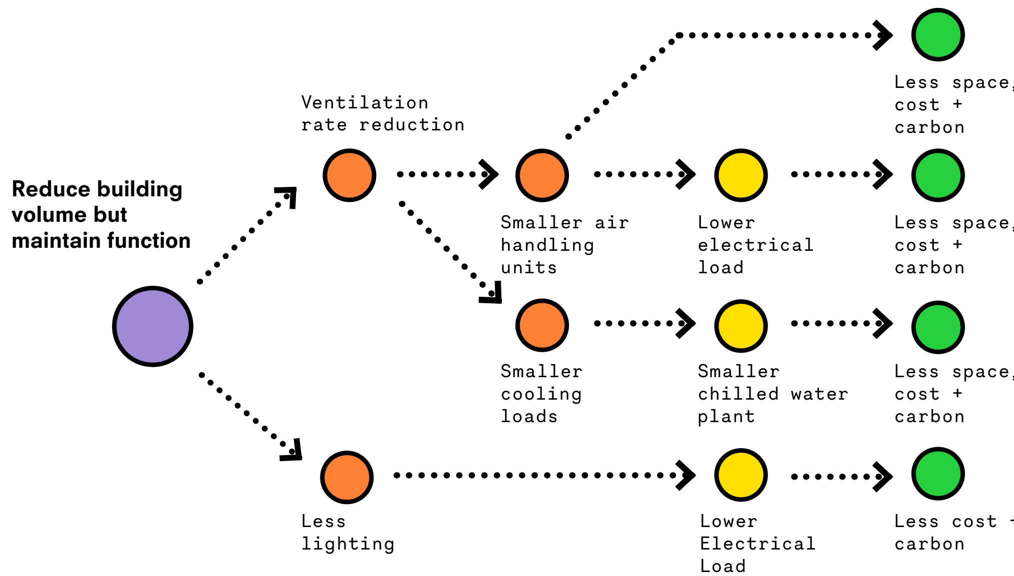
- Floor-to-floor heights at The Forge are 3.5m, compared to the typical 4m+.
- This reduces the overall building volume for a given footprint, reducing in turn the energy need to heat and treat the space.
- It increases volumetric efficiency - 10 storeys at 4m floor heights would accommodate 11 storeys at 3.5m floor heights, so a developer can achieve more storeys in the same volume.
- This reduced the depth of the spandrel panels, allowing the glazing height to be increased, resulting in more natural daylight and reduced the use of aluminium (which is a higher carbon intensity material than glass).

Carbon benefits of highly integrated superstructure + M+E

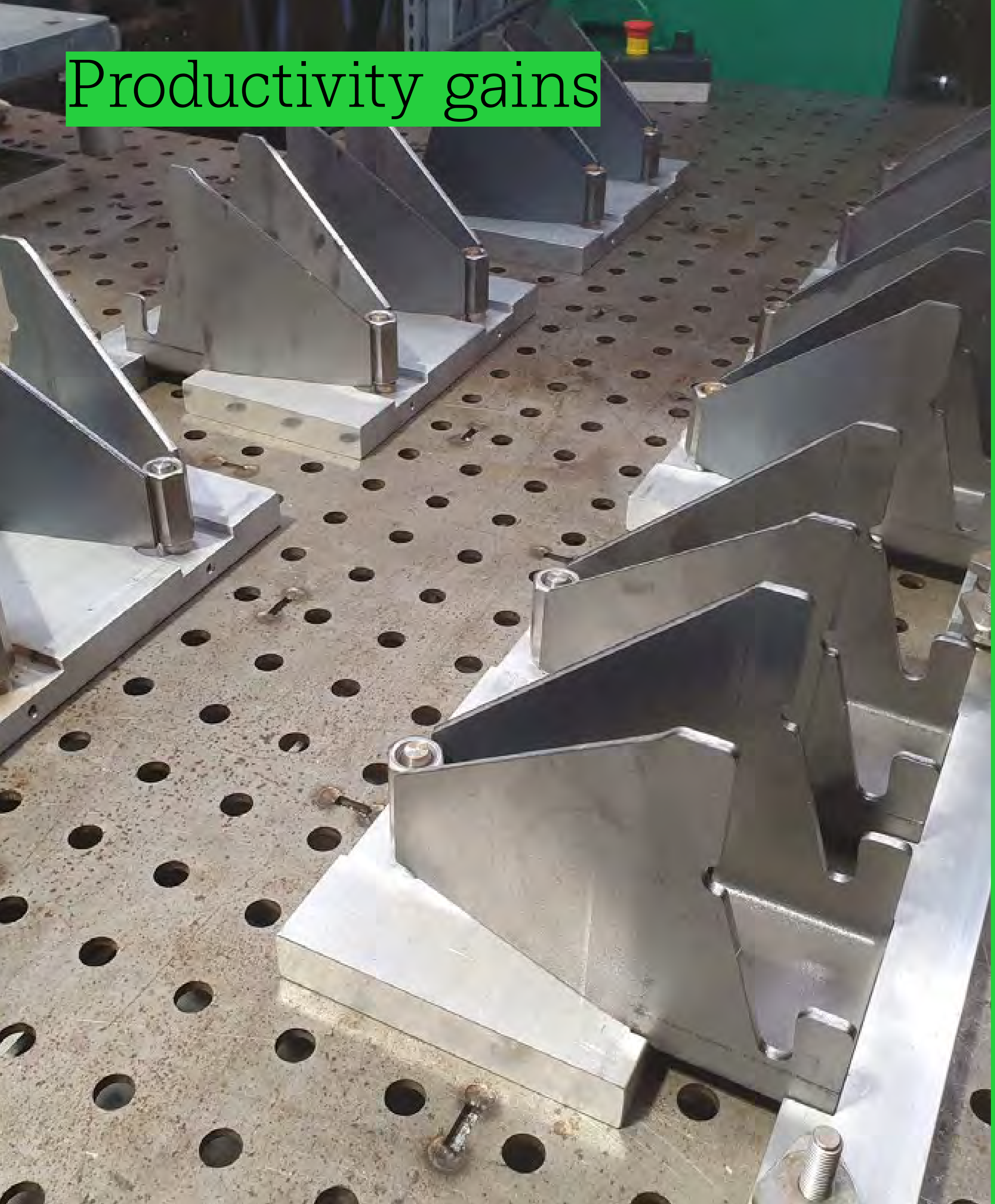


Section through floor + benefits of reduced floor-to-floor heights





Productivity gains



"There is an opportunity for parts of the construction industry to move to a production system and boost productivity up to tenfold... if construction were to depart from entirely project-based approaches to more consistently employ a manufacturing-like system of mass production with much more standardization and manufacturing of modules and parts in factories off-site, the productivity boost could be an order of magnitude greater."

McKinsey & Company

Reinventing Construction:
A Route to Higher Productivity
McKinsey Global Institute
2017

Introduction

Improving productivity was at the heart of this project - it is a critical objective of Platform II.

In order to ensure knowledge transfer, a study at The Forge was led by Dr Danny Murguia, Research Associate at the Laing O'Rourke Centre for Construction Engineering and Technology at the University of Cambridge.

This study is to form part of the wider research being conducted by the University of Cambridge, to develop a performance and productivity framework for the UK construction industry:

- To ensure consistency on what is measured, how and why.
- To set benchmarks.
- To conduct data analytics.
- To use lessons learned for continuous improvement.

> "With the benefit of the learnings from its first-time use, this [a 40% reduction in programme] is highly possible in future projects. When linked with a scalable logistics solution this could translate to a significant reduction in build time and cost."

UNIVERSITY OF CAMBRIDGE

LAING O'ROURKE CENTRE for CONSTRUCTION ENGINEERING and TECHNOLOGY

Dr Danny Murguia
Laing O'Rourke Centre for Construction Engineering and Technology
University of Cambridge

Scope

The Forge comprises two separate blocks (Bronze and Phosphor). While the studies considered both, the extracts included here focus on the former.

Platform II is a superstructure designed as a carrier frame to unlock productivity in complementary trades. Therefore, the study was also interested in identifying what impact it had on the productivity of these elements.

The buildings were generally provided with Category A fit-out (raised floors, high-level M+E services, skirtings and blinds, etc.) by the owners, Landsec. Category B fit-out (office partitions, floor finishes, specialist lighting, furniture, etc.) will be provided by the occupiers.

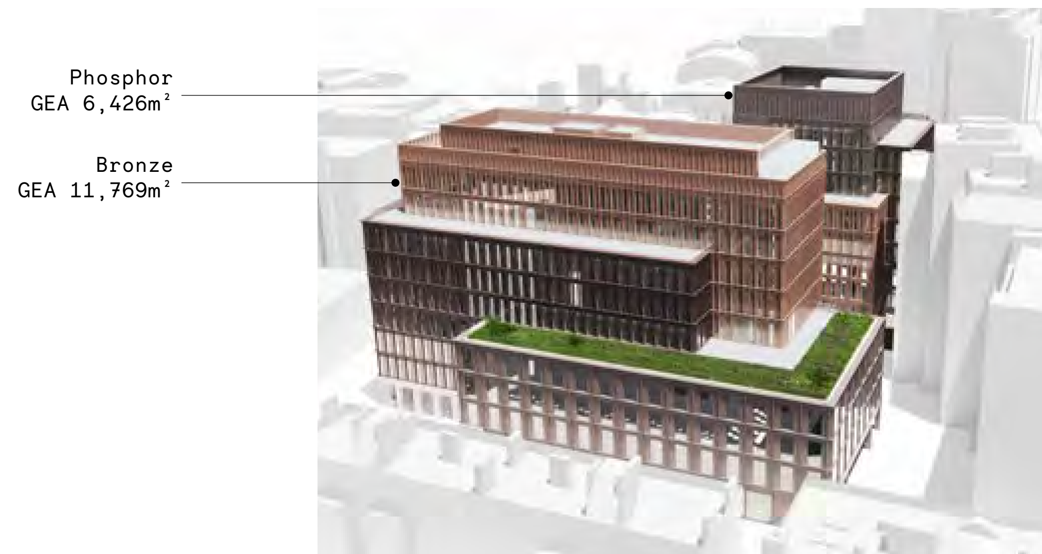
This study analysed productivity in three areas across Platform II and its complementary elements for The Forge:

- Platform II superstructure.
- Complementary elements.
  - Façade.
  - M+E.

Measuring productivity

The study analysed various measures of productivity beyond £/hour, as this was not considered to be the most reliable or insightful metric, considering it can be artificially inflated by the higher cost of some builds vs others.

It then considered integrated + optimised workflows looking at lagging metrics and understanding leading metrics to look to the future for potential productivity gains (considering that this was the first build of its kind) using Platform II.



Superstructure work packages - variability analysis

The team studied the following key activities:

- Installation rate of primary steels.
- Installation rate of ComFlor permanent beam shutters.
- Installation rate of slab shutters.

A detailed study of a sample of the installation rates for the key structural elements above showed a high degree of variability between the most productive and least productive days:

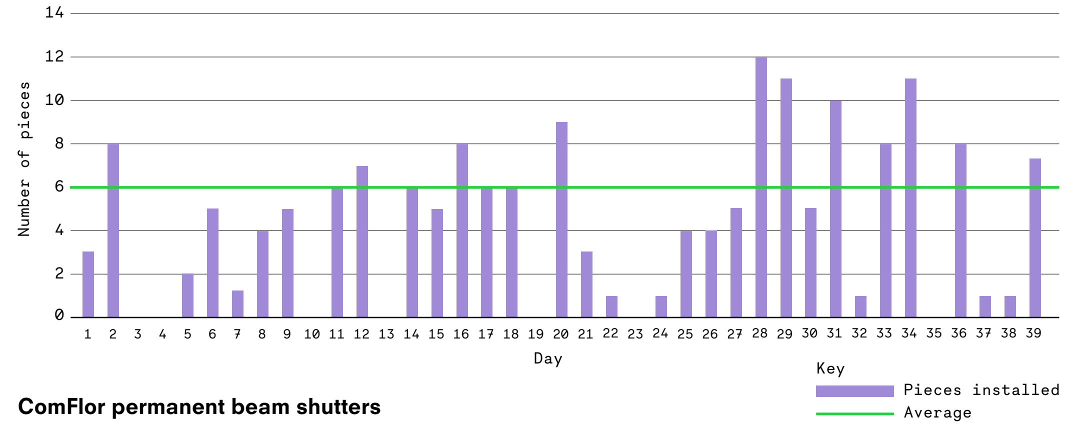
	Primary steel	ComFlor	Slab shutters
Sample size	173 pieces over 39 days	70 pieces over 31 days	151 shutters over 23 days
Maximum pieces per day	12 (with 10+ on 4 days)	10	18 (with 10+ on 9 days)
Minimum pieces per day	0 (on 7 days)	0 (on 13 days)	0 (on 8 days)
Average pieces per day	6	2.43	7

This yielded the first key insights:

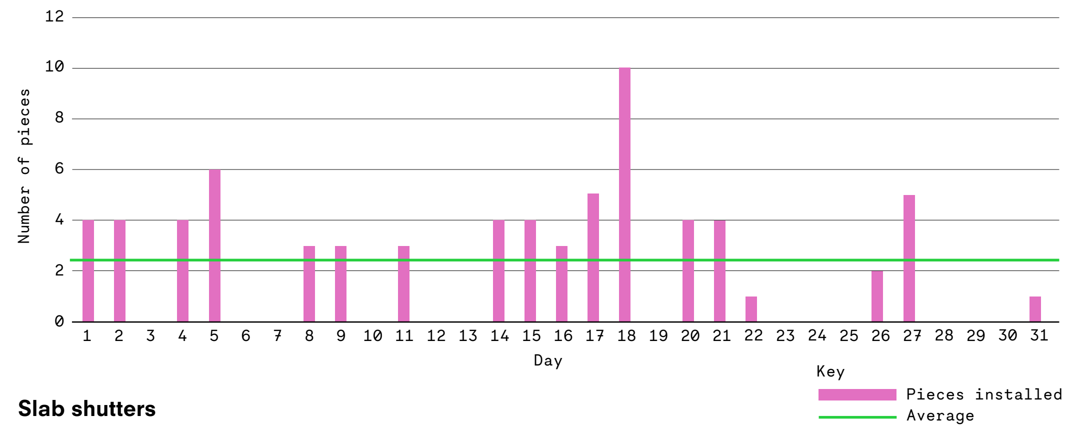
- **Consistency is more important than speed** (at least in the first instance).
- **Maintaining the average rates every day** (i.e. not going faster than was achieved, but simply being consistent) would have **dramatically reduced programme.**
- Consistently installing just the average number of components every day would have reduced:
  - Steel installation by **25%**.
  - ComFlor installation by **55%.**
  - Shuttering installation by **26%.**

Variability of installation for superstructure elements

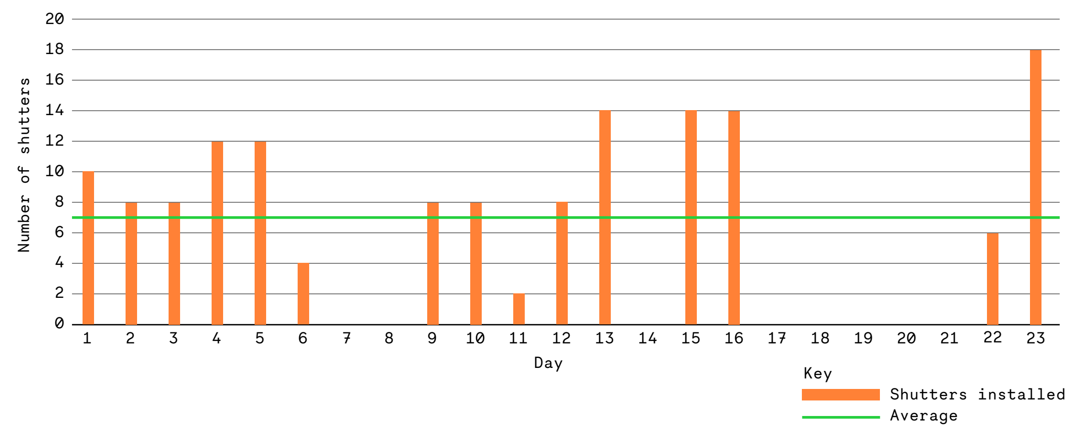
Primary steel



ComFlor permanent beam shutters



Slab shutters



Flow line analysis

The team represented a wider data set as 'flow lines' to analyse periods of activity (shown with sloping lines) and lines with inactivity (flat lines).

This allows the 'down-time' between activities to be identified i.e. where activity was stopped for a variety of reasons, e.g. operatives waiting for the next batch of components.

- For steel installation, 32% of available time was inactive.
- For ComFlor and shutters, 23% of available time was inactive.

This shows there is a huge opportunity to increase productivity by planning activities to minimise downtime. This is something that the manufacturing sector does well - one of the 'seven wastes of lean' is 'waiting'.

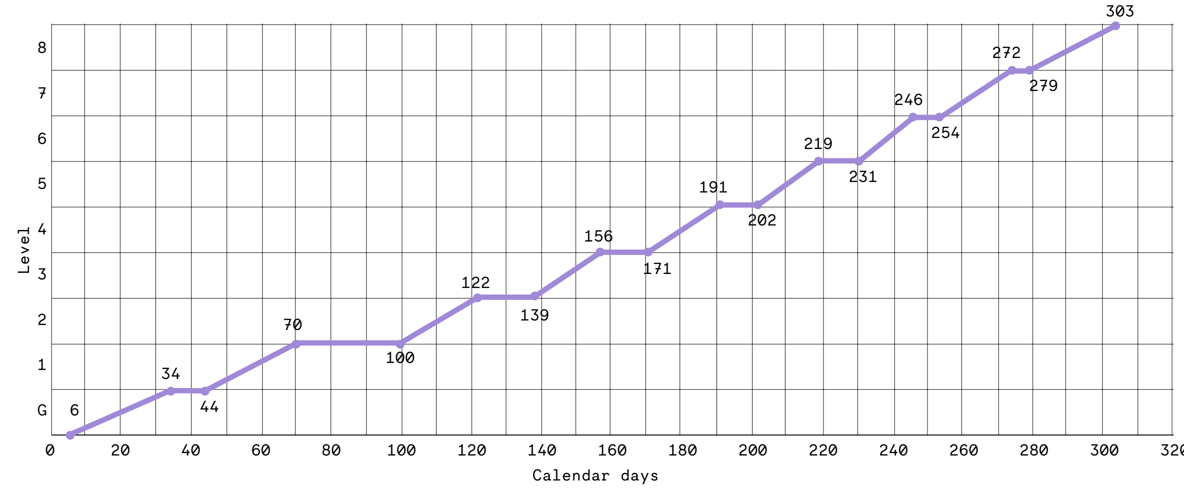
On a traditional construction site, it is very difficult to plan activities with high levels of precision due to the interdependence between multiple trades and complex supply chains.

However, Platform II provides numerous benefits that would facilitate project planning which is much closer to manufacturing. A relatively small number of repeatable, fungible components would provide the following benefits:

- Bills of quantities to be accurately generated from models, assisting in production + logistics planning.
- Installation through simple, repeatable tasks with a known timing to assist in accurate planning.
- Use of colour coding of components and poka-yoke assembly techniques (each component will normally only fit one way) avoids errors but also increases the consistency of assembly times, improving the accuracy of forecasting.
- Platform II super structure is designed to free up floor plates for following trades as soon as possible after concrete pour, allowing activities to be brought closer together.
- Platform II components are designed to be highly compact and lightweight (since the main mass, concrete, is not installed until on-site) facilitating movement and delivery of materials.
- Use across sectors would allow 'continuous improvement' rather than 'constant reinvention', i.e. learning and data from The Forge can be used to more accurately plan the projects that follow.

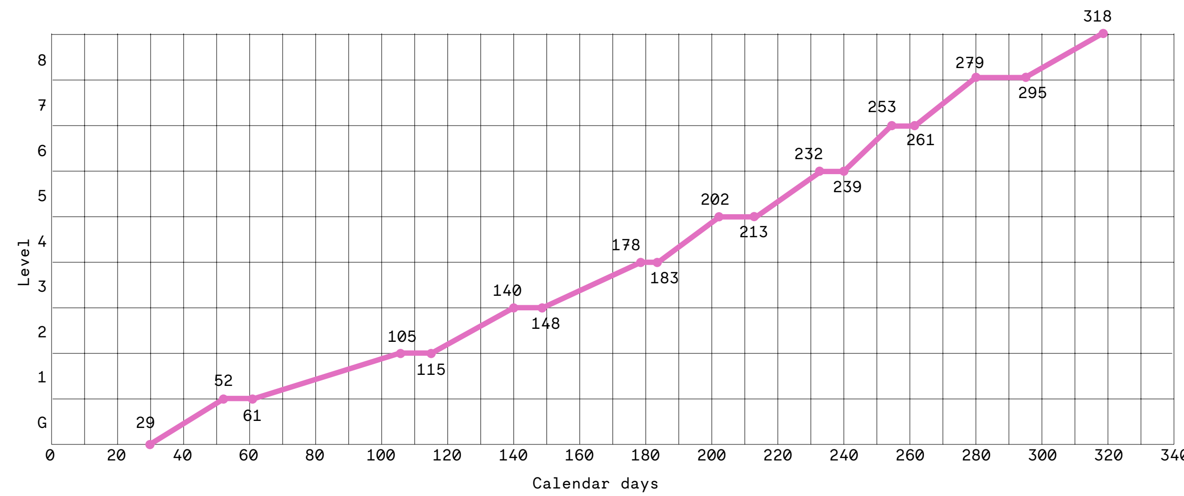
Flow line analysis

Primary steel installation



Total duration = 211 days + 27 Sat = 225 days
Active installation = 153 days
Active installation = 68%

ComFlor + slab shutter installation



Total duration = 204 days + 31 Sat = 220 days
Active installation = 169 days
Active installation =77%

Superstructure productivity metrics

This project encountered some key challenges. It was:

- The first project to be delivered using a novel hybrid superstructure platform approach, which required the workforce to adopt new and unfamiliar installation methodologies with a consequent learning curve.
- Reliant on the use of large material hoists, which were subject to two unexpected failures at critical times during the construction cycle.
- Delivered during the Covid pandemic, with the supply chain and labour planning challenges this presented.

However, despite these challenges, Platform II still achieved a very high level of productivity.

The graph on the right shows data from three comparable concrete frame structures: one traditional flat slab, one using precast, and The Forge platform super structure.

The horizontal axis shows the rate of work (m²/day) for a crew. The further along this axis, the faster the install.

The vertical axis shows labour productivity (m²/worker hour). Thehigher up this axis, the greater the productivity.

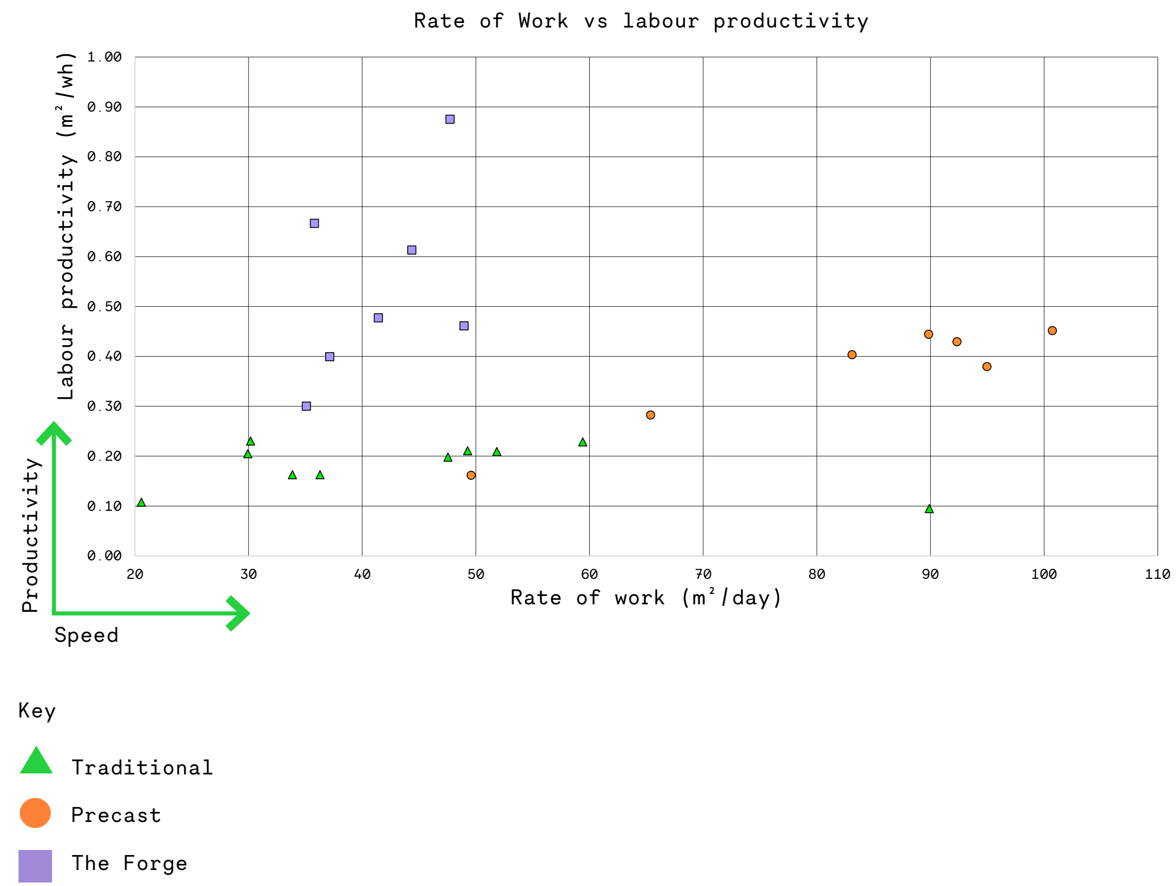
The graph shows that precast is rapid to install as it is a mature technology that has been refined over years.

'Installation speed' at The Forge was comparable with the traditional concrete structure, slower than the precast system, but up to twice as productive as both the other methods. Given that this was the first time the Platform system was used, this is a significant achievement.

This presents a huge opportunity:

> Increased familiarity with the system, combined with more accurately planned activities and logistics, would give Platform II the ability to **overtake precast in terms of both m²/worker hour and m²/day, i.e. to become very fast and highly productive.**

Rate of work vs labour productivity



Temporary props installed and on stillages at The Forge.

Façade installation

A unitised façade of aluminium and glass was designed for The Forge, with manufacturer, Aluprof, engaged through a Pre-Construction Services Agreement (PCSA) to develop the system in line with Platform II.

The highly rationalised design of the superstructure provided several benefits that were designed to improve productivity in façade installation:

- An accurate frame for the façade panels to attach to, reducing the need for site surveys and adaptations (which require significant time and labour on a traditional project). On the 9m bays, the tolerance was ±5mm.
- Fixing brackets were installed on the primary frame, facilitating installation.
- The microcolumns occurring every 3m at the slab edge eliminated the need for secondary steel, and the limited spans created a stiff slab with minimal deflections.
- The temporary site safety handrails were designed as an integral part of the Platform II superstructure and remained in place during the façade panel installation.
  - This removed the need for fall arrest systems, which slow operatives down on traditional sites.
  - The lack of a leading edge meant operatives felt confident to work at speed.

As a result, the Platform II superstructure enabled very high levels of productivity. The original programme was based on an install rate of seven panels a day, but data from the site showed a rate of ten or more panels a day was regularly achieved. At peak, the fastest panels were installed in just six minutes, indicating the potential to speed up the workflow on future projects.

A sample of a section of façade revealed the following:

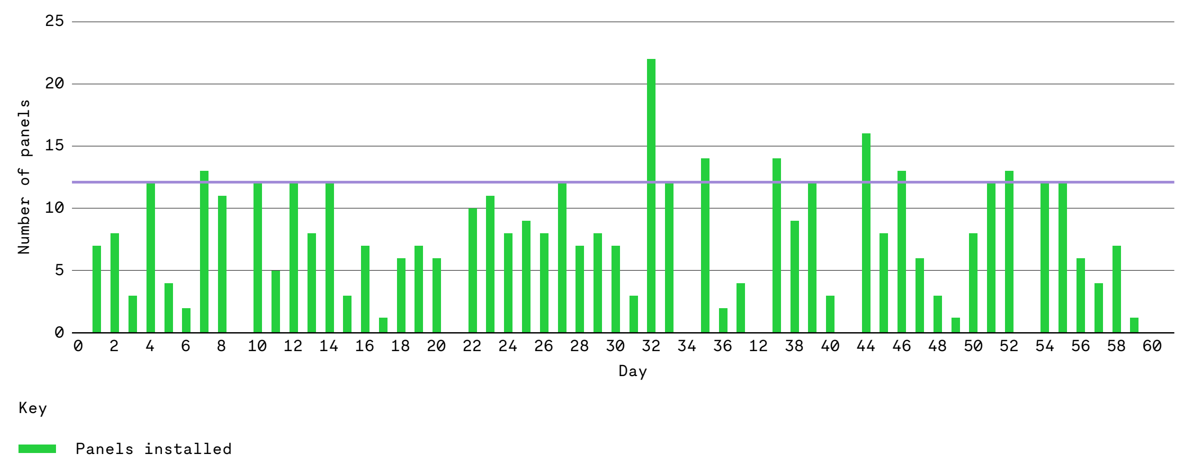
- Sample of 435 pieces over 60 days.
- Maximum = 22 panels/day (with 10 or more on 4 days).
- Minimum = 0 pieces/day (on 7 days).
- Average = 7 panels/day.
- Average rate was exceeded on 34 of the 53 days when panels were installed.
- 10 panels/day or more were installed on 20 days.

If a rate of 12 panels/day were achieved, the cladding would gave taken 37 days, **a nearly 40% reduction in the programme.**

The data also showed that the 3m panels were installed at a similar rate to the 1.5m panels but effectively covered twice the area, showing that, where logistics allow, the larger panels would result in even faster installation speeds and higher levels of productivity.

Again, Platform II allows very high levels of productivity but requires consistency and logistics planning to maintain these levels.

Variability of installation for façade elements



MEP cassettes

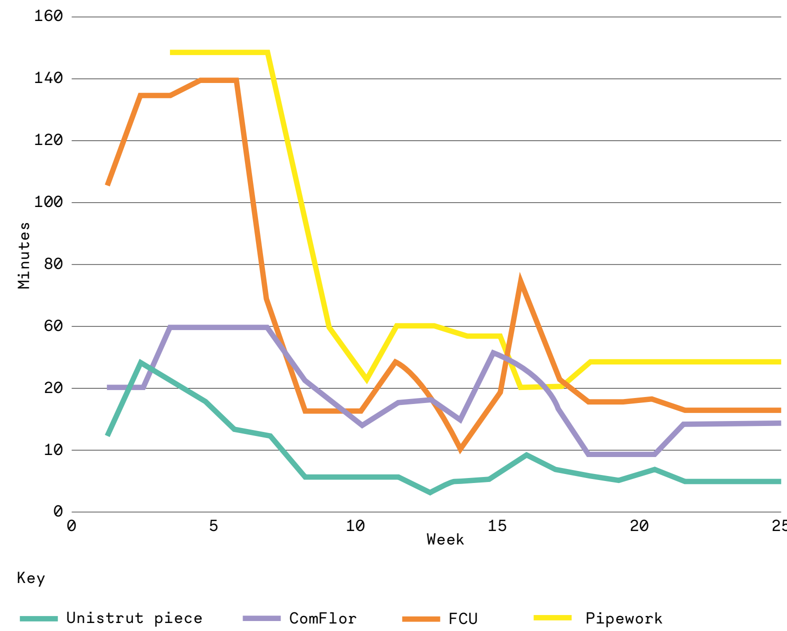
The key MEP complementary elements included:

- Unistrut frame fixed to the soffit.
- Fan Coil Unit (FCU) cassette module including controls, secondary ductwork, air diffusers and interconnecting pipework.
- ComFlor cassette module comprising a metal grillage (concealing sprinkler pipework and cable trays) mounted below the ComFlor shuttering to improve aesthetics and provide acoustic sound absorption.
- Pipework cassette module containing the main heating and chilled water distribution pipework and connections to link with the FCU module.

The MEP cassettes were designed to maximise the opportunities presented by the Platform II superstructure.

- The fixing points for the above were pre-installed when the slab was cast by locating a repeating pattern of fixing accurately on the shutters.
- A total of 23,500 fixing points were installed, each one removing the need for site-based drilling at height.
- The highly rational, repeatable superstructure bays allowed NG Bailey to set up 'bench to fabrication' stations in their Bradford facility.
- These bench tops replicated the structural soffit and allowed operatives to attach pipework, fan coil units, etc. to an 'adapter frame' that would be fixed to the structural soffit. Because operatives were working at bench height (rather than working from elevated platforms in a traditional site environment), safety, quality and productivity were improved.
- The M+E elements could also be more closely coordinated, creating compact cassettes rather than bulky volumetric units (leading to reduced floor-to-floor heights).
- A logistically compact set of up to six cassettes, separated by reusable tubular spacers could then be stacked together on a special wheeled base frame, which would be loaded into a lorry and delivered to site.
- On-site, an adapted forklift was used to transport the stacks across the floor plate and lift them into position. The top cassette was fixed into position and detached from the stack. The stack then moved to the next position and the process was repeated. The spacers and base frames were returned to the factory to be reused on a new stack of cassettes.
- The use of adapted forklifts **reduced install times by 66%-90%** compared with using hand-operated Genie lifters to install the cassettes.
- NG Bailey estimated the prefabricated nature of the MEP resulted in a **reduction of 30,000 hours of site labour.**

Installation times for MEP cassettes



Industry best practice: use of Genie lifts.

The dramatic reduction in install times coincided with the introduction of the adapted forklifts in weeks five to six.

Use of specially adapted forklifts.

Source: NG Bailey

MEP cassette transport and installation

NG Bailey's Bradford facility.
Source: NG Bailey.

Optimisation potential: Superstructure

The University of Cambridge team then undertook a study to show how the work packages could be better integrated and optimised to maximise productivity.

This was predicated on the following:

- The third quartile of the rates already achieved (i.e. not the fastest rates from The Forge, but the rates at the top 75% of the performance).
- Resequencing each package (structure, façade and MEP) to optimise the use of materials, equipment and operatives and eliminate downtime.
- Harmonising across the packages such that:
  - Façade and MEP installation commences as soon as possible with the shortest time possible between the start and finish of each activity.
  - The rate of installation is aligned so that packages proceed concurrently and one does not lag behind the others.
  - Overall schedule is compressed.

Superstructure

For the superstructure package, the study split the floor plates into six work zones and 3 concrete pours (rather than two zones with two pours as occurred during the build). Sequencing and crew size would be as follows:

- Twin walls + steelworks start at the same time (happened several times).
- Start-to-start steelworks + ComFlor = 2 days.
- Start-to-start ComFlor + shutters = 2 days.
- Start-to-start shutters & steel fixing = 2 days.
- Three concrete pours.
- One crew for steelwork install = 3 workers.
- One crew for ComFlors = 2 workers.
- One crew for shutters = 2 workers.

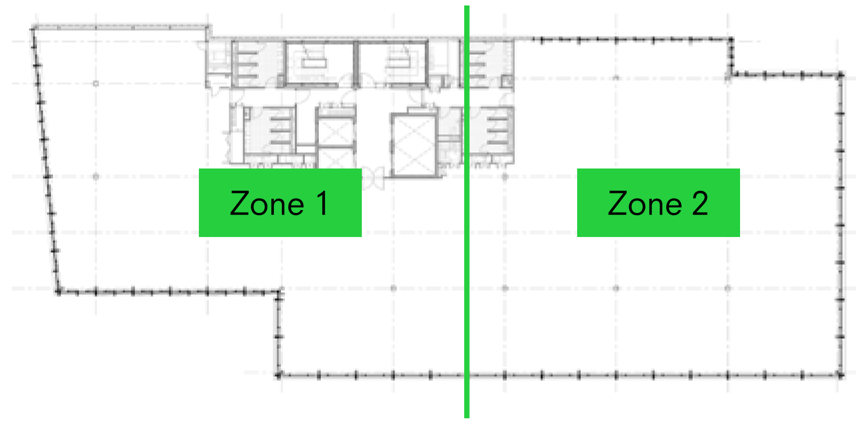
This smaller 'batch size' would rely on accurate logistics to ensure activities are fed with the right materials and equipment. However, the impact would be:

> A cleaner, safer and more organised work area with reduced inactivity.

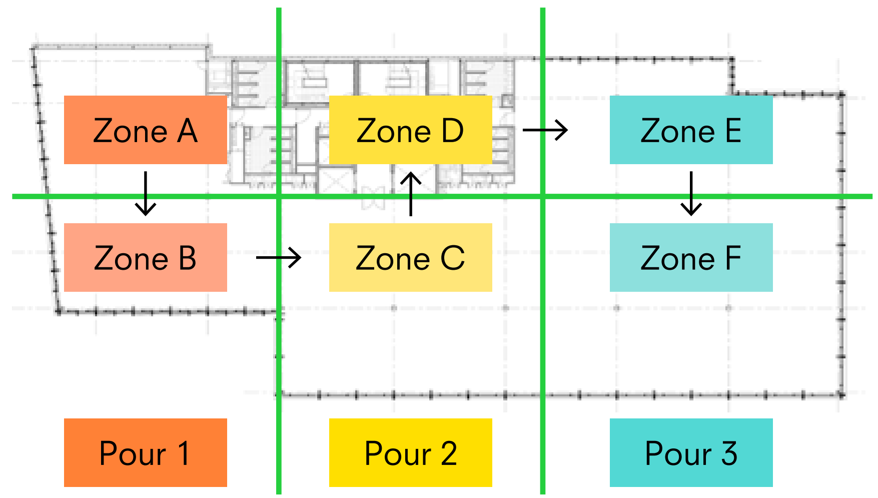
> Rate of work (per level): 1,575 m²/19 days = 88 m²/day.

> **This is an improvement of approximately 40%.**

Optimisation of superstructure installation



As built: Two work zones with two concrete pours.



Optimised sequence: six work zones with three concrete pours.

Activity	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Twin wall																			
Steelwork	A	A	B	B	C	C	D	D	E	E	F	F							
ComFlor	2 days		A	A	B	B	C	C	D	D	E	E	F	F					
Shutters			2 days		A	A	B	B	C	C	D	D	E	E	F	F			
Steel fixing + QC					2 days		A	A	B	B	C	C	D	D	E	E	F	F	
Concrete pour											AB				CD				EF

Optimised sequence of works - takt time = 2 days

Optimisation potential: Across work packages

The study was also carried out across the façade and MEP packages, using the following assumptions:

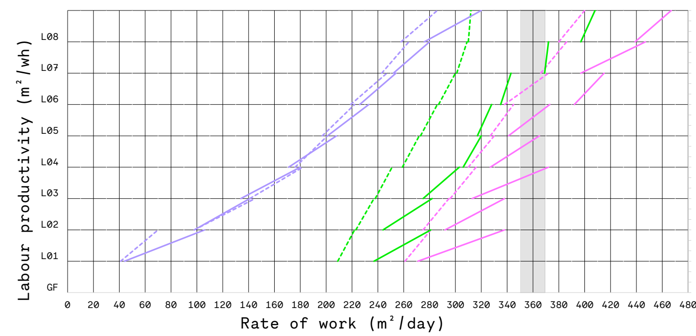
- Start-to-start superstructure + cladding = 4 levels difference.
- Start-to start cladding + CAT A modules = 2 levels difference.
- Third quartile (75% performance) for cladding:
  - 42 unitised panels/week.
- Third quartile (75% performance) for the CAT A modules
  - 35 Unistrut pieces/day.
  - 15 ComFlor pieces/day.
  - 6 FCU modules/day.
  - 8 pipework modules/day.

The graphs on the right show the impact.

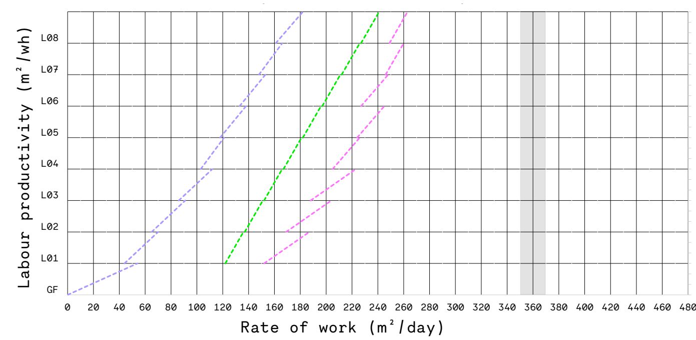
> **Without having to work faster than has already been achieved** (on the first-of-a-kind project), Platform II allows a readily achievable **overall schedule reduction of 40%**.

> The Platform II superstructure could, once familiar to operatives, **double the productivity while matching the speed** of a precast solution.

Impact of planned vs actual vs optimised rates



Planned vs actual work packages

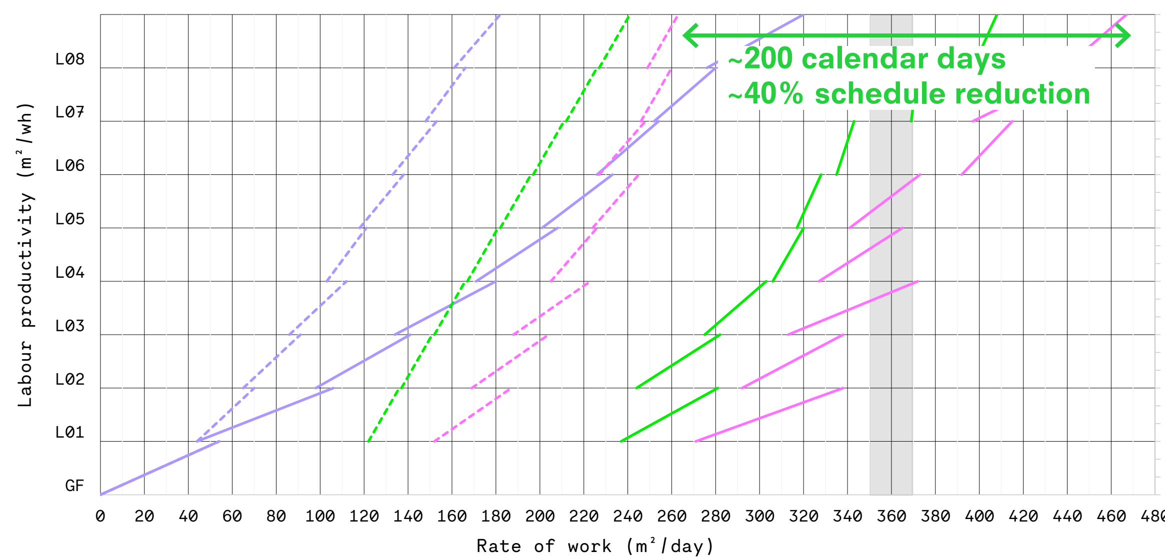


Optimised flow lines (75% performance)

Key

- Actual superstructure
- Optimised superstructure
- Actual cladding
- Optimised cladding
- Actual Cat A MEP modules
- Optimised Cat A MEP modules

Actual vs. optimised flow lines



Summary findings + achievable metrics

The analysis conducted by the Cambridge research team has shown that by consistently delivering on readily achievable installation rates and an improved workflow, it is possible to significantly reduce construction cycle times and increase productivity.

The team considers the following targets are viable for the next adoption of platforms.

› Superstructure

- Achieving a consistent installation rate (reducing variability) shows a potential programme reduction of 25%-55%;
- Maintaining a maximum productivity rate could reduce operative hours by 40%.
- Resequencing the floor plate to minimise periods of inactivity could result in a programme reduction of approximately 40%, achieving **a speed similar to precast with double the productivity.**

› Façade

- Achieving a consistent install rate equivalent to the top quartile performance achieved at The Forge (reducing variability) indicates a **potential programme reduction of 40%** for the façade installation.

› MEP

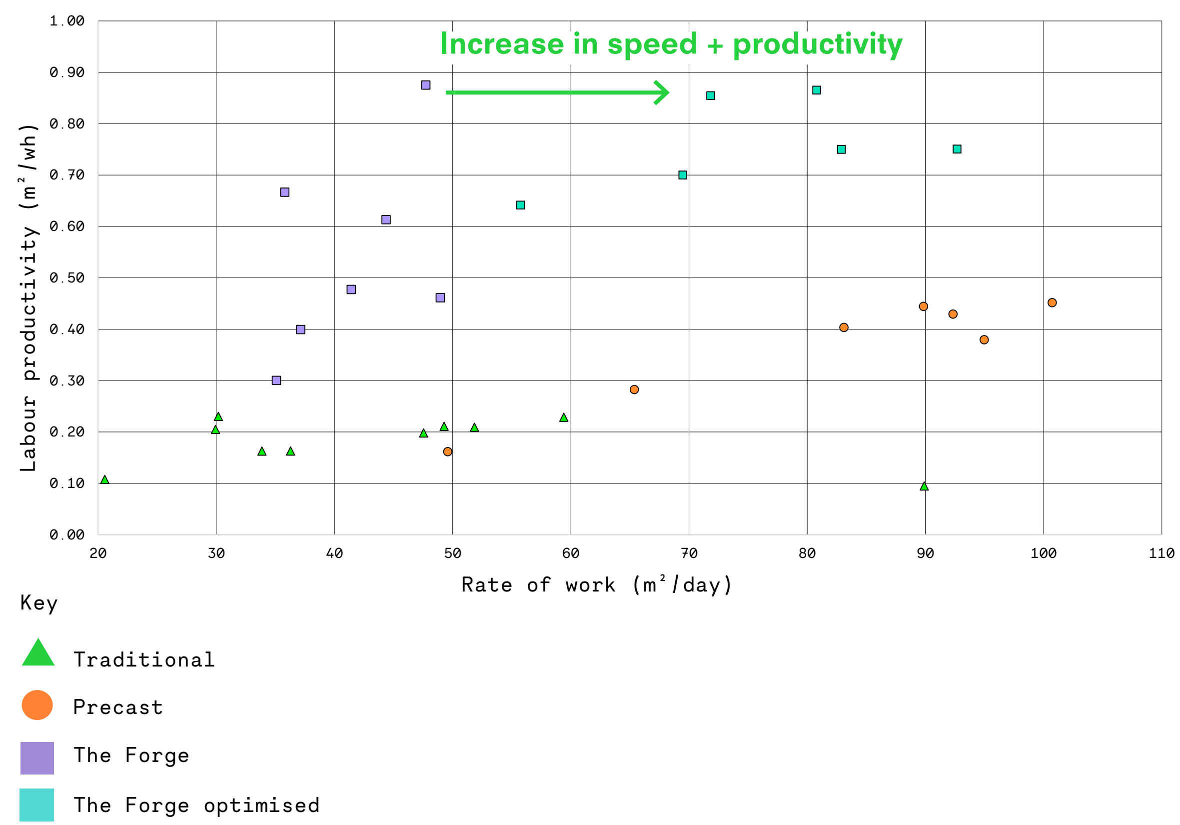
- The installation rates achieved for the high-level on floor M+E services using cassette modules at The Forge show **programme improvements of 66%-90%** are possible compared to traditional install methods.

Key takeaways + next steps

- The system reduces the need for operatives on-site;
  - Implementing multi-skilling would provide more capability to increase productivity.
- High variability of installation negatively impacts on productivity.
- To leverage the possible efficiencies, Platform II needs to be combined with an updated method of project management and site logistics:
  - Traditional Gantt Charts only consider site activity durations, but not piece count or logistics.
  - Think of P-DfMA as a factory process to achieve dramatic improvement.
  - Plot flow lines to visualise master plans and monitor progress.

- Benchmark production rates for all work packages:
  - Use flow line analysis to ensure a good level of ‘telescoping’ or ‘overlap’ within and between work packages.
  - Synchronise production rates between work packages:
  - Reduce start-to-start time.
- Consider smaller batch sizes for superstructure assembly.
- Prescribe performance measurement of key indicators (include in project contract preliminaries).

Achievable speed + productivity using Platform II



Alignment

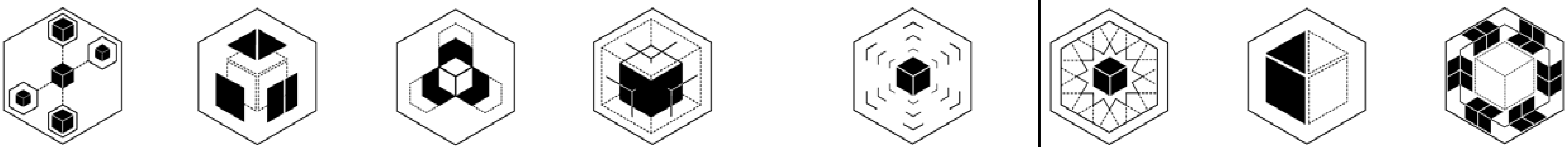
Platform II + the Product Platform Rulebook rules

The CIH's Product Platform Rulebook sets out some key rules and principles to assist in identifying the characteristics of a successful platform.

Platform II was developed in advance of the CIH being established. However, this section summarises how the Platform II design and benefits align.

Rules

Principles



Source: Construction Innovation Hub Product Platform Rulebook.

Deployable

Rule

- Product platforms shall be deployable across multiple, non-identical assets.

Platform II

Solutions have already been designed and tested for applications in a range of sectors, including:

- Education (DfE GenZero teaching blocks).
- Healthcare (standard ward blocks and New Hospitals Programme Hospital 2.0).
- Residential (for private developers in the UK and US and as part of a self- funded residential platform solution incorporating MEP and fit-out complementary products).
- The MOJ estate (women's and men's blocks for house block expansion programme).

By incorporating a longer-span beam as a complementary product, the system has also been used to deliver the UK's first Platform building, The Forge, for Landsec. Use of the system is one of the key reasons why this project is the UK's first net zero carbon commercial office, as defined by the UK Green Building Council's scheme.

Sample cross-sector configurations

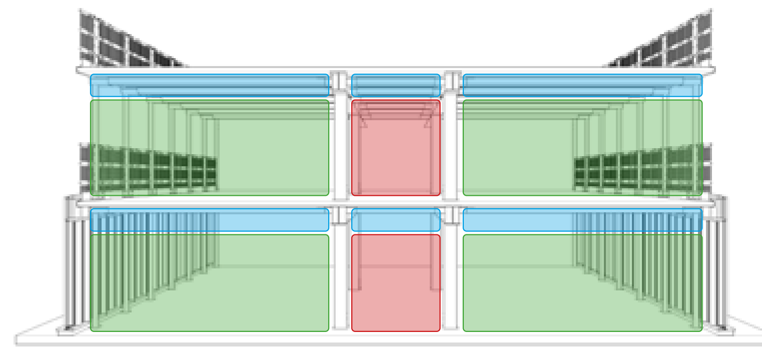
Key

MEP zone

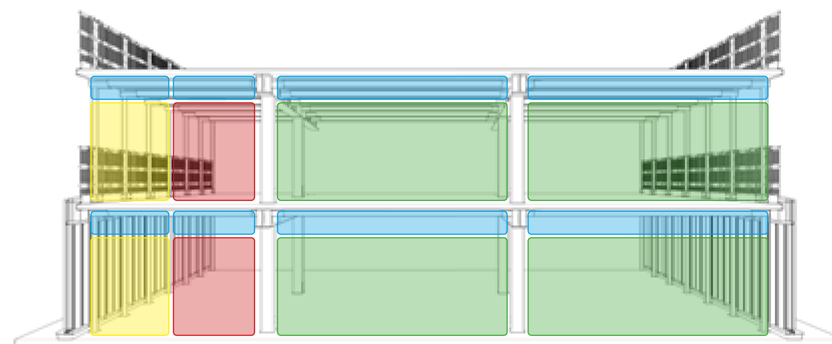
Functional space

Support space

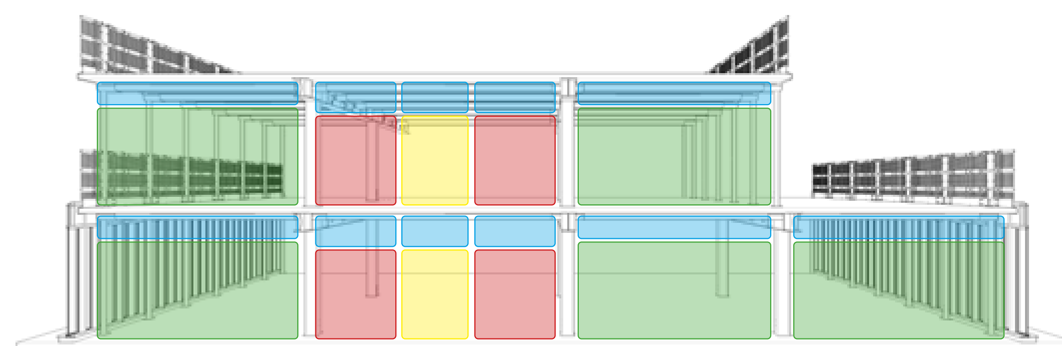
Circulation space



Residential or education configuration
(e.g. mid-rise apartment building or teaching block).



Commercial configuration
(e.g. open-plan office).



Healthcare configuration
(e.g. hospital).

Configurable

Rule

- Product platforms shall be configurable to suit individual project requirements.

Platform II

There are numerous options available to meet a specific requirements without changing the method of manufacture and assembly, on-site processes or repeatable brackets. The system allows the following adaptations at zero or minimal cost:

Superstructure

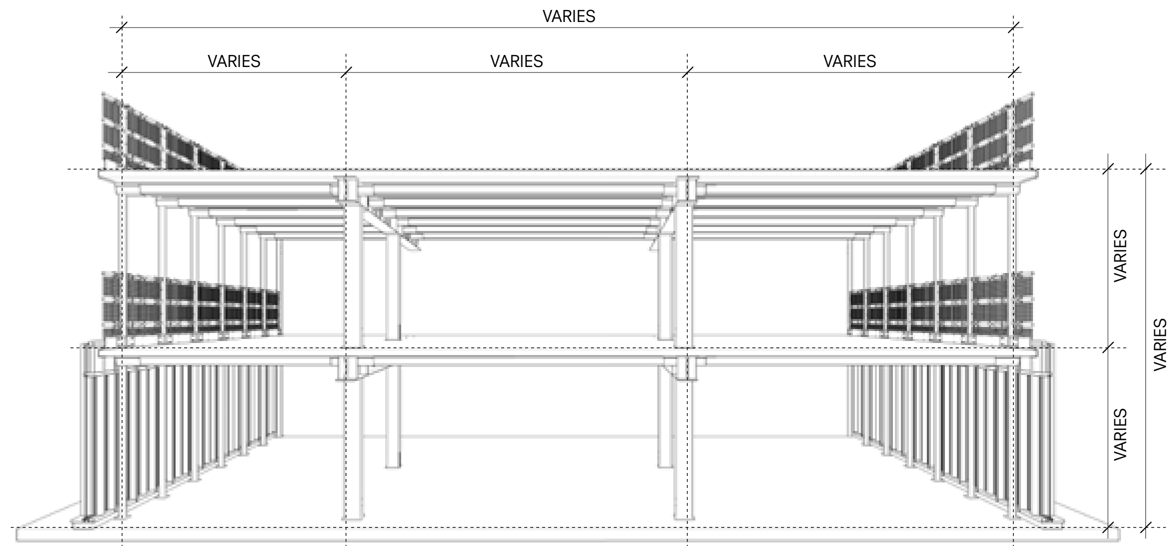
- Floor-to-floor heights: Because the columns require no fabrication, they can be cut to any length from standard sections. As column sizes are selected based on loading and building geometry, structurally, there is no limit on floor height. However, the installation methodology relies on standard props that may be suitable for 4.5m; an additional kit of props can be used to increase this if needed.
- Long spans: Because the permanent shutters use an existing product which is commoditised, it can be cut to any length. Standard components can achieve spans up to 9m; however, with extension pieces that increase the downstand size, long spans can achieve a 12-15m span.
- Short spans: The bay spacing can also be changed to suit particular planning grids by changing slab thickness.
- Slab thickness: Concrete can be poured to the depth required to suit the short spans and vibration or acoustic requirements.
- Edge downstand: Because this is a simple metal rolling, the depth can be changed to accommodate specific loads (depending on factors such as façade type) or fixings for balconies or solar shading.

Complementary elements

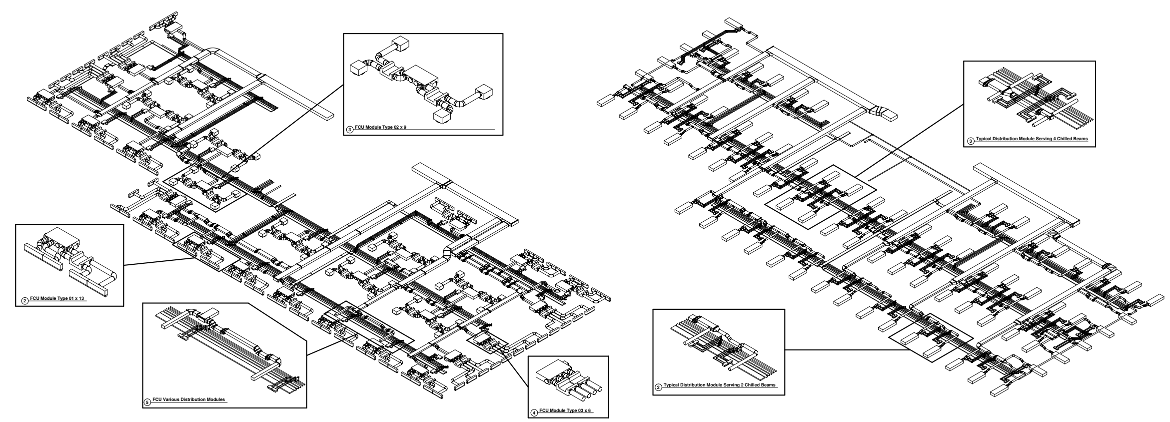
Without changing the method of manufacture, assembly or on-site processes, complementary products can also accommodate asset-specific design:

- MEP cassettes can be designed to accommodate FCU, chilled beams or other heating and cooling strategies.
- Façade interfaces can accommodate any unitised, precast or 'stick built' façade system to suit aesthetics, local context or thermal and lighting requirements. The original MOJ platform included a readily manufactured façade system using commercially available materials and low skills required in assembly.

Mass customisation opportunities built into Platform II



Options for mass customisation, allowing flexibility of asset while using standard components and processes.



Two MEP options for The Forge: One using FCU's and one with chilled beams. Both are designed to use common cassettes that are attached to fixing points precast into the slab.

Common repeatable elements

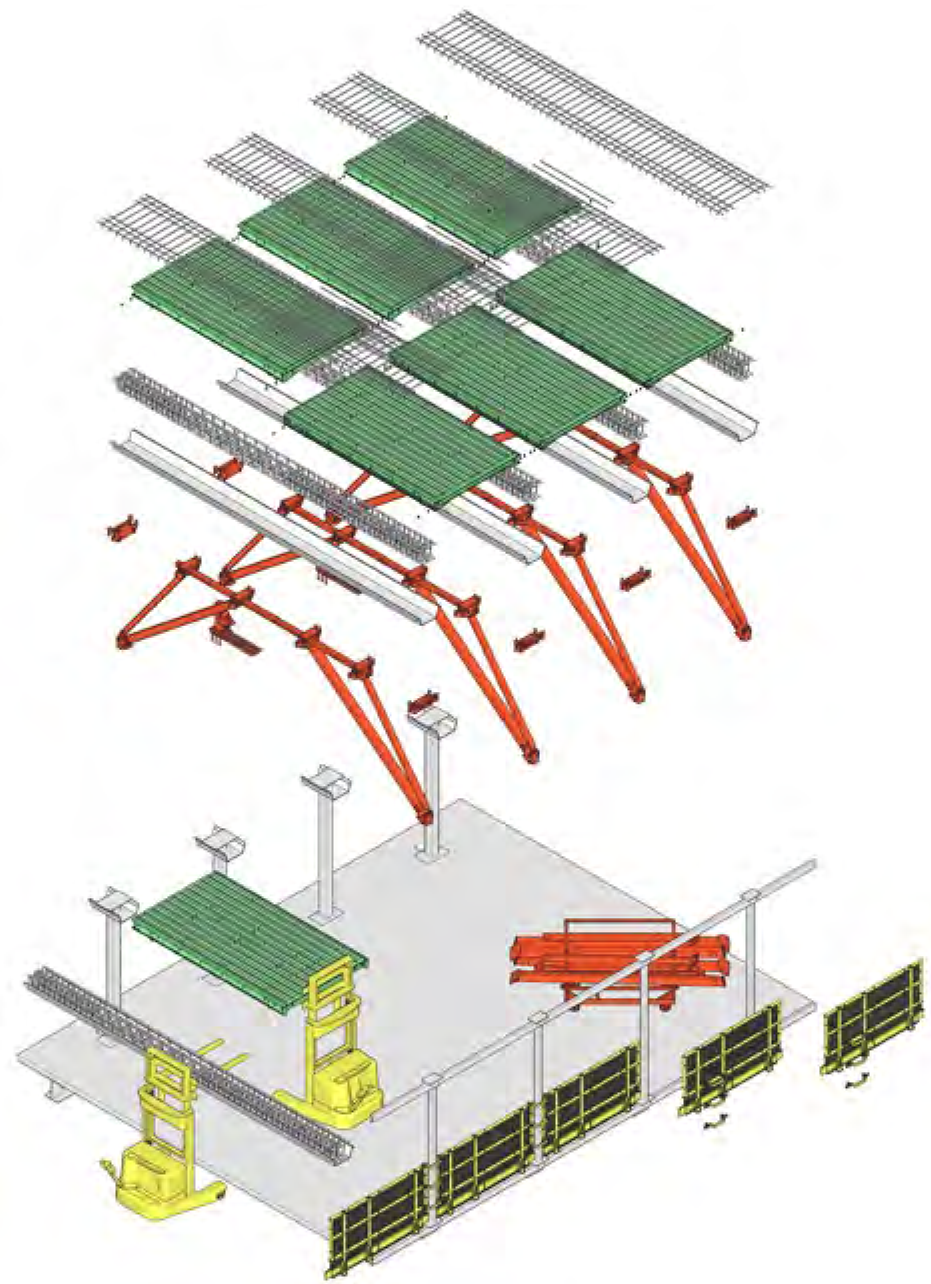
Rule

- Product platforms shall comprise common repeatable elements including:
  - Kits of parts.
  - Production processes, etc.

Platform II

This publication provides detail on the components, manufacturing + processes and equipment.

Platform II elements



Interfaces

Rule

- Product platforms shall have defined interfaces which can be made available to the designers and suppliers of peripheral or complementary products.

Platform II

The superstructure includes a number of built-in interfaces:

- The columns are standard square hollow sections, so there are already commercial systems designed to interface with these (fixing systems, fire protection etc.).
- The fixings cast into the soffit have a threaded socket, allowing for a range of common existing products such as drop rods and Unistrut etc. – to be fixed to the soffit without drilling. Overprovision of fixing pints allows for future flexibility and adaptability.
- The penetrations in the complementary long-span beam have been designed to maximise the number and type of MEP services that can pass through them.
- Façade fixing positions are designed to allow a range of existing unitised, precast, 'stick built' façade solutions to be used. The original work for the MOJ also included a readily manufactured façade system that used commercially available materials and required low skills for assembly.

Pre-configured interfaces for complementary elements

MEP attached to fixing points cast into the soffit.

Long-span beam with overprovision of penetrations for future MEP adaptability.

Open

Rule

- For a product platform to be deemed an open product platform, it shall enable any party to make, use and buy the common, repeatable elements, for legitimate purposes.

Platform II

Bryden Wood stipulated that the original contract with the MOJ (under which Platform II was developed) includes the following Intellectual Property clause:

> "The Designer grants the Client [UK government] an irrevocable, royalty-free, worldwide and non-exclusive licence in perpetuity to use, copy and reproduce the materials for any purpose whatsoever."

As a result, the UK government is already able to deploy Platform II widely.

As described in detail in the 'Platform II components' section, common, repeatable Platform II elements have already been shared with a number of industry parties to allow them to develop and deliver workflows and complementary solutions:

- **Easi Space** have developed robotic cutting and welding capability based on temporary works design.
- **NG Bailey** integrated MEP cassettes.
- **Aluprof** developed and delivered a façade system.

Sharing the learnings

The common, repeatable elements, processes and equipment have been well documented and the learnings shared widely:

- Platform II solutions have been developed and freely shared with organisations including the DfE, Vinci and Lendlease in the UK. Currently, they are being developed for a number of organisations in the US.
- Components and processes that were initially designed for the MOJ estate have already been adopted and further developed for Landsec.
- All learning from The Forge has been captured and disseminated via a series of reports created for Innovate UK (as part of the UKRI 'Transforming Construction' grant funding as a 'Demonstrator' project).
- The Forge has been visited by numerous government bodies, including representatives from the IPA, HM Treasury, DHSC, NHP, MOJ, DFE, MHCLG.
- The Forge has been studied by the University of Cambridge (Laing O'Rourke Centre for Construction Engineering and Technology).
- Learnings from this work have been incorporated into work for the New Hospitals Programme (NHP).

Encouraging innovation

The Platform II component designs have also been freely shared with a number of industry players, to enable them to explore how they might refine the components of developing complementary elements. These have created some interesting use cases, including:

- MetLase laser cut reinforcement.
- CIH robotically fabricated brackets to reduce piece count + cost.

> "Using P-DfMA... the partners demonstrated that office construction could be faster, more reliable, more productive and cost less - leading the way to an increase in quality, sustainable working environments and a new creation of skills and jobs in the construction workforce."

UKRI/Innovate UK

Click here to read more on the UKRI website

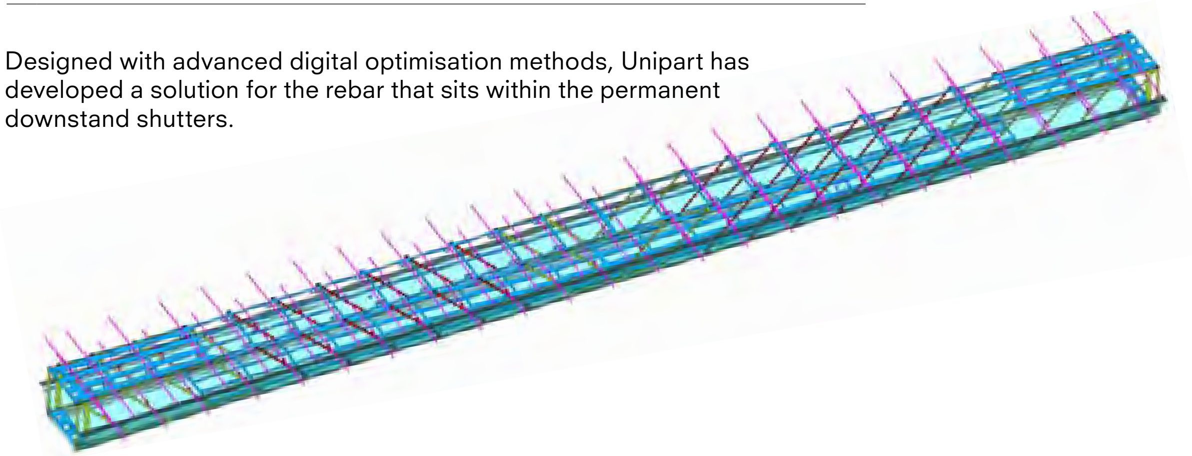
Case study: Laser cut reinforcement

In 2014, Unipart and Rolls-Royce decided to form a joint venture to bring a novel range of technologies, combining laser cutting, press-brake, and ingenuity, into a system to rapidly solve a huge range of engineering problems. As a result, MetLase has diversified into many sectors including aerospace, automotive, rail, energy, medical and construction.

Recently, MetLase has been developing a new technology for concrete reinforcement using laser-cut steel plates and its patented joining technologies. Due to the levels of interest from the construction industry and its potential to be transformative, a spin off company, Unipart Construction Technologies, has been formed. Proven benefits of the new reinforcing technology include:

- Highly optimised material placement: Reinforcing plates can be designed to use the minimal amount of material with steel only used where it is required. Reductions of 60% against current design practices can be achieved.
- A high degree of accuracy: Sub-millimetre precision through Computer Numerical Control (CNC) laser cutting to support modern methods of construction.
- Laser-cut reinforcing frames are faster to assemble and install. This new technology also offers opportunities for new approaches and innovation to further reduce programme duration.
- Patented joining technologies eliminate the need for tying rebar cages and reinforcing frames can be designed for safe transportation, installation and access/egress when casting.

Designed with advanced digital optimisation methods, Unipart has developed a solution for the rebar that sits within the permanent downstand shutters.



"By working with platform design initiatives, we have gained valuable experience through sharing knowledge, becoming aware of current developments and challenges and engaging and connecting with others.

The opportunities gained from industry leaders such as Bryden Wood, have allowed us to target and direct our resources to problems that may lead to the most advantageous innovations. As such, we now have a number of developing innovations that have been proven at full scale."

UNIPART CONSTRUCTION TECHNOLOGIES
Transformative technologies for the construction industry

Dave Allen
General Manager
Unipart Construction Technologies

Case study: MTC robotic fabrication of brackets

The Manufacturing Technology Centre (MTC) has been working with Bryden Wood since 2017. The MTC is a strong advocate of a manufacturing-led approach in the built environment, facilitating the transfer of knowledge, processes and technology from the manufacturing sector to help improve productivity, quality and health and safety.

The original Platform II brackets were fabricated from pieces of plate steel. The MTC undertook a study to re-design the brackets to reduce piece count, facilitate automated fabrication and ease of pre-assembly. Brackets were laser-cut from a single sheet of steel, with the key and lugs directly incorporated. The sheet metal was then formed in a press brake.

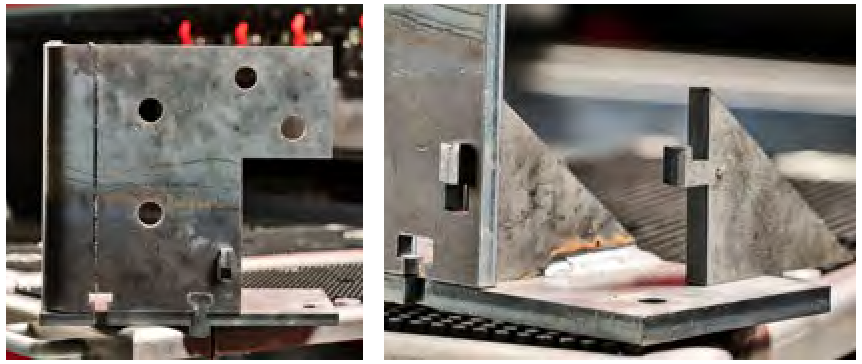
By allowing the brackets to be pre-assembled with an incorporated key and lugs, a single fixture plate could be used across six different patterns.

Proven so far:

- Using press-welding simulation software.
- Development of the key and lug, quick pre-assembly system.
- Low to high volume on and off-site manufacturing capability.
- Supporting agile fabrication methods.

Potential next steps:

- Automated loading and unloading of components.
- Advanced metrology and weld quality control.
- Provision for smart features in the design.



Laser cut Platform II brackets developed by the MTC

Read more about the MTC/Bryden Wood showcase event

Working Together Transforming Construction

"Bryden Wood's structural kit of parts provided a great opportunity to demonstrate how best practices in manufacturing can be applied to common, repeatable platform components.

In the particular case of the Platform II brackets, a DfMA approach was taken to reduce part count and enable the automation of the manufacturing processes to increase quality, functionality and productivity.

By applying this to the Platform II brackets, we were able to demonstrate how these could be manufactured repeatably and efficiently, at scale, using existing manufacturing tools and quality processes, resulting in predictable performance and outcomes."

mtc
Manufacturing Technology Centre

Liam Hill
Deputy Chief Engineer - Built Environment
Manufacturing Technology Centre

Quality + structured information

Principle - Quality

- Product platforms shall have a defined quality standard.

Principle - Structured information

Product platforms shall have a structured approach to information for:

- Product information.
- Deployment information.
- Organisational information including capability and credibility.

Platform II

Platform II has been designed to eliminate tolerance issues at source through creating a very accurate superstructure (±5mm achieved on 9m bays at The Forge). Quality is ensured at every stage of the process:

> Drawing down from a digital library of highly repeatable components allows each one to be optimised and the necessary information to be embedded in a database.

> Automatic configuration ensures the correct components are used, within their predefined parameters, and models contain correct and version-controlled components.

> Using a central data set (with BIM as one automated output) allows multiple parties to use the information reliably.

> Robotic cutting and welding removes the potential for human error and ensures consistency and accuracy of components.

> QR codes on components allow the provenance of components to be tracked and traced.

> Simple, repeatable assembly processes and 'poke yoke' design of components reduces reliance on skills and workmanship and ensure accurate and consistent installation.

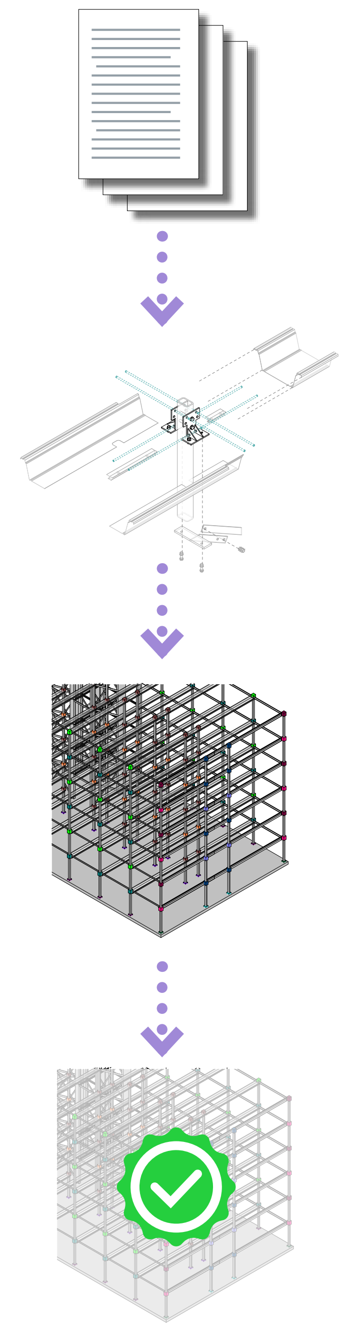
> Use of automation facilitates safe and productive working.

> Colour coding allows simple visual quality inspection.

> Converge sensors in the concrete slab to ensure reliable strength measurement for striking of shutters.

> Accurate placement of MEP fixings facilitates 'bench top' assembly of MEP.

Suggested quality assurance process



Design

- A set of common requirements are established for various asset types, for example, typical spans, loads, etc.
- These are set out and captured in a 'Basis of Design' (BoD) document.

- Components are designed to work within the ranges set out in the BoD of e.g. span for known loads and conditions.
- The component design is optimised for the method of manufacture.
- Component design is 'category 3' checked by one or more of a panel of nominated experts.
- Once validated, they are placed in a digital library (with linked manufacture and installation information) to be drawn down on projects.

- Components are used within design models by a range of designers who will take design liability for the overall design and ensure components are deployed correctly.
- Parametric rules checks checks, such as Dynamo scripts or Solibri, are used as the first point of verification/validation that the components have been deployed correctly.

- Initial models are then category 3 checked for further validation.
- The checking regime is reduced over time as users become more comfortable with the use of components.

Manufacture + assembly

- Manufacturing processes are developed and tested in line with the material and performance characteristics.
- Advanced Product Quality Planning (APQP) and other manufacturing quality assurance processes are put in place.
- Manufacturers demonstrate their ability to manufacture within defined tolerance and quality levels.

- Batches of finished components are tested in line with predefined checking regime.
- Manufacturing data, material provenance, etc. is documented and stored digitally (the 'golden thread') for future use (reconfiguring, re-purposing, recycling, etc.)

- Assembly processes, including tools and training, are linked to the digital components and available for 'toolbox talks' and point of use (via e.g. RFI tags/QR codes/laser projection).
- Components are installed in line with these assembly processes.
- Checking is carried out by an agreed inspection regime and automated point cloud scanning, etc.

QA + approvals process for design, manufacture + assembly.

Circular

Principle

- A product platform shall enable a degree of circularity for components and sub-assemblies beyond their first intended deployment. The degree of circularity shall be evidenced.

Platform II

Elements are designed for potential reuse or recycling, including a number of features:

- Temporary works components can be re-used across multiple projects:
  - All of the brackets and props are aluminium of painted/galvanised for protection giving them an indefinite lifespan. The surface off the slab shutters can be re-applied, extending the lifespan of the shutters.
- All temporary works components can also be recycled, with a known material content and provenance.
- Permanent steel elements are tagged with technical information for reuse.
- Reversible bolted connections mean steel columns can be easily removed.
- The steel and concrete elements use high recycled content.
- The superstructure is designed to facilitate ease of future maintenance and replacement of MEP and façade:
  - Repeated pattern of cast-in fixings in the slab allow for MEP cassettes to be easily removed and replaced.
  - Overprovision of cast in fixing points and penetrations in steel beams provides future flexibility and adaptability.
  - A stiff slab with façade fixing brackets facilitates ease of façade replacement without modifications to the frame.

However, Platform II also provides a 'long life, loose fit, low energy' solution that allows for a more elegant approach.

The CIH's 'Defining the Need' report shows that a mid-span superstructure would be appropriate for a number of asset types (70% of government assets across sectors, plus multi-occupation residential). A Platform II superstructure could therefore be re-purposed and adapted for different uses over a long period, by replacing and recycling the façade, MEP and fit-out kits. This approach has been demonstrated by the reuse of Victorian-built superstructures, which have been converted from schools to apartments, or warehouses to offices and commercial.

Façades could be designed with a lifespan of approximately 30 years, while MEP and fit-out components could have a lifespan of about 20 years (since these elements use aluminium, steel, glass, plasterboard, etc. which could be readily recycled). The use of a standard kit of parts would facilitate 'materials passports', documenting a known material content and residual value.

Components planned for reuse

QR code etched into temporary works to facilitate tracking and reuse.

Reusable Platform II temporary works elements.

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