EXPLORING THE ROLE OF INDUSTRY 4.0 IN THE BUILDING INDUSTRY: A CASE STUDY OF EMERGING BUSINESS MODELS IN THE AUSTRALIAN CONSTRUCTION ECOSYSTEM

Priyadarshini Das¹, Siddhesh Godbole², Duncan W. Maxwell¹, Robert Moehler¹

¹ Monash University, Melbourne, Australia
² The University of Melbourne, Melbourne, Australia

Abstract

As the building industry is a significant contributor to Australia's economy, understanding the impact of Industry 4.0 on this sector is crucial for its continued growth and competitiveness. This creates a need to explore the interdependencies between the implementation of an industrial and digitally enabled building industry and business model and value chain innovation to shape a digitally mediated platform ecosystem configuration. As the building industry faces challenges in adopting manufacturing techniques and technologies, the paper examines significant yet understudied implications of Industry 4.0 along industrial value chains. This study aims to understand how the building industry in Australia can adapt to the shift towards industrialised-digitalisation by exploring the opportunities for innovation in business models and value chains. The research approach will draw on a literature review, and a series of workshops in four Australian cities to understand perspectives determining business model innovation. Examining integration, servitization, and expertization the paper illuminates the impact of digital connectivity, information exchange, and design value on the industry. The paper’s framework focuses on assessing dynamic capabilities (sensing, seizing, and reconfiguring) and the ecosystem lifecycle (birth, expansion, leadership, self-renewal) to comprehend business model innovation in the Australian construction ecosystem. It also uncovers how diverse stakeholders, including developers, contractors, consultants, supply chain actors, and digital platform owners, create value and progress through these phases. Identifying prospects in offsite manufacturing, standardization, technological advances, and value chain integration allows developers, clients, and contractors to enhance efficiency and results. Consultants can utilize their design value and project management know-how to promote cooperation among stakeholders. Additionally, digital platform proprietors can access multi-sided marketplaces for direct communication and efficient procedures. Ultimately, implementing these insights assists industry participants in adapting to changing market dynamics, encouraging innovation, and bolstering the competitiveness of the Australian construction industry.

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Keywords: Industry 4.0, value chains, platform, ecosystems, business model innovation

1.0 Introduction

Industry 4.0 is catalyzing a gradual change in the construction industry's paradigms. Most existing research in the built environment focuses on the remarkable technological capabilities of Industry 4.0, with minimal attention given to its effects on the construction business model. However, responsible innovation takes place at the level of the business model itself reconceptualizing the fundamental role of business in society [1]. Since the advent of Industry 4.0, construction firms are experiencing significant changes in their existing business models; Industry 4.0 technologies can create new value propositions, expand customer segments, influence channels and modify key activities through automation and data-
driven operations [2]. Initial studies discussing business models in construction-related literature do not align with the definition of a business model as "a representation of an organization’s value logic"; Instead, these studies treat business models as a way to justify costs, essentially discussing to them as commercial models [3, 4]. In this regard, Pekuri, et al. [5] argued that construction managers had trouble articulating their company's business model and value-creation logic, indicating a limited understanding of customer values. Boldly, the study suggested that this could be a primary cause of the ongoing customer dissatisfaction prevalent in the industry. Although business model innovation has been recognized as a "theory of business" since Drucker [6], it has only recently captured the interest of researchers in the built environment primarily due to the emergence of two main streams of research, industrialised house building business models [7, 8] and circular business models [9, 10] because both of these approaches to construction created added value in terms of efficiency, sustainability, continuous improvement, customer-centricity to name a few that could be monetized. Analysing construction firms using the lens of a business model can help address two of construction’s eternal problems; firstly, develop an increased understanding of customer values [11] and secondly, look at a firm’s value creation and value capturing interlinkages with a holistic view and not stagewise (design, construction, operation) or project-wise (one project to another) [7].

In a very recent study by Criado-Perez, et al. [12], the authors investigated the prevailing issues in the digital transformation of the Australian construction sector. While the apparent cause identified were skill deficit, resistance to change, insufficient investment in digital infrastructure and regulatory challenges, Criado-Perez, et al. [12] stressed on an underlying cause; Construction firms are engaging in sporadic digital transformation efforts that primarily focus on technology, without giving due consideration to the underlying business model; as a result, these initiatives often face difficulties when it comes to scaling up. The authors They recommend embedding business model thinking in the industry which involves an understanding of how to proactively change an existing business model. Given the above, this paper is an attempt to answer the question, ‘How will business models transform in the Australian construction ecosystem in Industry 4.0?’ Therefore, this study aims to understand how the building industry in Australia can adapt to the shift towards industrialized-digitalization by exploring the opportunities for innovation in business models and value chains. The paper is structured as follows: Section 2 presents a critical literature review on Industry 4.0 and value chains, industrialized-digitalized business models and how to create, offer and capture value in Industry 4.0. Section 3 presents the research approach taken in this paper. Section 4 presents the findings followed by a discussion of the findings in Section 5. Section 6 concludes the paper and presents future research directions. The paper is a result of an ongoing research initiative, findings will be further developed as the project reaches completion.

2.0 Literature Review

2.1 Industry 4.0 and Value Chains

Industry 4.0 necessitates a re-evaluation of traditional business strategies by focusing on fostering collaborative ecosystems enabled by digital capabilities [13]. ‘Virtual value chains’ characterized by digital connectivity, information sharing, and real-time data exchange emerged in Industry 4.0 to facilitate better decision making [14]. Nottbrock, et al. [15] stated that Industry 4.0 innovations are shifting value chain structures from linear, hierarchical models towards more decentralized, networked configurations enabling greater flexibility, collaboration, and co-creation among various stakeholders. Dzwigol, et al. [16] also highlighted the importance of collaboration and ecosystem-based thinking in the Industry 4.0 era where organizations need to establish partnerships with various stakeholders, including suppliers, customers, research institutions, and competitors, to share knowledge, resources, and capabilities in a rapidly changing environment. Taking the case of the manufacturing sector, Culot, et al. [17] observed that Industry 4.0 technologies, such as IoT, AI, and big data analytics, are enabling greater integration within manufacturing value chains facilitating real-time data exchange, improved communication, and enhanced collaboration among value chain actors. The study adds that Industry 4.0 technologies also
impacts the scalability of manufacturing value chains; advanced manufacturing techniques, such as additive manufacturing and automation, allow firms to achieve greater flexibility and responsiveness to market changes, enabling them to scale production more effectively. Similar observations have been reported from the textile industry. Chen [18] stated that cooperation can facilitate knowledge sharing, technology transfer, and joint innovation, which can further boost value creation in large textile firms as well as SMEs. Thus, there is consensus in the literature that Industry 4.0 is driving the development of new business models that rely on collaboration, data-driven decision-making, and customer-centricity [14, 19, 20]. Consequently, it has been found that assessing the integration of digital technologies and innovative business models at each stage of the value chain can help organizations better understand the overall effects of Industry 4.0 on their operations [21].

2.2 Industrialized - Digitalized Business Models

Industry 4.0. business models are impacted by the twin currents of industrialisation and digitalisation. Weking, et al. [22] investigated 32 case studies of Industry 4.0 business model innovation and identified that integration, servitization and expertization are the three super patterns of business model innovation in Industry 4.0; integration attempts to integrate parts of the supply chain through new processes whereas new combined products and services are the basis for servitization. Expertization is a hybrid approach that utilizes product and process focussed business models including consulting services and multi-sided platforms. Mass customization is a form of integration, life-long partnerships a form of servitization and product or process-related platformisation are forms of expertization. Similar findings were reflected in Ibarra, et al. [23] where the authors identified three complementary approaches to business model innovation in Industry 4.0; service orientation, networked ecosystems and customer orientation. They can be described as specific product-service bundles as a solution for the customer where suppliers, customers and other partners become part of a networked ecosystem; often new actors arise and the roles of existing actors change. Customer orientation requires firms to develop new capabilities in learning more about their customers and their value creation process utilising digital means. Digital platforms serve as catalysts for inter-organizational cooperation and enable businesses to co-create value. Veile, et al. [24] investigated industrialised-digitalised business models by critically reviewing 11 cases to understand how digital platforms change industrial firm’s business model and inter-company relationships. The study highlighted key aspects of such business models; customer relationships - customer integration from silos to cooperation, new forms of buyer-supplier relationships; key partners – ecosystem partners with higher levels of trust among partners, new ways of digital communication and higher communication frequency; key activities – pre-phase platform creation, recurring tasks ecosystem development; key resources – technological and digital along with human resources and knowledge; value propositions – improved value offers (processes), extended value offers (services), value through data and digitalisation; channels – direct channels through the platform and indirect channels through the ecosystem. Thus, it is evident that digital platforms serve as catalysts for inter-organizational cooperation and enable industrial firms to co-create value [25].

2.3 Creating, Offering and Capturing Value in Industry 4.0

Exemplars of how value is created, offered and captured in industrialised-digitalised business models were demonstrated in Müller and Buliga [26]; real-time sensor data, simulation and data analytics, condition monitoring, predictive maintenance and preventive maintenance are exemplars of value creation; reducing time customers spend designing prototypes, reducing customer’s unexpected downtimes, optimizing energy consumption in the production line are exemplars of value offer and licensing, subscription, pay-per-use, pay-per-feature, pay for guaranteed results etc. are exemplars of value capture. Similar findings are reflected in an extended work by Müller, et al. [27] where they stated that value is created at manufacturing sites through high-grade digitalization of manufacturing data which allows demand optimization, failure reduction, and productivity increases (value offer). Ibarra, et al. [23] propose a four-step framework to shift from traditional business models to new business models and illustrate how value can be created, delivered (offered) and captured at each step. The four steps
proposed in the study are internal and external process optimisation, customer interface improvement, new ecosystems and value networks and new business models (smart product and services); they demonstrate a shift from incremental innovation to radical innovation. For example, at the process optimization stage, value is created through more efficient production, logistics, quality control and more transparent management (data-driven); value is delivered through more flexible offers including customization and value is captured through cost optimization due to more efficient processes and use of resources. On the other end of the spectrum, at the new business model stage value is delivered through smart products, innovation in associated services (such as predictive maintenance), co-creation that includes customers in the value creation process and direct relationships between the firm and the customers. This requires value creation through new physical, human and intellectual resources and allows for value capture through new revenue streams such as dynamic pricing, pay-per-use etc. The different mechanisms for value creation, offer and capture in Industry 4.0 business models were assimilated from literature and presented in Table 1.

Table 1. Value creation, offer and capture in Industry 4.0 business models [22, 23, 27]

<table>
<thead>
<tr>
<th>Value creation</th>
<th>Value offer</th>
<th>Value capture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customization</strong> - Mass production, mass customization, mass individualisation</td>
<td><strong>Products</strong> - Physical only, physically, digitally charged, digital only</td>
<td><strong>Market</strong> - B2B only, B2C only, B2B &amp; B2C, multi-sided market</td>
</tr>
<tr>
<td><strong>Role of a value chain firm</strong> – integrator, service and support, intermediary</td>
<td><strong>Service</strong> - Repair &amp; maintenance, monitoring and predictive maintenance, production, technology, advice &amp; consulting, digitalization services, data analytics services, virtual product development</td>
<td><strong>Segmentation</strong> - Based on customer knowledge and data analysis</td>
</tr>
<tr>
<td><strong>Factory</strong> – mega factory, micro factory</td>
<td><strong>Production paradigm</strong> – pull / on-demand, push &amp; pull</td>
<td><strong>Customer interaction</strong> – hybrid (direct and intermediary), direct selling leading to long-term relationships</td>
</tr>
<tr>
<td><strong>Partners</strong> – higher intercompany connectivity, co-design of value offers, joint data analysis, higher information transparency</td>
<td><strong>Information exchange</strong> – real time information about production, inventories, sales, availability of personnel, etc.</td>
<td><strong>Revenue model</strong> – sales, revenue sharing, freemium, rent/lease, subscription, pay-per-use, pay-per-feature</td>
</tr>
<tr>
<td><strong>Continuity of revenue</strong> – once, mixed, continuous</td>
<td><strong>Sales model</strong> – ownership / service delivery, use / availability, result</td>
<td><strong>Payment methods</strong> – Digital accounting and automated invoices, increased payment reliability</td>
</tr>
<tr>
<td><strong>Cost</strong> – Potential for cost reduction for all stakeholders due to most efficient processes and information sharing</td>
<td><strong>Payment methods</strong> – Digital accounting and automated invoices, increased payment reliability</td>
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The following section will elaborate on the research approach taken in this paper.

### 3.0 Research Approach

Workshops as a research methodology have been used in prior research to identify, articulate and explore problems in areas where there is a lack of common language to produce reliable and valid data about the domain being investigated [28]. The research approach in this paper follows the four-step framework proposed by Storvang, et al. [29] to use workshops in business research. The four steps as illustrated in Fig. 1., comprise the diagnosis, planning, facilitating and analysis phases. The diagnosis phase involves understanding the system within which the research problem resides which was accomplished through a critical review of literature on Industry 4.0 value chains and business models in this paper. The planning phase involves selecting the participants, venue and developing the content for the facilitated workshops. In this phase, the social process of what the participants will be doing in
the workshop and what would they get out of it is defined along with technical considerations such as context, time and place. In this paper, workshops were scheduled to be conducted in four Australian cities of Adelaide, Melbourne, Sydney and Brisbane; of which the workshops in Adelaide and Melbourne have already been conducted and the ones in Sydney and Brisbane are scheduled for the month of May 2023. The participants were invited from all stakeholder groups in the construction value chain including architects, engineers, consultants, contractors, government bodies, digital platform providers and representatives from client bodies. The total number of participants in the Adelaide and Melbourne workshops amounted to 60. The facilitated workshops ran for an entire day with the morning sessions dedicated to presenting the literature findings and educating the participants about Industry 4.0, the shift in value chains from linear, hierarchical models towards more decentralized, networked configurations or ecosystems and the various mechanisms of value creation, offer and capture in Industry 4.0 business models. The afternoon sessions were utilised to facilitate discussions on the opportunities and challenges of the new ecosystem in the context of the Australian construction sector. Mentimeter, which is considered as an effective tool to engage a cohort of participants [30, 31] was used for real-time data collection on the opportunities and challenges. The final phase is the analysis phase where the data collected from the workshops were evaluated and related back to the original research question, ‘how will business models transform in the Australian construction ecosystem in Industry 4.0?’ The four steps are iterative given there are four facilitated workshops, with minor fine-tuning after each workshop to evolve from pre-understanding to understanding to a new level of understanding and so on [29]. The following section presents the findings of the paper.

Fig. 1. Research Approach

4.0 Findings and Discussion

4.1 Digitally mediated ecosystems business models

The Australian construction ecosystem has produced exemplars of all three archetypes of Industry 4.0 business model innovation identified from the literature; integration, servitization and expertization [22]. One of the main benefits of the ecosystem business model that the workshop participants consented to
was the opportunity to move value adding activities upstream; which is an exemplar of integration. Some of the Mentimeter outputs have been quoted as is; “I am a prefab manufacturer, and I can be involved at a design level as early as possible in a project lifecycle to provide constructability input…. I am a modular builder and I can assemble a complete value chain and bid for a complete package rather than small elements…. ” Complementing what the literature says, the participants believed that such supply chain integration is enabled through digital connectivity, information sharing, and real-time data exchange [14]. New combined products and services is the basis of servitization which was also evident among the workshop responses. “I am a steel manufacturer and supplier, and I can bundle value-added elements for example, I can embed digital services for condition monitoring…. ” As seen in Müller and Buliga [26], real-time sensor data, simulation and data analytics, condition monitoring, predictive maintenance and preventive maintenance exemplify value creation in industrialised-digitalised business models. Exemplars of expertization represents a blended strategy that employs both product-centric and process-centric business models, incorporating consultancy services and multi-sided platforms [22]; the participants belonging to the stakeholder group ‘architects’ aligned most with the expertization business model. “I am an architect and I can pivot to the design of systems and not buildings using parametric and generative design tools; I can then directly engage with the supply chain during design instead of traditional linear additive procurement. I can design smarter and cleaner as part of an ecosystem led by multiple agendas…. ” This supports the fact that design value holds the key to accessing untapped markets, ensuring responsible design and enhancing cost-effectiveness; This value not only brings about tangible business advantages, but also enriches the wider social, cultural, and economic aspects of a building [32]. The workshop participants repeatedly raised the point about directly engaging with the supply chain. This is also evident in some real industry cases where multi-sided platforms are being utilised for direct buying and selling. A start-up that originated in Sydney, Australia called ptblink, offers a digital platform that enables the parametric design of multi-storey buildings as a kit of configurable parts and then provides a marketplace for direct dealing between buyers and sellers. They consider themselves a software development company now, but they have evolved from a construction background in the 1990s thereby representing ‘expertization’.

4.2 Dynamic Capabilities

The workshop inputs were further analysed by mapping them to existing frameworks in the literature to understand the current status of business model innovation in the Australian construction ecosystem. Dynamic capabilities empower business models, as organizations with such abilities can swiftly test and fine-tune novel business models [33]; dynamic capabilities include the evaluation of technological opportunities and threats in relationship to customer needs (sensing), mobilization of resources to address those needs and capture value from doing so (seizing), and continued renewal (reconfiguring) [34]. A set of dynamic capabilities are required for each stage of the ecosystem lifecycle [35]. The lifecycle of an ecosystem commences when a value proposition is devised (birth), continues with scale and refinement (expansion), becomes stronger by keeping customers and partners engaged (leadership) and finally reconfigures with new ideas (self-renewal) [36]. Industry stakeholders are sensing business model innovation opportunities through shifting of on-site construction to offsite manufacturing, standardising components into a predefined platform, systematically using building projects to develop the platform and aiming for improved efficiency through technology innovation; as they integrate value-chains by building specifications that conform to both the platform and client requirements through standardization of processes and long-term agreements or relationships, they are moving into the seizing stage; and they can reconfigure through cross-industry collaboration and research, routinized learning and cyclic business streams [37, 38]. From the responses, developers, clients and contractors are actively sensing opportunities and moving into the expansion stage of the ecosystem lifecycle. Consultants have capability within their businesses to guide this ecosystem; both in terms of ‘design value’ and ‘project management’. Quoting a project management consultant among the participants; “I am a project management consultant and I can curate a team of likeminded businesses/ producers on a project. I can bring the client, design team, builders and subcontractors together to work towards the best outcomes for all involved…. ” As noted earlier in the discussion,
associated supply chain actors such as prefab manufacturers, material manufacturers and suppliers and modular builders are already seizing business model innovation opportunities through value chain integrations and servitization business models. Slightly ahead in the trajectory are some of the digital platform owners that are already reconfiguring through multi-sided marketplaces. Fig. 2 illustrates the current status of business model innovation in the Australian construction ecosystem.

![Business Model Innovation in the Australian construction ecosystem](image)

**4.3 Challenges**

The workshop also discussed the challenges towards adoption of an ecosystem business model. The primary concern among supply chain stakeholder groups was interoperability in case the ecosystem business model encompassed a product platform. According to platform theory, product platforms should have defined interfaces which can be made available to the designers and suppliers of peripheral or complementary products. This should enable the product platform to be reliably integrated with other parts of a building without being wholly dependent on the platform provider [39]. However, the participants expressed concern on whether the products they offer will be compatible with the platform. “I am a bathpod manufacturer and I don’t know if my products will be compatible with the platform…” Ecosystem business models yield advantages when shared resources are utilized at scale; Although this presents opportunities for enhanced efficiency and cost savings, it may also raise issues related to intellectual property, risk management, and liabilities [39]. This was a major concern among the workshop participants too. “I am a contractor and now I have more data, risk and exchanges occurring across the ecosystem…” The workshop participants were of the view that cultural barriers will perhaps be the biggest roadblock towards implementing such an ecosystem business model. Collaborative exchanges and early involvement are difficult in an industry that is historically categorised as fragmented with adversarial relationships among its stakeholder groups [7]. There was consensus among the participants that traditional expectations of return on investment and short-term thinking were still prevalent in the industry. Owning and participating (ecosystem business model) can provide better returns over a longer term; however, a collaborative commons approach is yet to take over from pure capitalism in the industry. “I am a modular builder and it is a challenge to convince all stakeholders to collaborate and initiate a cultural shift in the industry…” “I am a modular builder and it is a challenge to convince the client to adopt a new business model…” Embracing an ecosystem approach as a novel
business model, might necessitate modifications in the contractual arrangements among organizations. Ensuring well-defined relationships, aligned interests, and suitably distributed risks within the ecosystem will be crucial [39]. The participants concluded that even though stakeholder groups have the ability to involve from the moment of inception to create better value for the client, the current rigid procurement model and contractual arrangements do not allow for such innovation to occur. The final challenge identified was skill deficit. “I am a contractor and my challenging is keeping up with the changing perceptions within the business and building the skills to deliver prefab projects....” To achieve the benefits of an ecosystem business model it requires the development of new skills, new ways of works and collaboration, both across and within organisations in the value chain [39]. It is a subject of further research leading to policy decisions.

5.0 Conclusions and Future Research

The theoretical contribution of this paper lies in illustrating the application and manifestation of Industry 4.0 business model innovation within the Australian construction ecosystem. By exploring integration, servitization, and expertization, it sheds light on the role of digital connectivity, information sharing, and design value in shaping the industry. The framework proposed in the paper centres on the analysis of dynamic capabilities (sensing, seizing, and reconfiguring) and the ecosystem lifecycle (birth, expansion, leadership, self-renewal) to understand business model innovation in the Australian construction ecosystem. The paper reveals how various stakeholders, such as developers, contractors, consultants, associated supply chain actors and digital platform owners are embracing opportunities and transitioning through these stages. By examining their roles and progress, the paper offers insights into the current state and future direction of business model innovation in the Australian construction sector.

The practical implications of the paper suggest that stakeholders in the Australian construction ecosystem can benefit from understanding and embracing dynamic capabilities and the ecosystem lifecycle stages to drive business model innovation. By recognizing opportunities for offsite manufacturing, standardization, technology innovation, and value chain integration, developers, clients, and contractors can improve efficiency and project outcomes. Consultants can leverage their expertise in design value and project management to facilitate collaboration among all parties. Furthermore, digital platform owners can tap into multi-sided marketplaces to enable direct interactions and streamlined processes. Overall, applying these insights can help industry players adapt to the evolving market conditions, foster innovation, and enhance the competitiveness of the Australian construction sector.

The challenges associated with the ecosystem business model identified in this paper provides a clear direction for future research. Future research needs to (a) investigate strategies to ensure compatibility and seamless integration between product platforms and peripheral or complementary products to address concerns raised by industry stakeholders (b) examine the challenges and potential solutions related to shared resources, intellectual property rights, and risk distribution in an ecosystem business model (c) explore the factors that hinder collaboration and early involvement in the construction industry, and identify ways to foster a shift towards a more collaborative commons approach (d) assess the impact of novel business models on contractual arrangements, and develop frameworks for well-defined relationships, aligned interests, and suitable risk distribution within the ecosystem (e) analyze the skill gaps and challenges faced by industry professionals in adapting to ecosystem business models, and propose strategies for skill development and capacity building within the sector and (f) examine the potential policy decisions that can support the adoption of ecosystem business models in the construction industry.

Acknowledgments

The authors would like to acknowledge that this research is funded by the Building 4.0 CRC, an industry-led research initiative co-funded by the Australian Government.
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