INDUSTRY WHITE PAPER

Industrialised Construction: The Rebound from COVID-19

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Industrialised Construction: systematic control of the total supply chain from design, fabrication, and manufacture, to installation and management

This white paper will establish a global framework for the use of industrialised construction as the way for the construction industry to rebound from the COVID-19 pandemic and seize this opportunity to transform. The framework identifies recommendations that must be implemented by policymakers and private clients.

The Authors appreciate the input from these people and organisations:

The global construction industry cannot continue operating the way it does

Even before the COVID-19 pandemic struck, disrupting the sector's supply chains and halting activity on some projects, the construction industry was weakening. The current issues include labour shortages, rising material and employee costs, increasing project complexity and the need to adopt more significant safety measures. Furthermore, the adoption of technological advancements seems to be harder and slower than in any other sector.

COVID-19 will have a long-lasting impact on the global economy, which will highlight further the precarious position of the construction industry. To ensure the industry is better prepared for future global economic, climate, cultural turmoil, it needs to move towards a model of industrialised construction. The authors of this white paper believe these challenges can be addressed by pursuing the opportunities identified in Figure 1 below.

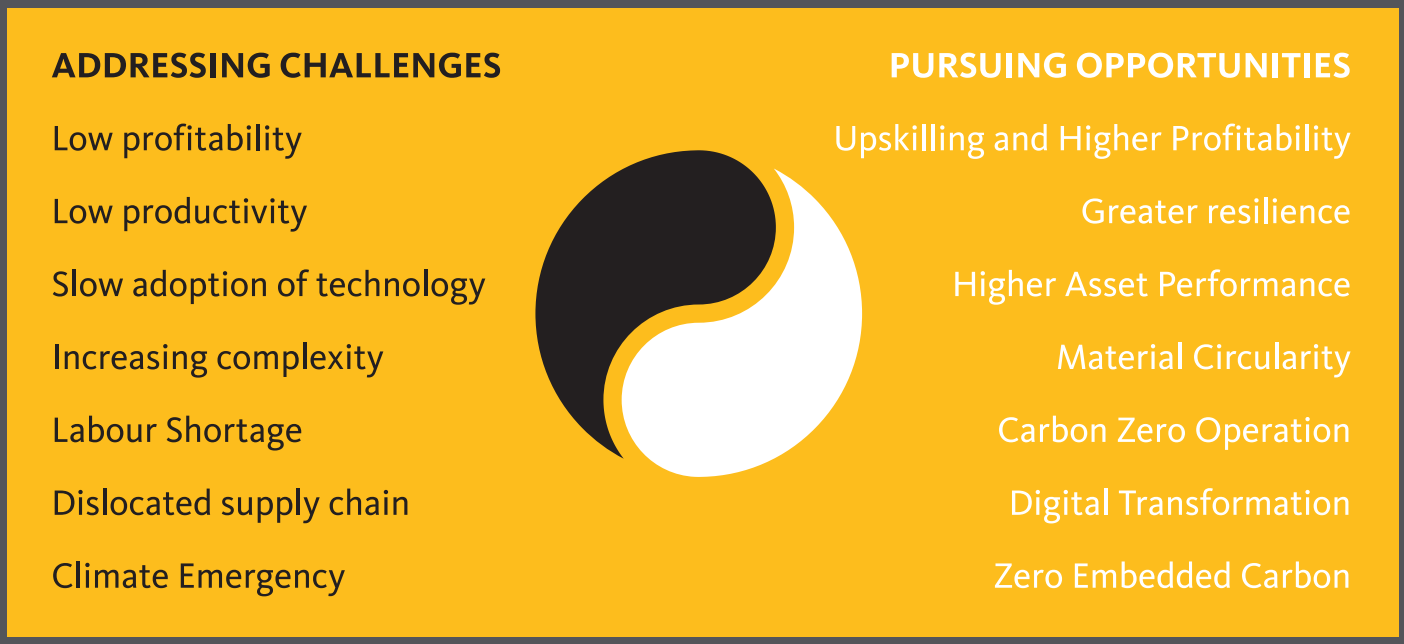


Figure 1 Addressing challenges by pursuing opportunities

Industrialised construction will transform the industry and bring it to a place of resilience. The only path to achieve this requires us to abandon our existing model and move to the mass industrialisation of the built asset sector.

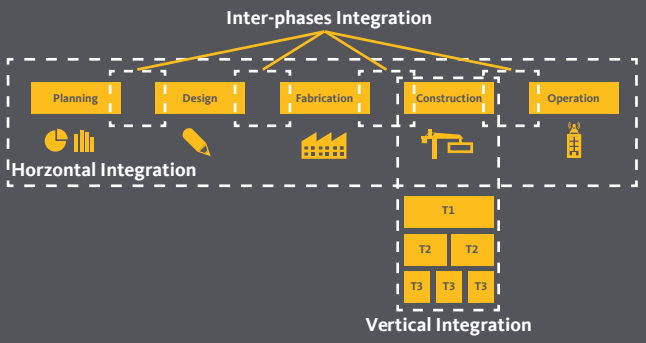
Industrialised construction will transform the building and construction industry through actions which include:

- Acceleration of digitisation and automation of all parts of the supply chain, so these new activities become business as usual.
- Reallocation and acceleration of upskilling employees.
- Acceleration of the implementation of required structural measures to create a significant increase in efficiency while reducing the cost structure.
- Re-structuring of the supplier base through waves of integrations, divestments, and mergers of companies to align their capabilities with the new value chain of industrialised construction.
- The creation of intelligent procurement platforms for live projects, new sources of project finance and the reorganisation of the new supply chain and the unearthing of resource planning.

This white paper includes four sections that pursue opportunities to rebound from COVID-19

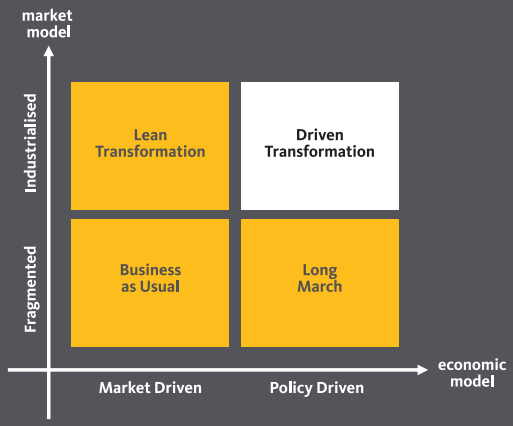
1.

Industrialised Construction (IC) – "COVID-19 ready" – the new operating model for construction



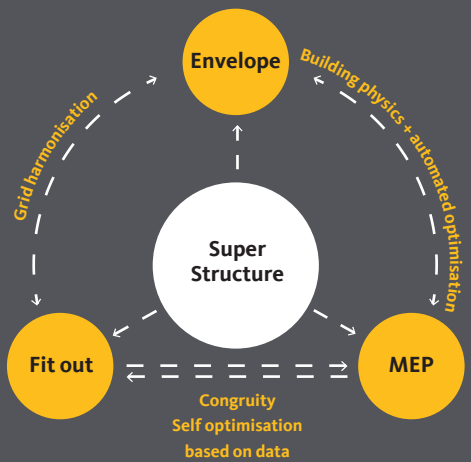
2.

How do we target and use the economic stimulus post-COVID-19 to transform the industry?



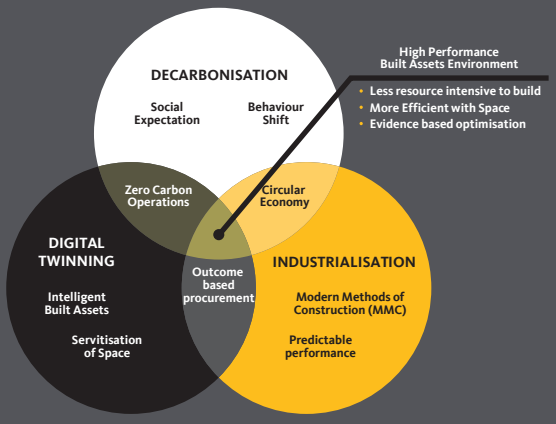
3.

Unearthing a new supply chain which is industrialised and mobilises modern methods of construction?



4.

Industrialised construction leads to better Building Performance – What does a high-performance Built-Environment look like?



Section 1: Industrialised Construction – the new operating model for construction – COVID-19 ready

Pre-COVID-19, the emerging operating model for our industry was Industrialised Construction (IC). Since new safety-standards such as social distancing, hygiene and operating procedures are being introduced for the sector post-COVID-19, IC has become the best, most sustainable and most resilient model with which to move forward.

Adopting IC brings the increased productivity and re-organised processes required in a post-COVID-19 world, this Is enabled through technology to deliver:

- **A safer workplace under COVID-19 conditions.**
- **A more resilient sector.**
- **Upskilling workforce and labour mobility.**
- **Increased productivity.**

Under IC conditions, firms shape processes and technology to follow production and manufacturing principles. Industrialisation enables process, product lifecycle and supply chain optimisation and reorganisation. Until this time, IC has only been possible for more straightforward buildings, typified by temporary structures (e.g. Portakabins©) or emergency re-construction efforts such as in post-war Europe. When attempted on schemes larger than single houses, IC has typically led to the simplification of buildings in an attempt to limit complexity and fit within the level of available technology. This reduction in design options has led to disappointing outcomes in term of form and social wellbeing.

In the 21st century, powerful technology platforms such as Katerra Apollo™ and Autodesk Construction Cloud™ help manage the combination of complexity and the bespoke site adaptations, which are unique to our industry. With this leap in technologies, IC can now be adopted for a greater diversity of typologies, as proposed by the UK government "Modern Methods of Construction" initiative, based on a "platform DfMA."[1]

In the process of industrialising, sectors have typically gone through four stages: specialisation, standardisation, automation, and digital integration. This journey has been transformational in the past 100 years with industries such as automotive and aerospace. In contrast, the construction industry has stagnated in this first stage of specialisation for decades, which has led to a fragmentation of the industry which has stifled innovation.

To move forward, the construction industry must follow the journey of industrialisation undertaken by other industries [2]:

1. Specialisation – the process by which organisations become increasingly specialised in the delivery of a product or service. The process of specialisation typically occurs in pursuit of a sustainable competitive advantage.

2. A move to a production mindset through standardisation of the process. This stage is subdivided into three. The first step is control. This ensures that a process is repeatable, and can be managed. This is typically achieved by co-locating workers in a setting in which the environment is controlled to ensure consistent production, historically a factory. Figure 2 shows how the production approach can be translated to construction. This indicates that today, it is possible to reach a similar level of control even when we now need to consider physically distancing processes.
   With the processes captured and routinized, they are subject to a high degree of optimisation. This occurs through informal means – suggestions, observations, etc., or more formal approaches, such as the adoption of Lean.

[1] Projects worth £600 billion in the pipeline as government gets Britain building – www.gov.uk
[2] P-DfMA; A Proposal for a New Approach to Building, MACE, Feb 2019

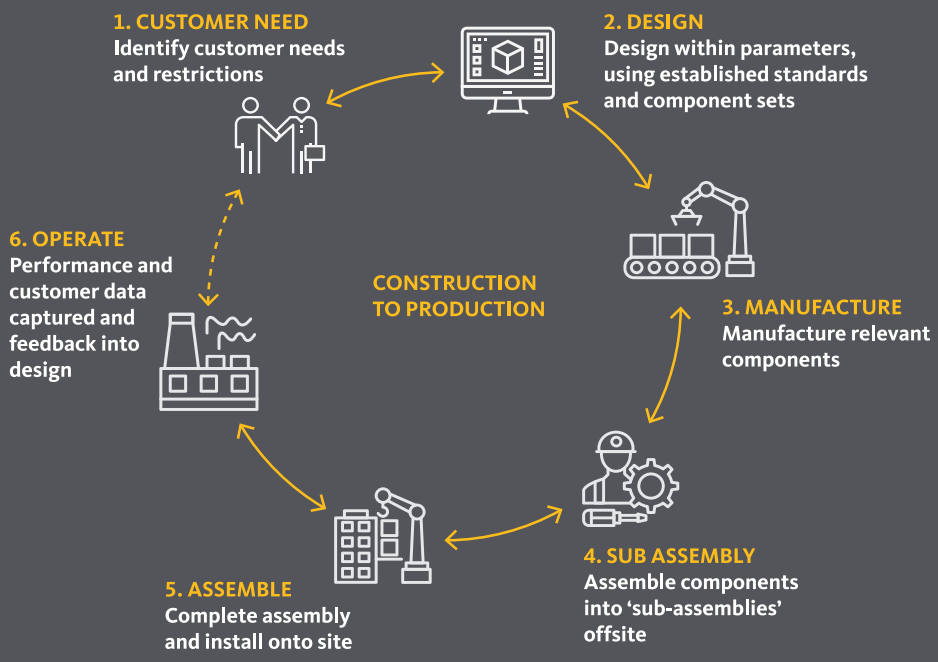


Figure 2 - From Construction to Production © MACE Construction 2020

3. Automation – Once processes have been standardised, they can then be considered for automation, the application of single-use technology (typically mechanical) to enhance the process efficiency. Opportunities in site-based construction are limited due to the uncertain and unpredictable physical environment. However, if organisations have progressed through the 'control' stage above, the opportunities for efficiency gains are increased significantly. MACE award-winning 'Jump Factory' provides an excellent example of this sequence being applied in good order. This example is illustrated in figure three.

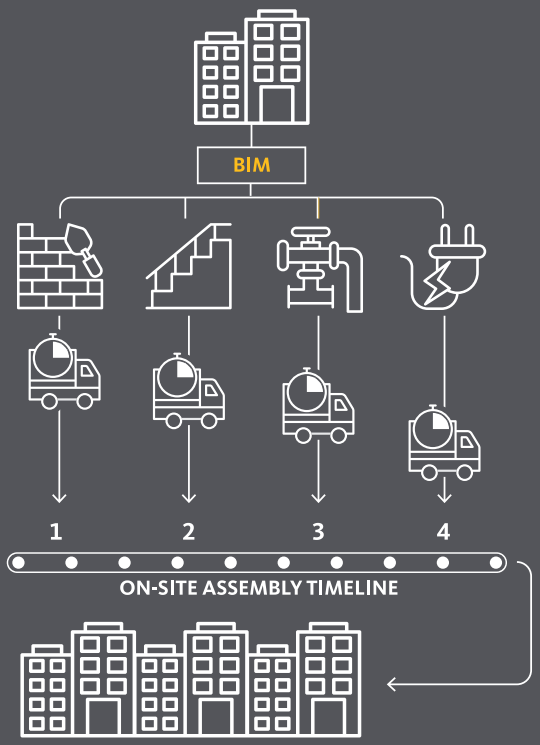


Figure 3 - Assembly approach to Construction © MACE Construction 2020

4. Digital enabling – The final stage of the industrialisation process is the application of digital technologies to optimise further, control or inform the production process (industry 4.0). In IC, this has been manifested as the horizontal integration of the supply chain, in ways that have not been used before in construction. Using digital platforms to smooth out the interphase integrations, as seen below in Figure 4, this allows for iteration and optimisation of products with timely, relevant feedback as well as minimising unexpected costs andcomplication in the construction and operation of the built asset.

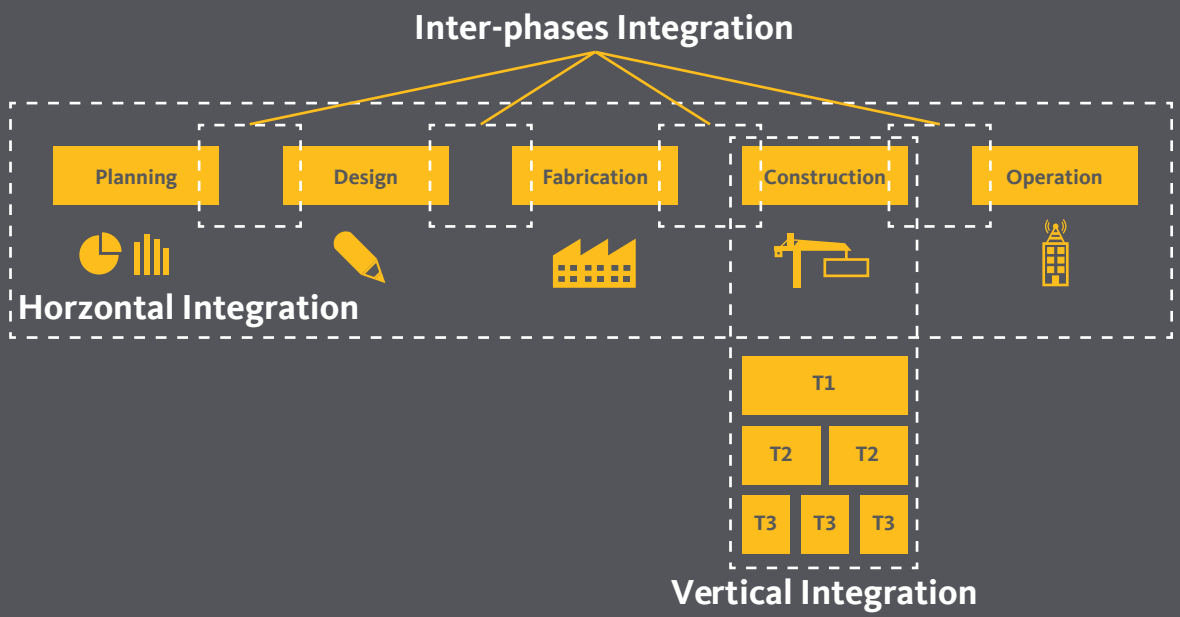


Figure 4 - Integration of the Construction Industry © Cogital 2020

Industrialised Construction will allow the application of manufacturing approaches such as:

1. sort, set in order, shine, standardise and sustain (5S)
2. schedule control
3. safety and quality control
4. motivation improvement

In these extreme times, IC will provide construction the level of control over the workforce that is required to implement effective COVID-19 distancing measures. These processes, which already exist in workplaces such as factories, have allowed them to restart production much earlier than construction sites. Jaguar and Aston Martin are looking to reopen their factory in South Wales as soon as 5 May 2020, while many others are well on their way to that goal. They can achieve this through the stricter control over their workforce, which is only possible in a production environment.

Every process and every activity has been carefully and explicitly defined. This allows systems to be developed, which keep the factory operational while ensuring that workers can socially distance. Working with IC processes would allow the construction industry to respond in a similar way to this crisis, by adapting their current, well-defined plans to meet new safety requirements, instead of scrambling to create these from the outset.

We want to emphasise production thinking in both offsite and jobsite activities. We have seen a strong take-up of production thinking in places where construction has moved offsite, which has delivered productivity improvements of up to 30%. The same production thinking should extend to the jobsite. The Stanford Centre for Integrated Facility Engineering (CIFE) research on jobsite productivity found that on a typical day, activities only occupy 3% of production slots.

The CIFE research suggests doubling this productivity rate is possible.[3] This philosophy, coupled with sequencing labour by work zones, would both satisfy COVID-19 requirements while improving productivity. Figure 5 shows a model presenting "factory thinking" extending to the jobsite by Katerra.

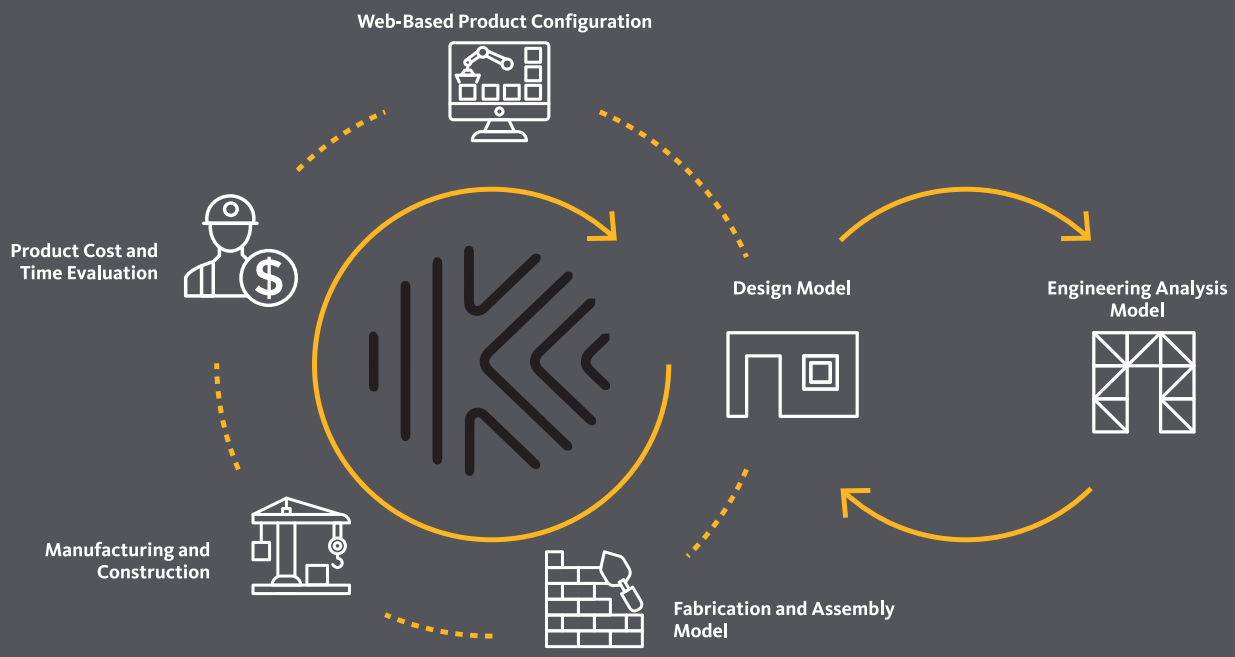


Figure 5 – Factory Thinking © Katerra 2019

In summary, IC can emerge when construction firms invest in technology, and in integrating their supply chain. Under these investments, the industry will achieve:

1. Integrated Project Delivery – as proposed by Stanford CIFE[4]
2. Integrated Digital Delivery, made possible by BIM – as proposed by the Singapore BCA[5]
3. P-DfMA, as proposed by the UK-led Construction Innovation Hub[6] - see Figure 6

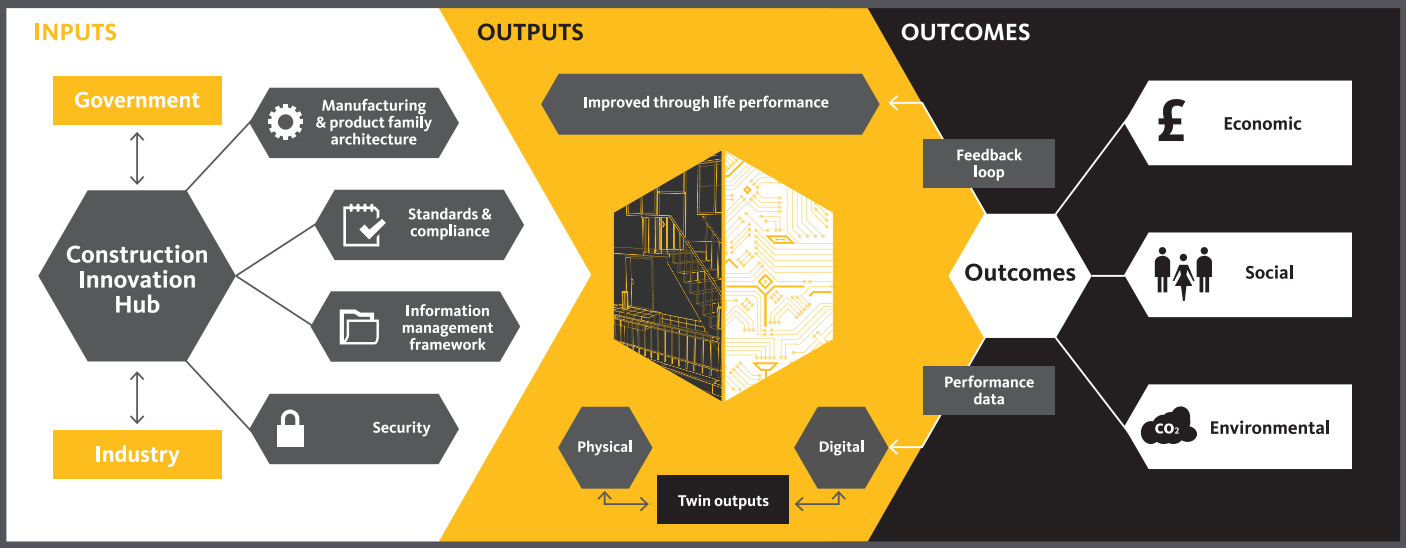


Figure 6 - UK Construction Innovation Hub to Achieve P-DfMA ©CIH 2020

[3] *Morkos, Renè (2015) Operational efficiency frontier: visualizing, manipulating, and navigating the construction scheduling state space with precedence, discrete, and disjunctive constraints, PhD Thesis, Department of Civil and Environmental Engineering, Stanford University.*
[4] *A simple framework for integrated project delivery - Martin Fischer, Dean Reed, Atul Khanzode and Howard Ashcraft - Proceedings IGLC-22, June 2014 | Oslo, Norway*
[5] *Integrated Digital Delivery (IDD) : https://www1.bca.gov.sg/buildsg/digitalisation/integrated-digital-delivery-idd*
[6] *Construction Innovation Hub – https://www.constructioninnovationhub.org.uk*

Our Recommendations:

1. A guaranteed spending commitment and pipeline to catalyse investment.

The industry model at present operates on low margins and do not adapt easily to new technologies and techniques. For the industry to innovate, governments need to set out cross-party agreement generating a guaranteed annual capital spend, through an IC procurement route. A guaranteed turnover would support industry and create a clear path to return on investment (ROI) Our estimates suggest a start point of $100m USD in revenue per annum, over five years to ensure a guaranteed ROI for a given facility.

2. Stimulate adoption through a plan for regional hubs, creating enterprise zones – aligned to areas where a qualified workforce is available due to plant closures.

The IC approach creates an excellent opportunity to distribute the value of the construction sector across regions. We propose that governments should support and foster an 'enterprise zone' model with associated tax breaks to promote accelerated regional growth in construction manufacturing.

By concentrating on the developments of network hubs geographically, it will support the ability of suppliers to work collaboratively and share learnings.

3. An approach to intellectual property that drives both the standardisation of interfaces and continuous improvements.

In order to create a common approach to platforms across the industry, governments need to lead on creating a suite of standard interfaces to form generic systems, components and connections. In effect, this would create the built environment's equivalent of a Bluetooth or the USB-C connector. To achieve this, government and industry need to establish a set of systems and components, which are developed and owned by industry (refer to the Construction Innovation Hub initiative in the UK).

Once completed, governments need to foster an environment where an element of invention or breakthrough of innovation is encouraged within that set of standards and specifications. If that invention sets the new standard, the inventor should be recognised through some form of ongoing intellectual property licensing or reward.

4. Rethink the "stages process" to improve outcomes throughout the design and construction process.

At present, the construction industry operates a process defined by national bodies such as RIBA in the UK or AIA in the USA. A platform-DfMA approach requires a positive difference in manufacturing-led processes with an increased emphasis on specific stages. This includes:

- Increased time for concept/requirement setting: An accelerated delivery process can create more time for establishing the right business case, and clarity on requirements and outcomes, which are then effectively met through a standardised product platform.
- A product development approach to design: An appropriate detailed design will eliminate any need for change once production commences. Post concept, the process needs to engage the right parties at an early stage and must take a 'product development' approach to manufacture and assembly, creating early commitments to time, cost and quality objectives.

5. Reset the measures of success and establish a new industry Global Scorecard.

We must re-imagine the key performance indicators through which we measure success, both in the method by which we have created (produced) that asset, and how it is performing in delivering the expected outcome. In other words, we must measure the commercial model for IC through the whole-life performance and the productivity (including on-site, off-site and in-use performance).

The measures to be included in the new scorecard for our industry include:

Capital cost/m2	**Days on site/m2**
Embodied carbon	**Units completed**
Productivity	**Pre-manufactured value (PMV)**
EPC rating	**Quality rating**
IM to the principles of ISO19650	**Waste generated**
ISO 9001 Accreditation	**RIDDOR**

Table 1 New Measure of Success © MACE 2020

Section 2: How do we target and use the economic stimulus post-COVID-19 to transform the industry?

Over the past ten years, trends in globalisation, heightened competition and short-term commercial and investment decisions have resulted in low net profit margins for contracting, typically between 2-5% for head contractors and subcontractors in the commercial sector. The disruptive effects of COVID-19 are challenging the industry's way of operation. This level of disruption could not have been contemplated when allocating risk and agreeing to contract terms. Post COVID-19 there is no doubt that businesses in the construction industry will need to adapt, and should be supported in the transition, to new, more efficient operating models.

To summarise, the crucial factors adding to the vulnerability of the industry during COVID-19 are:

- **The lack of strategic consideration by parties to reorganise their work practices long-term.**
- **The reliance on a supply chain that has under-invested in its technological proficiency.**
- **The economic impact to parts of the supply chain with limited liquidity.**

Governments response to COVID-19

Governments around the globe are responding to this crisis through instigating broad (not just specific to the building and construction sector) economic survival packages and stimulus policies to support small and medium-sized business. They have asked firms to continue to do whatever they can to help their real assets: their employees.

Many Governments believe that they are well-positioned to provide the investment pipeline that is needed in the economic recovery phase. Generally, they have re-affirmed that they will continue to work with industry to help ensure a stable and robust building and construction sector. The hope is that this vital sector can stabilise the economy and play a central role in the future economic recovery. The construction industry occupies this unique position as it produces the buildings and infrastructure that are essential to the operation of all other industries, underpins the future competitiveness of the entire economy, and adds to the prosperity of the country. An example is demonstrated through sound Government leadership[7].

Industry general approach to lobby Governments for changes

During these challenging times of COVID-19, the building and construction industry will lobby policymakers. The solutions that the industry will likely consider communicating to governments will include:

- Legislative relief by Government for COVID-19 for problems related to construction delays in the form of:
    - Deemed extension time to existing commercial construction contracts.
    - Deemed extension time to all associated affected agreements.
    - Freezing of related securities.
- Governments should support payment for the 'cost of capital' to financiers (both bank and non-bank financial institutions) for the COVID-19 delay event for each project, allowing the neutralisation of liquidated damages. Tax solutions concerning rebates and write-offs can assist the government in reducing the 'cash impact' upfront.

[7] The Victorian Treasurer reaffirming the state government's commitment to the building and construction industry, https://amca.com.au/Public/News/News_Items/202004/AMCA-welcomes-statement-from-Victorian-Treasurer.aspx

- Governments could review current support for small and medium enterprises to ensure construction industry businesses can access various initiatives to help offset the costs of productivity losses due to Government directions implemented to control the virus such as social distancing on construction sites.

These measures, as quickly and effectively as they may be implemented, can only hope to return the industry to the prepandemic status quo. They do not address how the industry needs to fundamentally change its approach to technological innovation.

Current perceived industry innovation

The construction industry's (employers and trade unions) combined actions are seen as relatively innovative and expedient in their efforts to keep the sector operating safely but effectively. Employers have lobbied the government to communicate how their work is an essential service, and that their representatives apply as much flexibility as is necessary to underpin the construction industry during such a challenging period.

Other discussions include:

- The flexibility of working hours with potential multiple construction site shifts throughout 24-hour days.
- Suspension of penalty rates and site allowances and other on-costs.
- Working on rostered days off and allowing workers to bank them for the future.
- Holding tight on wage adjustments for the duration of the current period of low productivity.
- Adopting a proactive position when dealing with return to work procedures (after inclement weather events or safety incident).

The tactical actions instigated by industry have included:

- Social distancing of personnel on construction sites with 1.5-metre distances, including reduced numbers in each working space.
- Staggering start and finish times to reduce pressure on the use of hoists and focus on access and egress issues.
- Staggering lunch, rest, and break times to reduce numbers in lunchrooms/ bathroom facilities at any given period.
- Employees taking lunch where they work to avoid unnecessary use of hoists.
- Employees bringing their lunch to work to reduce hygiene exposure and allowing for lunch where they work to have an effect.
- Practising walking between floors (including more than four levels) to avoid hoist exposure.
- Widespread dissemination of information and guidelines across projects (refer to the Victorian COVID-19 Building and construction guidelines consistent with global marketplaces).[8]

[8] *Building and Constuction COVID-19 Guidelines*, https://amca.com.au/Public/News/News_Items/202004/COVID-19-Guidelines-for-Victorian-building- industry-Version-3.aspx

Government policy measures, industry innovation and opportunity not considered

As we emerge post Covid-19, Government will stimulate contruction; however, this is not strategic, it is tactical.

In our view, there are strategic opportunities which should be pursued alongside those tactical measures. This follows the model proposed by Erdogan et al[9]. that transformation requires policies that address both the market model and the economic model of the industry to achieve effective transformation - see Figure 7.

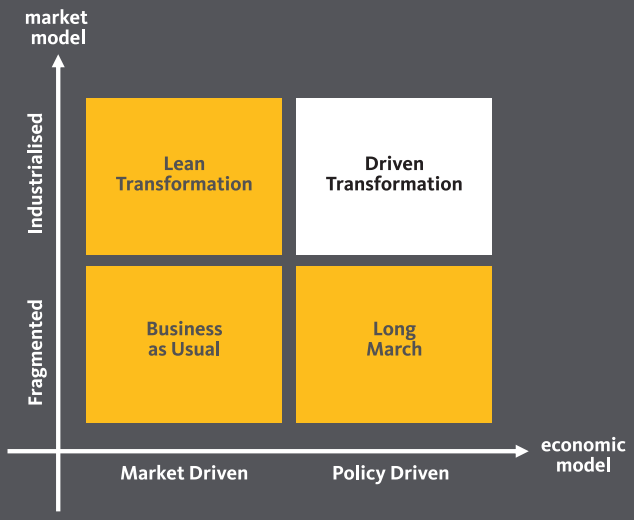


Figure 7 - Possible Scenarios for the Industry - source Erdogan

These strategic measures include:

- Shifting the business model of the industry to make it a more resilient sector through government investment in technology. These changes in technology should be reflected in the economic demand by specifying and procuring new products and construction methods. The government, through its procurement policies, can increase the market for these new products by shifting its needs towards those.

Let us stimulate industrial construction, as the major opportunity to transform construction.

- Typical stimulus packages do not incentivise businesses to change their operating model, leading to a further endorsement of the "status quo". At constant market conditions, industry actors have no incentives to deviate from their chosen strategy after considering other competitors' choices: they have reached a "Nash Equilibrium"[10] for the current operating model.

- There is currently no incremental benefit for the industry players from changing course towards the new operating model. The lack of short-term incentives to deviate from the current model, prevent the industry from reaching a new, and more efficient, Nash Equilibrium for the Industrialised Construction operating model.

[9]Construction it in 2030: a scenario planning approach, Erdogan et al, Aug 2009, http://www.itcon.org/2009/35
[10] Nash equilibrium is a solution to a non-cooperative game where players, knowing the playing strategies of their opponents, have no incentive to change their strategy.

Our Recommendations:

6. Governments must define industrialised construction contractually.

This requires a change to existing procurement frameworks and establish prequalification for participants based on proficiency of businesses (both technical, non-technical and financial acumen). Defining IC for future assets to be delivered will share improved supply chain outcomes. They will reform legacy business models which have continued to present suboptimal outcomes.

7. The government must procure industrial construction by directing 50% of their new funding towards "industrially constructed" assets.

Carefully selecting the assets that are most appropriate to IC will create demand. The government can promote the use of IC to help adoption and understanding by their other Government Departments and private clients. This will assist with the appropriateness of their investment for their building stocks. The promotion of IC will support the appropriate asset classes through a platform supporting design flexibility into the other barriers such as insurance and quality assurance.

8. Governments should instigate a new round of investment incentives.

These incentives must be scaled to create on a competitive basis for up to 20 large contractors, 30 medium-sized contractors, and 40 small contractors to receive grants to invest in digital infrastructure that would boost resiliency. Government could quickly conduct and complete its review of this competitive process.

9. Government must provide matched funding to support technology investment.

Matched funding programs will support to improve the technological capability of building and construction supply chains, energy-efficiency programs, and loan guarantees for the construction of large facilities that use new technology in their supply chain.

10. Governments must invite investment proposals for better COVID-19 resilience.

The business case for investment must be solicited from industry, focused on technologies such as data analytics and the Internet of Things; to enable better public services, and improve resilience to COVID-19. In the process, the government could develop detailed plans and a baseline for a business case on how to invest additional funding to enable smart cities.

11. Promote activities that reduce the input costs of production through advances in technology.

Technological advances that improve production efficiency will shift a supply curve to the right. Once the cost of production goes down, and clients and governments will be in a position to achieve excellent building, construction, and facility management outcomes at lower prices.

Section 3: How do we unearth a new supply chain which is industrialised and enables modern methods of construction?

The supply chain is challenged by a lack of trust in delivering on time and budget, and in an increasingly complex environment. With low profitability level, investments are not sufficient to overcome a fragmented material and supplier logistics, convoluted multi-party project communication, and an adversarial contractual context.

As a consequence, the supply chain continues to be challenged with a multiplicity of structural issues:

- Specialist providers are not in a position to advise on the design at the pre-tender stage before it goes to market.
- Packages of work are split into trade packages which introduce complexity in design co-ordination, assembly and installation.
- Many processes in fabrication and installation remain labour intensive, wasteful of material and error prone. There is currently not enough repetition in the volume of activities and orders to automate them.
- It is not currently possible to move towards behaviour adopting material circularity.
- A fragile supply chain ecosystem, as procurement and finance teams are not empowered to make the most of the technology that is readily available to reduce errors.
- The project nature of the industry prevents the use of traditional enterprise resource planning systems, which would automate the administrative and transactional processes that are still handled through manual methods using paper, Adobe PDF and Microsoft Excel. This includes the high volume of purchase orders, delivery notes, contractual variation orders and delay or completed work notice documentation.
- After they are ordered, materials based on weight, such as cement and sand, are often varied, leading to further inefficiencies and decisions made on the wrong basis.
- Payment scheduling is not tied to, and often miss-aligned with, project activities, work completion, and scheduling; leading to payment risk and lack of transparency with the work completed.

A dislocated supply chain needs to transform.To improve profitability for all parties it must be allowed to pursue new efficiencies and new value adding activities. This will be achieved by examining and redesigning its work processes and implementing a new operating model.

Opportunity for a new supply chain

Today, our buildings are created by tradesmen and structures conceived in the middle age: joiners carpenters, tilers, and roofers; and in the modern-day, plumbers, electricians, HVAC specialist, among others. This specialisation means that buildings “come together” under a prime contractor without much opportunity for rationalisation in assembly, or labour provision, or for optimisation at systems level and around multi-function components.

There is an opportunity for the industry to move directly to industry 4.0 through the adoption of digital techniques for manufacturing and assembly. For this to happen, a new supply chain will have to emerge, one which is “Industrialised” and structured for Systems thinking.

As shown in Figure 8, a systems approach enables both alignment of the incentives towards the project outcomes, and provide a new framework for the supply chain to organise itself around performance targets.

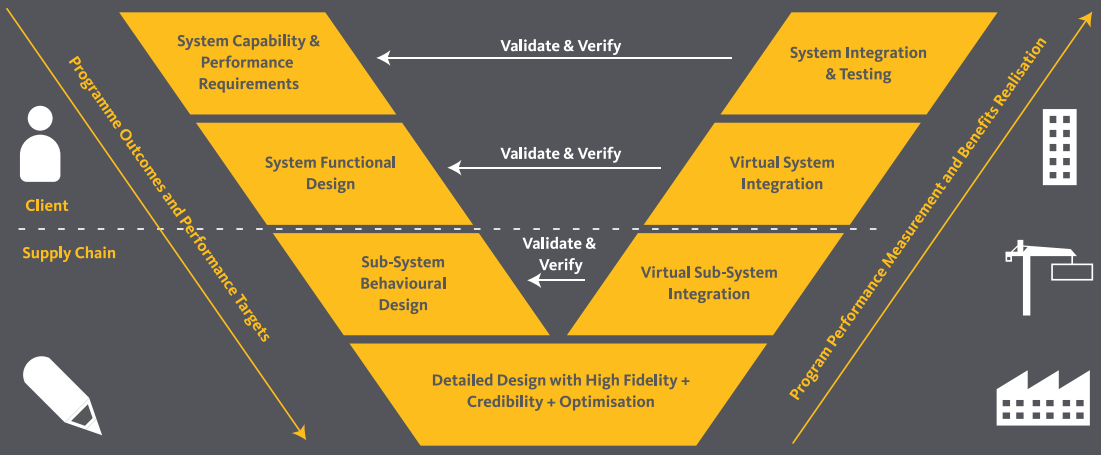


Figure 8 -Systems Thinking Approach for an outcome driven supply chain - © Cogital 2020

Industry participants will assume new roles in a new supply chain structured around systems capabilities, with investments aligned to sub-assemblies and components. It will transform the traditional trade-based thinking and activities delivered in silos focused on cost reduction, towards component and system thinking to deliver outcomes.

For example, the UK construction innovation hub initiative is making an IC supply chain emerge to meet the UK public sector demand. In this case, the industrialised supply chain is organised around four main system types and 19 sub-assemblies, as shown below in Figure 9.

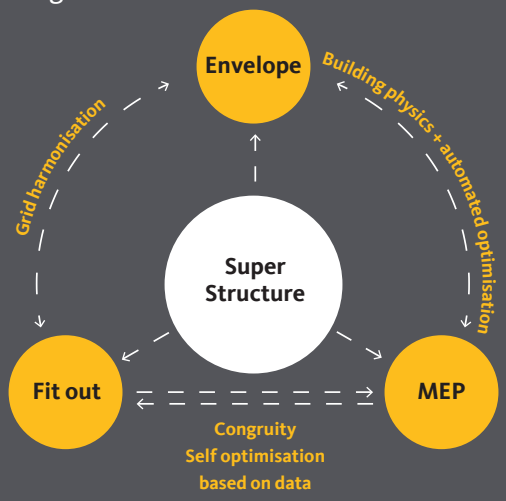


Figure 9 -Re-structuring of the Supply along Systems - © Construction Innovation Hub 2020

The new supply chain will require support, through upskilling and investment so that current industry participants can invest in new waves of fulfilment, automation, and delivery capacity. This includes having sensors that provide visibility of components in transit to construction sites, cloud platforms for equipment management optimisation, robotic fulfilment vehicles in agile plants. This approach enables real-time fulfilment, asset tracking, and whole of life monitoring. Critically, the new supply chain will allow collaborative behaviour, so specialist subcontractors affectionately known as the “super-sub” will emerge, with the competencies and resources to participate in the design phase.

Specialist subcontractors and suppliers need early integration to participate in the design phase. This saves money as we embed multifaceted assembly and production thinking earlier into the process.

Material circularity is a feature of the new IC supply chain, enabled by component-based thinking and digitally-enabled information tracking. In Figure 10, the products used in sub-assemblies are configured or customised reduce material and process waste occurring in assembly processes, or once the sub-assembly is delivered and installed at the construction site. For example, the Construction Products Association (CPA) in the UK proposes a new, more circular industry model – underpinned by better information flows.

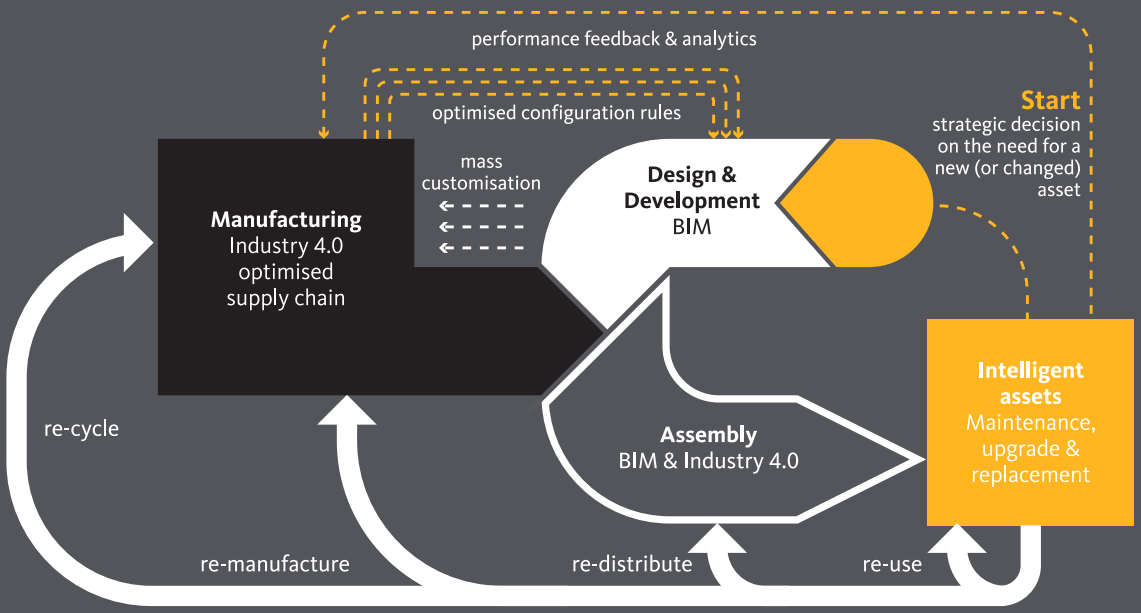


Figure 10 - Structuring of the Material Flow © Building Product Association

The emergent IC supply chain will reorganise itself around systems and sub-assemblies rather than trades as shown in Figure 8 (and illustrated in Figure 9). The suppliers offer whole sub-assemblies rather than singular trade products (illustrated in Figure 11), which creates value by realigning interfaces to functions and outcomes, streamlining high-level processes. These reorganised companies will also be able to iterate and optimise their complete systems offerings much more effectively, which will create additional value in the longer term.

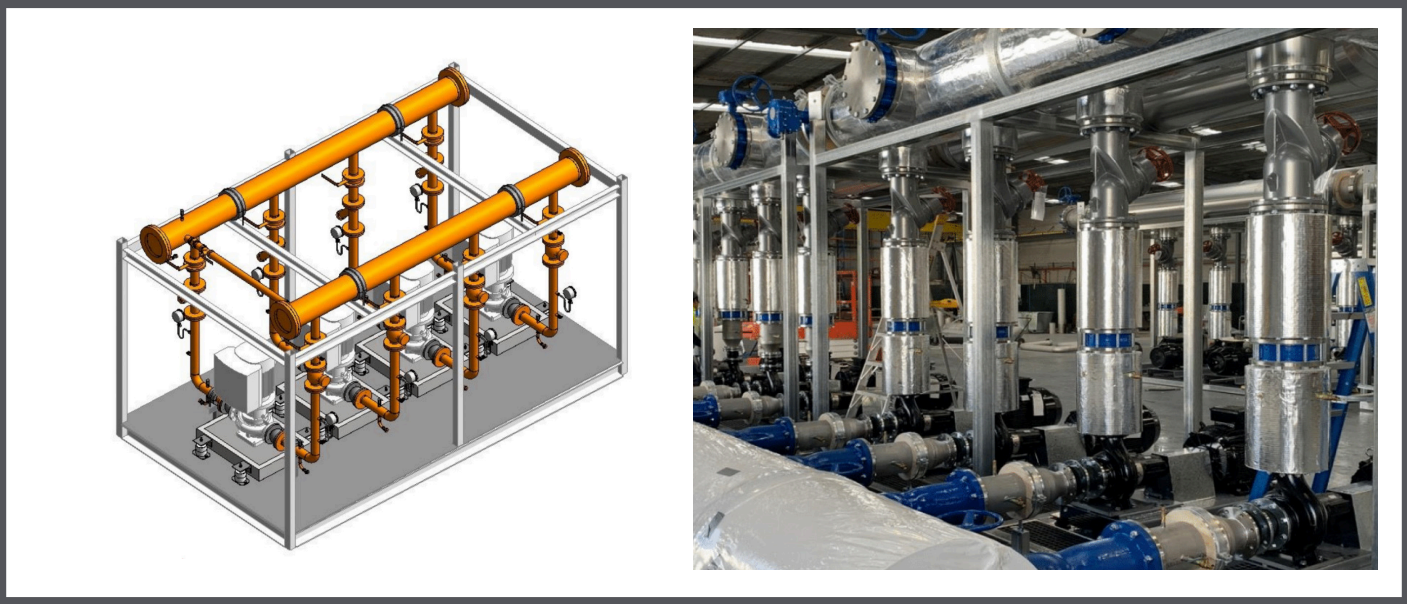


Figure 11 - Multi Trade System Assembly - © Kavanagh Industries and Prefab Solutions

Post industrialisation, we can expect the value distribution in the industry to evolve as described by the "smiling curve" in Figure 12.

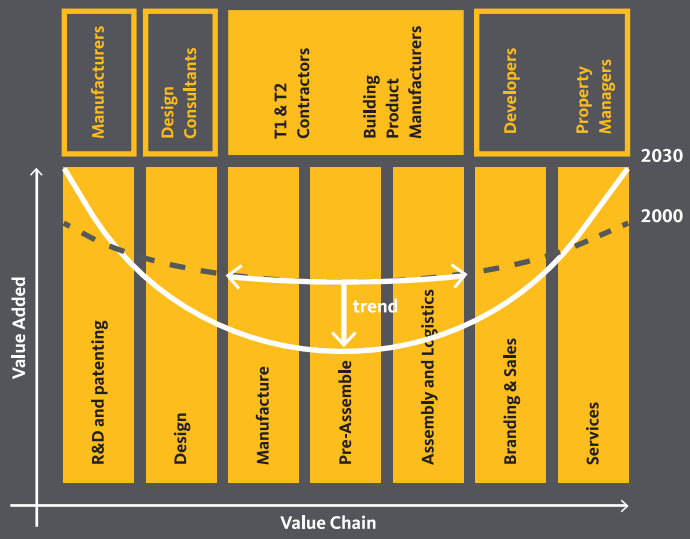


Figure 12 - Evolution of the Value Distribution © Cogital 2020

The clear trend is for physical manufacturing activities becoming less wasteful and more efficient. This leads to a commoditisation of production, and a relative increase in the value of design, research and development, service and operational performance. The profit pool shifts from "metal bashing" to system design and system performance at both extremities of the value chain. This creates an opportunity for the super-subs to increase profitability by performing high-value design optimisation activities and offering "in-use" services. This is further enabled by systems-based thinking which is aligned to measurable outcomes, and the competencies of the super-subs.

For the supply chain to reshape itself and meet these challenges, it is likely to go through a series of mergers and acquisitions (M&A). This will enable companies to quickly bring together the talent of disparate, trade-based, sub-contractors and suppliers. By aligning their companies' operating model and organisational structure to their new production processes, these new companies will become more efficient.

The M&A activity is likely to come in waves of consolidations and disposal seen elsewhere, such as the automotive industry[11]. Ultimately, these will result in a new industry structure, adapted to the regional economic condition, policy context, and segment specificity. Lavikka et al[12]. show how multiple scenarios exist, with the "internet of buildings" emerging where open data standards, open data platforms enable distributed decision making with an open regulatory environment. In this scenario, the new ecosystem becomes most fluid and agile – see Figure 13 opening the possibility of Uberisation and servitisation of all or part of the supply chain, and the Built-Asset lifecycle.

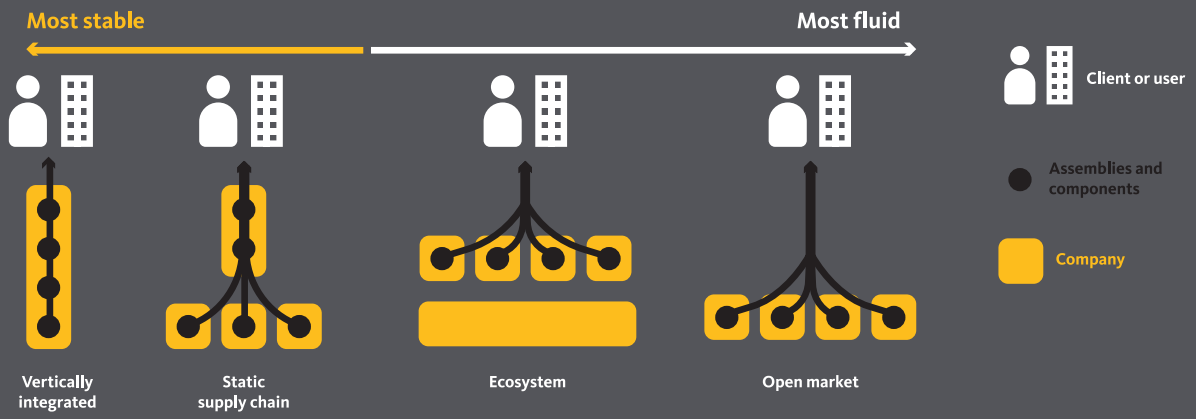


Figure 13 - Opportunities for Uberisation of the Industry © Cogital 2020

[11] A preliminary overview of emerging trends for industrialized construction in the United States, 2019, Pulle, Hall, Jerker
[12] Digital disruption of the AEC industry: technology-oriented scenarios for possible future development paths – 2018 – Lavikka et al, construction management and economics 2018, vol. 36, no. 11, 635–650

Our Recommendations

12. Support the upskilling of the supply chain by equipping them with new "industrialised construction" capabilities.

This requires the identification of expertise and concepts that exist in manufacturing and are not part of the current trade-based supply chain capacities. These manufacturing disciplines should then be embedded into every construction activity to make component-based thinking becoming the norm. Governments should support this upskilling through workforce training and innovation grants and reflect this in their supply chain assessment during procurement.

13. Engage the owner to ensure they are committed and invested in the new supply chain.

The client cannot let supply chain thinking only be the remit of the construction teams. They need to become involved in specifying the level of industrialisation, as ultimately, they want positive outcomes that can be translated into future projects. Further, the owner needs to be ready to restructure how they raise finance and allocate capital to project delivery, including factory investments.

14. The prime contractor to become an "assembler", orchestrating and mobilising an industrialised supply chain; taking on the role of setting up the digital platform.

We believe the role of the prime contractor must become that of an assembler/integrator and an orchestrator of the supply chain. The role of acting as the procurement arm of the client must lose its importance. A vital part of this role is to establish the digitally integrated delivery platform where the new supply chain can synchronise and exchange information seamlessly at low cost and with high frequency across corporate interfaces.

15. From design to realisation, activities must be redesigned so that the supply chain re-focuses on delivering performance and outcomes, rather than an "object".

Unlock new waves of optimisation in the industry, using manufacturing approaches such as Lean and Quality Function Deployment, focused on customer and user outcomes. This will force us to re-examine sub-assemblies and how we have commissioned and tested them before installation at the construction site. Specifically, this allows the systemised supply chain to iterate on components and optimise how they play a role in improving energy and management of the whole building.

16. Consider capital and investment zones to encourage the wave of mergers and acquisitions that is required to re-structure from trade thinking to system thinking.

For companies to invest in moving towards a systems-based approach, companies need both predictable demand and a favourable investment environment. Governments must establish economic zones with investment incentives, to encourage the current trade-based supply chain, and external new entrants, to create the new type of companies serving IC.

Section 4: Industrialised construction leads to better Building Performance – What does a high-performance built environment look like?

To meet society's expectations of high-performance buildings in a low carbon future, we need to dramatically improve how we design, construct and operate buildings. The performance of the buildings "in use" should better support the activity and outcomes for which we created them. The attention needs to move away from measuring what is physically created – such as the availability of a meeting room – to what is achieved in the space – such as having a productive meeting. This must be delivered within the context of the climate emergency where the Built Asset is a significant contributor to carbon emissions.

First, the performance of the Built Asset as we create it today still falls short of what is achievable and expected by users of space and society at large. BuroHappold has eloquently suggested (in Figure 14 below), that technology is a crucial factor: "*today's smart buildings optimise our use of people, space, and operations. Reducing energy demand is key, but creating environments which make people more productive, use space more effectively, and support efficient operations is vital in our move towards a low to a zero-carbon economy*[13]."

Second, the global building and construction sector must play its part in meeting international goals set out by the Paris Agreement. The 2019 Global Status Report for Buildings and Construction highlighted a 'slow-down' and persistent underinvestment in the energy efficiency measures needed to lower emissions and set the stage for the decarbonisation of the sector. Buildings and construction generate 39% of CO_2 emissions, yet action continues to lag far behind the opportunities[14]. Traditional construction cannot deliver the carbon reduction targets set by the Paris Agreement goals.

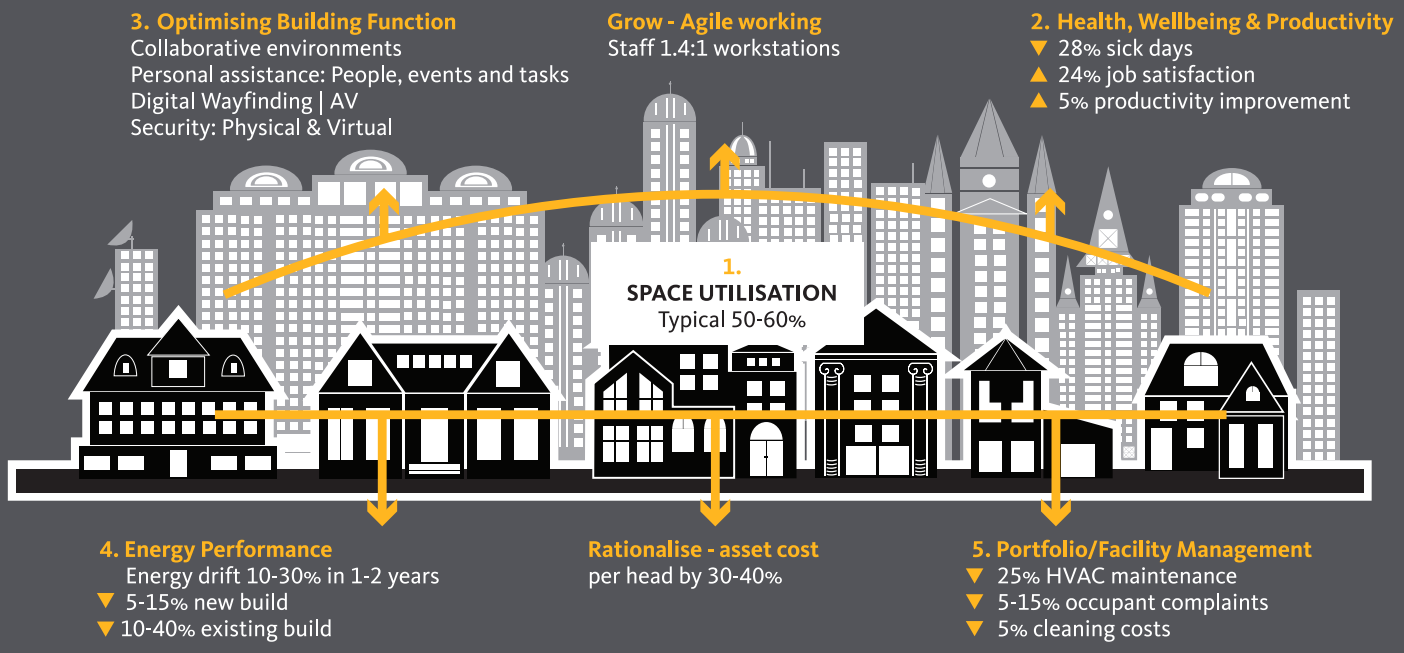


Figure 14 - Placing Value before technology © BuroHappold 2020

[13] *Buro Happold: https://www.burohappold.com/articles/how-we-are-improving-building-performance-with-data/*

[14] *2019 Global Status Report for Buildings and Construction: Towards a zero-emissions, efficient and resilient buildings and construction sector, International Energy Agency & United Nation Environmental Programme*

Better performing buildings are critical to the achievement of environmental and productivity objectives and are an essential contributor to improved living standards. These will allow the industry to plan and invest in low carbon construction practices and technologies while providing a significant boost to each country's ability to meet international environmental obligations.

Industrialised Construction is the only option to meet the targets. Industrialised Construction (IC) will go beyond better construction, it will deliver better buildings

Healthy buildings convert to high performing people and buildings

People value non-tangible benefits in buildings such as natural light, thermal comfort and indoor air quality, public transport proximity, location to social and business meeting engagements. People are the most valuable asset of any corporate entity. When a corporate entity saves money by placing their employees in a workplace environment in a lower value building asset, their employees will underperform.

Post COVID-19, this will only become more evident, as new health considerations, such as physical distancing, will strain all designs for the workplace. It will magnify the impact a lower value building has on the workforce. There is an overwhelming body of evidence published over the past decade that draws a clear link between employing best practices for the indoor environment and the benefits gained in the forms of a healthy lifestyle and more productive staff. The economic savings from a high-performing building for tenants provide a business case for choosing a better office; better being identified through effective office plan.

Figure 15 below considers the factors of high performance-built asset environment. It demonstrates the available opportunities to address measures in unison. Most literature in high performing buildings has not considered linking complementary measures in the sector.

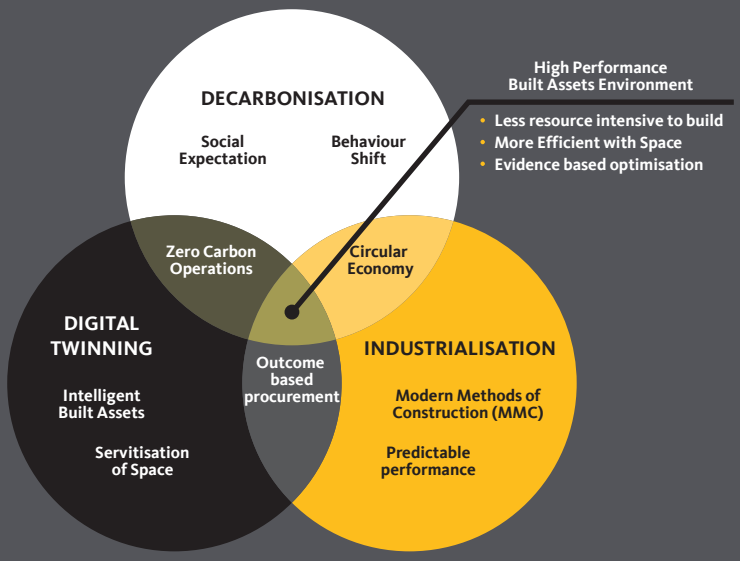


Figure 15 - High Performance Built Environment © Cogital 2020

Industrialised Construction will accomplish high performing buildings by bundling these measures. Industrialised construction considers the above in four major complementary measures:

1. Digital Twins
2. De-carbonisation
3. Platformisation
4. Behavioural shift

Digital Twins and data for better decision-making

Digital twinning activities allow the modelling of the processes which enable outcome-driven design and co-creation of solutions between the supplier and the customers. Using digital twins, it becomes possible to down-scale construction by delivering a better experience with a smaller, higher performance asset. More bespoke, site-specific, user-specific solutions can be conceived and assembled. Data availability and transparency are the vectors which ensure that investors, consumers, and businesses make more informed decisions. For example, data relating to the performance and energy costs of existing buildings must become available to make reliable forecasts of the return that might be expected from investments in building upgrades.

De-carbonisation

The industry can meet the government's obligations of decarbonisation through complete control of materials, recycling, maintenance, embodied and whole-life GHG emissions. The Government can work with industry to focus on strategies that reduce the use of products, recycle the products at end-of-life and re-use accordingly.

In the Australian context, an excellent example is Refrigerant Reclaim Australia (RRA) which has an objective to reduce the level of emissions of refrigerants through its take-back program. Since being established in 1993, RRA has become integral in the management of used and unwanted refrigerants deployed in stationary (buildings) and non-stationary (automotive) sectors. In recognition to the impact the RRA is having, it has received multiple international awards including the Ozone Protection Award for "exceptional contribution to global environment protection" in 1995, the Montreal Protocol Implementers Award in 2007, and a Climate Protection Award from the United States Environment Protection Agency in 2006.

The RRA scheme demonstrates that we can develop a similar approach to product stewardship in our industry whereby whoever designs, produces, sells, or uses a product takes responsibility for minimising the product's environmental impact throughout all stages of its life cycle, including end of life management. We must be thinking of existing buildings a "material mines" and future buildings as "material depots."

Platformisation

Platformisation allows the transition to 'Space as a Service' and "non-ownership" models where space is hired on a needs-basis and space ownership is no longer a status symbol. Through technology, this approach makes explicit the utility that the built environment provides, rather than just it's physical attributes. This enables the reduction in the direct linkage between input factors for providing the utility – such as square meter of floor space – and the actual utility, such as delivering productive office space. Servitisation of the utility is the economic enabler to find new efficiencies. Under the economic incentives of a servitised model, Rolls Royce and Michelin managed to offer better utility (power by the hour and tyres by the mile respectively) at lower utility price for their customers, reduced environmental impact, and higher profitability for themselves[15]. Similarly, WeWork managed to improve the floorplan efficiencies for their members by as much as 20% through data-powered optimisation.

[15] *Digital Transformation of Industries. World Economic Forum. January 2016. pg. 10*

Behavioural Shifts

A shift of attitudes to homes and space is needed to re-calibrate space and space ownership. A mix of communication, incentives and regulatory approaches will be required to encourage better use of our assets and resources throughout the lifecycle.

Since the end of World War II, there has been an extended period of continual growth that has fuelled our cultural expectation of ownership. From cars to houses, our expectations have been inflated as increased efficiency and prosperity have provided larger and more impressive products. Figure 16 shows the visible differences in Australia from a housing layout in the 1950s to one in the modern-day. The inflation in space and amenities provided on average has led to an underutilisation of scarce resources. However, this cultural shift is already being reversed in some areas, including office space. The rise of hot-desking has increased the efficiency of the floorplate as well as the wellbeing of employees, who now experience more personal interactions in areas with more natural light.

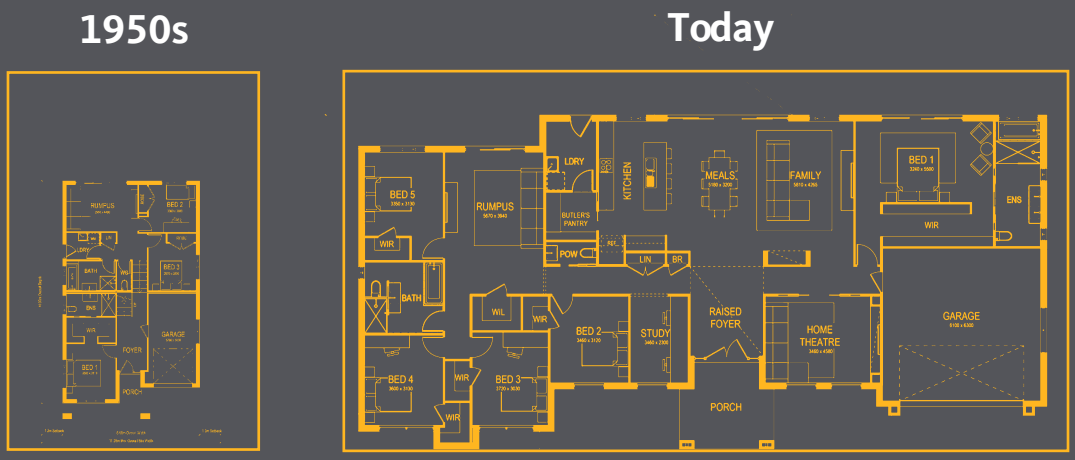
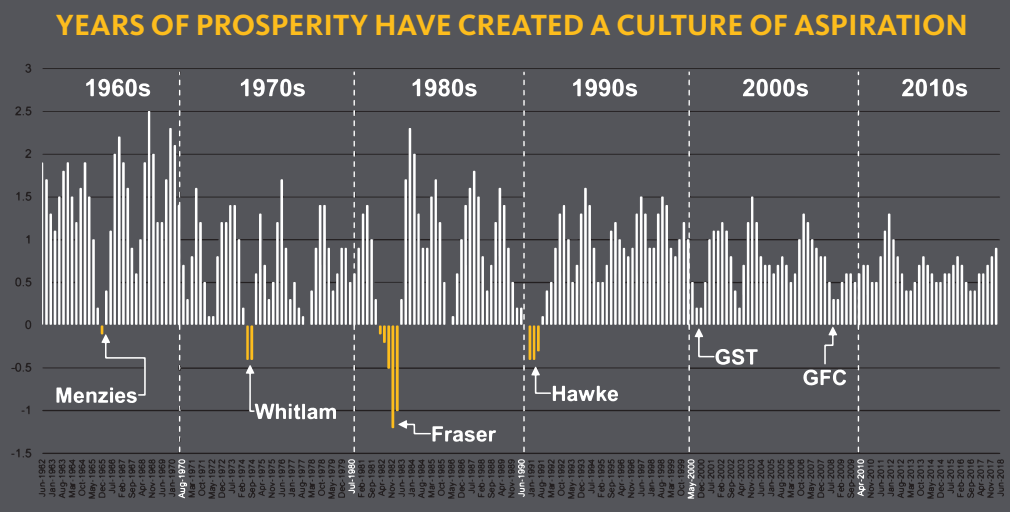


Figure 16 - Housing Expectations and Aspirations [16]



Per cent change in Australian GDP by quarter from June 1962 to June 2018

Underpinning these approaches in mutualisation of good data for the public good, put to work for the benefit of all. As in the field of immunology, performance data for space must be shared in a trust, to gather the evidence we require for the performance of space and the wellbeing of all.

[16] *Source: Bernard Salt AM – Building Better Buildings: Understanding the demographics of how we live, work and play Presentation to AMCA National Conference, Fiji, 3 October 2018*

Our Recommendations:

17. Digital Twin: All buildings must have a Digital Twin, with mutualised data for the public good.

Building rating tools need to link to a digital twin; it cannot continue to be based upon design-based thinking. Rating tools should drive changes in behaviour that reduce the number of paper-based plans from architectural to construction to facility management. Building operation should link to the digital tools used from design, installation, commissioning, and facility management.

18. Material Circularity: All building materials must be inventoried in a Material Register for future reuse, including product stewardship programs.

This discussion has been especially significant since Government and industry reports after the Grenfell Tower disaster and others that looked to address non-compliant cladding. These recommendations have encouraged the establishment of a building information database that provides a centralised source of building design and construction documentation.

19. In-use, actual building performance, must be reported and meet net-zero for all new buildings by 2025.

There needs to be an international plan for net-zero, high-performance buildings and sustainable building practices, and accelerate upgrades to government-owned and inhabited buildings. Provide industry with policy certainty by establishing a clear trajectory for increases in minimum standards and building performance of the Construction Codes.

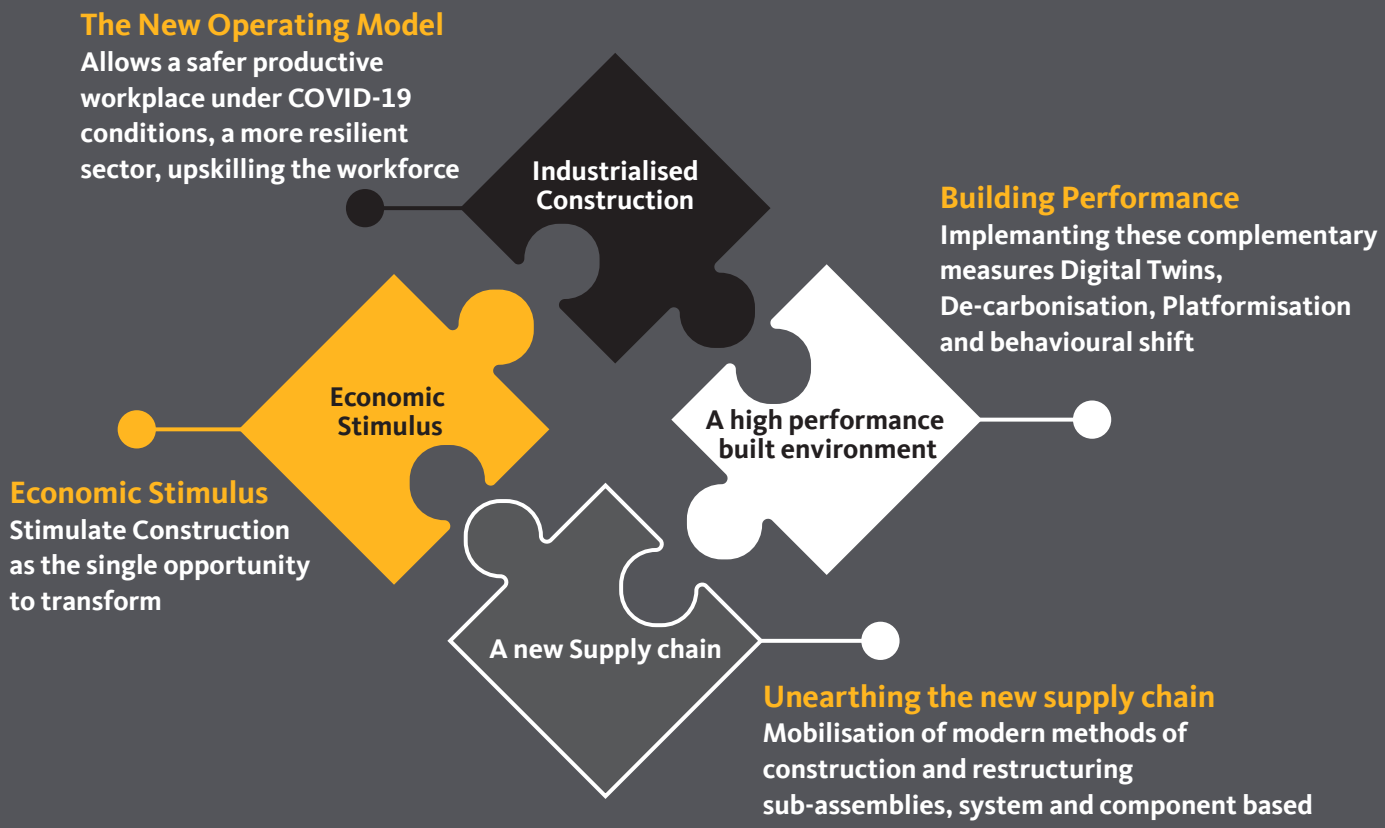
20. From 2030, the net growth of built space must be reduced to match the increase in population only.

For the current building stock there should be targeted tax incentives or “green depreciation” for a one-off tax deduction for the cost of building upgrades, especially in the mid-tier building sector, and align current incentive programs aimed at energy efficiency and upgrades of existing stock.

21. From 2050, all new buildings must be 75% constructed using previous construction material through material circularity.

Provide targeted incentive programs to the buildings supply chain to adopt more sustainable building practices, especially those aimed at increasing more efficient and sustainable offsite construction methods. In automotive, the industry has a line of sight for embodied carbon and CO2 per mile in a car.

Opportunities to Rebound Beyond COVID-19



Our recommendations – in summary

1. *A guaranteed spending commitment and pipeline to catalyse investment.*
2. *Stimulate adoption through a plan for regional hubs, creating enterprise zones – aligned to areas where a qualified workforce is available due to plant closures.*
3. *An approach to intellectual property that drives both the standardisation of interfaces and continuous improvements.*
4. *Rethink the "stages process" to improve outcomes throughout the design and construction process.*
5. *Reset the measures of success and establish a new industry Global Scorecard.*
6. *Governments must define industrialised construction contractually.*
7. *The government must procure industrial construction by directing 50% of their new funding towards "industrially constructed" assets.*
8. *Governments should instigate a new round of investment incentives.*
9. *Government must provide matched funding to support technology investment.*
10. *Governments must invite investment proposals for better COVID-19 resilience.*
11. *Promote activities that reduce the input costs of production through advances in technology.*
12. *Support the upskilling of the supply chain by equipping them with new "industrialised construction" capabilities.*
13. *Engage the owner to ensure they are committed and invested in the new supply chain.*
14. *The prime contractor to become an "assembler", orchestrating and mobilising an industrialised supply chain; taking on the role of setting up the digital platform.*
15. *From design to realisation, activities must be redesigned so that the supply chain re-focuses on delivering performance and outcomes, rather than an "object".*
16. *Consider capital and investment zones to encourage the wave of mergers and acquisitions that is required to re-structure from trade thinking to system thinking.*
17. *Digital Twin: All buildings must have a Digital Twin, with mutualised data for the public good.*
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19. *In-use, actual building performance, must be reported and meet net-zero for all new buildings by 2025.*
20. *From 2030, the net growth of built space must be reduced to match the increase in population only.*
21. *From 2050, all new buildings must be 75% constructed using previous construction material through material circularity*