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Addressing specialization and fragmentation: product platform development in construction consultancy firms

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ABSTRACT

Construction product platforms provide the opportunity to improve productivity in construction projects while maintaining heterogeneity of output. The growing literature on construction product platforms describes how product suppliers develop product platforms either top-down or bottom-up, independently from project delivery. Through a single case study of a consultancy firm, this paper shows how a specialist consultancy firm operating in the construction sector developed their own product platform on projects while iteratively developing and augmenting their delivery capabilities. Distinguishing between activity integration, coordination, and consolidation, the platform development process highlights how vertical and horizontal consolidation of capabilities *within* the engineering phase of delivery enables early resolution of both product and process specifications. This means that vertical coordination *between* engineering and manufacturing phases can be managed by a fully specified contract, rather than acquisition. The analysis of the case shows how construction can be more closely aligned with the linear and sequential models found in manufacturing through clarifying and distinguishing the roles of engineering, manufacturing, finishing and sub-assembly.

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Introduction

To address the twin challenges of low productivity and an ageing workforce, construction firms are being encouraged to adopt manufacturing techniques and processes (for example, HMG 2013). However, heterogeneous market demand is typical in the construction sector, and commonly met through specialist firms coming together in temporary multi-organizations to deliver new buildings (e.g. Hoekstra and Romme 1992, Wheelwright and Clark 1992). This specialization and fragmentation in the sector across multiple dimensions creates inefficiencies in delivery (Howard *et al.* 1989, Fergusson and Teicholz 1996). This paper shows how construction consultancy firms can overcome the challenges of fragmentation by developing product platforms – originally found in manufacturing – for buildings.

Previous research has explored the capacity of product platforms to concurrently deliver efficiency gains in manufacturing contexts, and meet customer demand for heterogeneity (Meyer and Lehnerd 1997,

Robertson and Ulrich 1998). Indeed, well executed platform projects can offer fundamental improvements in cost, quality, and performance (Sköld and Karlsson 2013). Recent literature has begun to explore how product platforms are used in construction, and in particular housing delivery (Lundbäck and Karlsson 2005, Chai *et al.* 2012, Jansson *et al.* 2014). These studies describe how product platforms are deployed and developed (Simpson *et al.* 2001, Veenstra *et al.* 2006), and how they help to meet market demand for heterogeneity, while improving efficiency of construction (Robertson and Ulrich 1998, Sköld and Karlsson 2013). They also explore existing product platforms, or the development of platforms, notably by product-based firms in integrated, rather than fragmented contexts. However, for specialist construction consultancy firms, such as architects and contractors, the advantages of product platforms are less clear. Little is known about how such firms, operating in a fragmented and competitive sector like construction, can transform their

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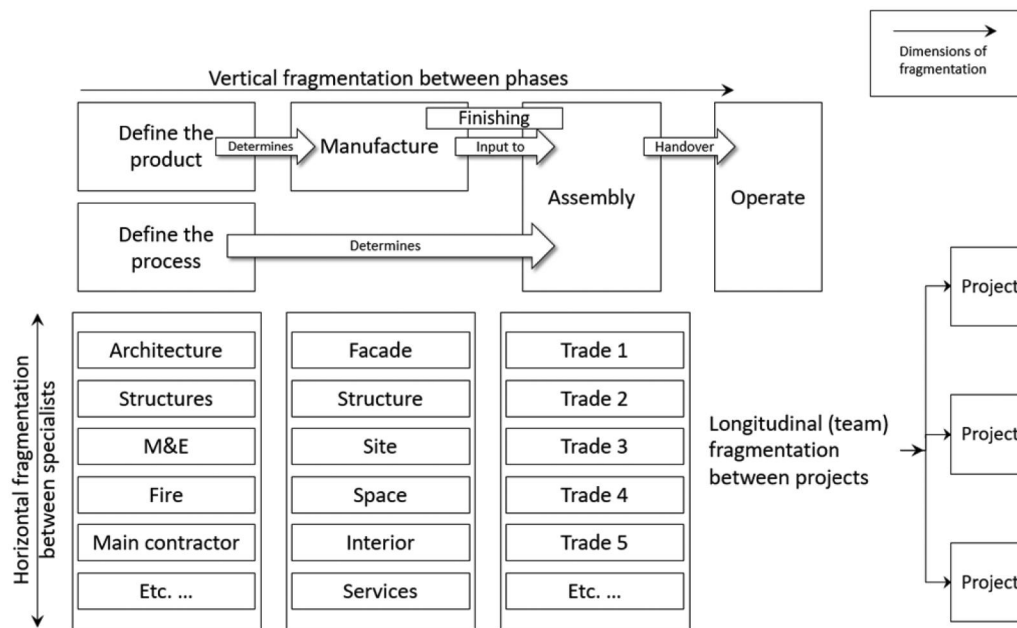


Figure 1. Three dimensions of fragmentation in construction (adapted from Sheffer and Levitt 2010).

role and existing value delivery approach by developing their own product platforms.

This research contributes to the debate on product platforms in construction by exploring the following research question: how can specialist construction consultancy firms in fragmented industries develop product platforms? Adopting the UK construction sector as context, this paper uses a single case study to explore how a long-established consultancy firm developed a new product platform. The paper contributes empirically to the construction product platform literature, and the construction literature on fragmentation and integration by describing how in-phase consolidation supports industry and firm-level attempts to improve efficiency.

The paper is structured as follows. The next section describes the research context with a brief exploration of industry fragmentation in construction and the use and development of product platforms. The section entitled methods and case description presents our approach to the study, and introduces the case firm, a specialized construction consultancy which has developed a product platform. The findings section presents our analysis of the data. The wider implications of the study for theory and practice are then explored in the discussion. Here the processes of in-phase consolidation that led to the development of the product platform are highlighted, along with the implications for practice in moving towards a manufacturing-based view of delivery. After summarising the contributions, the study concludes, highlighting limitations and research areas for further study.

Research context

Specialization and fragmentation in construction

Fragmentation is a long-running issue in the construction management literature, with Bossom (1934) observing that “[t]he process of construction [...] is all too apt to become a scramble and a muddle” (Cain 2003). This fragmentation reflects the extreme specialization in construction.

In construction, specialization in the project-based delivery model has led to fragmentation in three dimensions (Figure 1):

- *Vertically*, where different firms deliver different phases of a project (e.g. product and process definition, manufacture, assembly and operation) (Fergusson 1993, Alashwal and Fong 2015);
- *Horizontally*, when different actors deliver complementary products and services (provided by specialists) at, approximately, the same stage of a process (Fellows and Liu 2012); and
- *Longitudinally*, where continuity of teams is disrupted by reassignment at the end of a project, taking any tacit, accumulated knowledge with them (Fergusson and Teicholz 1996).

Vertical fragmentation between project phases leads to multiple knowledge hand-offs in the delivery process, and risks of displaced, or broken agency (Sheffer and Levitt 2010, Henisz *et al.* 2012). Nam & Tatum (1992) describe four broad strategies to help firms overcome the inefficiencies introduced by

vertical fragmentation between phases. First, under vertical integration by *acquisition* (Williamson 1971, Fergusson 1993) firms augment their end-to-end capabilities by acquiring other firms or assets, establishing managerial control over the workflows, enabling coordinated, integrated delivery throughout the project's lifecycle. Such acquisition-based approaches are being pursued by construction firms in the US (e.g. Hall *et al.* 2020) and the UK (Cousins 2014) to incorporate production facilities. However, such asset specific investments introduce risks of asset redundancy in the face of intermittent demand (Costantino *et al.* 2011). Second, firms can develop *non-contractual methods* of alignment in which parties coordinate their activities, leveraging long-term relationships, client leadership, or the professionalism of participants (Nam and Tatum 1992). However, such trust-based approaches risk opportunism (Winch 2001). Third, the historical reliance on *contracts as vertical coordinating mechanisms* between phases, struck almost entirely under incomplete designs, can lead to costly litigation (Li *et al.* 2012). Each of these forms of integration introduce risks for construction firms. This paper, therefore further explores the fourth strategy for addressing vertical fragmentation, the *integration of information* and the use of common data and standards across the project team (Nam and Tatum 1992).

Horizontal fragmentation results from the complexity of the built form, with specialist, disciplinary knowledge required to ensure safe performance of various aspects of the building in a given phase of delivery (Fellows and Liu 2012). Problems arise from a lack of consideration or understanding of other disciplines' needs, and a failure to communicate between disciplines (Jansson and Viklund 2015). An efficient flow of information between disciplines (Fergusson and Teicholz 1996), coordinates and accelerates decision-making between engineering disciplines (Mintzberg 1983, Tee *et al.* 2019). Literature on concurrent engineering (e.g. Love *et al.* 1998) and Integrated Project Delivery (Matthews and Howell 2005) explore the benefits of in-phase horizontal coordination of decision-making.

In one-off projects, longitudinal fragmentation means that problem-solving know-how developed on projects often remains with the individuals who have worked on the project, removing opportunities for organizational learning and continual improvement (Addis 2016). Despite the availability of knowledge management systems, they are little used in construction project contexts due to time pressures and the perception that project-specific problems are unique

and, therefore, not generalizable (Newell *et al.* 2006, Addis 2016). The development of long-term relationships with supply chains provides opportunities to address these knowledge management challenges, and introduce opportunities for continuous improvement (Brown and Riley 2000, Lessing 2006), with firms' supply chains embedding new knowledge in manufactured assets. Initiatives in the UK construction ecosystem, such as the i3P, are attempting to address some of the challenges of project-to-project learning through establishing communities of practice that span firms. Longitudinal integration ensures the smooth flow of knowledge and information over time, notably between projects, enabling economies of repetition (Davies and Brady 2000) and productivity gains from continuous process and product improvement (Lessing 2006, Thuesen and Hvam 2011).

In delivering construction projects, the fragmentation shown in Figure 1 is overcome by coordinating the activities of designers, manufacturers and assemblers through a process of information and knowledge exchange, using boundary or knowledge objects, such as drawings or models (Ewenstein and Whyte 2007, Fellows and Liu 2012), and subsequent mutual adjustment (Mintzberg 1983, Mosca *et al.*, 2021). Investments in horizontal and vertical coordination happen anew on each project, but longitudinal fragmentation means that these project-specific investments are often lost.

Construction product platforms

The fragmentation of decision-making can be addressed by applying manufacturing and standardizing techniques to construction projects, which can lead to multiple benefits (e.g. Bughin *et al.* 2017). However, there remains demand and institutionalized pressure for variety (e.g. Pan *et al.* 2004, Styhre and Gluch 2010), providing a counterbalance to motivations to standardize.

Exploring this tension in a construction setting, the early construction-as-manufacturing literature featured accounts of fully coordinated kits of parts, or building systems. For example, Gann (1996) and Barlow and Ozaki (2001) showed how Japanese house builders maintain varying levels of customer choice while delivering production efficiency. Barlow *et al.* (2003) adopted insights from Hoekstra and Romme (1992) to distinguish between house builders' delivery models. Winch (2003) and Wikner & Rudberg (2005) highlight that in the "pure customization" contexts described by Barlow *et al.* (2003) (termed engineering-to-order, or

ETO), the dynamics of the design/engineering phase should be distinguished from those of physical product delivery. That is, the physical, material flows are distinct from, and should be explored and described separately from the conceptual information flows of the design/engineering phase. Gosling *et al.* (2017) described the ETO design/engineering delivery phase in more detail, highlighting the importance of increasing granularity to fully describe the intricacies of the construction process. The delivery pathway described, however, remained linear and sequential, assuming that each successive design/engineering phase is completed in full. This fails to accommodate a typical construction process with partially complete phases, and the fragmented delivery structures of construction projects. Building on the work of Wikner & Rudberg (2005) that distinguishes between the production and design dimensions of delivery, Johnsson (2013) explores the different ETO production strategies adopted in the delivery of industrialized housing, highlighting the lack of manufacturing capability in their engineering case company that limits coordination with the marketing function. Together this group of papers describe pre-existing platforms and delivery processes, but they have little to say on how firms can adapt to develop such kits of parts.

Product platforms deliver the benefits of volume production while enabling some product heterogeneity through the re-use of common components, processes, knowledge and capabilities in multiple products, augmented by a limited range of peripherals, via a coordinating mechanism (interface) (Robertson and Ulrich 1998, Wikberg *et al.* 2014). Other benefits of such platform approaches include rapid market responsiveness; reduced development time; an improved ability to upgrade products; a reduction in testing; and the promotion of better learning across products (Wortmann and Alblas 2009).

The construction market demand for heterogeneity, however, means that most construction projects incorporate a degree of novelty (Maxwell and Aitchison 2017). In this context, the application of product platforms to construction is not straightforward (Johnsson *et al.* 2013). Construction product platforms need to strike a balance between the use of standardized coordinated solutions, and solutions required to deliver the design aspirations for a particular client, building or site (Jensen *et al.* 2015). As a result, a distinction is drawn in the construction platform literature between the coordinated product platform, and any novel elements that have not previously been integrated into the platform that are

required to address project-specific needs. For example, Jansson *et al.* (2014) identify a series of “platform support methods” that ensure that any new components or processes are coordinated with existing components before they can be admitted to their platform. Maxwell and Aitchison (2017) distinguish between the existing product platform and a distinct service layer that defines and incorporates design novelty into a building development. Meanwhile, Lidelöw *et al.* (2015) differentiate open and closed platforms, where closed platforms offer no opportunity for client customization (i.e. building systems), and open platforms accommodate novelty. In construction platforms, therefore, it remains important to distinguish between design problems that have previously been resolved and incorporated into the platform, and novel problems relating to new design elements. This throws attention on the governance of the platform’s interface.

Developing a platform strategy – insights from manufacturing

The manufacturing and platform literature describes two broad approaches for developing a product platform (Simpson *et al.* 2001). In a top-down platform development approach, a firm strategically develops a family of products based on customer requirements to deliver a modular product platform and its derivatives (Jiao *et al.* 2007, Johannesson *et al.* 2017); A bottom-up development process occurs when an existing product, already shaped by market demand, is deconstructed into its separable components before re-combination into a product platform to meet market demand for variety (Simpson *et al.* 2001, Kudsk *et al.* 2013). Veenstra *et al.* (2006) provide an early and typical exploration of platform development for an existing house builder, using a bottom-up approach in their single case study.

Developing a product platform for complex products is, however, costly (Kudsk *et al.* 2013). In both top-down and bottom-up approaches, platform development requires a greater investment of financial resources over time than developing a single product, potentially lengthening both delivery and payback time (Veenstra *et al.* 2006). Firms wanting to leverage the benefits of product platforms are expected, therefore, to invest in platform development separately from their day-to-day delivery of projects, lest as products they become uncompetitive. Indeed, research suggests that construction product platforms and platform strategies are better developed independently of

specific projects (Lessing 2006, Jansson and Viklund 2015).

As a result, platform preparation and platform execution are usually seen as two distinct modes in the development of product platforms (Johannesson *et al.* 2017). In their exploration of these two modes, Johannesson *et al.* (2017) present a granular exploration of the product platform development phase, describing the processes and methods required for the creation of product families. Implicitly pursuing a top-down approach to product platform development, they recommend methodically exploring first the conceptual modelling of the platform, before moving towards system modelling, and then detailed platform development. Each stage informs and constrains the next. Kudsk *et al.* (2013) provide an example of a bottom-up development process for balcony and shaft modules at product producing organizations. Together, these papers highlight the need for close collaboration between system architects and design engineers during system and detailed modelling of the platform. That is, there should be an ongoing conversation during platform development between those with design and manufacturing capabilities (Johannesson *et al.* 2017), not typically seen at the early stages of construction projects.

The extant research shows that platforms are usually developed top-down or bottom-up by *existing producers*. In fragmented contexts, product platform developers seek and capture the knowledge and capabilities of external designers and consulting engineers, retaining and re-using their knowledge through subsequent platform deployments. The development of construction product platforms by manufacturers and developers, therefore, presents a risk to the businesses of these project-based consultancy service providers.

Methods and case description

This paper adopts an explanatory case study approach (Pettigrew 1990, Yin 2003) to explore how a construction consultancy firm developed a product platform. It considers the changing value delivery model of a case firm, ABC, and its architectural collaborators, DEF. ABC was selected purposively for the study as being particularly well-suited for addressing the research question in two ways. First, it has developed a new, efficient product design and delivery platform investing in neither vertical integration by acquisition, nor production facilities. This makes it an extreme case where the mechanisms of interest manifest themselves in a purer form than usual (Danermark *et al.* 2002,

Table 1. Details of research interviewees.

	Role
1	Director of Strategic Planning and Implementation
2	Engineering and Programme Director
3*	Architect & Senior Partner
4	Director, Digital Project Delivery
5	Head of Commercial Sector
6	Business Unit Chief Executive
7*	Senior Partner (Architect/Engineer)
8	Director of BIM
9	Director of Technical Practice
10*	Architect
11*	Architect & Senior Partner
12	Technical Director
13	Director
14	Business Unit Managing Director
15	Supply chain designer

*Interviewees from project partners DEF.

p. 104). Second, ABC is operating in the construction sector which demonstrates horizontal, vertical, and longitudinal fragmentation (Howard *et al.* 1989, Sheffer 2011, HMG 2013).

Data collection

Fifteen semi-structured interviews were undertaken with the platform leadership and delivery teams from August 2019 to December 2020 (Table 1). On average the interviews lasted 55 minutes and were framed around a consistent interview protocol (Appendix A).

Semi-structured interviews allowed the content to emerge as understanding of the case developed, and the particular experiences of the interviewees to be explored (Barratt *et al.* 2011). Interviewees were selected through snowball sampling (Goodman 1961), with respondents proposed and introduced by respondents after their own interview. Snowball sampling represented the most effective way to identify and approach individuals who were responsible for the development of the platform. Three further semi-structured interviews were conducted with industry experts (senior directors, policy advisors and spokespersons of the UK Transforming Construction Challenge) along with four informal conversations with senior managers from the UK construction community. These interviews were guided by the protocol in Appendix B. One semi-structured interview and two informal conversations were conducted before data collection began to support the identification of the case study firm. Two other semi-structured interviews and two informal conversations were conducted to validate the preliminary findings of our research.

All interviews were transcribed. Reviews of publicly available reports and statements, site visits, and discussion with the research project's industrial steering

committee provided opportunities to combine multiple sources of data to enhance our understanding of the construction context and to triangulate our findings (Siggelkow 2007, Pala *et al.* 2016). In line with McCutcheon and Meredith (1993), data was analyzed in parallel with data collection. Data was analyzed incident by incident (Charmaz 2006), adopting a process of constant comparison with reference to theoretical and practice-based understandings (Suddaby 2006). During data analysis, extensive use was made of diagrammatic memo-writing to understand incidents and explore emergent novelty. A feedback session was held with ABC's Senior Vice President to confirm understanding and to internally validate emergent findings.

Case details

This study explores the changing value delivery model of ABC, one of the top twenty UK construction consultancy firms. ABC deliver professional consultancy services throughout the project lifecycle – from planning, design and engineering to programme and construction management. Working in a long-term partnership with DEF, who provide architectural design input in a formalized joint venture, ABC brought together a multidisciplinary team to develop a digitally enabled, fully coordinated, component level building system that admits novelty, that is, a product platform. Product delivery using this platform is carried out via a separate business unit from ABC's consultancy offering, albeit with staff employed by ABC or DEF. The product platform can be applied to design and deliver any building type up to thirty storeys, but was launched to a selected test market for affordable housing. Manufacturing design input was provided initially by a manufacturing firm in the delivery supply chain, but ABC have since employed manufacturing specialists to support the design and assembly of the building system.

Findings

The following sections introduce the key elements of ABC's product platform that supports the design, manufacture and assembly of new buildings. We then turn to an exploration of ABC's journey from project-based specialist service provider to product platform owner, and consider how their platform development process addressed industry fragmentation.

Product design

Design components (objects) are held in ABC's virtual knowledge management system, their "digital warehouse", which is shared collaboratively with DEF. The digital warehouse contains the rules-based knowledge to support the production of 1:1 virtual models, a set of component-level core specifications, and fully-defined interfaces. Information-rich digital objects represent the fully specified, costed and coordinated physical components that will be used to assemble the building. These objects are held in the digital warehouse at multiple levels of aggregation. Site layout, elevation, and capacity planning is undertaken by the architectural design team at DEF. Thereafter, digital design components (the core of the building design) are re-used by the design team on each project, with concept designs modelled by combining components from the digital warehouse. The digital objects contain sufficient knowledge, information and detail to enable the design to proceed from RIBA stage 2 (concept design), to RIBA stage 5 (manufacturing and construction) without further design activity; they are also used to create drawings required for the planning application process. The design process is intended to take 12 weeks. Opportunities to automate the design process – developing a design process platform (Lessing 2006) – are recognized by both ABC and DEF, but they have decided that the early place-making role should be retained by design professionals to allow them to respond to specific site conditions and constraints.

Designers are not limited to components in the digital warehouse. Additional physical componentry (peripherals) may be required to meet the needs of a particular client or site. Peripheral design elements, representing complementary components, are identified, designed, or digitally assembled and pass through a rigorous quality assurance process before being added to the digital warehouse. This process requires sign-off from every design discipline, including manufacturing specialists, to ensure that the objects in the digital warehouse details remain fully coordinated.

Manufacturing procurement: outsourced to a well-established supply base

The fully specified component-level information in the design platform is used to procure components directly from pre-approved, well-established third-party manufacturers, rather than an extended supply chain. Competitive procurement remains possible with

multiple suppliers having previously agreed pricing and delivery envelopes for components and sub-assemblies, with details held in ABC's digital warehouse. Transaction costs are minimized in this exchange through the complete specification of the contract. The validated ability of these manufacturers to deliver the specified components within an agreed timeline and price means that orders can be placed by ABC in response to demand. Components and materials are supplied pre-finished and pre-drilled, with a manufacturer's warranty. The intention is that procurement takes 12 weeks – the longest lead time for any building component in the design – and can run concurrently with the planning application process if the client is willing to initiate procurement at risk.

Assembly design and delivery

Sub-assembly of building elements is undertaken on a site that is subject to a short-notice lease. ABC has a team of semi-skilled assemblers who receive and assemble pre-finished components, guided by a pre-defined delivery process controlled through a digitized workflow on tablets. Workflows are an element of the coordinated digital warehouse, with exceptions integrated only after rigorous process control. There are two leased gantry cranes at the site, but few finishing tools. Digital stills cameras are used by the assemblers to evidence progress and quality. The sub-assemblies are then consolidated into finished volumetric units for transfer to site and final assembly. The process flows enable elements of the assembly process to be relocated readily, so volumes or sub-assemblies can be brought together nearer to the site or on-site, if the context and site scale permit. The short-term commitment to facilities and sites ensures that ABC can scale delivery up or down more easily to meet demand, reducing the risk of stranded investments (i.e. in permanent manufacturing facilities). Final building assembly takes place on the development site, with site finishing activities (beyond the foundations) minimized. Once planning permission has been granted, project delivery can be completed in 12 weeks, with output scaled up or down by altering the number of assembly lines locally, or centrally, depending on the desired delivery pace. At the time of the research, the assembly phase was retained within ABC's control, but as this process is tightly defined, there is scope to out-source this work.

At the conclusion of the research period, approximately a dozen sites were being developed using the platform, with nine having gained planning

permission. Interviewees reported the design and delivery process had been improved such that projects can be delivered at a lower cost than traditional builds, and significantly faster. While the up-front governance of the design and delivery process costs a little more than a traditional build, the time and waste reduction more than make up for that difference.

Overcoming fragmentation – from project to product

Interviewees described how, in the design/engineering phase of traditional projects, early specifiers caveat their outline product specification with "or equal approved". This provides the ultimate product specifier with flexibility in procurement. Interviewee 6 described how this decision deferral is based on the assumption that value "*comes out of [the] competitive tension*" between contractors and suppliers as the building elements are procured. It introduces inefficiencies into the engineering process, however, and the building's spatial efficiency can also be compromised, as early configurations must have sufficient flexibility to accommodate any of the potential solutions to a given design problem.

ABC explored many ways to address these inefficiencies, recognizing that an investment in a manufacturing facility exposed them to risks through the redundancy of investment. Using third party manufacturers to develop ABC's building designs would also bring risks to their intellectual investment in design. Further the need to deliver distinct products in response to a given context meant that ABC preferred not to use another provider's pre-specified building solutions. Together, these factors mitigated against ABC using an existing provider to deliver the product, or from becoming a manufacturer itself. A strategic decision was taken to develop a design and assembly solution in which ABC owned and managed the risks of delivery, but could ensure that underlying components would be made and warranted by a firm that would be likely to survive market turbulence. ABC and DEF had thus decided together to become a product supplier of buildings.

ABC had previously worked with DEF on a housing scheme which the client wanted to be manufactured off-site. The development was delivered quite conventionally with horizontal and vertical coordination activity occurring to ensure building integrity. [Figure 2](#) shows how the building concept was developed by ABC with their project partners. In this process, a building concept is developed, then decomposed into

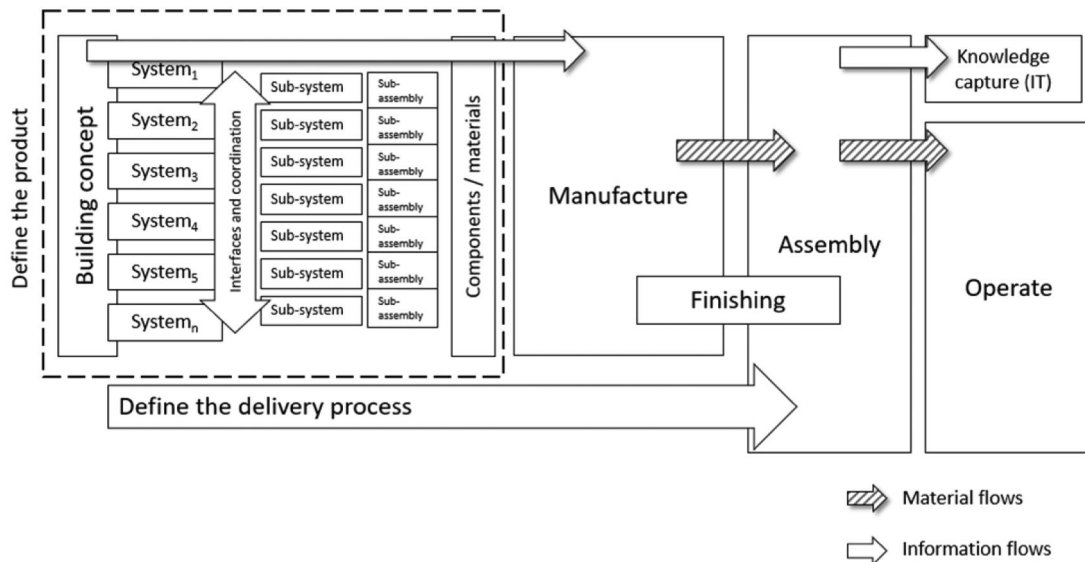


Figure 2. A typical construction project lifecycle.

its major systems (structure, services etc., Brand 1997) by different specialist designers, with interfaces between systems defined and coordinated. In typical projects, concept designers will often “*throw [the design] over the fence*” (interview 6) meaning that manufacturing capabilities (needed to define the detailed manufacturing, finishing and assembly processes) must be procured later in the project, fragmenting the design/engineering phase. A contractor is engaged to refine the delivery process, and to deliver the building, but they will sub-contract detailed design and delivery of the systems and sub-systems to specialist sub-contractors. This sub-contracting process continues until the specification of the components and materials is sufficiently defined to enable procurement from manufacturers, and assembly. On traditionally delivered construction projects there is also an element of problem solving and finishing – a form of deferred design/engineering decision – on site, such as cutting to size. This means that the design/engineering phase continues until the point of site-assembly (interview 15), overlapping with the assembly phase.

Each new bespoke construction project delivered in this way represents the top-down orchestration of a unique product for a customer, which has the potential to be re-used, that is, a potential product platform. However, re-use rarely occurs due to longitudinal fragmentation, the dispersal of project teams, and heterogeneous client requirements.

After completing that initial project, ABC and DEF committed to work together to develop a product-based “Design for Manufacture and Assembly” (DfMA) strategy, using similar teams, and knowledge

accumulated on the previous project, retaining the team’s collective learning. Figure 3 shows how the decision to work together on successive projects began to address knowledge loss between projects. Knowledge was captured from the first project in an early iteration of the digital warehouse, enabling re-use of design solutions in the second project, reducing the need for interface design and coordination. Figure 3 also shows that ABC integrated their capabilities with DEF by agreeing to form a dedicated team to work closely together, increasing the pace at which designs could be developed. The supply chain, however, retained manufacturing and assembly knowledge and design capabilities, remaining vertically and horizontally distinct from ABC and DEF. Physical manufacturing and finishing was undertaken by external firms, with design decisions still being made on site.

With the decision taken to work together to develop a housing product, and a base building product having been established, ABC and DEF were able to enter into a product development process using coordinated design details. However, with manufacturing and assembly knowledge and facilities still separated, the design supply chain remained fragmented vertically, with its associated inefficiencies.

The final stage of the platform development process was the acquisition of manufacturing, finishing and assembly design capabilities via tactical employment of staff at ABC (Figure 4). The definition of both product and assembly processes could be undertaken simultaneously, leveraging the coordinated design details contained in the digital warehouse. As these capabilities were integrated with other design

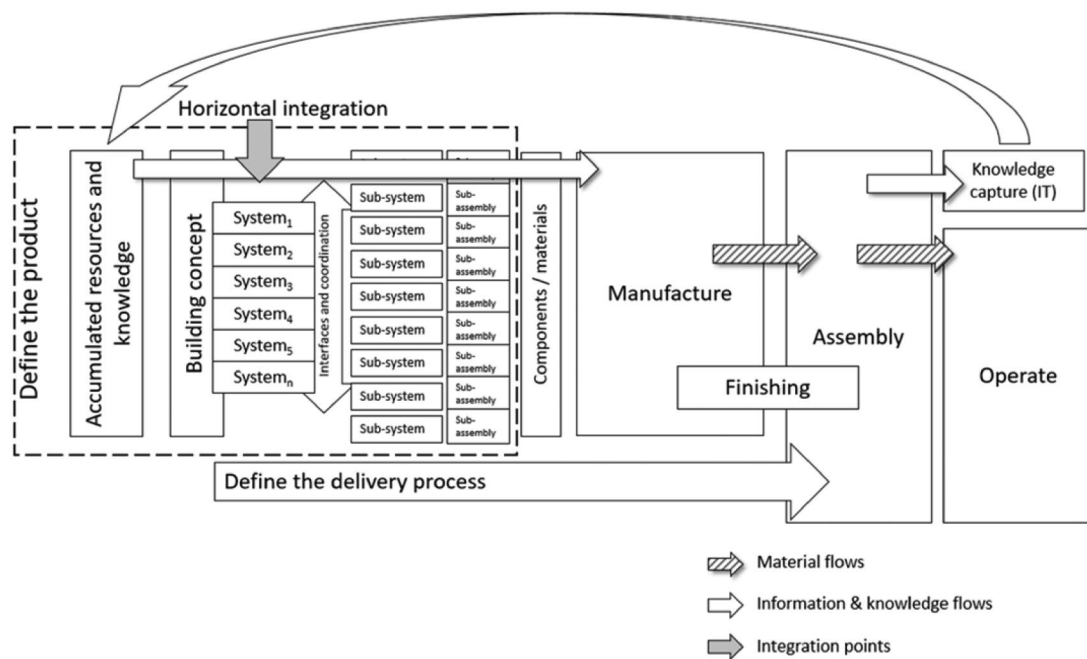


Figure 3. Stage one of product platform development, transition to a product-based lifecycle.

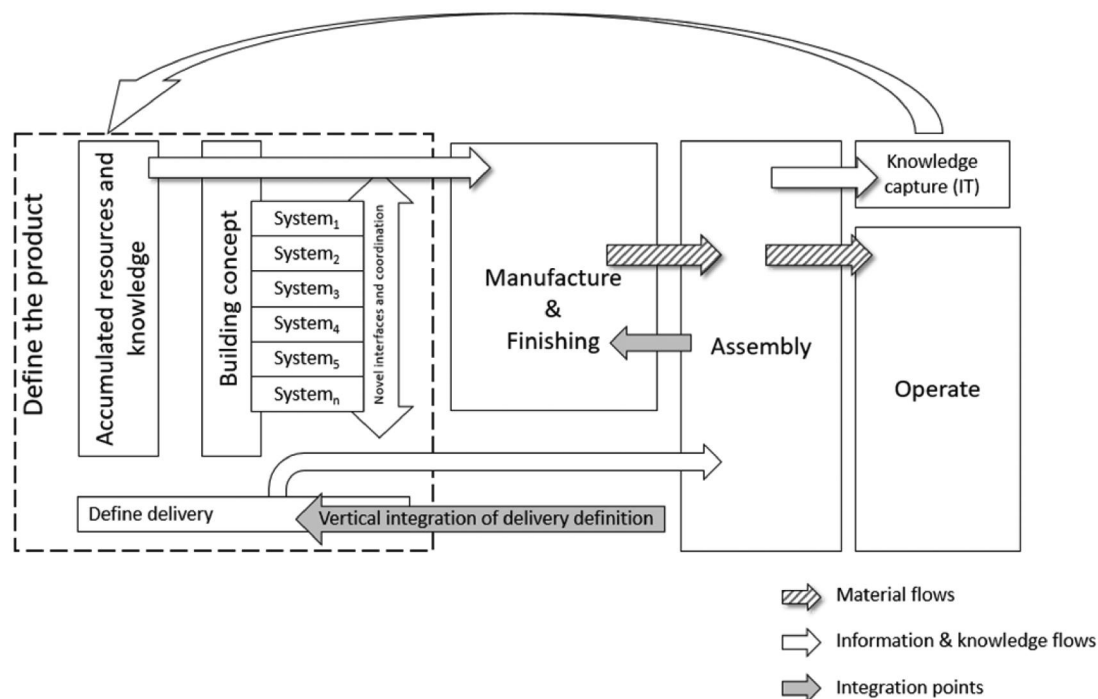


Figure 4. The final stage of product platform development.

disciplines, full specification of the building became possible, enabling almost all finishing to be undertaken by the manufacturers, rather than by assemblers. This led to the assembly of a show apartment, during which several hundred potential process and product improvements were identified. The assembly process was overseen by the new team members with manufacturing and assembly capabilities.

Throughout the platform development process, ABC was working with software providers to develop the digital tools needed to support deployment of the collaborative digital warehouse. At the time of the research, ABC had developed the technology stack so the information-rich (rules and product data) objects held in the digital warehouse could be used seamlessly in the building modelling process at 1:1 scale.

Coordinated objects in the digital warehouse reduced the need for repeated coordination between disciplines, enhancing design efficiency. Further to this, early, complete and concurrent specification of all aspects of the building design avoided the need for design deferral and trade design, reducing designed-in inefficiency and the loss of value associated with the sub-contracting of the design phase, that is, no more “*margins on margins*” (interview 6). Having a unitary team controlling the platform removes the element-by-element price cutting that threatens building quality, and enabled ABC to provide a warranty on the delivered building, underwritten by an offsite assurance scheme. With the building design fully coordinated prior to procurement, componentry can be ordered from well-established manufacturers, fully finished in response to demand. Further, with the assembly process tightly defined, problem solving activities at the assembly site are minimized or eliminated, with activities limited solely to assembly.

Discussion

Having shown how a construction consulting firm is adopting and developing a product platform and addressing the challenges of fragmentation and specialization, we now present new insights for construction management scholars, practitioners and policy makers from the exploration of ABC’s product platform. This section begins by describing ABC’s iterative platform development process in the context of the three types of fragmentation in construction. We then offer new perspectives on in-phase fragmentation in construction, before highlighting some of the practical challenges to the wider use of construction product platforms. The section ends by describing the implications of the study on the ongoing discourse of *construction as manufacturing*.

ABC’s iterative approach to platform development

This case shows how a well-established construction consultancy firm operating in a fragmented industry can develop a product platform. Rather than separating product platform development from delivery of projects as proposed by other authors (Lessing 2006, Jansson and Viklund 2015), ABC and DEF have taken an iterative approach to platform development, combining it with project delivery. This has enabled them to develop and augment their capabilities gradually over time, with investment in the platform supported by, and undertaken on client-funded projects. As a

result, their product platform development approach is neither entirely top-down, nor bottom-up (cf. Simpson *et al.* 2001).

In developing a product platform, ABC and DEF have created two distinct platforms which address the need to define both the product and the process of delivery (Lessing 2006). Early research on product platforms acknowledge that such platforms consist of both process technologies and organizational capabilities (e.g. Meyer and Lehnerd 1997). Others similarly differentiate between the technical platform – that is, the assets and components – and the process platform which supports product delivery (Lessing 2006, Eriksson and Emilsson 2019). Accordingly, when describing product platforms, it is important to distinguish product and process elements (Lessing 2006, Alblas and Wortmann 2014), while paying attention to physical and knowledge elements (e.g. Winch 2003, Kivrak *et al.* 2008).

The first of ABC’s platforms is a product development platform, the digital warehouse, from which information-rich digital components are re-used and reconfigured to address many of the design problems for a given site. Jansson *et al.* (2014) describe how the accumulated knowledge of design, design coordination, and product data – the design problems already solved – are retained in a platform, often virtually. Together with the relevant design rules governing the permissible combination of virtual components, these knowledge assets describe a virtual *product development platform* (Cao and Hall 2019). The digital warehouse is thus a form of internal platform (Gawer 2014), and a virtual manifestation of Lessing’s (2006) technical platform. During the design/engineering phase ABC and DEF leverage the platform support methods described by Jansson *et al.* (2014) to ensure buildings respond to both client needs and context. This means that buildings can remain responsive to the development context. To deliver this heterogeneity, the core (design) components are augmented by peripheral (design) elements to resolve novel design problems related to a given development. Establishing the interface between these new design peripherals and pre-coordinated components is a design problem that requires resolution prior to a new peripheral being admitted to the product development platform. Heterogeneity of final products is further enhanced by component-level specifications, which provide significant scope for component re-configuration or replacement.

The second form of platform developed is a process platform (Lessing 2006) for defining assembly of the physical componentry represented in the digital

warehouse. The core (assembly process) is retained between building projects, and new peripherals incorporated (into the assembly process) as necessary. This process asset of the platform captures knowledge about efficient manufacture, finishing and/or assembly of the physical platform product. In line with the generic description of a platform, these processes have a core set of routines which can be developed to produce market variety (Jiao *et al.* 2007, Jansson *et al.* 2014).

With ABC accepting product liability, ensuring the quality of the finished building is critical. This places more emphasis on their ability to control the digital and physical peripheral components that are added to the platform. In both product development and process platforms, governance of the interface is, therefore, closed, with access controlled tightly by ABC and DEF to ensure platform integrity (Gawer 2014). While this closed platform approach reduces the opportunities for ABC and DEF to learn and improve through their long-term relationship with a supply chain (Lessing 2006), they are able to take advantage of innovations in the market by admitting new materials and components to the product platform.

ABC create value through the efficient delivery of quality-led, heterogeneous buildings, with early certainty over the timing and costs of delivery. This distinguishes their value proposition from a traditional building procurement approach, with its focus on deferred decision-making and cost management that can lead to inferior specification. Ownership of the product platform also enables ABC and DEF to capture value from their capabilities being embedded in their own platform solution, rather than it being re-used by a competitor.

In-phase fragmentation in construction

ABC's platform development demonstrates how an increasingly granular exploration of a project's engineering phase can generate new insights on delivery coordination mechanisms – and this has informed ABC's development of a product platform. As a point of departure from the existing literature on fragmentation (e.g. Fellows and Liu 2012, Alashwal and Fong 2015) we observe that in addition to the vertical fragmentation *between* the delivery phases of the institutionalized construction process, there exists a fragmentation *of* the design/engineering phase. That is, vertical fragmentation, as discussed by Sheffer and Levitt (2010), occurs both *between* and *within* the design/engineering phase. This in-phase fragmentation

manifests in supplier design and site-based problem solving, with engineering and finishing activity taking place concurrently with construction. The consolidation of design decisions into a well-defined and appropriately sequenced design/engineering phase was achieved at ABC by establishing a joint venture with DEF, and by co-opting or employing manufacturing specialists in the product platform team.

The in-phase vertical and horizontal consolidation of design for manufacturing capabilities into ABC and DEF's product platform team ensures that an efficient building design can be developed quickly. This enables the complete specification of the building's componentry and assembly process prior to contracts being agreed for material manufacturing and finishing. Accordingly, vertical coordination between the design and manufacturing phases can be achieved by a fully specified contract, rather than through acquisition, and assembly platforms can also be pre-defined.

Longitudinal fragmentation is overcome by the use of the same team on subsequent projects, and ABC's digital warehouse of information rich, coordinated digital components. These strategies and tools ensure that knowledge developed in each product cycle can be retained (Lessing 2006), re-used and further developed, addressing the challenges of organizational learning and tacit knowledge in construction firms. Rather than the long-term supply chain relationships described by Lessing (2006), these relationships exist within and between the delivery team. The digital warehouse of coordinated design solutions reduces the number of novel design and assembly problems to be addressed on each new project. Being engaged on multiple delivery cycles, the platform team are well aware of the content of the digital warehouse, and can exploit opportunities for knowledge re-use.

In-phase horizontal fragmentation is addressed by the creation of a small integrated team, dedicated to the delivery of the product platform. Platform improvement activities are routinised, and coordinated through a formal, digitally enabled process. Horizontal coordination of disciplines was made easier by the large scale of ABC, meaning that they already had capabilities relevant to the engineering of many aspects of a building. Missing capabilities have been addressed by employing manufacturing specialists, and forming a trust-based working partnership with DEF.

In summary, considering construction projects as arrays of decisions (Jones 2019), longitudinal integration reduces the number of novel design problems that each new project presents. Horizontal and vertical

consolidation of decisions in the design/engineering phase of delivery increases the pace at which any novel problems can be resolved, ensuring that complete component-level building specifications can be produced rapidly, and before procurement begins. By accelerating the resolution of design decisions, and reducing the number of decisions made during assembly or on-site, construction more closely resembles the linear and sequential delivery pathways we see in the manufacturing literature.

Challenges to construction platform use

Achieving inter-phase coordination by adopting a vertical integration by acquisition strategy introduces significant risks to the company investing in manufacturing facilities when demand is intermittent. Some firms have addressed this risk by further integrating vertically to take control of the development pipeline, or making their production facilities available to competitors. ABC's approach, however, has been to ensure that their delivery process remains entirely demand responsive, and can be scaled up or down in response to varying customer demand, while minimizing their investments in long-term physical assets. The bulk of their investment has been in the detailed design, and the development of integrated digital solutions, much less than the cost of a factory. This mitigates the challenges of asset redundancy facing firms with substantial investments in facilities. Manufacturing is undertaken in response to demand by third party specialist firms that have multiple routes to market, ensuring that they too remain competitive.

Taking a product perspective, however, ABC and DEF are seen to be bundling design and delivery services which are – in a UK context – typically provided by distinct firms, in sequence. Traditional procurement routes are not set up to purchase buildings in this way, with clients typically procuring a design, and subsequently the means to deliver that design. Further, procurement departments will seek to ensure best value by obtaining multiple quotes for a given service or product. With few comparable providers of product platforms in the UK market, this institutionalized procurement practice presents challenges to the longer-term success of ABC's platform. Indeed, ABC have previously been asked to re-design buildings to ensure that other bidders can submit tenders for their schemes, despite the negative impacts on delivery cost and schedule certainty. This reversion to a traditional procurement process introduces unnecessary waste to the client and delivery process, reintroducing

deferred decision-making and blurring the boundaries between delivery phases. The UK's planning authorities also have a significant influence on ABC's ability to deliver to their desired timetable, as they can request changes to the scheme to meet local planning requirements, requiring further design iterations. ABC have mitigated against this risk by allowing for time in their delivery process to address any planning conditions raised.

Achieving alignment with manufacturing model

By clarifying and distinguishing the activities needed to deliver a building, our case has demonstrated how construction product platforms enable a closer alignment between the delivery models of manufacturing and construction. This section briefly explores what ABC's platform development can tell us about an appropriate application of insights from manufacturing to construction.

Figure 2 shows how buildings are typically delivered in construction, distinguishing between the key phases of delivery on typical construction projects: definition of the product and delivery process; manufacture; finishing; and assembly. Our analysis has highlighted how task fragmentation and incomplete resolution of the building design causes decisions to be deferred, and component finishing (ultimately, a design decision) to be undertaken during the assembly process.

In comparison to manufacturing, vertical fragmentation of the design/engineering phase in construction reduces clarity over the responsibilities and capabilities deployed in the delivery of projects. There is a blurring between the roles of design, finishing and assembly, as crafts-based delivery teams resolve problems as they arise on site. This reduces the efficiency of delivery on-site as tools are picked up and put down to solve problems. Decision deferral also necessitates the use of procurement contracts with incomplete information, introducing misunderstanding and conflict. Decision deferral does protect clients, ensuring value at each client procurement stage through competitive tendering, and minimizing losses if a project does not come to fruition. However, it also creates incentives in the procurement process for suppliers to reduce quality to enable them to create and capture value.

In the production literature (Hoekstra and Romme 1992, Gosling *et al.* 2017), the four major product delivery phases are each consolidated, distinct, and assumed to be completed sequentially. Products are fully defined before manufacturing begins. In

construction, this final definition is deferred. Addressing in-phase fragmentation and decision deferral has moved ABC closer towards this manufacturing model: delivery phases are now clearly defined and distinguished, with tasks being completed sequentially. This brings analytical clarity, enabling ABC to separately articulate the roles of product and process design/engineering, manufacturing/finishing and assembly, and to mobilize these capabilities in response to demand at an appropriate location. In particular, this also means that coordination between design/engineering, manufacturing and assembly phases can be coordinated by fully specified contracts, rather than ownership or incompletely specified contracts, reducing the risk of asset redundancy or supply chain conflict respectively.

Our case suggests, therefore, that ABC's in-phase vertical consolidation of the design decisions in the design/engineering phase, coupled with longitudinal integration between projects act as key enablers in their efficient delivery of built assets using a product platform. This vertical and horizontal consolidation of manufacturing design capabilities permits the efficient resolution of new design problems, and the early complete specification of a building's manufacturing and assembly processes.

Conclusions

Product platforms have been adopted in construction to increase the efficiency of the construction delivery process, while maintaining variety of market offer. Prior research has focussed on the top-down or bottom-up approaches to product platform development in product-based firms as standalone exercises, independently of project delivery.

The study extends this stream of literature, making two novel contributions to scholarship.

First, our empirical analysis describes, for the first time, the dynamics of product platform development in a specialist construction consultancy firm. Our case has shown how a firm overcame their role- and service-based specialization to develop a product platform on consecutive projects, rather than as a standalone exercise. This was achieved by iteratively developing and augmenting their engineering and manufacturing capabilities, rather than the standalone top-down or bottom-up development approaches described elsewhere in the literature.

Second, we contribute to the literature on industry fragmentation and integration by highlighting how consolidating decision-making *within* the delivery

phases can address in-phase fragmentation, enhancing the efficiency of the overall building delivery process. Consolidating decisions both horizontally and vertically enable complete resolution of the engineering phase of delivery, and supports vertical coordination between phases to be managed by fully specified contracts, rather than by acquisition. This means that manufacturing and assembly can be responsive to demand, rather than being dependent upon it.

Our analysis focuses on a large UK-based construction firm. This study has highlighted further research required to understand how small firms can similarly transform their value delivery models, and how the institutions in other countries enable or inhibit constructions transformation. Further, this study opens up significant research opportunities to explore the role of client demand, and the existing, institutionalized procurement processes in retarding construction's transformation.

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Appendices: Interview Protocols

Appendix A.

Main research protocol

1. Can you please tell us about your role in the company?
2. How long has your company been operating in the construction sector/industry?
3. Can you describe your company's value proposition, and your core business?
4. Do you deliver offsite manufacturing projects and how is the delivery managed?
5. Can you tell us about some projects in which you have adopted offsite manufacturing?
6. How have you used digital technologies to deliver projects? Could you provide us some examples?
7. Have you recently introduced a novel digital technology to deliver your products? If yes, could you give some examples of how it has changed your project delivery?

Appendix B.

Industry expert protocol themes

1. What do you consider to be the key current business models of the construction industry?
2. What are the emerging business models of the construction industry?
3. Which companies are leading the transformation of construction?
4. What are the enablers and the barriers/inhibitors of the emerging business models?
5. What is your view of ABC's changing business model?
6. What are the future business models of the construction industry?
7. What do you think (hope) the industry will look like in 10 (20) years' time?
8. Where do see the allocation of risk and the IP strategy in this world?