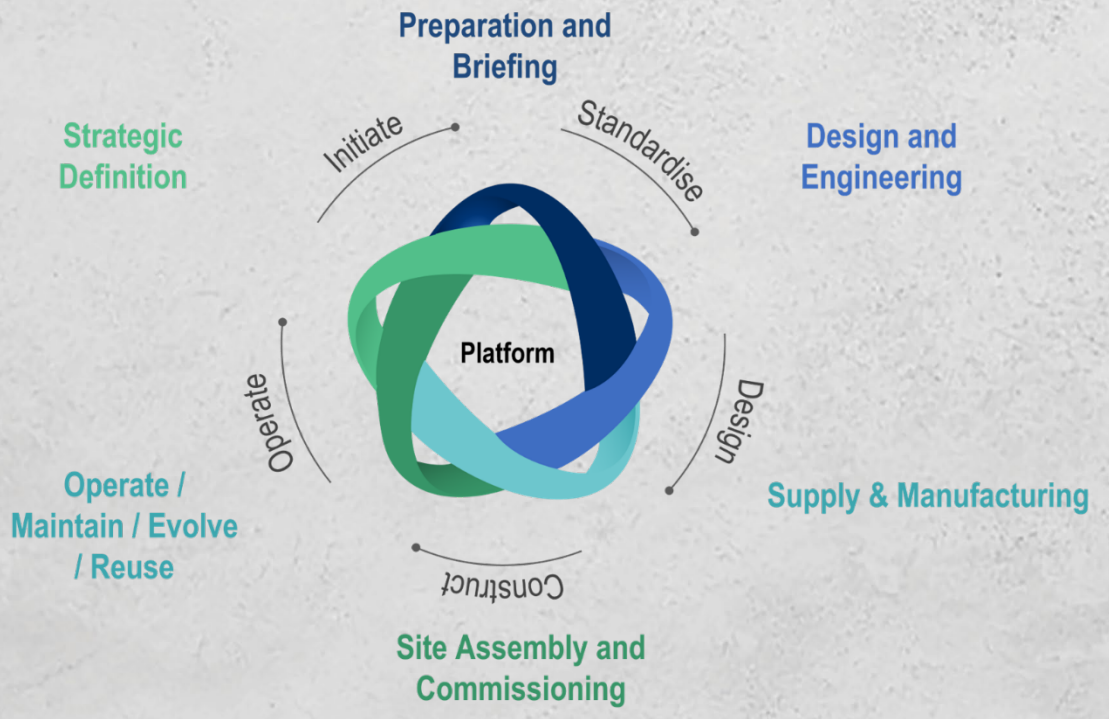
building 4.0 crc

PROJECT #3: PROJECTS TO PLATFORMS

FINAL REPORT



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Australian Government Department of Industry, Science and Resources

Cooperative Research Centres Program

CONTENTS

Project #3: PROJECTS TO PLATFORMS SCOPING STUDY

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Disclaimer

1. EXECUTIVE SUMMARY

The research conducted by the six streams of CRC Project #3 has provided valuable insights into the changed nature of interactions in the building industry during the transition from project-based work approaches to a platform-based approach. The project encompassed a market review of building platforms and in-depth case studies, shedding light on the challenges, opportunities, and implications of this shift. By examining other sectors that have undergone similar transitions or disruptions related to platforms, the research extracted important lessons that can be applied to the building industry context.

The findings and insights from the research can be categorised as follows:

1. **Definition of platforms:** The research defined physical, digital, and hybrid platforms within the context of the building industry. Physical platforms refer to product architectures that generate derivative streams of products through material and information flows. Digital platforms act as 'online intermediaries' facilitating value exchange through information flow, with supply chain actors playing a crucial role. Hybrid platforms incorporate cyber-physical systems, combining physical components with digital functionality.
2. **Platform development in other sectors:** The research explored platform development in other sectors and examined its implications for the building industry. While platform development in building presents challenges such as higher adoption hurdles and upfront investment requirements, involving key players like investors, developers, and facilities managers can drive platform success. Consolidating standards and interlinking different aspects of the building process are crucial for effective platform implementation. Investors, developers, and facilities managers should collaborate to maximise investment opportunities and capture benefits in the operational phase of buildings.
3. **The concept of an ideal platform:** The research redefined the perception of an ideal platform, emphasising the readiness of companies for a platform ecosystem rather than solely evaluating their platform quality. Open and interoperable platforms are considered optimal for future platform ecosystems, enabling the leveraging of maximum benefits. Strategic partnerships and an understanding of platform ecosystems, drivers, barriers, and key performance indicators are subjects of future research.
4. **Lessons from platform case studies:** The research highlighted several lessons learnt from platform case studies. Early prototyping is crucial in platform development, encompassing both components/modules and process simulation. Repurposing existing products with a platform DNA allows integration with a platform ecosystem. Platforms should cater to the project-based delivery mechanism that remains a significant driver in the building industry. Commonality in processes, enablers, and physical components is essential for platform success. The platform logic enables decision making on onsite and offsite tasks. The platform approach also offers opportunities for circularity in design, material, process optimisation, and automation.
5. **A shared vision roadmap for platforms:** The research defined a shared vision that facilitates a shift towards the platform approach and outlines new roles for different stakeholders in the platform ecosystem. The vision includes moving value-adding products and services upstream, expanding contribution to the value chain, continuous improvement through data-driven insights, seamless collaboration, and early prototyping. The role of the general contractor may transition to the developer or platform consultant as the main point of engagement with the supply chain actors.

The research concluded by highlighting areas for future investigation, including contractual arrangements that align with business practices, the balance between open and closed platforms, and effective models for platform implementation. Overall, the research aimed to stimulate discussions, inspire innovative ideas, and provide a thought-provoking roadmap for the future of platform development in the building industry.

2. PROJECT OVERVIEW

2.1 Background – Why platforms?

Platforms represent a collection of assets that are shared by a set of products; comprising components, processes, knowledge, and people (Robertson and Ulrich, 1998). While platforms originated with manufacturers using product platforms, today, technological platforms underpin many of the world's most valuable companies and it is increasingly being considered that platforms have the potential to create value in the building sector (Mosca et al., 2020).

Platforms establish commonality with the strategic intent of achieving revenue benefits by finding and serving niche requirements, reducing costs by leveraging economies of scale, and reducing risk through increased quality and reduced susceptibility to changing environments (Construction Innovation Hub, 2022). While academia and industry have focused on the efficiency and productivity of platforms, it is now being demonstrated that platform thinking also enables new possibilities to effectively deliver design value to end-users (Maxwell and Aitchison, 2017).

Design for Manufacture and Assembly (DfMA) supports the technical realisation of the platform approach in building. When combined, DfMA and platforms can unlock the true potential of digital design and simulation, utilising computational design processes to achieve component-level standardisation while retaining design flexibility at the asset level (Bryden Wood, 2018).

Figure 2.1 summarises the holistic benefits that platforms can bring to the building industry as collated from different sources in literature.

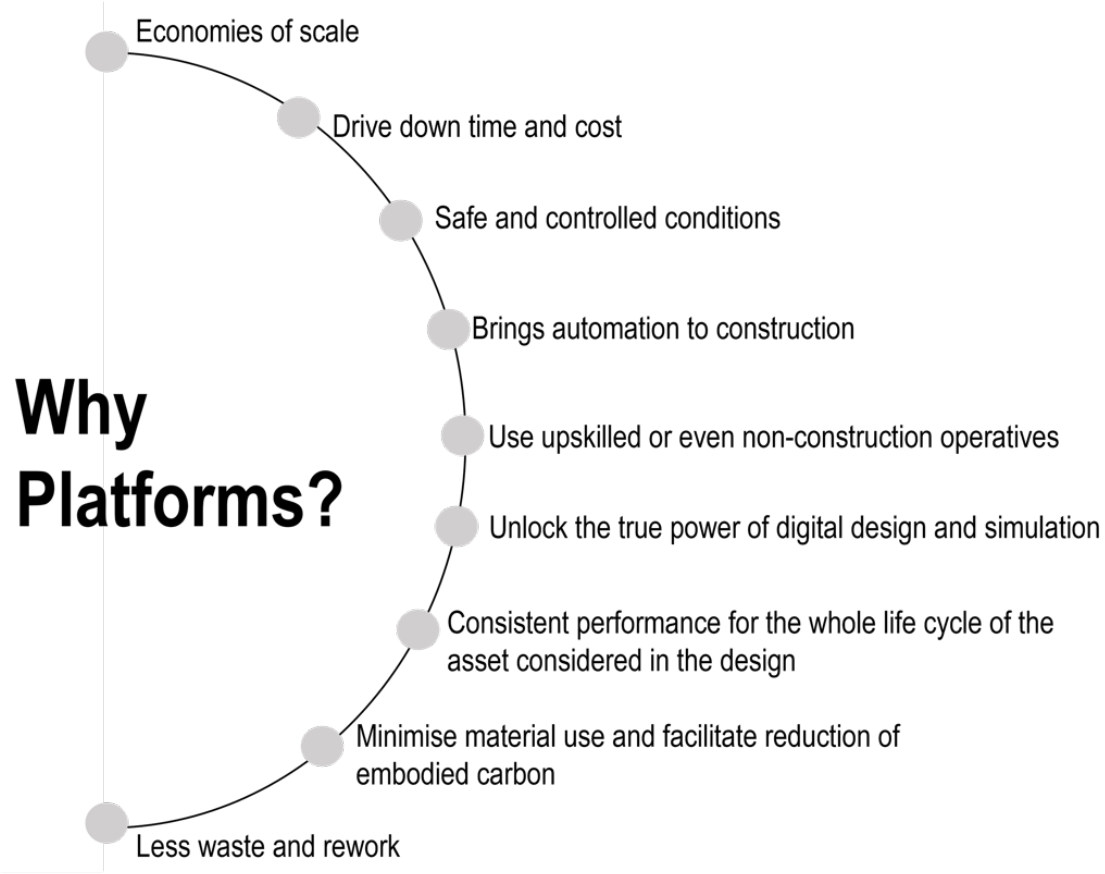

Figure 2.1 Benefits of platforms to the building industry

2.2 Research questions

The project aimed to address the following key research questions:

1. **What value can platforms bring and for whom?** [Definition of platforms in the building context]
2. **What will an ideal platform design consideration look like?** [Potential result being a set of requirements / conceptual framework]
3. **How mature are existing platforms in building, when evaluated against the ideal platform design consideration?** [Maturity levels to inform timeline of roadmap]

2.3 Research objectives

1. To understand and define the changed nature of interactions in the building industry when moving from project-based work approaches to a platform-based approach.
2. To learn from other sectors and how they have transitioned or been exposed to disruption in terms of product and process.
3. To define the basis of a common and shared logic for a building industry-wide platform business model and work approaches at both strategic and operational levels.
4. To develop a shared vision roadmap for future platform-based building participants, identifying opportunities for—transactional, innovation, integrated, and investment—digital platforms within an industry-wide platform approach.

2.4 Method and report structure

Each chapter covers distinct aspects of the project and is designed to be self-contained and complete. This organisation ensures readers can focus on specific areas of interest without needing to refer extensively to other chapters. By adopting this approach, readers can gain comprehensive knowledge and insights on each topic, even if they choose to read individual chapters independently. This structure facilitates a modular and flexible reading experience, enabling readers to delve into specific areas that align with their interests.

The research adopts a six-pronged approach:

- **A theoretical foundation** helps the reader understand the concept of early product platforms in building and why they are important. The reader gains an understanding of the definition of physical platforms, digital platforms, and hybrid platforms, drawing from the classic supply chain management literature that describes the supply chain as a collection of nodes and flows. our knowledge, this is the first attempt to define physical, digital, and hybrid platforms within the context of the building industry. The section also explains the differences between point solutions and digital platforms, as well as the distinction between Building Information Modelling (BIM) tools and digital platforms. Finally, the section concludes by exploring the emergence of integrative frameworks. The theoretical foundation can be found in section 3.1.
- **A cross-sectoral mapping of platforms** thoroughly studies 190 platforms across 16 the Australian and New Zealand Standard Industrial Classification (ANZSIC) industries, using a Popperian satisficing evidence-based management approach to provide as wide a view as possible of platform use across sectors. This section helps to elicit lessons for developing building platforms, learning how other sectors have transitioned or been exposed to disruption in terms of product and process. The cross-sectoral mapping of platforms starts by analysing the findings of product platform development in other sectors, then digital platform emergence in other sectors and the platform value chain, concluding with ‘what are the implications for building? The cross-sectoral mapping of platforms can be found in section 3.2.
- **A market review of building platforms** contains a comprehensive analysis of 12 platform companies in building identified through a market review. The companies identified represented different platform approaches; physical, digital, and hybrid. The market review and analysis helped to map the existing platform companies in building with the attributes of an ideal building platform and understand the value chain they operate at. The attributes of an ideal building platform were suitably modified from the Product Platform Rulebook (Edition 01) published by the

Building Innovation Hub and United Kingdom Research and Innovation (UKRI) in the September 2022. The identified platform companies were qualitatively assessed against the attributes of an ideal building platform because it is still a nascent area of research and there are no well-defined maturity scales or detailed case studies to quantitatively assess the existing platforms. The platform value chain was arrived at through a comparative analysis of relevant frameworks in Australia and abroad. The market review of building platforms can be found in section 3.3.

- **Platform case studies** comprise detailed case studies on three leading building organisations that are implementing physical, digital, or hybrid platform approaches in their companies: Volumetric Building Companies (VBC), Intelligent City, and Bryden Wood. They were identified in the preceding market review and were considered for the case studies as they demonstrated exemplar characteristics of the platform logic. In the case of the project participants, the findings from this section reveal how similar or different their operations could be in a platform-based value chain and likely provide an interesting lens for them to assess their own position. The platform case studies can be found in section 3.4.
- **A shared vision roadmap for platforms** envisages redefined roles for each stakeholder in the building value chain. It creates a shared vision roadmap by understanding their motivations for moving towards a platform ecosystem. The market review and detailed case studies provided the foundational understanding of the potential motivations, roles, and changed nature of engagement among the stakeholders of the platform ecosystem. This was followed by individual discussions with project partners who represent key stakeholders of the building value chain. However, the inspiration behind this shared vision roadmap originated in the thought starters presented in the report '*The next normal in construction: How disruption is reshaping the world's largest ecosystem*' by McKinsey and Company. Given this, the perspective pitches for the primary stakeholders comprise developers, designers, engineers, and specialised contractors, while the rest of the value chain is grouped under associated stakeholders. General contractors can also utilise the perspective pitches to better understand the changed nature of engagement among building value chain stakeholders a platform ecosystem. The shared vision roadmap for platforms can be found in section 3.5.
- **Thought starters for the future of platforms** present several thought-provoking areas that demand attention and exploration. Open platforms can be reliably integrated with other products and services, and often allow external parties to make, use, and buy the common, repeatable elements, for legitimate purposes. It has a potential to create a dynamic marketplace for diverse supply chain contributors with a low barrier of entry. However, at present there is a lot of hesitance in the industry relating to intellectual property. Thus, safeguarding sensitive project information and ensuring robust security measures are essential to maintain trust and protect stakeholders' interests. By leveraging blockchain, platforms can establish secure and verifiable records of transactions, contracts, and project information, minimising the risk of fraud or tampering. Platforms that incorporate Web 3.0 technologies can foster transparent communication, streamline supply chain management, and promote effective collaboration among various stakeholders. As the building industry evolves, it is crucial to embrace Industry 5.0 principles, which emphasise social responsibility and sustainable practices. Platforms in Industry 5.0 will prioritise ethical considerations, such as environmental sustainability, worker safety, and community wellbeing, ensuring that technological advancements, including blockchain, align with the industry's social and ethical responsibilities. Additionally, integrating platforms with digital twin technology holds tremendous potential to transform building practices, enabling enhanced visualisation, simulation, and monitoring of projects. The thought starters for the future of platforms can be found in chapter 4.

3. PROJECT FINDINGS AND OUTCOMES

3.1 Theoretical foundation

The earliest definitions of product platforms were "… the collection of assets that are shared by a set of products" (Robertson and Ulrich, 1998) and "…a set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched" (Meyer and Lehnerd, 1997). Product design was traditionally viewed as a singular, isolated activity in manufacturing. According to Meyer and Lehnerd (1997), this traditional approach understated the potential for "commonality, compatibility, standardisation, or modularisation among different products and product lines." Manufacturers developed product platforms to create simple product lines that could share elements of a common family structure in response to this challenge. Utilising a product platform allows for the efficient development of differentiated products through sharing physical components and production processes (Maxwell, 2018). By summing up their definition as "a collection of basic assets that are reused to produce a competitive advantage," Kristjansson et al. (2004) highlighted that 'reuse' was a prevalent theme across product platform definitions. The product platform concept ultimately enables organisations to effectively adjust to shifting market conditions and needs for mass customisation, all while enhancing manufacturing and design efficiency via a mind-set centered on constant process improvements (Maxwell, 2018).

//Defining 'physical platforms'

Product platforms are termed as 'physical platforms' in this report because of the emergence of digital platforms (discussed in the next section) which also offer products, but only digital products. That is, 'physical platforms' represent the physical nature of product platforms where the end result is a physical product. To define the different types of platforms, we drew on classic supply chain management literature which describes the supply chain as a collection of nodes and flows. Biswas and Sen (2017) stated any supply chain comprises information, material, and financial flows through four nodes:

- **Supplier node** – design data, objects status, schedule, finance data, and ownership
- **Manufacturer node** – production data, process data, yield data, compliance, reliability data, maintenance, and warranty
- **Distributor node** – Schedule, order information, customer feedback, and finance data
- **Client / customer node** – product information and ownership, product delivery, and warranty.

Given environmental sustainability is now a big driver, we added carbon flow to the three flows stated in Biswas and Sen (2017).

Physical platforms are product architectures that create derivative streams of products which operate through material and information flows where the manufacturer node is most active. Physical platforms are 'information centered' and essentially mono-directional (one-way) where static production data and materials are fed into the platform. Thus, design information (supplier node), financial data, schedule, order information etc. (distributor node) and product information, warranty etc. (client / customer node) are maintained in supporting systems and often need to be made interoperable with the primary physical platform. Figure 3.1 demonstrates physical platforms and the operating nodes and flows.

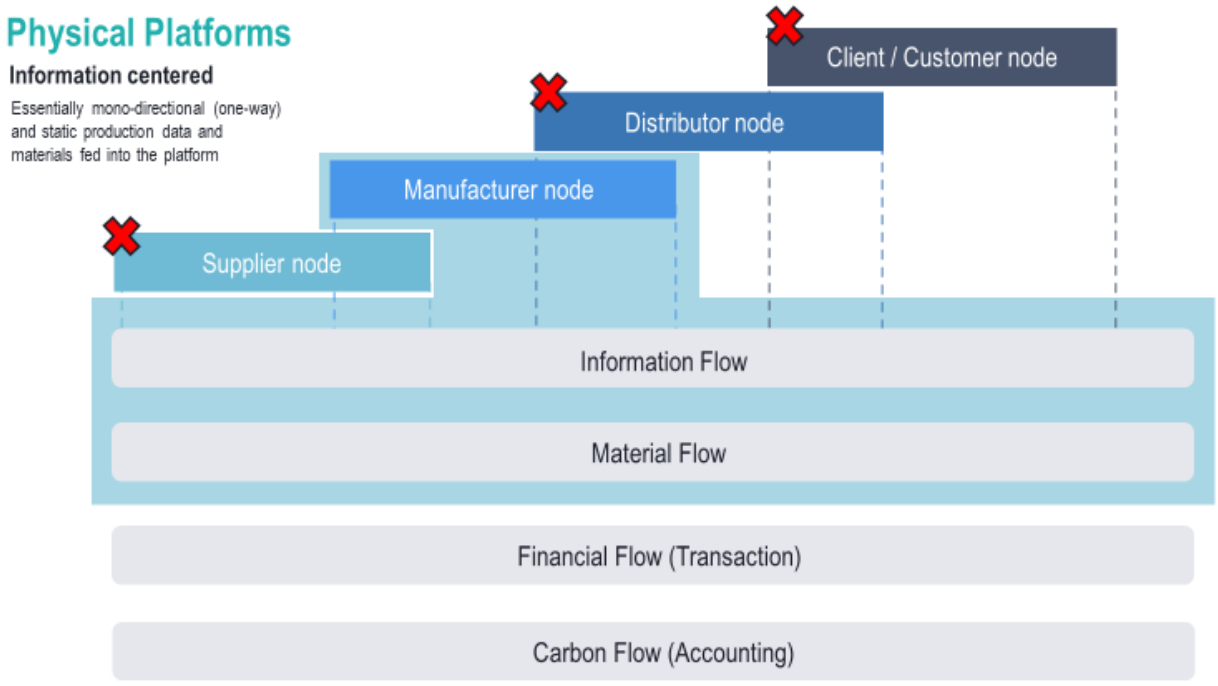

Figure 3.1 Physical platforms (nodes and flows)

//Defining 'digital platforms'

Like physical platforms, we defined digital platforms in terms of nodes and flows (Biswas and Sen, 2017). Digital platforms are 'online intermediaries' that act as facilitators of value exchange through information flow. They are 'people centered' in that supply chain actors play an important role in the exchange of value. Therefore, the supplier, distributor, and client / customer nodes dominate in digital platforms. As discussed in the previous section, digital platforms enable two-directional information flow that encourages cooperation and collaboration. However, digital platforms still do not go beyond the digital space to include machine-to-machine communication (the manufacturing node and material flow). Figure 3.2 demonstrates digital platforms and the operating nodes and flows.

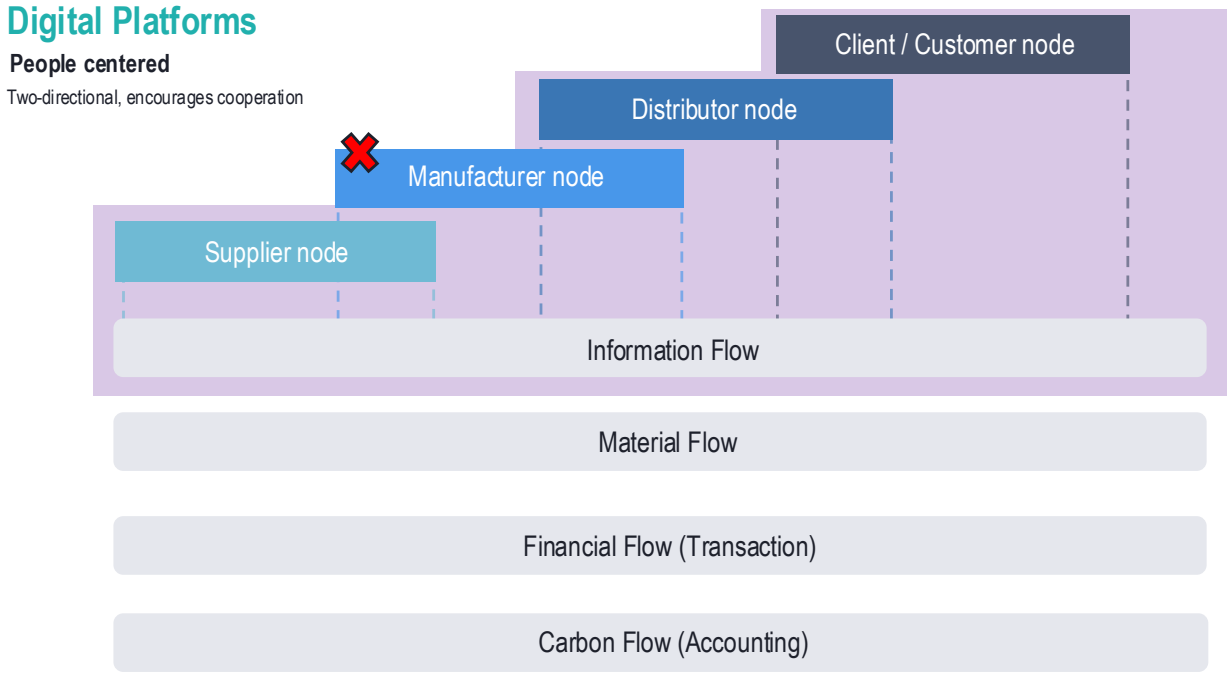

Figure 3.2. Digital platforms (nodes and flows)

BIM tools vs digital platforms: BIM tools like Autodesk Revit and Graphisoft's ArchiCAD enable an object-based digital representation of a building's physical and functional characteristics. BIM tools aim to expedite coordination (avoid gaps and overlap in team members' work) among building supply chain stakeholders (Rasheed et al., 2019, Yitmen and Alizadehsalehi, 2021). However, BIM is still managed using an electronic file-based model that significantly diminishes the potential usefulness and value of (BIM) data (Hijazi et al., 2022). The evolution of BIM aims to go beyond just object-based 3D modelling to structured and reliable datasets by transitioning into a digital ecosystem of linked databases (Rail industry Safety and Standards Board, 2022) which mimics a digital platform. Unlike BIM tools that enable coordination, digital platforms aim for cooperation (obtain mutual benefit by sharing work) and collaboration (achieve results that could not be accomplished alone) (Hijazi et al., 2021, Liu et al., 2022). Using Application Programming Interfaces (APIs), digital platforms can automate and customise workflows (Chen and Nguyen, 2019); an API is a software intermediary that allows two applications to talk to each other. Autodesk Forge® is an example of a digital platform that enables the transition from 'siloed electronic files' in Revit to 'an ecosystem of linked databases'. Autodesk Forge® is discussed in section 3.4.

//Defining hybrid platforms

Sandberg et al. (2019) stated "… during the last decades, a new set of industrial products have emerged in which physical and digital components (and associated functionalities) are increasingly integrated". They defined 'hybrid platforms' as the intermingling of modular physical components with digital functionality to increase their variability and evolvability. They further explained that in such platforms, states of the physical world are continuously mapped to digital representations (using sensors embedded in physical components), and the world is operated and controlled through a set of actuators (digital to analogue converters).

From a managerial and governance perspective, hybrid platforms create a completely new dynamic and require the integration of design and governance principles associated with both physical and digital platforms, which often generates tension. According to Sandberg et al. (2019), the hybrid platform approach demands bringing together technology, context, and strategy. Drawing from her earlier work on platform ecosystems, Gawer (2021) defines the hybrid approach as those containing both innovation and transaction platforms; innovation platforms serve as a technological foundation upon which other firms develop complementary innovations (more like the physical platforms described above), while transaction platforms serve as an intermediary for direct exchange or transactions, subject to network effects (more like the digital platforms described above). The verdict is that the future of platforms will witness more hybrid business models, driven by digital competition where companies grow rapidly with a "clever combination of data, software, and ecosystem strategies" (Cusumano et al., 2020).

Assimilating the above, we again define the hybrid approach to platforms in terms of nodes and flows. In hybrid platforms, all four supply chain nodes are active and there is simultaneous flow of information and materials (intermingling of modular physical components with digital functionality). Hybrid platforms are machine centred and often utilise cyber-physical systems (such as sensors embedded in physical components). While current hybrid platforms encompass information and material flows only, future hybrid platforms would need to integrate with financial and carbon flows to achieve complete circularity. However, such platforms require robust governance mechanisms for intellectual property and liability, data privacy, and security (Construction Innovation Hub, 2022). Figures 3.3 (a) and (b) demonstrate current and future hybrid platforms and their operating nodes and flows.

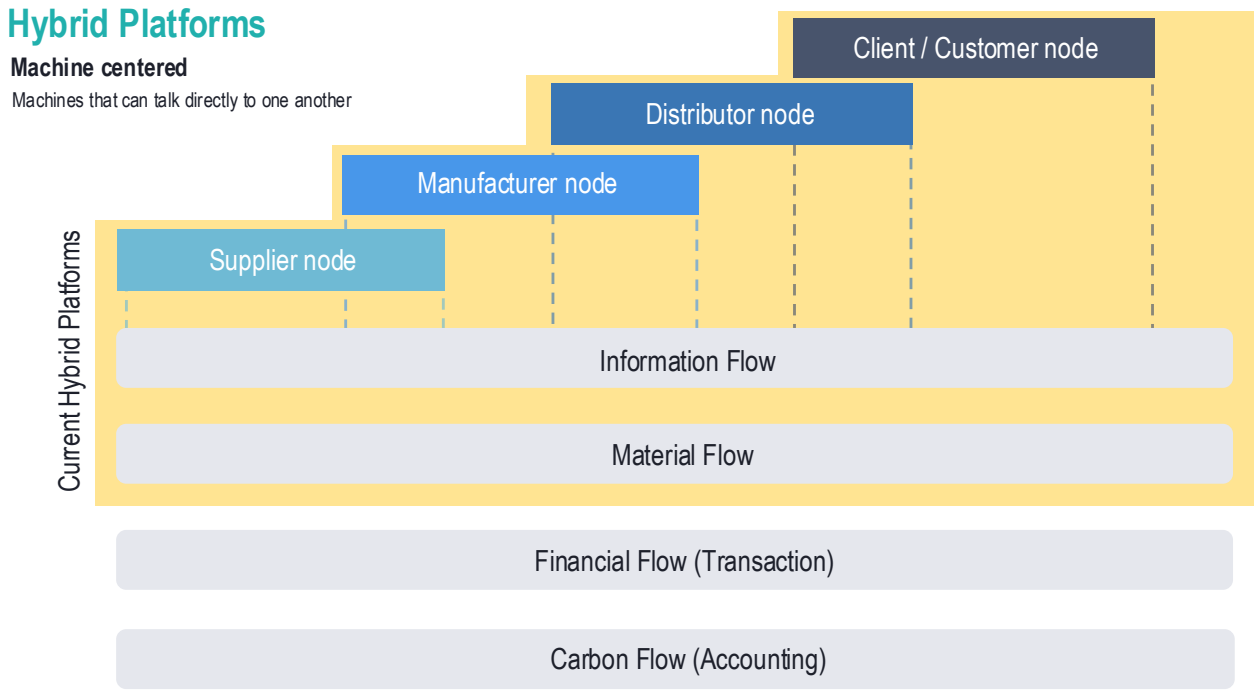

Figure 3.3 (a). The current hybrid platforms (nodes and flows)

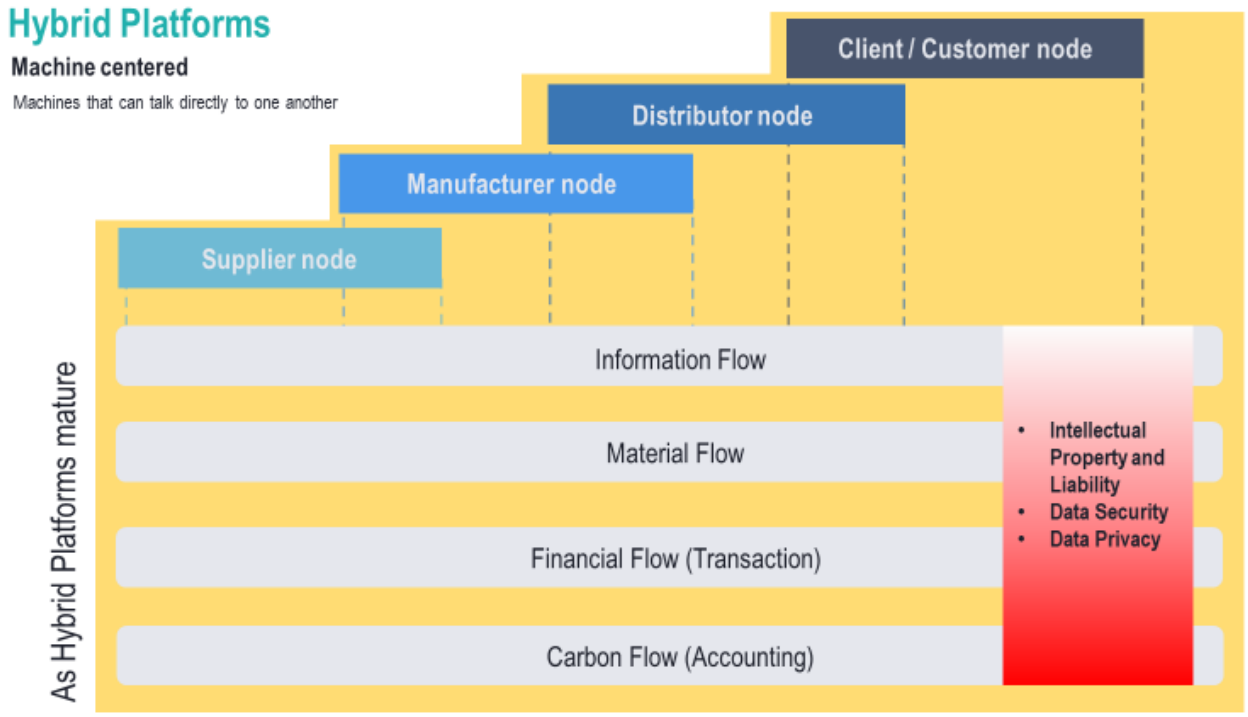

Figure 3.3 (b). The Future Hybrid Platforms (nodes and flows)

With this theoretical foundation, the following sections identify and analyse several physical, digital, and hybrid platforms, across sectors (section 3.2) and in the building industry (section 3.3).

3.2 Cross-sectoral mapping of platforms

Although this Popperian study did not assess all platforms available in each of the 16 ANZSIC industries, many valuable insights can be gained from the satisficing evidence-based review of 190 platforms in this study. First, most platforms are digital. Second, few platforms span both the digital and physical space. Third, only a small number of platforms span the entire lifecycle and, in such cases, these are typically either within the digital or physical space and not across both spaces. Fourth, the initiate stage of the lifecycle is typically dominated by a large player in the industry. Fifth, standardisation is widely observed in platforms, underpinning their operation. Sixth, digital technologies have shifted investment from the platform provider to the providers of products and services. And lastly, the operate stage is the domain of platforms studied and has provided considerable opportunity for business model innovation. Table 3.1 summarises our key findings and implications for platform development in building sector.

TABLE 3.1 Key findings and implications of the research for building

	Key finding	***What it means***	***Implications for building***
1	*Most platforms are digital.*	*Barriers to entry in digital platforms are lower than for physical platforms.*	*Building is principally a physical activity, so adoption challenges will be higher.*
2	*Few platforms span both the digital and physical space.*	*Value capture requires a higher level of innovation when spanning digital and physical spaces.*	*Higher level of investment in innovation will be required upfront to establish a building platform.*
3	*Only a small number of platforms span the entire lifecycle and in such cases, these are typically either within the digital or physical space and not across both spaces.*	*Sustainability of a platform has a short shelf life relative to product life.*	*The long life of buildings challenges the demonstrated capability of the platform model to sustain beyond design and construct to end of life.*
4	*Initiate stage of the lifecycle is typically dominated by a large player in industry.*	*Leadership is required to establish a platform.*	*Investors and developers have a lead role in the industry and would be well placed to initiate a platform.*
5	*Standardisation is widely observed in platforms, underpinning their operation.*	*Platforms need components like LEGO bricks that fit together effortlessly.*	*There are many standards in building, which will need to be brought together to enable interlinking with one another.*
6	*Digital technologies have shifted investment from the platform provider to the providers of products and services.*	*Exchange relationships, liabilities and responsibilities are changing.*	*Building has already captured the benefit of shifting responsibilities to subcontractors, so immediate return on establishing a platform will be less.*
7	*Operate stage is the domain of the platforms studied and has provided considerable opportunity for business model innovation.*	*Operate stage attracts investment in the platform business model.*	*Investors and developers seeking to develop platforms would benefit from including facilities managers who operate buildings to capture the operate investment opportunities.*

3.3 Market review of building platforms

This section contains a comprehensive analysis of 12 platform companies in building identified through a market review. The companies identified represented different platform approaches: physical, digital, and hybrid. Boklok, Lindbäcks, and Volumetric Building Companies (VBC) represented companies that are dominated by physical platforms. Digital platform solutions were represented by five companies including Project Frog, Ptblink, Willow, Autodesk Forge, and Openbuilt. The market review also identified four companies under the umbrella of hybrid platforms including Intelligent City, Bryden Wood, Blockable, and CREE Buildings. The market review and analysis helped to map the existing platform companies in building with the attributes of an ideal building platform and understand the value chain they operate at. We identified companies via accepted consensus based on expert knowledge from project industry partners. The discussions with partners created a series of prompts which were then further investigated through web searches and grey literature. The sample size was restricted to 12 platform companies given it is a scoping study with limited duration. Information captured from company websites was used to understand their origin story and value proposition, map them with the attributes of an ideal building platform and understand the value chain they operate at. The attributes of an ideal building platform were modified from the Product Platform Rulebook (Edition 01) published by the Construction Innovation Hub and United Kingdom Research and Innovation (UKRI) in the September 2022. The identified platform companies were qualitatively assessed against the attributes of an ideal building platform because it is still a nascent area of research and there are no well-defined maturity scales or detailed case studies to quantitatively assess the existing platforms. The platform value chain was arrived at through a comparative analysis of relevant frameworks in Australia and abroad.

//Platform attributes

The Product Platform Rulebook proposed eight rules; compliance with the rules determines whether something can be considered as a product platform or not. These rules were modified for this study to represent not only product platforms but platforms in general including those dominated by physical platforms, those offering digital platform solutions, and those adopting a hybrid approach. The modified rules and their definitions are below with modifications shown in italics.

1. **Deployable** – It is possible to deliver *products or services* related to building that are distinct and does not represent a cookie-cutter repetition.

2. **Configurable** – It is possible to comply with variations in requirements across different projects while still using the common repeatable elements of the platform.

3. **Common Repeatable Elements** – There is holistic consideration of improving productivity and risk across all aspects of the delivery process, while accepting that *different projects* will share elements to differing degrees.

4. **Interfaces** – The platform can be reliably integrated with other *products and services* without being wholly dependent on the platform provider.

5. **Quality** – A minimum level of quality can be achieved, and documents and procedures are in place (requirements, specifications, guidelines, or characteristics) that can be used consistently to ensure materials, products, processes, and services (as appropriate) are fit for purpose.

6. **Structured Information** – Actors in the client domain can make an informed choice about the use of the platform and how it will affect outcomes, and actors in the product domain can feed in their information seamlessly. Actors in the project domain can evaluate, configure, and deploy platforms correctly.
    - Apply appropriate and proportionate security controls to sensitive product, deployment, and/or organisational information.
    - *Platforms* should promote interoperability on a technical, legal, semantic, and organisational level.

7. **Open** – Any party can make, use, and buy the common, repeatable elements, for legitimate purposes.

8. **Circularity** – *It is possible to reduce waste, reduce embodied carbon and adopt a circular economy approach to building.* The degree of circularity shall be evidenced.

The eight rules described above will be used to analyse the companies identified in the market review.

// The platform value-chain

The cross-sectoral mapping of platforms illustrated platforms generally have five stages in their value chain; Initiate, Standardise, Design, Construct, and Operate (ISDeCO approach). With this as the basis, we used three relevant frameworks that propose the stages of a building value chain and include approaches that are aligned to the platform approach in building to arrive at a platform value chain for building:

- The RIBA Plan of work (DfMA Overlay), 2nd Edition, 2021 – It is one of the most widely accepted frameworks globally and it includes Design for Manufacture and Assembly (DfMA).

- The Handbook for Design of Modular Structures (DfMA construction) published by Monash University in 2017 – In an Australian context, this handbook has been widely used for DfMA construction as a guiding framework and is considered a predecessor to this study.

- The Digital Engineering Framework published by the Transport for New South Wales (TfNSW) in 2019 – This very comprehensive framework details the stages of digital (data) delivery in a construction project which forms a critical element of platforms as seen in the previous section (attributes like structured information and interfaces).

Table 3.2 illustrates the comparative analysis between the three frameworks to propose the stages of a platform value chain for building. Figure 3.4 illustrates emergence of the platform value chain for building from the cross-sectoral platform value chain.

Table 3.2. Comparative analysis between the three frameworks to propose the stages of a platform value chain for building

Ref.	0	1	2	3	4	5	6	7	8
RIBA Plan of work (DfMA Overlay	Strategic Definition	Preparation and briefing	Concept Design	Spatial Coordination	Technical Design	Manufacturing and Construction	Handover	Use	
Handbook for Design of Modular Structures (DfMA construction), Monash University, 2017	Manufacture	Feasibility / Funding	Design and Engineering	Site Preparation	Assembly	Fit-out & Finishing	Testing & Commissioning		
Digital Engineering Framework, Transport for New South Wales (TfNSW), 2019	Demand / Need	Plan (Concept, Specify, Procurement)	Acquire (Design, Build, Integrate, Accept)					Operate / Maintain / Evolve	Dispose
Our proposed stages (for mapping): Please note that this is not a deployment process and stages may run parallelly	**Strategic Definition**	**Preparation and briefing**	**Design and Engineering**	**Manufacturing**	**Site Assembly and commissioning**	**Operate / Maintain / Evolve**			

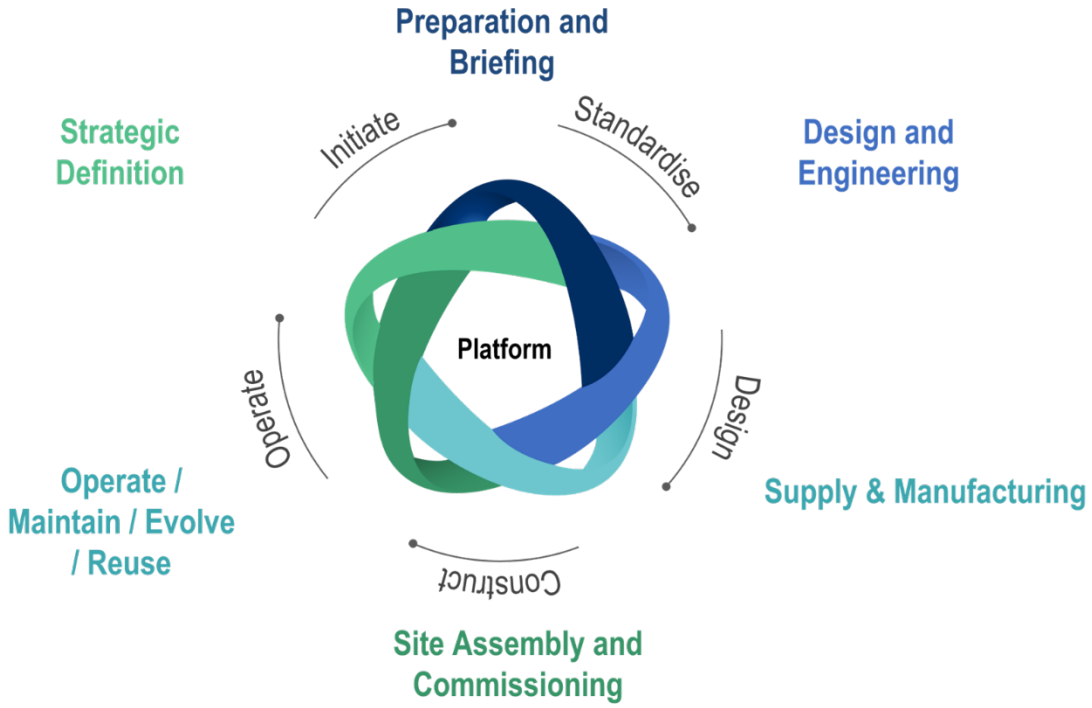

Figure 3.4 Emergence of the platform value chain for building from the cross-sectoral platform value chain

// Emergent market trends

This subsection illustrates the emergent market trends obtained through the review and analysis of the 12 platform companies building in the form of infographics and subsequent discussions. First, the trends observed when the platform companies were mapped to the eight platform tributes are presented from the perspective of physical, digital, and hybrid approaches to platforms. It is a simplistic traffic light visualisation of whether the platform companies exhibit the platform attributes: green for significant alignment to the platform attribute, yellow for moderate alignment which is not evidenced clearly on their websites, and red for no alignment. Following this, the contribution of these platform companies towards the building platform value chain is demonstrated.

To what extent are they platforms?

Physical platforms – The focus of physical platforms is on being ***deployable***, and ***configurable*** while providing ***common repeatable elements*** and ensuring strict ***quality*** assurance. Physical platforms start off in closed vertically integrated supply chains that have ***very few fixed interfaces***. For example, the Boklok catalogue of products depends completely on the Boklok modules that are produced in a single production line centrally controlled by Boklok. The physical platforms benefit from analysing the market segment critically before deciding on a catalogue of products. However, ***structured information*** is not considered a deliverable when handing over an asset to the client/customer. This stagnates the progression of ***structured information*** towards machine-readable datasets that can be utilised during the operation and maintenance phase. However, companies dominated by their physical platforms are attempting to serve varied markets often through merger and acquisition. For example, VBC recently merged with Polish modular building company, Polcom Group, as part of a strategy to expand its global reach and grow to US$1 billion in annual revenue over the next three years. ***Circularity*** is embedded in the physical platforms, however, often they have very stringent production lines centrally controlled which restricts the 'share and exchange' attributes of circularity. Further, evidencing circularity is still a question of more data acquisition and analysis. Figure 3.5 illustrates the mapping of physical platforms against the eight platform attributes.

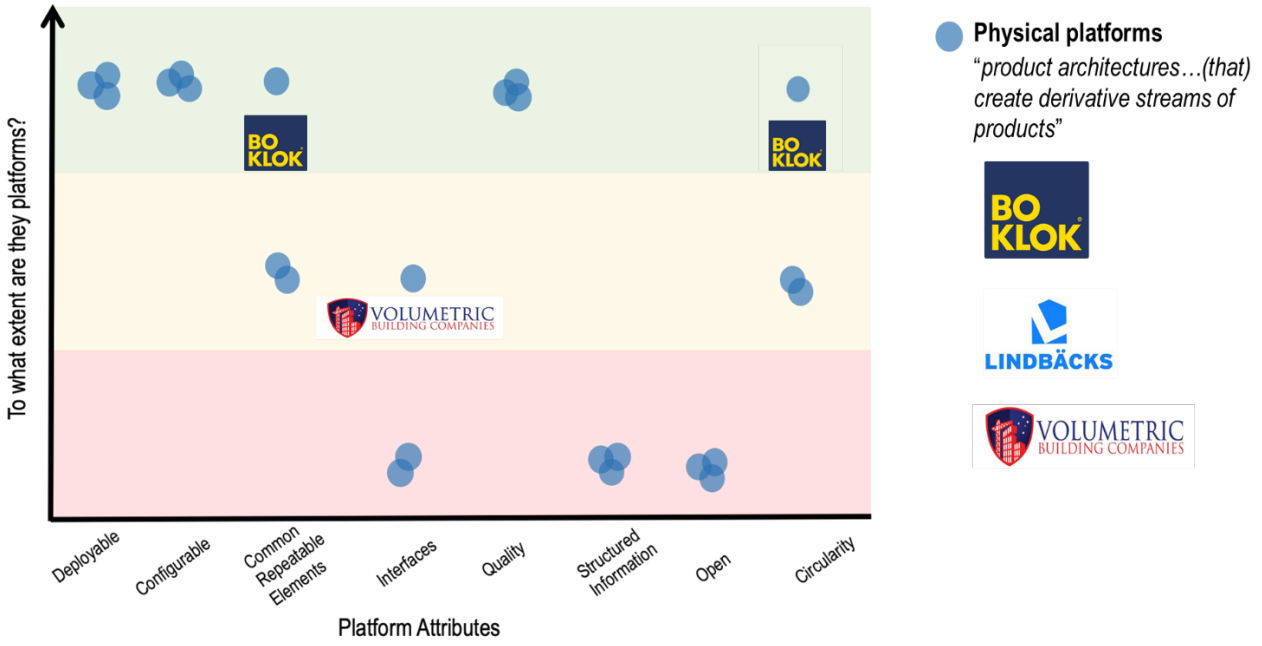

Figure 3.5 Mapping of physical platforms against the eight platform attributes.

Digital platforms – Digital platforms adhere significantly to the attributes of an ideal building platform. Since they are developed as software products, they are intended to be ***deployable***, ***configurable***, with ***common repeatable elements***, and are ***open*** platforms with strict ***quality*** assurance. Digital platforms are also competent when it comes to ensuring ***structured information***. For example, design automation in Autodesk Forge means API users can automate and customise workflows like creating custom Revit families, exploring and analysing model data, and extracting and producing automated reports. This leads to the progression of ***structured information*** towards machine-readable datasets (ideal platform). This also makes them far more advanced than point solutions that are hard-coded and are less ***configurable*** (such as Aconex, Procore). Their ***interfaces*** often depend on their value proposition. For example, Autodesk Forge APIs can be combined with existing software systems to innovate how you work and get more from your data because their value proposition is to unify the building workflow's data management. But Willow gives access only to native Willow applications through a single and secure integration point. The complete offering still operates through the Willow platform (platform dependent) because their value proposition lies predominantly in operation and maintenance. Digital platforms enable ***circularity*** in building and can acquire the data required to evidence circularity of operations. Figure 3.6 illustrates the mapping of digital platforms against the eight platform attributes.

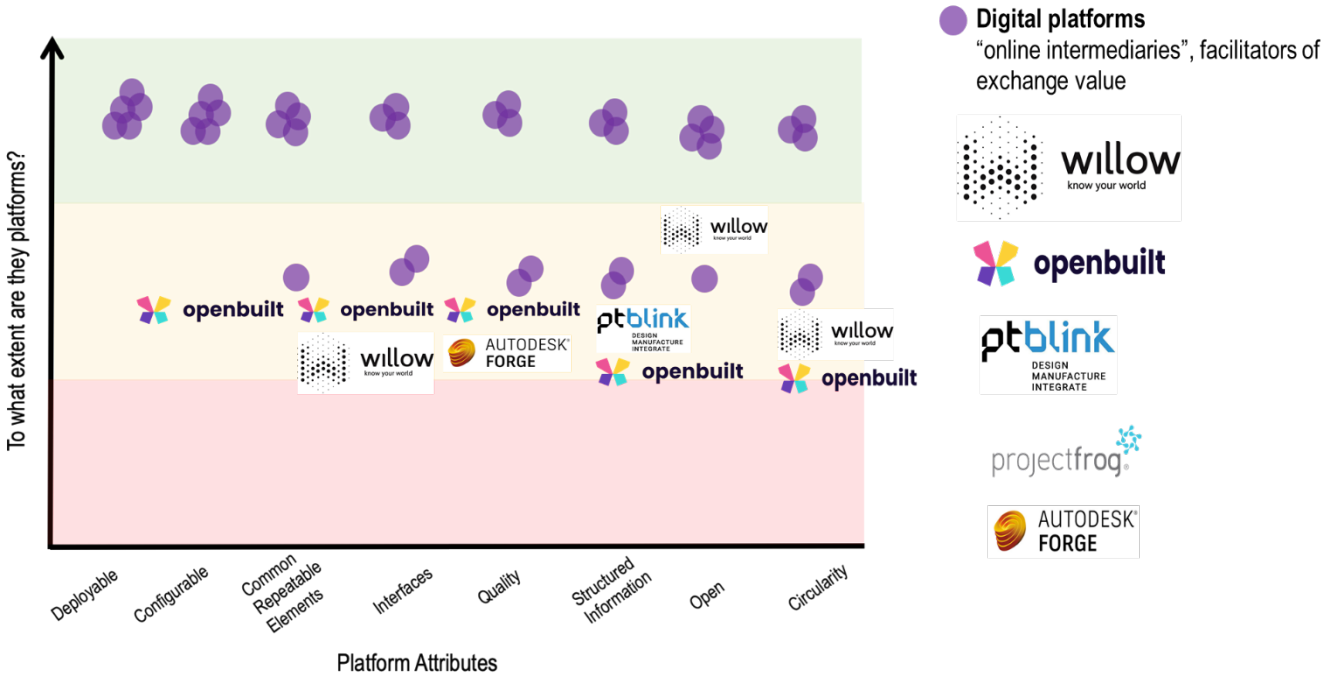

Figure 3.6 Mapping of digital platforms against the eight platform attributes.

Hybrid platforms – These platforms focus on establishing an end-to-end integration of the entire value chain from feasibility to delivery that is ***deployable*** and ***quality*** assured. In doing so, most offer ***configurable*** solutions enabled by ***common repeatable elements***; however, sometimes the value proposition is restricted to very standardised deliverables. For example, Intelligent City claims to have a powerful digital design process based on hundreds of parameters that can be adjusted in response to the design intent and in real time. Infinitely ***configurable*** and customisable, their software can run through hundreds of iterations to find the optimal balance between regulations, design intent, and cost. But Blokable's variability is low, most probably because their primary value proposition is affordable housing.

Since, the core of hybrid platforms often lies in the production line, they often struggle with their ***interfaces*** and are not ***open***. For example, Blokable streamlines a fragmented, one-off process and compresses it into a single development stack that they control. So, essentially, they are the platform provider and all interfaces are platform-dependent with centralised planning, development, and building. By contrast, Bryden Wood is an exception among companies taking the hybrid approach. The Forge by Bryden Wood showcased a complete hybrid platform approach from the perspective of a product platform and information exchange enabled by strategic partnering. Enabled by partnering, their hybrid approach is dominated by the aggregation of platform routines. Therefore, Bryden Wood's approach is ***open*** with the aim to potentially create a dynamic marketplace for diverse supply chain contributors with a low barrier of entry.

Hybrid platforms are a progression from physical platforms when it comes to ***structured information***. For example, CREE claims several simulations of all workflows are carried out in a digital twin, which facilitates optimised material and information flow and eliminates resource wastage. Companies taking a hybrid approach use parametric design to generate structured datasets; for example, Intelligent city says the advantage of parametric design is that one can always instantly have a fully resolved model that can be manufactured and constructed. Figure 3.7 illustrates the mapping of hybrid platforms against the eight platform attributes.

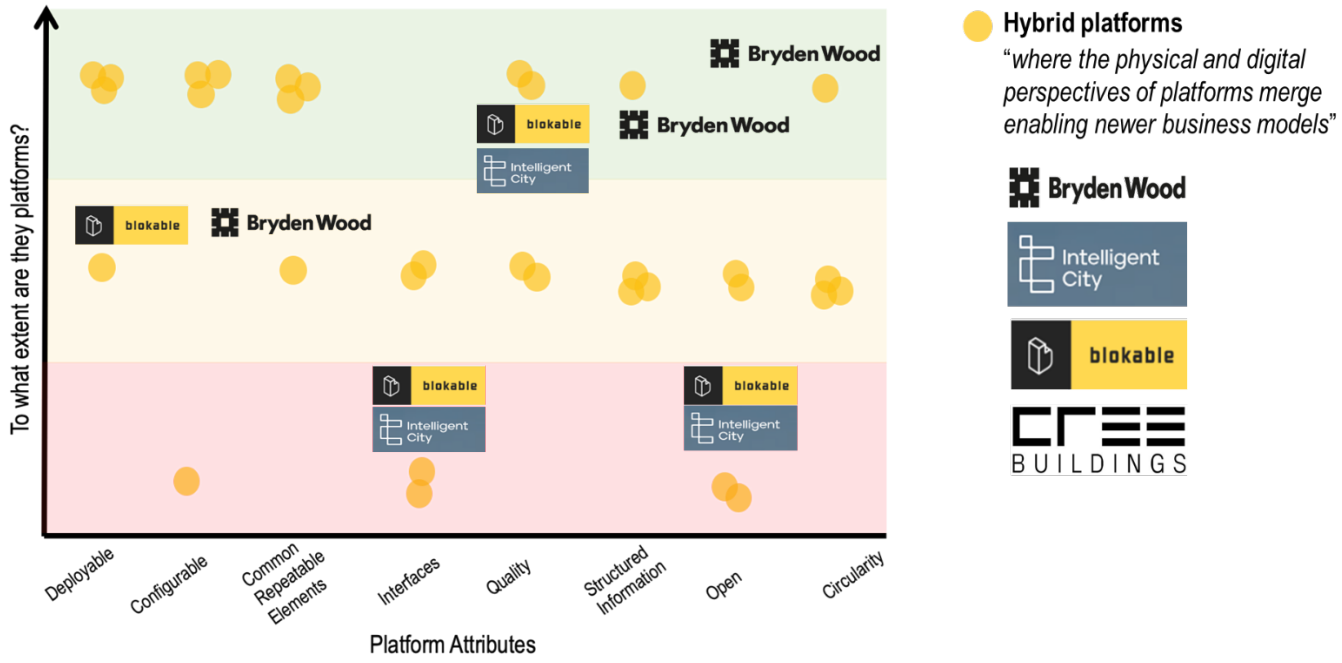

Figure 3.7 Mapping of hybrid platforms against the eight platform attributes.

This analysis illustrated that as a company attempts to enter the platform space, it must focus on how deployable and configurable their platform is and if they can use quality assured common repeatable elements. While these are must-have attributes, the choice of being open or closed with limited interfaces lies with the platform company and depends on their value proposition or what the market allows at present. As we move towards a matured state of digitalisation, where emerging technologies will enable processes in our industry, structured information will become more and more significant, However, the market review revealed platform companies are yet to achieve the required standards of structured information. Circularity, even though embedded in the vision and processes of platform companies, is rarely evidenced. However, if government mandates come into existence, circularity must be evidenced by platforms of the future.

Which stage of the building platform value chain do they contribute to?

Physical platforms – Physical platforms usually operate across the value chain. ***Strategic definition***, ***preparation and briefing*** is an ongoing, embedded process within the value chain, which is somewhat different from a traditional process. Some of the physical platform companies operate their assets and some do not, strictly based on whether they see value in it. For example, the Lindbäcks value chain comprises project development (***strategic definition + preparation and briefing***), design and purchase (***design and engineering***), production factory (***supply and manufacturing***), production building site (***site assembly and commissioning***) and aftermarket transfer (***operate/maintain/evolve***). Unless otherwise agreed, the warranty period is five years for Lindback houses. Working with continuous improvements is a fundamental component of Lindbäcks' production system. An important part of this is to follow up and learn from completed projects. They have renting / leasing services as well, all the more contributing to the operate/maintain and evolve stage of the value chain. Similarly, the Boklok value chain focuses on targeting the right customer, right customer offer, right land (***strategic definition + preparation and briefing***), right project process (***design and engineering***), right production methods (***supply and manufacturing+ site assembly and commissioning***), and right marketing and sales (***strategic definition***). Unlike Lindbäcks, Boklok does not operate their buildings according to their website. Figure 3.8 illustrates the mapping of physical platforms against the stages of the building platform value chain.

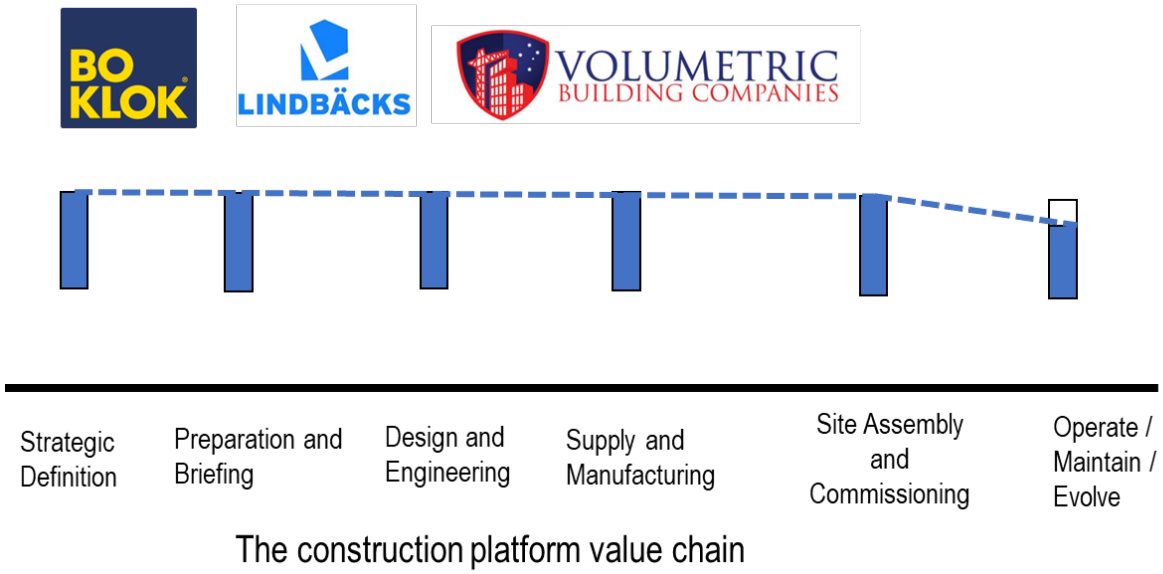

Figure 3.8 The mapping of physical platforms against the stages of the building platform value chain.

Digital platforms – Digital platforms have evolved from point solutions, and therefore one single platform operating across the value chain is rare. For example, Willow optimises building performance using the Microsoft Azure digital twin and contributes primarily to the ***Operate / Maintain and Evolve stage*** of the value chain. But Willow is not a point solution because they are not hard coded. Openbuilt contributes to parts of the value chain, including ***preparation and briefing*** and ***site assembly and commissioning***, focusing on information exchange. Openbuilt provides a low code development platform that enables us to connect software services and data to automate business processes. Autodesk Forge operates across the value chain, starting from ***design and engineering***. Using Forge APIs, users can automate processes, connect teams and workflows, visualise data, and generate automated reports. ptblink is the only digital platform in our mix that claims to operate across the value chain. It creates an ecosystem of all stakeholders in a property development project fostering collaboration and data sharing across all aspects of the development cycle, from design, manufacture and integration to certification, insurance, and facilities management. Because digital platforms contribute to parts of the value chain, there are opportunities for mergers between companies to aggregate functionality. The recent merger between Procore and Willow demonstrates how point solutions can widen the functionality of digital platforms or vice versa. Figure 3.9 illustrates the mapping of digital platforms against the stages of the building platform value chain.

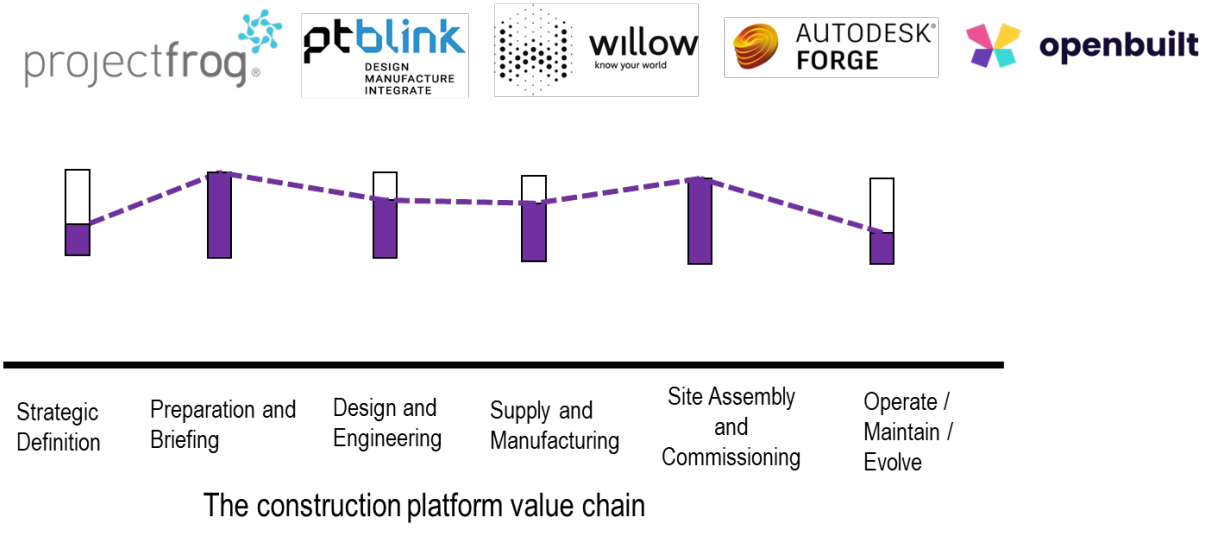

Figure 3.9 The mapping of digital platforms against the stages of the building platform value chain.

Hybrid platforms – Hybrid platform companies that focus on production such as Intelligent City, Blokable, and CREE Buildings, focus on proprietary end-to-end design processes and production lines that encode the relationship between parameters and design response with innovative algorithms. Thus, they operate across the value chain. What varies is the level of variability. For example, Intelligent City has a more powerful digital design process based on hundreds of parameters that can be adjusted in response to the design intent and in real time. By contrast, Blokable's variability is low, as observed from the developments, most probably because their primary value proposition is affordable housing. These hybrid platforms are creating robust information exchange mechanisms; however, this is not fully achieved yet.

However, an exception is Bryden Wood, which focuses on information exchange. They combine typical building software (Revit, Tekla) and platform-specific routines (in Grasshopper and Dynamo) to automatically generate a dataset describing the position and orientation of every structural component, drawing on a digital library of standard columns, beams, connections, etc. This leads to the progression of structured information towards machine-readable data sets, which is critical for an ideal platform. However, Bryden Wood does not operate across the value chain.

How they filled the Value Chain Gap? To achieve an end-to-end operation, Bryden Wood strategically partnered with Landsec in Forge and implemented a platform approach. However, this approach does not deprive them of drawing value from the data acquired throughout the project because they are platform consultants to the project. Therefore, one single organisation might not need to contribute to the entire value chain; they can plug and play based on their value proposition. Given this, a general contractor could be better poised to own (maintain) the platform. At the same time, designers and engineers, material/component manufacturers, material distributors, and logistic players can contribute to it. Figure 3.10 illustrates the mapping of hybrid platforms against the stages of the building platform value chain.

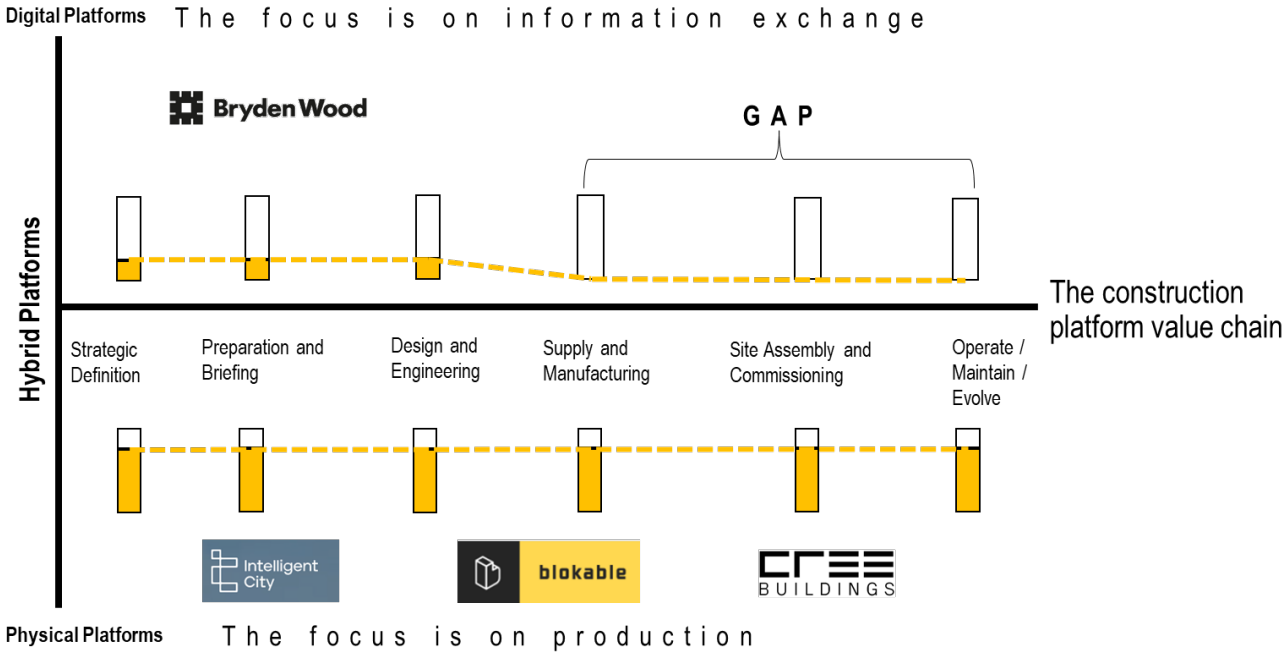

Figure 3.10 The mapping of hybrid platforms against the stages of the building platform value chain

//Is there an ideal platform?

The market review altered the perception of an ideal platform; while analysing platforms, the more effective question would be to explore 'how ready the companies are for a platform ecosystem' rather than 'how good platforms they are'. For example, even though a platform which is closed with restricted interfaces exhibits a successful business model, it cannot leverage the optimal benefits of a platform ecosystem; but an open and interoperable platform will be optimum for the platform

ecosystem of the future. Similarly, a platform that operates across the entire value chain might be considered the closest to an ideal platform; however, as Bryden Wood illustrates, strategic partnerships enabled an effective platform ecosystem for the Forge and possible future projects like the Forge. Understanding how a platform ecosystem might function – its drivers, barriers and key performance indicators – is the subject of future research.

3.4 Platform case studies

The case studies demonstrated exemplar characteristics of the platform logic in the building context and revealed how similar or different operations could be in a platform-based value chain. The three companies selected were Volumetric Building Companies (VBC) , Intelligent City, and Bryden Wood. They were chosen because they demonstrated exemplar characteristics of the platform logic. This section compares the three companies implementing a platform approach to highlight the questions related to platforms including contractual arrangements, open versus closed platforms, and aggregating the demand pipeline.

//Comparative analysis

- **Contractual arrangement:** There was consensus among the companies that the contracting model needs to be as close to 'business as usual' as possible to implement platform approaches in the industry because ultimately these companies need to exist in the market. For VBC, the contracting model comprised three different contracts – one for design, one for manufacturing, and one for building. However, VBC does not contract for manufacturing, without already having been involved in the design; that is, they chase the project at design, or before its designed and not when they need to fill their factory. Intelligent City, even though originating from an architectural background, takes up contracts for delivering a fully resolved, pre-engineered, high-quality building. Internally, even though there might be capacity for complete vertical integration, they consider putting the entire value chain in-house immediately a distraction and work with consultants / contractors / local trades of preference through subcontracts. While VBC and Intelligent City are the dominant players in the contracting model, Bryden Wood is different. Delivering Forge had multiple contracts, most of which are not hierarchical but collaborative and strategic. Bryden Wood (the platform consultant) was not part of the contract between Landsec (the developer) and MACE – Robert McAlpine JV (the construction managers). That was a closed book. However, the contractual arrangements were discussed upfront so that all stakeholders understand that they need to deliver certain pre-construction services. For example, N.G.Bailey (the MEP (mechanical, electrical, plumbing) provider) had two years' worth of pre-contract work to be conducted. It is agreeable that the contracting model is still an active discussion and there will be a need for an effective model to go forward. For example, VBC's current contractual arrangements (three separate contracts from design, manufacturing, and building) slows down the process and it opens for renegotiation halfway through a project. Therefore, there is a push to move towards a design-build contract instead, which would be a much more fitting model for VBC's operation. The contractual arrangements also need to resolve concerns around intellectual property (IP), risk ownership, and liabilities that are influenced by how open or closed the platform is.
- **Open versus closed platforms:** Open platforms can be reliably integrated with other products and services and often allow external parties to make, use, and buy the common, repeatable elements, for legitimate purposes. VBC and Intelligent City were similar when it comes to their approach to openness. The VBC platform does not integrate with other products in its current evolution, however, they are very well set up to enable integration with additional or external services. VBC does add to their catalogue of products by forming joint ventures with other companies. Almost similar is Intelligent City's approach; Intelligent City manufactures those parts that are important to the quality of the buildings, its longevity and perhaps the building envelope. But their platform logic is well suited to add secondary and tertiary components from other manufacturers such as prefab bathrooms. For both companies, integrating external products to

their platform is a question of scale and ensuring a win-win for both themselves and the supplier / vendor. Integrating with external services is primarily for two reasons: first, to exist in the market as clients sometimes come with their own consultants / architects (as seen in the case of VBC) and second, to enhance the functionality of the platform. (While the core of Intelligent City's software platform is proprietary, they often integrate with plugins that can perform energy analysis / LCA analysis.) Bryden Wood's approach is the most open among the cases studied. Bryden Wood / Forge's aim was to potentially create a dynamic marketplace for diverse supply chain contributors with a low barrier of entry (a positive supply chain competitive environment). For N.G. Bailey, who developed the MEP systems for the Forge platform, it opened an opportunity to provide a key component in an optimised platform solution that could be widely used across the commercial building sector. Also, this does not guarantee that each time a platform approach is used, N.G.Bailey will be contracted. Any other MEP provider who develops a solution that integrates with the platform can be utilised. This initiates competition and fosters innovation. In the future, VBC hopes the industry matures into interoperable connections and solutions that can be plugged together through a system that operates across multiple companies. However, at present there is a lot of hesitance in the industry in relation to IP.

- **Aggregating the pipeline of demand:** The building industry perceives the lack of a predictable pipeline of demand as the most critical barrier for implementing the platform approach. Complying with variations in requirements across different projects while still using the common repeatable elements of the platform ensures a pipeline of demand because it enables a platform to function in a project-based delivery mechanism. The case studies each demonstrated unique approaches to ensuring variability. The VBC platform can evolve with time and stakeholders inside the production–project chain are taught how to handle their platform rules, mostly through a high level of communication with the design team. An active discussion between the sales team, design team, and production team is key to a more accurate aggregation of demand and a feasible strategy. It might not be very efficient if the standardised platform standpoints alone are considered but it is a healthy choice in a very dynamic market. For Intelligent City, the need to ensure variation does not necessarily exist. Systemisation of the design is the key. Intelligent City designs everything to be adaptable in its geometry through parametric design. Parametric design is a fundamentally different thinking which ensures complete freedom for project-to-project volumetric production with the efficiencies of a platform. For Bryden Wood, commonality is not only in the components or modules; it is also in the processes, enablers, and equipment encapsulated in the platform rules. As mentioned earlier, through this approach, Bryden Wood creates a dynamic marketplace for diverse supply chain contributors where the pipeline of demand does not necessarily come from repeat clients but the market itself. In other words, understanding what the platform offering is and what the market needs always remains critical.

//Lessons learnt

- **Early prototyping** – Early prototyping is critical in developing the platform approach. As Bryden Wood shows, early prototyping was not only in the components or modules, it was also in simulating the processes. This early prototyping was possible with funds from different government schemes and research funds. Subsequent to the prototyping, early involvement of the stakeholders enables the platform logic. As already mentioned, the contractual arrangements must be discussed upfront so all stakeholders understand they need to deliver certain pre-building services.
- **Injecting platform DNA** – According to platform theory, companies often repurpose an existing suite of products, inject a platform DNA into them, and offer solutions that can integrate with a platform ecosystem. This creates an opportunity to provide a key component in an optimised platform solution that can be widely used across the commercial building sector.
- **Catering to a project-based delivery mechanism** – Platforms must still cater to a project-based delivery mechanism because projects will remain the main drivers with operations revolving

around the project delivery stream. VBC says, in a progressive manner, two-thirds of the revenue in the project is placed inside the factory.

- **Drifting versus leaping** – Generally, platforms are perceived as too complex and require a resource-intensive *leapfrogging* effort. However, the exemplar case studies demonstrated a progressive transformation (*drifting*) through experiential learning followed by a cognitive search for integrating the platform logic into a project-based delivery mechanism.
- **Aggregation of BIM tools can enable platform logic** – Bryden Wood, as a design team, typically use a BIM software (Revit) as the main design tool. For a platform-based project, the design approach uses different platform-specific routines and parametric tools, such as Dynamo, Rhinoceros and Grasshopper. However, established routines to carry digital models through to fabrication are necessary.
- **Moving towards parametric design** – The advantage of parametric design is that one can instantly have a fully resolved model that can be manufactured and constructed. The geometry starts the manufacturing because it has all the manufacturing instructions and the metadata that comes with it. It is beyond BIM. Intelligent city says parametric design enables them to design everything to be adaptable in their geometry.
- **Commonality in processes and enablers, not just physical components** – Similar to early prototyping, commonality in platforms is not just in the physical components, but also in the processes and enablers. Bryden Wood says the assembly process, the unit operations, the number of people, the tasks that they carry out, and the number of minutes they spend on each task are all part of platform rules. Simulating the physical components in a digital model is fairly easy, but the assembly and the labour content must be tested in the real world to get to validated numbers and make sure that it can be delivered on site with confidence.
- **Offsite versus onsite** – Interestingly, the platform logic allows for decisions on whether tasks need to be done on site or off site. For the Forge, there was a debate on whether precast concrete or in-situ pumped concrete would be used. When the processes were broken down, in-situ pumped concrete had a much shorter process flow – place shutters, pour concrete, initial curing, strike shutters, re-use shutters. By contrast, precast concrete would involve a longer chain of activities including transport to site which meant additional carbon footprint; given London is completely gridlocked it made sense to use in-situ concrete. However, MEP was mostly manufactured off site (although logistics were difficult). The aim was to pre-commission elements to the highest extent possible in the factory including most adding and fixings. Only one step – fixing – occurred on site.
- **Circularity is embedded in the platform approach** – The platform approach creates an opportunity for the industry to become more circular through design, material, process optimisation, and automation. However, better ways of assessing circularity of the platform approach must be developed.

3.5 Shared vision roadmap for platforms

This section envisages redefined roles for each stakeholder in the building value chain to create a shared vision roadmap, by understanding their motivations for moving towards a platform ecosystem. The market review and the detailed case studies revealed the role of the general contractor is impacted significantly in a platform ecosystem. Platform-based companies such as VBC play the role of a general contractor with an end-to-end value chain. Similarly, companies like Intelligent City, who started with an architecture background, also play the general contractor role. In the case of the Forge, there is a platform consultant (Bryden Wood), a developer (Landsec), a construction management expert (Sir Robert McAlpine and Mace JV), and several key trade contractors and suppliers (J Coffey Construction, N G Bailey, Tata Steel, Schneider Electric), but no explicit mention of a general contractor.

Despite this, the general contractor perhaps has the biggest opportunity in the platform ecosystem but would need to redefine their role based on their motivation and scale. Given this, the perspective pitches for the primary stakeholders include developers, designers and engineers, and specialised contractors, while the rest of the value chain is grouped under associated stakeholders. General contractors can also utilise the perspective pitches to better understand the changed nature of

engagement among building value chain stakeholders in a platform ecosystem. We acknowledge there are some blind spots in the value chain actors presented in this chapter in terms of financiers (upstream) and asset managers (downstream) who also will play critical roles in the platform ecosystem; however, it was not possible to collect primary data from these actors for this study. In defining new roles for stakeholders, a shared vision emerged that might enable a shift towards the platform approach. Stakeholder groups shared intent to move value adding products and services upstream, expand contribution to the value chain, continuously improve through data-driven insights, seamlessly collaborate in a partnering environment, and undertake early prototyping. The nature of engagement changed, where the general contractor ceased to be the single point of engagement with the associated supply chain actors; this role was most likely taken up by the developer or the platform consultant.

//Developers

What could a developer's motivation be? A developer's primary requirement from a platform is seamless evaluation of prospective sites through automated feasibility analysis. If a platform could help decide whether a site is valuable to acquire and can be turned into a positive business, it would benefit the developer. What a developer wants next is for a platform to enable partnering with other actors on the engineering, design, and supply side of the value chain. Developers would also be motivated by accelerating sustainable building methods by involving supply chain actors early through the platform. Platforms may also offer connectivity; a platform can take the feasibility model into production, solidifying the project's financial backbone. Moreover, these steps occurring in a collaborative platform with a partnering environment will help run iterations of different scenarios where developers can almost have a platform-based product and then back calculate to identify the lots that fit best with it. In the long term, large companies could leverage economies of scale through a standardised kit of parts, continuously made efficient by feeding projects involving similar building types and similar geographies.

What could a developer's role be?

- Enable the horizontal integration of the supply chain actors towards the platform approach.
- Initiate early prototyping with pre-building activities integrated into the contractual arrangements of specialised contractors and suppliers.
- Enable an end-to-end information flow to support project delivery from feasibility and acquisition to design and building.
- Continuously improve the design (standardised kit of parts) and building processes through capture and analysis of operational data.
- Seek to be more circular through design, material, process optimisation, and automation wherever possible.

How would a developer's engagement model change? A developer might engage with more supply chain actors than just the main contractor. This interaction might be facilitated by a digital platform (marketplace). The engagement could start earlier to enable prototyping and injecting platform DNAs into existing products and processes.

//Designers and engineers

What could a designer / engineer's motivation be? The primary motivation of designers and engineers is to better utilise their digital capabilities to streamline the design and delivery process. In a completely BIM and digital engineering enabled setup, designers and engineers can contribute to a larger part of the value chain. For example, using parametric design, they can instantly have a fully resolved model that can be manufactured and constructed. This places the designers and engineers in the most suited position to become go-to partners for design-to-manufacture. Designers and engineers are also well placed to assume an advisory role of the platform consultant that drives the platform approach for a client, from early prototyping to training specialised contractors for site assembly. This transforms the commercial model for designers and engineers from a typical hourly rate to an outcome-based percentage of cost. Designers and engineers might also be motivated to become technology providers enabling the platform approach. The platform approach benefits from

bringing value adding services upstream; by becoming technology providers, designers and engineers can license their proprietary platform technology to gain scale and internationalise. This could create an opportunity for them to build their business around data through advanced analytics.

What could a designer / engineer's role be?

- Develop strong customer relationships or a deep understanding of customer requirements to utilise the platform approach in the best possible way.
- Develop the knowledge and understanding of systemisation, commonality strategy (commonality in processes and enablers, not just physical components), and early prototyping.
- Establish routines to carry digital models through to fabrication.
- Create a dynamic marketplace for diverse supply chain actors to contribute to the platform ecosystem with a low barrier of entry.
- Train associated supply chain actors based on the knowledge gained from early prototyping.
- Continuously improve by obtaining data-driven insights.
- Embed circularity through design, material, process optimisation, and automation.

How would a designer / engineer's engagement model change? Designers and engineers might engage with more supply chain actors than just the main contractor. The engagement could start earlier to enable prototyping and injecting platform DNAs into existing products and processes.

//Specialised contractors

A specialised contractor simply does what is documented; it can be assembling on site, procuring materials, or supplying labour. Specialised contractors can also deliver a turnkey outcome including complete design and building and be responsible for the safe performance and operation of the asset. In other words, specialised contractors mostly deliver a subcomponent of the superstructure; they are usually downstream in the value chain and typically do not initiate, design, or manage projects in their entirety.

What could a specialised contractor's motivation be? Specialised contractors are primarily motivated to take advantage of the digitalisation of design, construction, and procurement to move upstream in the value chain, to avoid old school queueing and improve their market position. Another motivation could be options to collaborate with different stakeholders through workflows in an aggregator sense but also in a single stream sense (for their continuous improvement). Achieving economies of scale is another motivation; a specialised contractor with a platform solution can replicate it across the commercial building sector (wherever a platform approach is implemented). As with developers, specialised contractors are also looking for a trustful partner environment facilitated by the platform through sharing IP where all parties work towards project goals. Finally, safety is an important driver for specialised contractors because most play a key role in site assembly.

What could a specialised contractor's role be?

- Early involvement into the value chain to facilitate prototyping (mock-ups).
- Increase the level of modular designs and offsite production to limit time on site.
- Enable upstream integration into the value chain through digital interfaces thereby improving bargaining power over general contractors, distributors, and component manufacturers.
- Achieve operational excellence through continuous improvement of design, logistics, and assembly.
- Facilitate the reduction of embodied and operational carbon through design optimisation and the use of offsite facilities.

How would a specialised contractor's engagement model change? The engagement model might not change to a great extent but engagement through digital interfaces might increase. The engagement model might become more balanced through early involvement and equitable partnerships.

//Associated supply chain actors

The associated supply chain actors comprise material processors, component manufacturers, material distributors, and logistics players. These actors typically have a chain of business archetypes upstream to downstream. For example, they might produce a material, add value to it, provide value added products, provide total solutions, or provide a channel to distribute material.

What could their motivation be? These actors might be motivated by a platform approach that can enable them to not only optimise their material processing, but also contribute to better buildings through product innovation. They typically have numerous disjointed initiatives; the platform approach creates an opportunity to operate or participate in an end-to-end offering. The future ready state is not in selling material or products anymore, it is in participating in that whole end-to-end value generation through critical enablers like digital and strategic marketing. These actors might be motivated to shift to a platform approach because it can help them integrate businesses that they have acquired over time as a shared services model. The peak of this integration, however, sits beyond the organisational boundaries in a digital marketplace that is self-serving of their own products. Trusted information sharing among value chain players could enable better demand forecasting and ultimately enhance the total value of the system. Further, the platform approach may can allow these actors to set a clear decarbonisation pathway and contribute to the circular economy which becomes one of their biggest motivations and competitive advantage.
What could their role be?

- Develop a capacity to inject platform DNA into an existing suite of products and offer solutions that can integrate with a platform ecosystem.
- Strengthen their engineering capabilities in product development by integrating digital tools towards an end-to-end offering.
- Improve customer experience by understanding how to address their key challenges through digital interactions.
- Invest in upskilling a platform champion: a person who has the technical skills, theoretical knowledge and the motivation to lead and guide teams towards the platform approach.
- Advocate for products that embed circularity in the value chain.

How would their engagement model change? Detailed technical review and consultations between associated supply chain actors, the developer, and platform consultant to evaluate if products from an existing catalogue can be repurposed for the platform approach.

4. THOUGHT STARTERS FOR THE FUTURE OF PLATFORMS

This section envisions the next phase of platform development. It aims to stimulate discussions and provoke innovative ideas by presenting thought-provoking concepts and potential directions for platforms in the future. Whether you are an entrepreneur, a technologist, a policy maker, or a curious individual, this chapter invites you to delve into the realm of possibilities and contribute to shaping the trajectory of platforms.

Open platforms can be reliably integrated with other products and services and often allow external parties to make, use, and buy the common, repeatable elements for legitimate purposes. It has potential to create a dynamic marketplace for diverse supply chain contributors with a low barrier of entry. However, at present there is a lot of hesitance in the industry relating to IP. Thus, safeguarding sensitive project information and ensuring robust security measures are essential to maintain trust and protect stakeholders' interests. By leveraging blockchain, platforms can establish secure and verifiable records of transactions, contracts, and project information, minimising the risk of fraud or tampering. Platforms that incorporate Web 3.0 technologies can foster transparent communication, streamline supply chain management, and promote effective collaboration among various stakeholders. As the building industry evolves, it is crucial to embrace Industry 5.0 principles, which emphasise social responsibility and sustainable practices. Platforms in Industry 5.0 will prioritise ethical considerations, such as environmental sustainability, worker safety, and community wellbeing, ensuring that technological advancements, including blockchain, align with the industry's social and ethical responsibilities. Additionally, integrating platforms with digital twin technology holds tremendous potential in transforming building.

This section explores these thought-provoking concepts and potential directions building. By leveraging open platforms, blockchain technology, and embracing Industry 5.0 principles, platforms can address IP concerns, establish secure transactions, and promote transparency and collaboration. Further, integrating platforms with digital twin technology can revolutionise the building industry, enhancing productivity, sustainability, and decision-making processes

4.1 Data privacy, security, and intellectual property

Data privacy, security, and intellectual property are critical considerations for the future of platforms, where smart contracts are expected to play a significant role. As platforms evolve and incorporate advanced technologies like blockchain, it becomes imperative to address these concerns to foster trust and protect stakeholders' interests. One of the key benefits of smart contracts is their ability to automate and streamline various processes within the platforms. By using self-executing contracts coded on a blockchain, smart contracts can enhance transparency, efficiency, and accountability in contractual agreements. However, because platforms handle sensitive project information and financial transactions, data privacy and security become paramount. To ensure data privacy, platforms need robust security measures, such as encryption and access controls, to safeguard confidential information from unauthorised access or data breaches. Additionally, platforms should adhere to privacy regulations and best practices to protect user data and maintain stakeholders' trust. This may involve implementing anonymisation techniques or obtaining explicit consent for data collection and usage.

In terms of IP, smart contracts within platforms raises interesting considerations. Building projects (platforms in building) often involve developing and using proprietary designs, innovations, and intellectual assets. To protect these IP rights, platforms must implement mechanisms that ensure proper ownership attribution, licensing agreements, and protection against unauthorised use or reproduction of proprietary information. Integrating blockchain technology within platforms can help address these concerns. By leveraging the immutability and transparency of blockchain, platforms can establish secure and tamper-proof records of transactions, contracts, and IP rights. This not only provides a verifiable history of ownership and usage but also minimises the risk of fraudulent activities or disputes. Further, platforms should prioritise collaboration with industry stakeholders and legal experts to develop

standardised frameworks and protocols that address data privacy, security, and IP concerns. Clear guidelines and agreements can be established to govern the usage, sharing, and protection of data, ensuring all parties involved are aware of their rights and responsibilities.

As the future of platforms in the building industry unfolds, data privacy, security, and IP will continue to be significant considerations. Platforms must balance fostering innovation, enabling efficient processes through smart contracts, and safeguarding sensitive information and intellectual assets. By incorporating robust privacy and security measures, leveraging blockchain technology, and promoting collaboration, platforms can create a trusted ecosystem that facilitates the responsible and ethical use of smart contracts while protecting the interests of all stakeholders. Prioritising research in these areas holds the potential to create a dynamic marketplace for diverse supply chain contributors building. This emphasis on research helps establish a strong foundation of data privacy, security, and IP protection. By fostering an environment of trust, collaboration, and innovation, this research-driven approach drives transformative advancements and facilitates sustainable growth within the industry.

4.2 Platforms and Web 03

Web 1.0, known as the Information-Centered era, was characterised by content delivery networks (CDNs) that facilitated the presentation of data on websites. This phase focused primarily on delivering information to users in a static and one-way manner. Websites served as repositories of information, with limited interactivity or user participation. The Web 2.0 – the People-Centered (two directional – retrieving data – digital platforms) era revolutionised how users interacted with websites. Web 2.0 websites emphasised user-generated content, usability, and interoperability, empowering end-users worldwide. Users became active participants, contributing their own content, engaging in discussions, and collaborating with others on platforms like social media, blogs, and wikis. However, the reliance on intermediaries to ensure trust and security remained a limitation of Web 2.0 platforms. The limitations of Web 2.0 platforms revolved around the difficulty of connecting the virtual world with the physical world. Although Web 2.0 introduced user interaction and collaboration, there was a need for mechanisms to securely exchange value and verify authenticity without relying on intermediaries. This is where Web 3.0 comes into play, promising a more advanced and decentralised internet experience.

Web 3.0 envisions applications that can directly communicate with each other, allowing for more extensive searches for information through simpler interfaces. This is made possible by merging semantic markup and web services, enabling machines to understand and process information more effectively. However, one of the limitations of Web 3.0 is establishing trusted exchange. Blockchain can address this limitation because it offers a mechanism for securely exchanging value, verifying authenticity, and establishing trusted connections between participants, as discussed above.

Further, as part pf Web 3.0, integrating platforms with emerging technologies like Internet of Things (IoT) and artificial intelligence (AI) enhances the capabilities of building platforms. IoT sensors and devices can gather real-time data on construction sites, enabling proactive monitoring, predictive maintenance, and improved safety. AI algorithms can analyse vast amounts of building data, providing valuable insights for optimising project planning, resource allocation, and risk management. However, careful attention must be given to address security and privacy concerns. With the right approach, platforms can usher in a new era of innovation, productivity, and sustainability. Figure 4.1 illustrates the flow of information, materials, finances, and carbon within the building industry and how it lies with the transition from Web 1.0 to Web 3.0

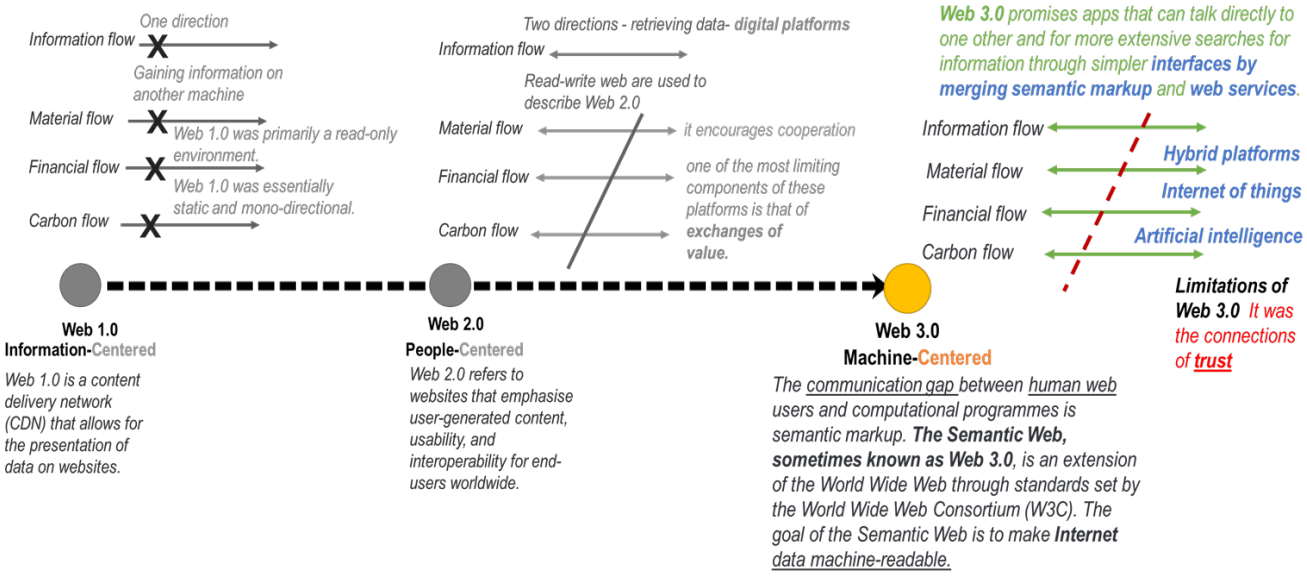

Figure 4.1 The flow of information, materials, finances, and carbon within the building industry and how it lies with the transition from Web 1.0 to Web 3.0

4.3 Platforms and digital twins

By capturing and monitoring data from sensors embedded in physical assets (products) , such as structural health monitoring or energy consumption tracking, digital twins enable predictive maintenance, identifying potential issues before they occur. Platforms leveraging digital twin technology provide a centralised hub for asset data, allowing stakeholders to monitor performance, schedule maintenance activities, and prolong the lifespan of assets. Moreover, digital twins foster collaboration and communication among various stakeholders involved in building. Platforms can serve as a shared workspace where project teams, architects, engineers, contractors, and owners can access and contribute to the digital twin, ensuring everyone has up-to-date and accurate information. This enhances coordination, reduces errors, and promotes effective collaboration throughout the project lifecycle.

For example, Willow optimises building performance using the Microsoft Azure digital twin and contributes primarily to the Operate / Maintain and Evolve stage of the value chain. It enables asset owners and operators to monitor, manage, and optimise their assets more effectively. This approach shifts the focus from reactive decision making to proactive strategies, as real-time data empowers stakeholders to identify potential issues, predict maintenance requirements, and optimise asset performance. Willow's perspective on the ‘digital twin’ for smart infrastructure and real estate sets them apart in the market. They have positioned themselves as leaders in this emerging field, combining innovative technologies and advanced analytics to deliver practical solutions. The company's success is evident in their recent funding round, where they raised over US$43 million, demonstrating investor confidence and support for their digital twin platform. With their substantial funding, Willow is well-equipped to further develop and enhance their digital twin technology. They can continue to expand their capabilities, refine data analytics algorithms, and collaborate with asset owners and operators to address specific industry challenges. This will likely lead to broader adoption of their platform and the integration of digital twin solutions into various sectors of the built environment. But Willow only gives access to native Willow applications through a single and secure integration point and the complete offering will still operate through the Willow platform (platform dependent) because their value proposition lies predominantly in operation and maintenance.

Data privacy and security play a crucial role in adopting digital twins within platforms. Because digital twins involve sensitive project data, it is essential to implement robust security measures to protect the integrity and confidentiality of information. Platforms should incorporate encryption, access controls, and secure data storage to safeguard against unauthorised access and data breaches. By prioritising data privacy and security, platforms can build trust among stakeholders and encourage widespread adoption of digital twin technology.

4.4 Industry 5.0 (Baking in the social responsibility angle)

Industry 5.0, with its emphasis on social responsibility, holds immense potential for the future of platforms in building. Industry 5.0 represents the next phase of industrial evolution, combining advanced technologies with a focus on ethical considerations, sustainability, and human wellbeing. Platforms that embrace Industry 5.0 principles prioritise social responsibility in their operations and decision-making processes. They recognise the importance of environmental sustainability, worker safety, and community wellbeing, aligning technological advancements with the industry's social and ethical responsibilities.

One key aspect of Industry 5.0 platforms is their commitment to environmental sustainability. They seek to minimise the industry's ecological footprint by adopting sustainable building practices, reducing waste, and promoting the use of renewable materials. These platforms integrate technologies that enable efficient energy management, waste reduction, and eco-friendly building designs. By leveraging data and analytics, they can track and optimise resource consumption, contributing to a greener and more sustainable building industry. Worker safety is another crucial focus of Industry 5.0 platforms. They strive to create safer work environments by implementing advanced safety measures, such as wearable technologies, real-time monitoring systems, and predictive analytics for identifying potential hazards. These platforms prioritise the wellbeing of workers, ensuring technological advancements enhance safety and minimise the risk of accidents or injuries. Community wellbeing is also a central aspect of Industry 5.0 platforms. They consider the impact of building projects on local communities and aim to create positive social outcomes. These platforms engage in transparent and open communication with stakeholders, involving local communities in decision making processes and addressing their concerns. They promote inclusive and sustainable development, integrating features like affordable housing, green spaces, and infrastructure that enhances the overall quality of life in the community.

The future of platforms in the building industry, within the context of Industry 5.0, is about leveraging technology to drive social and environmental progress. These platforms facilitate collaboration and knowledge sharing among stakeholders, enabling innovative solutions to complex challenges. They empower users to actively participate in the building process, fostering a sense of ownership and community engagement. To fully realise the potential of Industry 5.0 platforms, robust digital infrastructure and connectivity are essential. This includes reliable internet access, data sharing protocols, and interoperability among various systems and technologies. Additionally, data privacy and security remain critical considerations to protect stakeholders' interests and maintain trust in these platforms.

Thought starters for the future of platforms can further advance the future of platforms in the building industry, promoting innovation, sustainability, dynamic marketplace for diverse supply chain contributors with a low barrier of entry, and social responsibility.

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