Case Study

Digital Transformation in the Australian AEC Industry: Prevailing Issues and Prospective Leadership Thinking

Christian Criado-Perez[1]; George A. Shinkle[2]; Markus A. Höllerer[3];
Angel Sharma[4]; Catherine Collins[5]; Nicole Gardner[6];
M. Hank Haeusler[7]; and Shan Pan[8]

Abstract: The architecture, engineering, and construction (AEC) industry globally has a long history of prudently adopting novel technologies to improve products and services. Yet the rapid development of digital technology currently taking place is threatening to produce a more disruptive inflection, or substantial jolt. This paper explores the state of readiness of the AEC industry for such anticipated transformation. We illustrate our conceptual arguments with evidence from an explorative study across a sample of AEC organizations in Australia. At the core of this paper, we offer six provocations that highlight what we consider major challenges for the AEC industry—across multiple levels of analysis—related to the increasing role of digital technology. We then turn to lessons learned from other industries in order to propose a framework consisting of four leadership thinking schemas to enable digital transformation readiness: future thinking, strategic thinking, capability thinking, and experimental thinking. For these four schemas, we present practices and initiatives that may help AEC firms to better adapt—or to proactively create and shape a sustainable future. **DOI: [10.1061/(ASCE)CO.1943-7862.0002214](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002214).** *© 2021 American Society of Civil Engineers.*

Introduction

The increased use of technology in the architecture, engineering, and construction (AEC) industry has yielded substantial improvements in safety, cost, and efficiency over recent decades. Building information

[1]Ph.D. Candidate, School of Management and Governance, Univ. of New South Wales, Sydney, NSW 2052, Australia (corresponding author). ORCID: https://orcid.org/0000-0003-3975-1621. Email: c.criadoperez@unsw.edu.au

[2]Associate Professor, School of Management and Governance, Univ. of New South Wales, Sydney, NSW 2052, Australia. ORCID: https://orcid.org/0000-0002-4798-011X. Email: g.shinkle@unsw.edu.au

[3]Professor, School of Management and Governance, Univ. of New South Wales, Sydney, NSW 2052, Australia; Research Institute for Urban Management and Governance, Vienna Univ. of Economics and Business, Vienna 1020, Australia. Email: markus.hoellerer@unsw.edu.au

[4]Ph.D. Candidate, School of Management and Governance, Univ. of New South Wales, Sydney, NSW 2052, Australia. Email: angel.sharma@unsw.edu.au

[5]Associate Professor, School of Management and Governance, Univ. of New South Wales, Sydney, NSW 2052, Australia. Email: c.g.collins@unsw.edu.au

[6]Senior Lecturer, School of Built Environment, Univ. of New South Wales, Sydney, NSW 2052, Australia. Email: n.gardner@unsw.edu.au

[7]Associate Professor, School of Built Environment, Univ. of New South Wales, Sydney, NSW 2052, Australia. ORCID: https://orcid.org/0000-0002-8405-0819. Email: m.haeusler@unsw.edu.au

[8]Professor, School of Information Systems and Technology Management, Univ. of New South Wales, Sydney, NSW 2052, Australia. Email: shan.pan@unsw.edu.au

modeling (BIM) stands out as an example of technology adoption that has helped to reduce inefficiencies by centralizing and connecting information from multiple stakeholders. The use of simulations to support data-driven decision-making also provide opportunities for more efficient and collaborative processes (Renz et al. 2016). However, the slow and partial adoption of such digital solutions also sheds light on the multiple barriers to technology adoption and industry innovation. Importantly, the AEC industry has evolved over time to be highly conscious of safety and error prevention (Zhang et al. 2013). Therefore, prudent practice in the AEC industry is characterized by conservatism and risk aversion (Blayse and Manley 2004; Xue et al. 2014). The evolved state establishes a constellation of professions and stakeholders with partly competing rationales and a general skepticism of innovation and change.

The AEC industry stands in stark contrast to a wider set of radically shifted industries, such as media, retail, and entertainment, where digital technology has transformed much of the core activity and business practices of firms (Van Alstyne et al. 2016). The array of technologies underpinning this transformation is progressing at an exponential rate, allowing organizations to reinvent their value propositions, reimagine processes and value chains, enter into new markets, serve a wider range of clients, and provide more complete and integrated solutions rather than single products or limited services (Lanzolla et al. 2020). These changes remake industries and shift the business models of firms, but also require new skills and capabilities (Van Alstyne et al. 2016). While the transformation of industries often leaves a trail of destruction, with incumbents being displaced or reduced in prominence (Cozzolino et al. 2018; Nambisan et al. 2019), there are indications and examples that strategic players can indeed prosper during and after such change. There is much to be learned from others' experiences—both in their successes and failures.

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As a classic example, John Deere has moved from manufacturing farm machinery to being an artificial intelligence (AI) and data-driven business that is now an agritech platform, making farming smarter and more efficient (Marr 2019). In the AEC industry, Katerra attempted a vertically integrated business model that included design, component manufacturing, supply chain management, and construction. By heavily investing in computational modeling and process automation, their designs went straight to the factory floor, suppliers, and the construction site. As a result, Katerra was able to demonstrate significantly reduced project schedules for their customers. For example, Katerra built a 4-bedroom 1,860-ft^2 family villa for Saudi Arabia's Ministry of Housing in less than 48 h. While Katerra's business approach has proven unsuccessful, they demonstrated the potential impact that a digital transformation within a solution (end-to-end) focused business model can have within the AEC industry—providing a window into a possible, if not likely, future.

The development of disruptive digital technologies and the subsequent impact on AEC as one of the driving industries in the global economy have been forewarned for some time (Ribeirinho et al. 2020). While the general trends are easily observed, the uncertainties regarding pace and scope of digital evolution and the wide range of emerging technologies that come with it preclude precise prediction (Lavikka et al. 2018). Given the expectations toward the digital transformation on the horizon—as noted in the concept of *Construction 4.0* (Sawhney et al. 2020)—and the acknowledged generally low capacity for strategic planning in AEC firms (Chinowsky and Meredith 2000), we ask two pivotal questions: (1) What is the state of readiness of the AEC industry, and firms within it, for a likely forthcoming digital transformation? And (2) what lessons can be learned from digital transformations in other industries that may assist the leaders of firms within the AEC industry to enhance their readiness?

In this paper, we engage—across multiple levels of analysis—with the challenges and demands that will be crucial for the AEC industry during digital transformation, as well as share critical insights and lessons learned from our engagement as (mainly) business and management scholars with this industry. We illustrate our conceptual arguments by drawing on empirical evidence from an explorative study across a sample of architecture and engineering firms and industry associations in Australia (hereafter, we distinguish firms and associations when distinct, and otherwise use the general term *organization*). By digital transformation, we here refer to the technology-driven process of change derived from ubiquitous data, connectivity, and digital tools that aid decision-making (Ebert and Duarte 2018). Such a transformative process may substantively impact the core business model of many AEC firms, the relationships across the industry, as well as the nature of the work of employees. Consequently, this is likely to entail explorations into uncharted territories that will frequently be characterized by a high degree of uncertainty.

Our analysis examines digital transformation at the AEC industry level through an institutional fields perspective; at the firm level through a business strategy perspective; and at the operational level (i.e., within the value creation activities of the firm) through a collaboration and capabilities perspective. These analytical levels are nested within each other and focus on specific theoretical constructs and stakeholders involved. We offer six central provocations related to the increasing role of digital technologies. We then turn to lessons learned from other industries to bring to the fore a number of practices and initiatives that may aid successful adaptation to the shifting environment and enhance digital transformation readiness. We accumulate these practices and initiatives into a framework of four distinct leadership thinking schemas: future thinking, strategic thinking, capability thinking, and experimental thinking. Cultivating these thinking schemas will guide AEC firms toward initiatives that may help them to better adapt to—or proactively create and shape—their future.

Research Methodology

Our work aims at understanding the emerging industry trends related to digital transformation and the challenges that these changes are providing for the social systems, firms, and people within the Australian AEC industry (and more globally). We therefore relied on a mosaic of evidence, including industry reports, expert interviews, and the academic literature. We collected qualitative data through conversations with key informants across selected firms and associations in the field. Our sample focused mainly on senior-level actors who have been engaged in executive-level activities and strategic decision-making. We opted for a combination of management roles responsible for digital transformation (e.g., digital technology experts, architects, and engineers) as well as executives with more general management roles and extensive experience in the AEC industry. We coded the interviewees based on their role and assigned a random letter to protect their anonymity. Further details regarding our sample are provided in Appendix I. We performed 10 semistructured interviews with 12 senior executives at medium and large AEC firms within Australia as well as in industry associations (see Appendix II for interview protocol). These organizations provide variance for our study due to their diverse perspectives on the industry given their distinctly different clients, types of projects, and geographic scope (Appendix I). We conducted these interviews in 2020, with each interview varying between 60 and 90 min. We followed standard academic research protocols to collect and analyze the interview material through an inductive approach (Patton 2002). Content analysis was done by segmenting activities such as open coding to summarize each segment of data with a conceptual label. This process allowed us to discover patterns and themes in the data that were related to the research questions. Further, our interview findings were corroborated through a brief survey that was sent following the interviews to verify our exploratory findings, as well as through subsequent presentation of the provocations to the interviewees.

Provocations: Why Digital Transformation in the AEC Industry Is Hampered

Our analysis revealed several key challenges for the AEC industry, its firms, and their employees. We transformed these into six provocations, providing perspectives on three different levels of analysis: at the AEC industry level, at the firm level within this industry, and at the operational level within these firms. With this we invite constructive dialogue and debate across disciplinary boundaries. Our work is intended to define the emerging challenges so that corrective actions might be better informed. We strive to specify what is; we are not pejorative because the industry has evolved to meet the past and present needs. Rather, we wish to lay out the present state of the industry, and its readiness for a likely forthcoming digital transformation through the lens of business and management theory.

Provocation 1: The AEC industry is characterized by various field-level barriers for strategic innovation.

> We are very much entrenched in an industry which spans hundreds of years in construction and building, and in some cases not a lot of that has changed, and I don't expect it to necessarily change overnight. (Senior Manager C)

The AEC industry operates under a range of legal and wider socioeconomic constraints that leave little room for the adoption of disruptive innovation. For starters, and as well documented in other compliance-driven industries, such as in professional service firms or the public sector, there prevails a high level of failure-avoidance culture (Empson et al. 2015; Gardner 2012; Keith and Frese 2011). The legal-bureaucratic procedures produce an environment with little to no reward for being boldly innovative or strategically forward looking; actors in the field are busy enough adhering to the existing array of building codes and norms, perceiving evidence as a source of justification (or protection) rather than a source for innovative ideas (Criado-Perez et al. 2020b; Gardner 2019). Professionals in the AEC industry often point to industry-wide routines and expectations that hinder their ability to propose innovative approaches to their work.

More broadly, the AEC industry is characterized by rather big capital investments with comparatively small margins and limited financial slack, resulting in a rather hostile environment for any corrections—or, put in different terminology, innovation. In Australia, average profit margins in the architecture industry stand at 13%, with annual revenues declining at −5.2%, compared to the construction industry where average profit margins are 7.1% (lower in major cities) and annual revenues are declining at −0.66% (Baikie 2021; Kelly 2021). The declining revenues and low margins, in combination with the large investments required and the considerable possibility for cost overruns, result in a highly risk-averse approach within AEC. A single failed project has the capacity to put a firm's survival at risk; hence, the road most traveled often remains the most attractive. Tightly managing risk (and potential failure) is viewed as prudent practice in the industry. All this has ripple effects across the AEC industry in terms of an unfavorable climate for innovation and a pronounced past-orientedness in managing the complexity of each project. Such an environment of stifled innovation will hamper firms' ability to adapt when necessary. Indeed, when our interviewees were asked to rate to what degree their firms are flexible enough to adapt to the changing environment, respondents reported an average of 59 out of 100. The mantra was captured succinctly in a quote from Criado-Perez et al.'s (2020b) study on evidence-based decision-making in AEC: "For our industry, evidence is that we've delivered it before—and it works." (p. 31).

Provocation 2: The fragmented AEC industry is ill prepared for strategic collective action in the face of novel challenges.

The AEC industry has been characterized as a highly fragmented field with a number of heterogenous actors, often with divergent goals, objectives, and criteria for legitimacy (Cherns and Bryant 1984; Lai et al. 2019; Rezgui and Zarli 2006). Despite technical overlaps, architecture, engineering, and construction encompass rather different approaches, tasks, constraints, and required expertise. Further, each of these professions do business with a diverse range of clients and stakeholders that vary greatly in terms of their demands and expectations (such as in cost-efficiency, sustainability, occupants' well-being). This diversity in stakeholder demands and the opportunities provided by digital technologies has also led, per our observation, to a tendency toward increased specialization of tasks as well as to the formation of vested interests—which, in turn, further exacerbate the existing plurality and fragmentation. Such tendencies prevent concerted efforts toward strategic collective action that tackles the emerging challenges head-on.

> Now on the most humdrum boring apartment building, it's multiple levels, car park, probably has a retail in, it may have an office or whatever, 25–30 consultants is the minimum. So, there are so many consultants because buildings are more complex and they will continue to become more complex

[. . .] there's a myriad of so many other consultants who are feeding information in that needs to go into this model. (Senior Manager D)

Moreover, from a sociological perspective, cultural differences abound. With rather different professions involved, social actors in the field are characterized by several competing rationales for action, including legal/compliance oriented, economic/business oriented, technical/task oriented, and creative/design oriented. For instance, a legal/compliance-oriented rationale might prioritize conservative designs with a proven track record, whereas the creative/design-oriented rational might value going beyond what has been replicated in multiple buildings. Such rivalry of guiding rationales and criteria for legitimacy, as well as their consequences, has been well documented in the proliferating literature on institutional logics, plurality, and complexity [for an overview, see Greenwood et al. (2011), Meyer and Höllerer (2016), and Thornton et al. (2012)].

As a direct consequence, a fragmented institutional infrastructure (Hinings et al. 2017) (e.g., systems and a relational network of actors that bind a field together) as well as a lack of collective governance and planning of the overall industry are features we clearly witness for the AEC sector, at least in the Australian case. The lack of integration between the different professions and key players in the AEC industry has also been reported for the UK (Sawhney et al. 2020) and referred to as vertical fragmentation. Self-interested behavior and difficulties in adopting collaborative tools effectively are some of the highlighted consequences of this lack of integration (Zomer et al. 2021). Such fragmentation and plurality of differing professional values among AEC specialists obscure the possibility for an efficient and collaborative approach to the industries problems and opportunities (Bos-de Vos et al. 2019; Fellows and Liu 2012; Thornton et al. 2012). For instance, customers' increased expectations for smart and sustainable buildings might be at odds with established protocols, legal norms, economic constraints, or limited capabilities of the various trades involved in the delivery—preventing, as our informants reported, fully integrated digital solutions from the design phase to lifetime maintenance of a building. As such, the ability to coalesce strategic collective action and adaptation to a changing landscape for the entire industry is hampered.

Provocation 3: Strategic thinking regarding business models and how digital transformation may radically shift business models is generally nascent in AEC firms.

> We're still having some friction between understanding that the strategy needs to actually move beyond just seeing the project, as the architectural project is the only thing that we do. And as a mark of quality, and science, think about other services that we can offer in the market that move beyond that. (Digital Technology Leader B)

> We don't really challenge the methodologies or the ways that we do things using technology. And we don't actually leverage technology as a way to uncover new opportunities. (Digital Technology Leader B)

> I don't think we are a collective group saying, this is where we're headed, and this is what we're expecting. The greater body is just going on. (Senior Manager J)

The current way AEC business is conducted, with nonrepetitive activities and complex interactions of the components and actors involved, has constrained both digital transformation and the development of strategic business thinking in many firms. Our interviews and assessments indicate that most AEC firms have limited

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resources in business foresight and long-term strategic planning. On the surface, this is surprising because AEC firms are designing and constructing facilities that have long lives. However, the focus is on current execution and delivery of projects, not the long-term business health. Our interviews and assessments also indicate that there is very limited organization-wide acknowledgment of the underlying business model of AEC firms in terms of value proposition, value capture/appropriation, and value distribution. Further, our interviewees reported an average of 65% when asked to rate how clearly they can view what their future business model will look. These aspects are concerning because they have been indicated as important to other firms progress in arenas of digital transformation (Ross et al. 2019).

Given the industry structure, diversity of clients, and specific client expectations, the industry has developed skills and capabilities in efficiently developing designs using rational project management approaches. The competitive situation and low-price-bidder-wins environment force efficiency to be a high priority over flexibility and innovation, while meeting project requirements forces a largely reactive business approach for most firms. When asked to rank a list of potential drivers for the adoption of digital technology, our interviewees listed faster delivery and efficient use of resources as top drivers, whereas future-oriented drivers such as service enhancement, organizational direction, and environmental sustainability were listed last. As a result of these pressures and priorities, current activity—finding, bidding, and managing projects efficiently—consumes most organizational time, leaving little time for strategic thinking about the future of digital technologies or business models. Further, the reactive, project-based approach to business strategy precludes development of capability in business foresight and long-term strategic planning. Supporting this perspective, a recent industry report indicates that fewer than 20% of AEC firms in the Asia–Pacific region are working on initiatives to create a strategic plan for implementing technology (Deltek 2020).

> We're still having some friction between understanding that the strategy needs to actually move beyond just seeing the project. (Digital Technology Leader B)

> Essentially that's what we're trying to do. We're trying to get throughput, we're trying to get things to happen quicker, leaner, more efficient. (Digital Technology Leader C)

> There's a lot of competition. We have been hurting each other by a race to the bottom on fees. (Senior Manager J)

Developing business foresight and adapting during a digital transformation requires an understanding of the existing business model (Aspara et al. 2013). That is, an understanding of the value-creating interlinkages within existing business model enables firms to retain business model elements that are considered contributors to the firm's success while renewing those that are not beneficial to value creation, delivery, and capture (Aspara et al. 2013; Snihur and Zott 2020). As Johnson et al. (2008, p. 3) note, "few companies understand their existing business model well enough [...], its natural interdependencies, and its strengths and limitations." Our interviews and assessments suggest that this limited understanding of business models is also common among AEC firms. This is crucial, because without an understanding of the linkages of existing activities and stakeholders, firms will struggle to recognize opportunities presented by digital technologies, and to transform their activities in a coherent way that helps them achieve their business goals. As a result, we find that firms lack confidence in knowing which activities to augment with digitization and which activities to renew and/or replace.

We don't necessarily have a focus for where we invest in terms of research or innovation. There's no larger ethos to which to attach that, and because of that it makes it very, very hard to put forward proposals for research or technological innovation because you can't talk to whether this is satisfying some kind of goal for the company as a whole. (Digital Technology Leader B)

Provocation 4: Investments in a digital transformation are most frequently reactive and fragmented rather than strategically driven.

> Technologists are keen to jump onto the next thing and the next thing. [The] biggest concern with digital transformation is that we need to prioritize and do it properly, and finish what we started. (Senior Manager C)

> I feel like we're far too worried about making the wrong move [. . .]. What we're doing is even worse, which is making no moves. (Digital Technology Leader B)

Our analysis indicates that the majority of AEC firms focus their attention on delivering projects and thus are very reactive regarding digital technology. By reactive, we mean that firms respond when (1) a client demands a shift in technology to win bids or deliver projects to requirements; (2) the economic benefit is clear and demonstrated by others, and the competitive position is at risk; or (3) there is no longer capacity/capability to continue using legacy approaches (such as antiquated information systems). There is external pressure from some clients and regulators to step up in terms of digital technology. For example, a number of governments have made the use of BIM mandatory (e.g., Teo et al. 2015) and industry associations in Australia and around the globe are calling for similar requirements (Gruszka et al. 2017; Porwal and Hewage 2013). However, such requirements from the external stakeholders will also lead to reactive investments to maintain legitimacy in the eyes of a large array of potential clients. Overall, for most AEC firms, this results in a strategy of complying to stakeholder demands—but do not go beyond them.

Complying with stakeholder demands, even when forward looking, is still reactive. While we observed proactivity and digital experimentation in some interviewed firms, much of this activity seemed underdirected—that is, highly improvisational. Our observation aligns with other industry analyses where a majority of firms within the AEC sector (67%) report their digital transformation initiatives to be either disconnected with the company's strategy or executed ad hoc due to a lack of predictability (Deltek 2020).

> We just don't have enough data out there to be able to make those decisions. (Senior Manager K)

Without boundary constraints and direction, such improvisational activities have a low probability to deliver valuable outcomes for the firm (Davis et al. 2009). A clear vision and strategic implementation plan for the digital technology being adopted have also been identified in a recent systematic review as one of the most salient enablers for BIM adoption and its contribution to firm performance in the AEC industry (Abbasnejad et al. 2020). More broadly, many firms in different industries have experienced poor returns on investments in digital technologies largely when the projects are not thoughtfully or strategically selected (Sutcliff et al. 2019). The lack of clarity and commitment to business foresight, long-term strategic planning, and explicit business model understanding (Provocation 3) also aggravates the ability to guide digital transformation investments.

Provocation 5: AEC firms are failing to adopt an orchestrated and common approach to digital technology impeding effective collaboration.

There's a lack of standards established. There's a perception that, well, who knows when it's going to happen. Are there going to be more standards coming in for more digital technologies like BIM? It's a question mark. (Senior Manager J)

There isn't a clear definition in Australia for BIM, because do we use the British system? Do we use the American system? Do we use some developers will have their own definitions? So it's understanding what level is required because it's not consistent. So it's like anything, if you want to get strength in an industry, you need to have clear definitions of what the expectations are. (Senior Manager E)

Half the work we do is trying to get the data to be consistent, and the other half is writing the stuff that works with that consistent data, and once it's consistent, that's when things take off [. . .]. As long as that data is kept consistent, or in a consistent structure, the reports should be instantaneous. (Digital Technology Leader A)

An increasingly important driver of productivity for knowledge workers is information and communications technology that facilitates easy and timely access to accurate information (Criado-Perez et al. 2020a; Lim et al. 2011). Digital workflows consolidate vast arrays of information efficiently. This creates timely access to information such as through cloud-based BIM and other software. Such technical data have historically been experienced as quite static in industries such as architecture, whereas now the various stakeholders involved in the design and development of projects could potentially access and update this information, making for a dynamic and efficient workflow. The benefits of using a common standard and having a digitally centralized and shared source of information are substantial for all parties involved, reducing lead times and costs by improving coordination and collaboration (Barlish and Sullivan 2012; Bryde et al. 2013). Efforts to reach such a goal were emphasized in several of our interviews:

We are bringing more and more digital workflows into the process to try and either make things interoperable between one program and another, or to automate certain things, things that architects really don't want to do, like schedules, and to create a single source of information that then trickles down. (Digital Technology Leader A)

Despite the appeal for a more collaborative process within a common platform, research suggests the AEC industry is struggling to capitalize on this opportunity. In fact, 40% of Australian firms report very little collaboration between their firms' departments (Deltek 2020). These difficulties shed light on how the success of an innovative tool, or any substantial digital transformation, will depend on more than the IT solutions available. Indeed, research that examined 27 different industries supports that an integrated digital strategy drives a digital transformation more so than technology (Kane et al. 2015). These findings align with more recent research that highlights the high rates of failures of digital transformation when the digital strategy and the business strategy are not closely integrated (Baeza et al. 2021). The use of a digital centralized platform will only be adopted and helpful if the organization is ready to use it properly—that is if the employees perceive support from the top management for a clear road map and an alignment with the strategy of the firm (Ali and Miller 2017; Holland and Light 1999).

Further, the impact of digital centralized platforms goes beyond technological aspects, impacting the nature of tasks and the required knowledge, processes, and trust between stakeholders (Liu et al. 2017). That is, the evolving digital innovations and a true digital transformation in the AEC industry will influence the professionals' roles, and increase the required alignment and collaboration between stakeholders (Bos-de Vos et al. 2019). Unfortunately, as presented by our previous provocations, the AEC industry is typically characterized by a fragmentation between professions within a project team, but also between phases of the project to transfer critical information, and between previous and future projects to facilitate learning (Sawhney et al. 2020). As a result, the introduction of various digital tools and collaborative systems can result in overlapping platforms with contradictory information, failing to facilitate easy and timely access to information that is viewed as accurate and trustworthy (cf. Ross et al. 2019; Wade et al. 2019).

Provocation 6: Crucial knowledge and skills required to harness the benefits of a digital transformation are lacking in the sector.

Technology is definitely a constraint, but the only way to break that constraint is through technology, right? [. . .] So, we need people who know how to use tech to its full capability for us to be able to get past those constraints. (Digital Technology Leader A)

As the digital technologies reshape the business models of firms in the AEC industry, the role of professionals in this sector is evolving (Bos-de Vos et al. 2019). Digital skills are increasingly necessary and often lacking, and yet these skills alone will be insufficient for a digital transformation. Other aspects of the workplace—culture, leadership, ecosystem networks, and the design of work tasks—will also need to be transformed to support different ways of working. Hence, management skills are also required as digital transformation changes what work is done as well as how work is completed (Gagné et al. 2021). Managers will be required to evaluate what needs to be transformed beyond the skills of individuals to support such changes.

Previous research has highlighted the importance of creating the right business environment, as well as providing adequate training to develop digital capabilities and facilitate the adoption of technological innovations (Gu and London 2010). Achieving this has proven important but difficult in the AEC industry. Our interviewees indicated that despite their efforts, they had only been 51% effective in retraining managers for digital capabilities and only 63% effective in finding suppliers or partners to fill digital skill gaps. Thus, a shortage of adequate training and technical support is hampering digital capability development, but training alone is likely insufficient to transform capabilities in the required time frame.

Drawing from the management literature, this is unsurprising. Training is typically voluntary, resulting in selection of those who are most motivated and/or capable, and once trained, skills transfer can be problematic (Blume et al. 2010), with other aspects of the organization hindering progress, a wider view of changing skills is starting to be acknowledged. This point also emerged in two interviews:

I just think there's not enough education training and that sort of systematic and systemic framework available to be able to implement [digital technology and the required transformation]. (Senior Manager K)
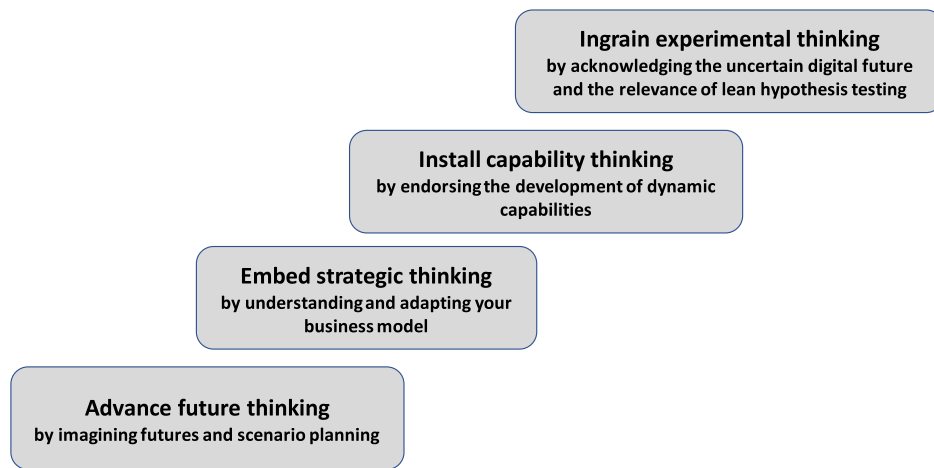
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Fig. 1. Framework of four leadership thinking schemas to aid digital transformation.

[Technology] seems to be able to enhance every factor of what we do. We haven't discovered a single element of how we deliver architecture that can't be enhanced by technology. But, that being said, processes that include the way people think and work in architecture intuitively are just as important, and hence, investing in technology to be able to attach to that is really important. (Digital Technology Leader A)

Put differently, digital skills development is necessary but, on its own, insufficient. Digital transformation requires technical knowledge and skills development *as well as* adapting routines and job designs to facilitate the application of the newly acquired skills. Furthermore, digitally driven projects frequently increase the diversity and complexity of interorganizational activities (Provocation 2), and the boundaries between architects, engineers, builders, and specialized consultants become increasingly blurred. Digital transformations will also require such actors to *pioneer* in interdisciplinary arenas that require a completely different know-how (Laurent and Leicht 2019). As such, the knowledge and skills required for professionals in a digitally transformed AEC industry are currently lacking.

Shaping the Digital Future of the AEC Industry: Four Thinking Schemas to Cultivate

Our investigation and the subsequent provocations are grounded in a view that digital technologies will create ongoing change in the AEC industry and at some juncture may reach an inflection point (where the pace of change accelerates). In an anticipated changing future business environment, the management literature strongly advocates structured planning processes to assess, understand, and make informed choices—that is, to establish a deliberate strategy road map (Arend et al. 2017; Puthiyamadam 2017; Venkatraman 2019) and to build organizational change readiness (Rafferty et al. 2013; Stouten et al. 2018). Because the AEC industry is not alone in facing digital disruption (Ross et al. 2019; Venkatraman 2017), we take the view that valuable evidence and ideas on effective ways to strategize and prepare for digital transformation can be found in other industry sectors that have been similarly impacted over the last two decades (e.g., retail and media).

From the immense literature on management theory, we coalesced (through a multiple-round idea generation and debating process of the coauthor team) on a limited number of practices and initiatives based on their prevalence in the literature, relevance to the six provocations, pertinence to digital transformations, and relationship with creative-technology industries. Acknowledging that support for organizational change as well as resistance to change have been associated with mindsets and mental models of organizational leaders and employees (Gary and Wood 2011; Solberg et al. 2020), we accumulate these practices and initiatives under four distinct thinking schemas. In this, we join other scholars in the AEC literature (and beyond) to examine thinking approaches; for example, systems thinking (e.g., Huber et al. 2020), agile thinking (e.g., Shaughnessy 2018), and lean thinking (e.g., Tommelein 2015). We refer to the four thinking schemas as leadership thinking, defined as ways in which "business organizational needs are met successfully when there are leaders in place who understand their people, industry, and societal concerns" (Johnson 2021, p. 1). Our four distinct leadership thinking schemas are visually presented in Fig. 1 and subsequently further unpacked: future thinking, strategic thinking, capability thinking, and experimental thinking. We view cultivating these thinking schemas as building stronger stepping stones toward *digital transformation readiness*.

Advance Future Thinking by Imagining Futures and Scenario Planning

"If you do not know where you are going, any road will take you there (Carroll 2015)." This famous quote by the Cheshire cat from *Alice in Wonderland* provides the underpinning for future thinking. To properly consider what path to take, it is necessary to have some concept of where one would like to go. Scoping and scaling possible futures aid the development of vision, intent, and purpose of the organization to better fit with the evolving context.

Foresight is imperfect because the future is largely unknown and unpredictable. To prepare under such circumstances, the strategic management literature recommends the use of scenario-driven thinking (Andries et al. 2020) and envisaged futures (Beckert 2021) to explore and discover the spectrum of possibilities (Schwartz 1991). The future can be simulated as imaginative constructions of hypothetical events or scenarios, and firms can engage in imagining possible mechanisms of change and the potential outcomes of different actions (Arikan et al. 2020). As one example, the information systems literature provides a specific set of guidelines for a future-ready design process (Pee et al. 2021). Such approaches allow for what strategy scholars refer to as future-making (Beckert

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2021; Wenzel 2021), a more strategic and proactive stance to shape the future. Shaping the future may include developing a view of clients' future value propositions, building a network that collectively influences how the industry evolves, and engaging with industry regulators. As such, organizations that engage in the creation of credible future scenarios and align stakeholders behind these scenarios gain power and control over their environment (Beckert 2021). This exercise is particularly important at a moment in time when digital technologies are providing multiple opportunities for AEC firms to shift their business models, but also for competitors and firms providing complementary products (e.g., IT providers) to disrupt the sector by gaining more power in the current ecosystem (Lavikka et al. 2018).

As a part of future thinking, AEC firms will need to understand client requirements and needs as well as how they may change with progress in digital technologies. Keeping a high focus on current clients as well as likely future clients is most frequently identified as the prime priority (Markey 2020; Mawdsley and Somaya 2018). Likewise, competitor actions need to be considered. One of the most challenging considerations is to project the actions of possible disruptors (Adner and Lieberman 2021; Ribeirinho et al. 2020). Further exasperating these challenges is understanding the exponential pace of technology changes where many people are striving to analyze trend lines and inflection points (Schoemaker and Tetlock 2016). Collectively, these different unknowable possibilities are why scenario analysis is suggested—so that action can be taken to enhance readiness for various plausible futures.

While organizational time and effort is required to build and evaluate future scenarios, when undertaken by the top management team, this effort naturally begins to reshape the vision and intent of the firm. Most will find such vision changes will benefit from additional change initiatives (Obwegeser et al. 2020) and many will define a leadership position/champion (Ernstsen et al. 2021; Wade and Obwegeser 2019) for managing the strategy as well as the digital initiatives. Overall, investments in future thinking underpins the ability to develop true strategic thinking in the organization.

Embed Strategic Thinking by Understanding and Proactively Changing Your Business Model

We need a strategy in a way that we've never needed it before. (Digital Technology Leader B)

The big paradigm shift is happening now is that people need to start thinking of these [digital] things as models, rather than drawings. And I guess a great analogy would be ... You wouldn't want a business drawing, you want a business model. (Digital Technology Leader A)

In times of transformational change, the optimum solution is unlikely clear. Prudent advice is to proactively consider strategic alternatives and make choices consciously and judiciously based on the available evidence. Inferences in the management literature suggest that strategic thinking will be increasingly important to respond to and keep pace with the novel challenges in the AEC industry. This will require managers to examine their business models as well as potential ecosystems that they can develop and orchestrate (Ross et al. 2019; Wade et al. 2019).

To understand existing business models, research on strategic management recommends taking an activity-system view (Zott and Amit 2008; Zott et al. 2011). This approach begins with a detailed understanding of the activities that allow the firm to create and capture value for its customers. The process of analyzing

a business model as a system of interrelated components and activities promotes understanding and questioning (Osterwalder and Pigneur 2010). More specifically, firms are likely to reveal the assumptions that need to be challenged, identify possible threats and opportunities, and develop a pathway toward an improved business model that maintains a competitive advantage. Business model analysis can be undertaken at different levels such as functional areas, projects, and firms, as well as industries.

Business model understanding along with digital technology awareness almost always enhances the focus on data. Organizations should be increasingly thinking about how to enable operating decisions by machines fueled by data and managed by algorithms rather than by humans (Zeng 2018). Digital business models are more than using digital technology to do the work of today, they frequently move firms from product/service provision into providing more complete solutions (Ernstsen et al. 2021; Venkatraman 2017). This type of digital, solution-oriented business model requires that organizations gather deep insights on customers, build a digital operating backbone (significant effort toward standardizing and digitizing), and think of a digital approach as a platform to manage digital components (Ross et al. 2019). Increasingly, prudent proactive firms are developing multiple business models and managing them distinctly, especially when disruptors enter their market (Markides and Oyon 2010).

Digital business models frequently include the idea of being an orchestrator of ecosystem players or being a player in an ecosystem. Ecosystems move substantially beyond traditional supplier-customer relationships, whereby they establish novel relationships and contracts to share both risks and rewards. As one example, in ecosystems management, a higher focus is given to ecosystem value than customer value because maintaining the ecosystem is critical to perpetuating the ability to deliver customer value in the future (Van Alstyne et al. 2016). The logic underpinning this approach is straightforward: managing risk in uncertain digital arenas through risk sharing. While many AEC firms collaborate on projects, some are strongly imprinted to protect intellectual property rather than work in shared-value ways. An ecosystem orchestration strategy takes substantial effort—to manage multiple partners that may include startup ventures, academia, government organizations, and other businesses—yet it provides a way to compete with larger firms such as the digital giants—Google, Microsoft, and Apple (Ross et al. 2019).

Install Capability Thinking by Endorsing the Development of Dynamic Capabilities

The digital knowledge, skills, and capabilities required in the AEC industry have evolved and are anticipated to continue to evolve—if not radically shift. Digital transformations most frequently prompt an uncertain, complex, and fast-moving environment. This environment is created by the convergence of the fast pace of digital technology progress, the response of savvy competitors and peripheral suppliers, the enablement of new competitors and suppliers, and the demands of clients for new solutions and improvements that make use of these technologies. The competitor offerings and client demands are often at odds with the existing capabilities of many firms. Consequently, such AEC firms will benefit from developing the ability to quickly adapt or proactively respond to their environment by incorporating the relevant knowledge and capabilities (Teece and Leih 2016). The ability to sense opportunities and rapidly create new capabilities to seize the sensed opportunities is called dynamic capabilities (Teece 2007; Teece et al. 1997). A capability comprises a set of resources, skills (knowledge), and activities that delivers desired organizational outcomes. As such,

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dynamic capabilities require that firms be able to integrate, build, and reconfigure internal and external (e.g., ecosystem partners) resources and management systems to address rapidly changing business environments (Helfat and Peteraf 2015).

The necessity of upskilling in digital technology skills and digital capability is not unique to the AEC industry. A myriad of sectors are impacted by this trend. In most cases, it is uncertain what specific skills will be required for future jobs, but we can be confident that many of these skills will be digitally oriented (Davenport and Westerman 2021). In addition to digital technology skills, many organizations are prioritizing the competence of their management team in digital technology and the management of technology professionals. As an example, Amazon has committed to spend $700 million on retraining on digital skills with a particular focus on teaching software engineering skills to its nontechnical corporate staff. Indeed, companies like Amazon are not focusing on specific digital skills but are preparing their leaders and staff for the digital economy and evolving (or radically shifting) technology.

Traditionally, organizations have relied on educational institutions to deliver graduates with sufficient knowledge and training for their career. Acknowledging that this can no longer be the case, firms have adapted to a changing environment by emphasizing employee training. Yet, training is typically a one-off or transactional event, which does not provide the required ongoing learning and support for employees to apply their new skills appropriately and adapt their job processes. In environments that are uncertain and unpredictable—such as digital transformation environments—the required training and subsequent skills are uncertain and evolving. As such, a whole-organization approach including the rapid adaptation of work design and routines is increasingly becoming standard practice within digitally disrupted industries (Gagné et al. 2021).

Organizational capabilities are frequently captured in organizational routines, rules, policies, and management systems as well as employees and managers. To update capabilities, AEC firms may have to unlearn what they have learned. Indeed, dynamic capabilities scholars argue that the process of learning to unlearn followed by learning to learn is important in the development of dynamic capabilities—and is often difficult to achieve (Fainshmidt et al. 2016). A relevant part of organizational capability and knowledge resides in collaborators outside the firm and in collaboration processes (Figueiredo and Piana 2018). Following from the preceding perspectives, dynamically managing capabilities is becoming one of the top strategic issues for organizations. This is because the development of dynamic capabilities requires much more than skills training for technologists; it requires thinking and action on skills, knowledge, collaborators, managers, management systems, and organizational culture (e.g., Ambrosini et al. 2009).

Ingrain Experimental Thinking by Acknowledging the Uncertain Digital Future and the Relevance of Lean Hypothesis Testing

The fast pace yet uncertainty of digital technology evolution and digital transformation have made clear that unpredictability rules the day. Organizations evolving through and living in digital transformations and digital environments most frequently operate using agile, lean start-up concepts (Beck et al. 2001; Ries 2011) wherein exploration, experimentation, and hypothesis testing become commonplace. This has also been called discovery-driven planning (e.g., McGrath and McManus 2020). Minimum viable product (MVP) experiments are particularly challenging for traditional organizations to accept as good practice. However, they minimize

total costs and increase the speed of learning, thereby increasing the speed of development. Indications are that MVP experiments will be particularly challenging for AEC firms because a part of the intent is to fail fast, promoting learning over success rates, while AEC firms have organizational cultures aimed at avoiding errors and failure altogether. For many organizations, the pace and uncertainty leads to a strategy through experiments, where directional intent is clear but hard targets of traditional goal setting are intentionally lacking (Doerr 2018). In this experimental thinking approach, organizational culture and strategy (with its associated structures and systems) need to work in tandem. The culture needs to promote/accept experimentation and the strategy needs to guide, that is, provide boundaries for, the experimentation on how to work with digital approaches and management systems. Many legacy companies in other industries (e.g., retail, distribution) have used this experimental, discovery-driven, learning approach to evolve their organization toward digital solutions while simultaneously managing the current business (McGrath and McManus 2020).

Reflections

Is There a Case for a Purely Reactive—A Do Nothing Until You Have to—Strategy?

The uncertainty and riskiness of digital transformation may cause some to ask why not keep doing what you have always done and change as little as possible until required by clients? Because strategy is indeed a choice, it is an option. Further, there may be remaining traditional niches after digital transformation of the industry—even today some companies make candles even though electric lighting covers most of the market for light. While digital technology is rapidly evolving, the possible inflection point for the AEC industry is difficult to predict and the market hype does not always match the reality (Wade et al. 2020). Careful assessment and ongoing monitoring of the firm's situation is nevertheless recommended.

Some companies may not be able to afford digital investments. Digital investments remain risky and some AEC firms simply may not have the resources or risk tolerance for such investments. Digital transformation in the AEC industry is moving much slower than many projected (Howard et al. 1989), so there may indeed be time to adapt in a more conventional way. However, fast reaction to new requirements may be constrained by lack of internal capability and lack of market access to such capability. Building internal capability, ecosystem capability, and the necessary systems that bind and coordinate an industry also requires time, which may not be available anymore if a firm waits too long. If an organization chooses the reactive strategy, the literature suggests building approaches to monitor the environment so that weak signals quickly gain management attention and responsive action is expedited (Schoemaker and Day 2009). In other words, build an early warning system and develop latent preparedness.

How Do the Four Thinking Schemas Build on Each Other to Change an Organization?

We have proposed a framework consisting of four leadership thinking schemas and corresponding actions to aid digital transformation and digital transformation readiness in the AEC industry. As presented in Fig. 1, we propose that each of the schemas will generally become a stepping stone for the following schema. That is, future thinking and scenario planning (Schema 1) will enable managers to better understand plausible scenarios, which in turn will inform their strategic thinking and the required proactive changes to their

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business model (Schema 2) (Beckert and Suckert 2020). Further, once managers understand how they intend to adapt their business model they can develop their firms' approach to capability building accordingly (Schema 3) and begin experimenting with the most effective ways to achieve their future goals (Schema 4). However, iterative processes between the schemas will likely emerge and the optimal order in which organizations should build on these schemas does not necessarily follow a linearly ordered, one-size fits all approach. For example, building capabilities and embedding experimental thinking may unveil new scenarios to consider and promising strategies to pursue. This may be particularly evident in the digital transformation of the AEC sector because upper management will likely benefit from insights provided by tech-savvy employees working on the front line.

Regardless, shifting the four thinking schemas that we have highlighted will be both important and difficult to achieve. We urge managers to consider change management strategies that rely on experimental thinking and strong scientific evidence to improve success probability. Business as usual and intuitive decision-making are less likely to be appropriate under novel environments (Kahneman and Klein 2009). While a full review of change management in digital transformation is beyond the scope of this paper, useful suggestions are prevalent in the management literature (Ross et al. 2019; Stouten et al. 2018; Venkatraman 2017). Key points include putting such items on the top of the leadership team agenda, assigning and empowering champions, realigning metrics and incentives, and repetitive consistent communication to build confidence in management's commitment to the new ways of thinking.

Future Research Investigations

We have offered six provocations representing the major challenges for the AEC industry, and proposed actions to aid digital transformation based on research in other industries. Future research may address some of the boundary conditions and limitations of this study to further examine or elaborate on the proposed provocations and actions. Although we relied on multiple sources of evidence to inform our provocations, we were able to interview only a limited number of managers from architecture and engineering firms. We did not interview managers from construction firms, who might have provided additional insights.

Further, in developing the proposed thinking schemas to aid digital transformation, we anticipate the transportability of ideas across industry boundaries. However, the AEC industry has several unique aspects that may reveal novel conceptualizations and prescriptions. We therefore encourage business and management scholars to work closely with AEC scholars to investigate this transformation process as it emerges across different levels of analysis. This paper highlights four leadership thinking schemas that crucially assist in preparing for digital transformation. These thinking schemas may also inform future research that aims to study the digital transformation strategies and actions that AEC firms take—and their success rates over time.

Conclusion

With the rapid advancement of digital technologies covering all walks of life, digital transformation is more than just a technological evolution. From a perspective of enabling business agility and changing the way people work to optimize business performance, proactive changes in the strategy and subsequent future business models of AEC firms will likely be called for—to be future ready. While we expect that digital transformation will eventually lead to profound changes in the global institutional fabric of the industry (Hwang and

Höllerer 2020), we hope that the provocations and insights presented here may assist AEC firms to better adapt—or to proactively create and shape a sustainable future. To this end, we provided a set of ideas and possible actions revolving around four leadership thinking schemas: future thinking, strategic thinking, capability thinking, and experimental thinking. Cultivating these thinking schemas should instigate more-informed questions and anticipatory actions, as well as prompt tackling the management issues equipped with an evidence-based approach. Our hope is that our work will enhance the probability of successfully navigating what might be one of the most significant challenges for the AEC industry so far.

Appendix I. Sample Characteristics

| | | | | Number of interviewees | |
| | | | Size (based on number of studios) | Digital technology leader | Senior director |
Organization	Specialization	Geographic scope			
1	Architecture	National	Large	2	2
2	Architecture	Regional	Medium	1	1
3	Engineering and development	Global	Large	1	1
4	Industry association	National	NA	—	2[a]
5	Industry association	National	NA	—	2[a]

[a]Interviews undertaken simultaneously.

Appendix II. Interview Protocol

Introduction

We will ask some questions about your organization's business situation and its strategies with a particular focus on digital technology. In this interview we are interested in all types of technology, including working from home technology and building information modeling (BIM), as well as artificial intelligence and automation technology.

The questions are open ended so that you may describe your organization's and your view (Questions in parentheses are follow-up prompts).

Current Business Situation

1. Please describe your organization's strategy and business model
2. How well is your strategy working? (e.g., are organizational goals and customer desires met?)
3. Please briefly describe what you see as the major shifts and trends within your industry with regard to technology, and how you see your organization affected.

Digital Activity

4. How does technology fit into the business strategy and practices? (What is working? What challenges emerge? What problems are you seeking to solve?)
5. Please describe your IT architecture. (What technologies are you working on, implementing, or purchasing? How do you currently manage digital data networks, digital infrastructure, and standardized processes to share data?)
6. How digitally innovative is your company compared to key competitors?

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Future Outlook

7. Focusing on technology, what is your future outlook for the business and the industry? (e.g., artificial intelligence and automation, BIM, working from home technology)
8. What are the barriers for achieving this future outlook? (e.g., workforce, managing innovation and change)

Data Availability Statement

Some or all data, models, or code generated or used during the study are proprietary or confidential in nature and may only be provided with restrictions. Sections of the interview transcriptions and survey responses may be shared with anonymized information about the names and company affiliation of interviewees. Due to the small sample size the authors will exclude information that may lead to a plausible identification.

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