Seizing opportunity in today's construction technology ecosystem

A new analysis of the construction technology ecosystem finds emerging trends, constellations of solutions, and an ever-increasing universe of technology use cases that are disrupting the way we plan, design, and execute projects.

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After decades of under-digitization, the engineering and construction (E&C) sector is making bold moves in a new era. Last year, we mapped the industry's technology ecosystem with a focus on the solutions that are proliferating in the construction phase of the project life cycle. The research shed light on the emergence of technology clusters, industry-wide technology investment of more than $10 billion in less than a decade, and the lack of integrated solutions that span three identified use case clusters: on-site execution ("field"), digital collaboration ("team"), and back-office and adjacencies ("office").

This year, we expanded the study to include the entire asset life cycle—concept and feasibility, design and engineering, preconstruction, construction, and operations and maintenance—across more than 2,400 technology solutions companies, creating the most comprehensive database of the construction ecosystem worldwide. In this article, we explore three key topics based on our latest research:

1. *What are the emerging trends from this year's research?* We explore how the landscape has changed over the past year in terms of constellations of technology, accelerated investment, and an expansion in the number of use cases.

2. *How will the market evolve in the coming years?* We discuss the changes we expect over the next few years, including continued fragmentation of the industry, which will lead to consolidation, as well as an intensifying fight for talent.

3. *How can the industry accelerate its transition to a digital future?* We outline recommendations for AEC firms, technology providers, and owners to accelerate the impact of technology.

1) What are the emerging trends from this year's research?

Three key trends are shaping the industry: emerging constellations of solutions around established use cases, accelerating technology investment, and an expanding set of promising use cases.

"Constellations" of solutions emerging around established use cases

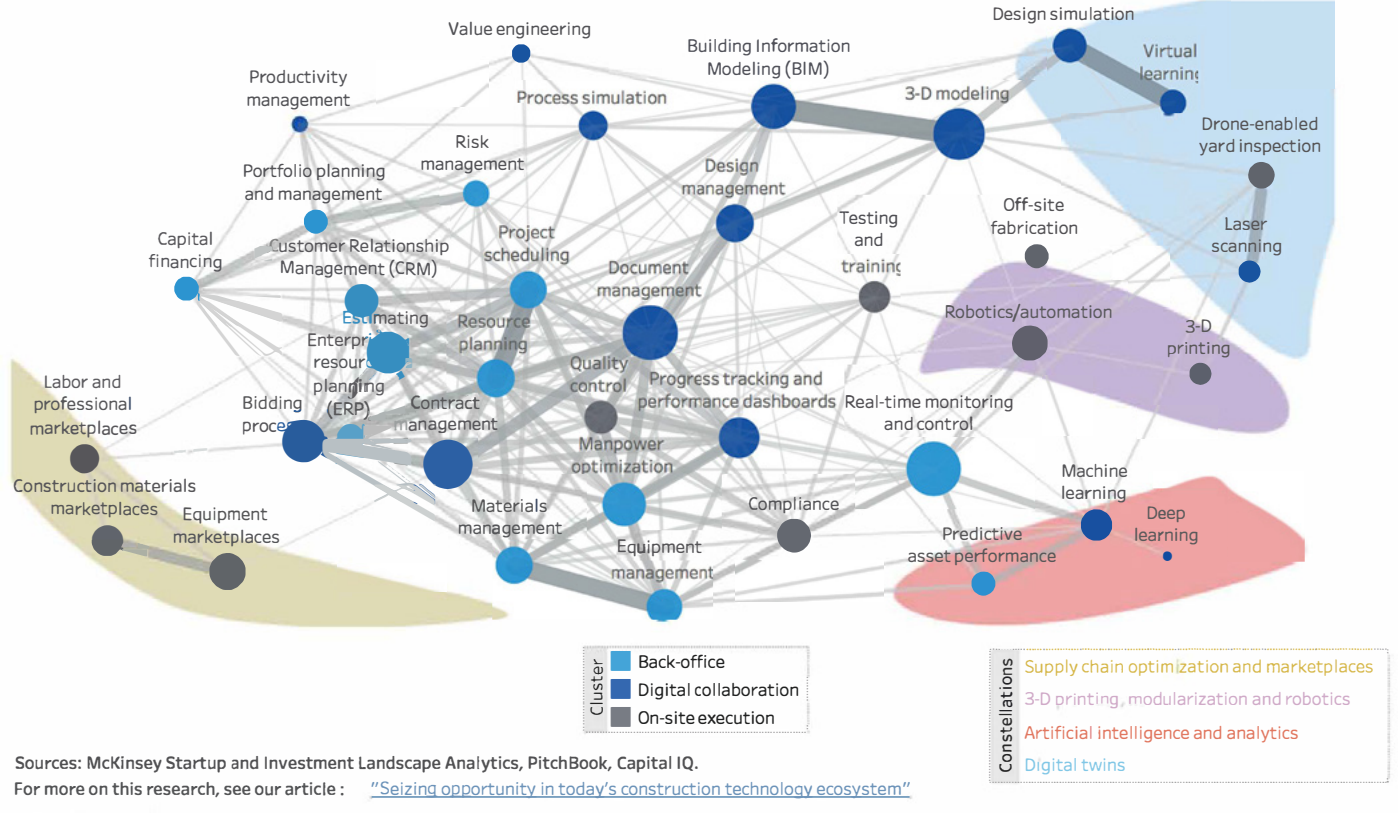
In our continuous mapping of the construction technology landscape, we see the concept of different "constellations" of connected solutions emerging around established use cases, which serve as indicators of what technologies are gaining the most traction and where their impact can be expected to rapidly increase in the near future. Today, the most prominent constellations include 3-D printing, modularization, and robotics; digital twin technology; artificial intelligence (AI) and analytics; and supply chain optimization and marketplaces.

Within each constellation are three or more use cases that span the three use case clusters we identified last year: on-site execution ("field"), digital collaboration ("team"), and back-office and adjacencies ("office"). For example, the digital twin technology constellation includes drone-enabled yard inspection, which is an on-site execution use case, as well as several digital collaboration use cases: laser scanning, virtual learning, and design simulation. In the sidebar, "Mapping the construction technology ecosystem," the thickness of the lines connecting various use cases indicates use cases that are often addressed together; in the digital twin technologies constellation, design simulation and virtual learning are strongly linked given the increasing amount of solutions offering these two uses cases in combination.

In particular, three of the constellations—3-D printing, modularization, and robotics; twin models; and artificial intelligence and analytics—are poised to be transformational for the industry. A fourth constellation, supply chain optimization and marketplaces, is notable due to its quick rise as dozens of smaller players have entered into this market over the past year.

Mapping the construction technology ecosystem

McKinsey analyzed the construction technology ecosystem to look for trends and constellations of activity around established and emerging use cases. Thicker lines connecting two use cases indicate a greater number of technology companies offering both technologies simultaneously.



Sources: McKinsey Startup and Investment Landscape Analytics, PitchBook, Capital IQ.
For more on this research, see our article : "Seizing opportunity in today's construction technology ecosystem"

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Artificial intelligence and analytics. In the long-term, AI and analytics have boundless potential use cases in E&C. Machine learning is gaining some momentum as an overarching use case (that is, one applicable to the entire construction life cycle, from preconstruction through O&M), particularly in reality capture (for example, in conjunction with computer vision) as well as for comparison of in situ field conditions with plans (for example, supporting twin models). Indeed, by applying machine learning to an ongoing project, schedules could be optimized to sequence tasks and hit target deadlines, and divergences from blueprints could be caught closer to real time and corrected using a variety of predetermined potential scenarios.

In the immediate future, we expect AI's proliferation in the E&C sector to be modest. Few leaders have the processes, resources, and existing data strategies in place to power the necessary algorithms and meaningfully implement this technology. However, the potential impact is so large that the industry can no longer afford to ignore it. AI methods are increasingly able to work across industries, elevating the threat of competition from nontraditional market entrants. And a narrow set of start-ups are already gaining market traction using AI-focused approaches.[1]

3-D printing, modularization, and robotics. Parts of the construction industry are moving toward a manufacturing-like system of mass production, relying on prefabricated, standardized components that are produced off-site. Our research finds that consistent use of these techniques, on projects where they are economically feasible, could boost the sector's productivity by five- to tenfold. Such a system would include applications such as fully automated prefabrication processes that turn a 2-D drawing or 3-D model into a prefabricated building component, or fabrication directly off a 3-D model or shop drawings; construction robotics such as bricklaying or welding robots; self-driving heavy machinery to make construction safer, faster, and more affordable; exoskeletons and wearable robotics to improve the mobility of workers with injuries or to harness the strength of robotic arms; and metal 3-D printing of long-lead components such as joints, enabling the production of high-performing components and, ultimately, more efficient, cost-effective parts.

On the robotics side, the E&C industry is at the beginning of its journey to embrace the hardware innovations that enable field augmentation with exoskeletons and drone-enabled yard. These advances are particularly important given a labor shortage in many geographies as well as the natural ceiling of human physical productivity. Pairing humans with robots can assist in tasks that would take a human worker more effort (for example, lifting heavy objects and placing them in exact coordinates).

Digital twin technology. In E&C, productivity gains are directly driven by transparency and proactive problem resolution. Digital twin platforms and reality-capture solutions enable stakeholders to minimize rework in the field by allowing a dynamic view of the project and real-time comparison of progress to design blueprints—and the ability to adapt those blueprints as the work progresses and inevitably results in changes. Drones and satellite imagery, as well as LiDAR and photosphere based-solutions, are key components of many reality-capture efforts.

The most exciting applications of twin models can be found in the seamless integration of 3-D models generated by drone imagery, turbocharged by live key performance indicators that are monitored using Internet of Things sensors. This approach creates an exact digital replica of a project's physical reality, allowing us to rapidly advance data accuracy and incorporate as-built data into 3-D models for automated, real-time progress updates. It also

enables users to virtually interact with "mixed reality" models that combine 3-D design and as-built configurations. What is truly exciting about these applications is the ability to reduce decision-making cycles in a construction project from a monthly basis to a daily basis through full automation of the project's scheduling and budgeting updates.

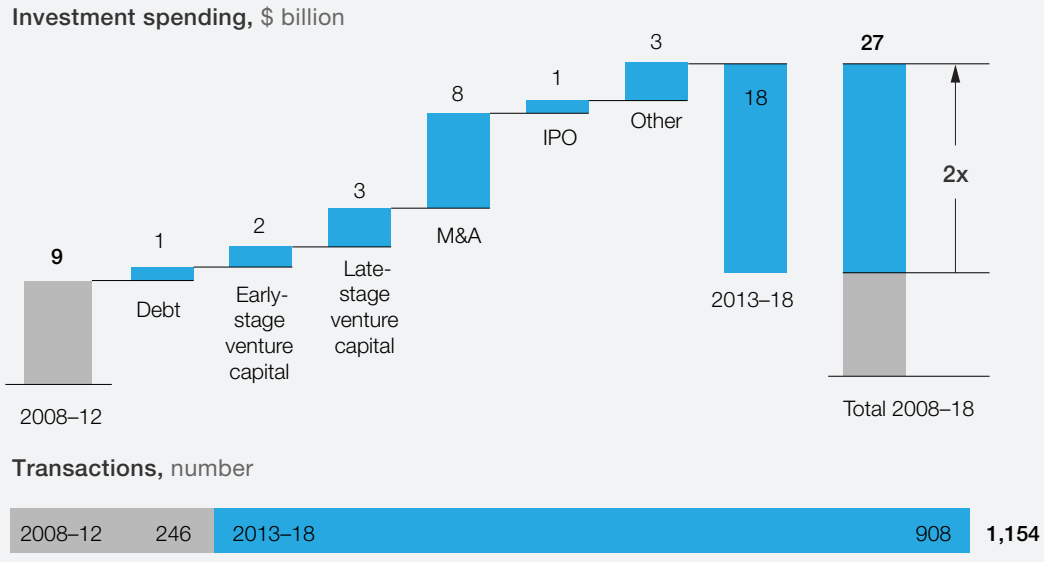
Supply chain optimization and marketplaces. Currently, procurement of materials, equipment, and labor is a largely manual and cumbersome process. However, start-ups that offer marketplace platforms for the buying and selling of goods as well as hiring have begun to gain traction in certain regions. Some of these start-ups have been acquired by large suppliers, which have quickly deployed these platforms at scale. By enabling players to match supply with demand, these marketplaces have huge potential to optimize the supply chain—much the way such marketplaces have revolutionized industries such as retail—improving productivity and profitability. In construction, these marketplaces can also enhance competitive bidding by improving transparency on costs and availability of materials, labor, and equipment for both future and ongoing projects. They will also become increasingly important given the rising use of prefabricated components that are manufactured off-site. Despite the progress, this constellation is nascent and limited to North America.

Increasing and evolving technology investment

Through the mapping of the investment flows we found two critical insights:

Investment has doubled in the past decade: Last year, we found that construction technology companies had garnered $10 billion in investment between 2011 and early 2017. Our updated research has pointed not only to a greater volume of outside investment but also an acceleration in investment. Between 2008 and 2012, construction technology received $9 billion in cumulative investment. Between 2013 and February 2018, that number doubled to $18 billion, largely driven by mergers and acquisitions (Exhibit 2).

Exhibit 2 Investment in construction technology has doubled over the past decade.



McKinsey&Company | **Source:** Pitchbook data

Early technologies are delivering on their promise: Our research reveals that by count of transactions, early-stage venture capital (VC) is on the rise. Of the 908 transactions from 2013 through February 2018, three in four were early-stage VC. Indeed, since 2015—a peak year for VC investments—the construction technology space has sustained a relatively high level of investment from VCs, suggesting that more solutions will be ready for scaling and that high levels of merger and acquisition (M&A) activity will continue unabated. M&A activity tends to occur one to two years after late-stage VC.

Furthermore, late-stage VC has been trending upward in the market (Exhibit 3). From 2010 onward, late-stage VC has almost steadily increased (except a small dip in 2016). Such a steady rise indicates that certain use cases are market-backed and ready for growth financing,[2] delivering on the promised impact.

An expanding set of use cases

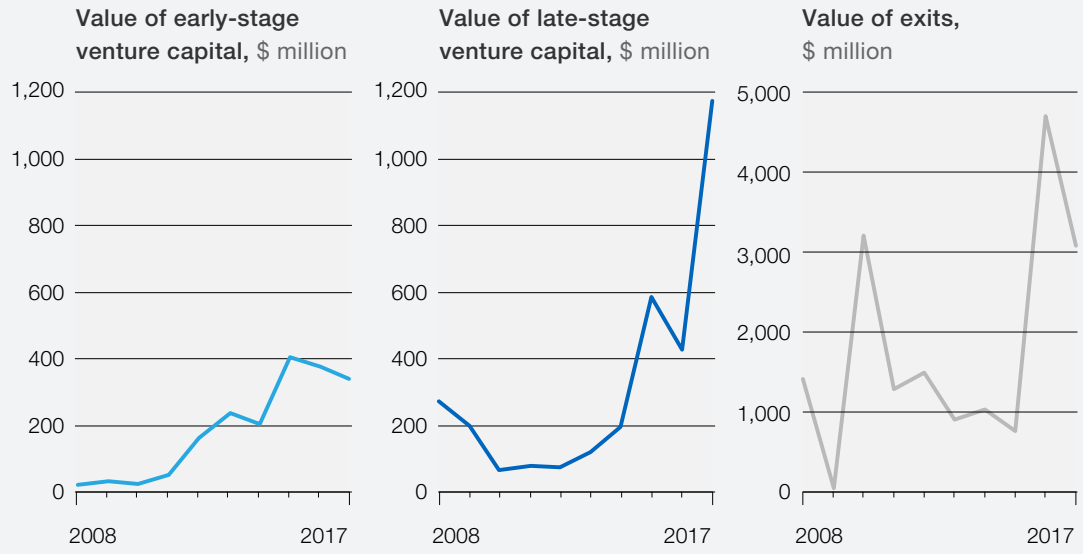
Last year, our research focused on technology in one phase of the asset life cycle: construction and commissioning. As we expanded our taxonomy to look at the entire asset life cycle, we found that two phases are attracting the most growth: construction and commissioning and operations and maintenance (Exhibit 4). Other phases tend to be already established—for instance, preconstruction and back-office—while others are small or still maturing.

Construction remains the highest invested phase of the asset life cycle. Construction leads the ecosystem in garnering the most overall capital from 2013 to February 2018, with both the highest number of use cases and the highest number of transactions. It is also relatively mature; only one-third of companies in this phase are newcomers. Over time, we expect to see M&A investments related

Exhibit 3

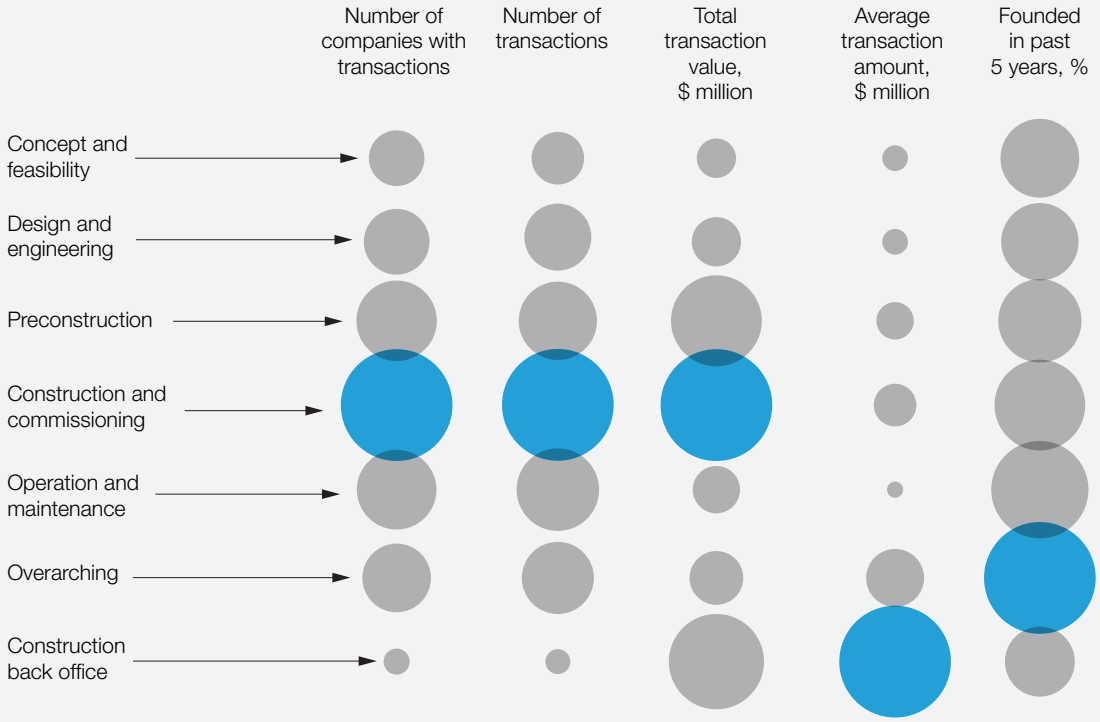
Early- and late-stage investments in venture capital have trended upward since 2008, whereas exits have peaked erratically.

Value of total transactions, (n = 676 unique companies)



McKinsey&Company | **Source:** Pitchbook data; McKinsey analysis

Exhibit 4



McKinsey&Company | **Source:** Pitchbook data; McKinsey analysis

to consolidation as well as incremental late-stage VC investments (for example, for scaling sales operations).

Preconstruction and construction back-office phases are both garnering large investments. Investment in the preconstruction phase is primarily driven by labor and equipment marketplaces, a relatively fragmented solution space where regionally focused players will eventually face consolidation. Construction back-office, on the other hand, is a very mature solution space. Investment in this phase is driven primarily by mature companies through M&A or private equity transactions with high average values.

Cross-cutting technologies are gaining the most momentum. We classified 3-D printing, virtual learning, design simulation, machine learning, and deep learning as "overarching," given their applicability across different stages of the life cycle. While we found relatively few transactions in this category compared with construction and commissioning, the number of companies founded in this space over the past five years exceeds any other category, and the dollar value of transactions is quickly catching up with the rest of the categories. The average transaction amount is particularly high in capital-intensive use cases in this category such as 3-D printing.

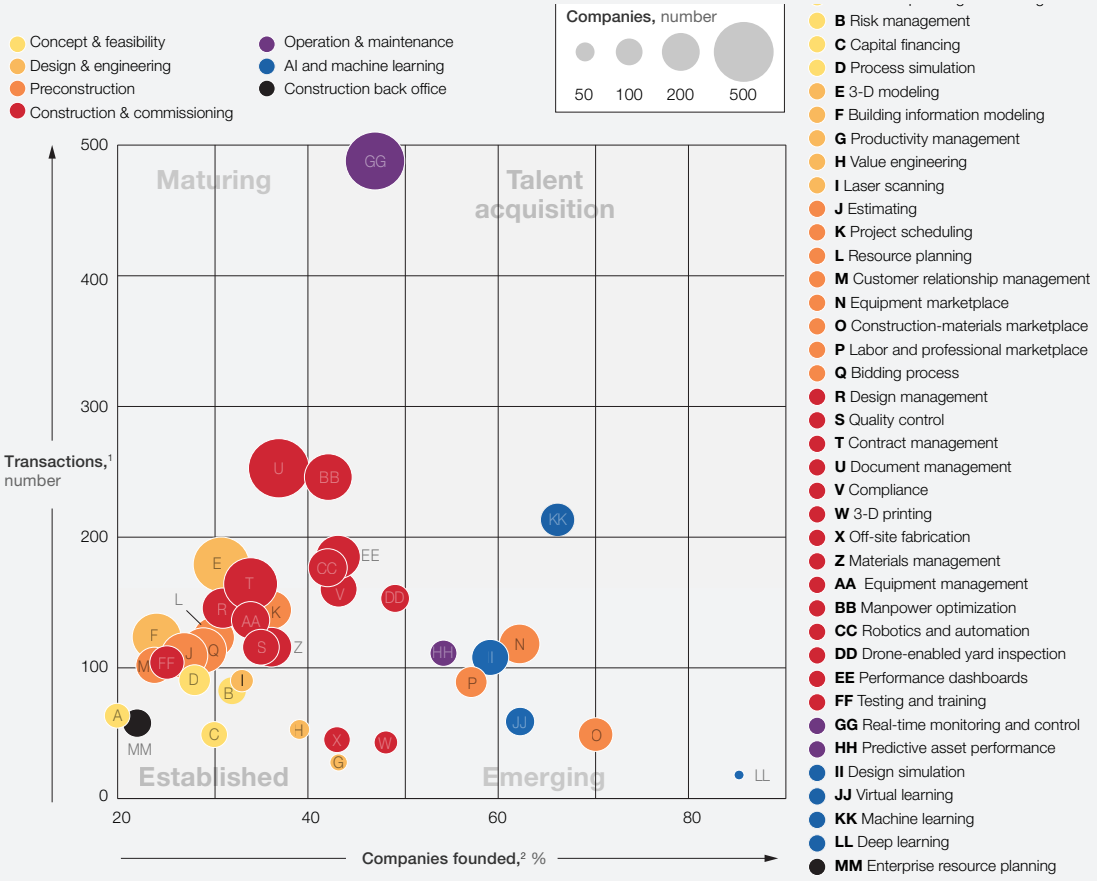
There are two untapped markets: design/engineering and concept/feasibility. This may be because entrepreneurs have focused on life cycle stages that hold the majority of project value. Alternatively, the office-based nature of these phases also means their relevant solutions (such as CAD or BIM) may already be relatively mature and sophisticated. We foresee less disruption in these stages and more continuous improvement (for example, new features for existing software).

2) How will the market evolve in the next 2–3 years?

Mapping the number of transactions in each of the 38 use cases against the number of new companies in the past five years in that space reveals a detailed picture of the current construction market (Exhibit 5). Four archetypes emerge:

1. *Talent acquisition.* In the upper right quadrant, we find both a high concentration of new

Exhibit 5



[1]Total number of transactions in past 5 years, includes private equity, venture capital, M&A, and private placements. Does not include debt financing.
[2]Number of companies with transactions in the past 5 years, companies with multiple use cases are counted toward each use case (total is not exhaustive).

McKinsey&Company | **Source:** Pitchbook data; expert interviews; McKinsey analysis

companies and a high number of transactions in machine learning, among several other use cases. This quadrant can be described as "talent grab," which means that companies are using acquisitions to onboard new talent and skills.

2. *Emerging.* In the lower right quadrant, we find use cases, such as deep learning, where there are a lot of new companies but not a lot of transactions, suggesting these use cases are primed to emerge into the tech investment space in the next few years.

3. *Maturing.* In the upper left quadrant, we find use cases, such as document management, with a lot of transactions but relatively fewer new companies, suggesting that these use cases are dominated by relatively established companies operating in a fragmented market. These areas may thus be facing consolidation in the near future.

4. *Established or unproven.* Finally, in the lower left quadrant we find established or unproven use cases, such as enterprise resource planning, where few new companies and few transactions are underway. These markets may be saturated—but for the exception of some use cases, such as laser scanning, that have simply not yet realized momentum.

Increasing consolidation against a backdrop of continued fragmentation

The fragmentation of technology offerings will continue to be an issue. In last year's analysis, just 13 percent of the companies we studied had engaged a technology solution that addressed more than one of the three clusters (on-site execution, digital collaboration, and back-office and adjacencies)—meaning that most companies are engaging solutions that address a very specific, narrow application rather than more integrated solutions.

Our new research confirms that more than half of companies are still engaging a solution that addresses just 1 or 2 use cases out of the 38 (Exhibit 6).

This fragmentation is one of the biggest challenges we've heard from companies that want to engage with technology solutions. Many are older, venerable companies using legacy systems and various information-collection methods. For these companies, integration may sound more like it's yet another solution to layer in on the top of all the other processes and solution on hand—when in fact, technology can be used to cut down on the number of solutions and methods being used.

The lack of use case integration is one of the drags on technology adoption at scale. As such, more companies are exploring the potential to consolidate solutions that address multiple use cases. While integration won't "grease the wheels" of every aspect of technology adoption, it certainly represents a viable path forward to bring more layers up to speed. (See sidebar, "Integration plays.")

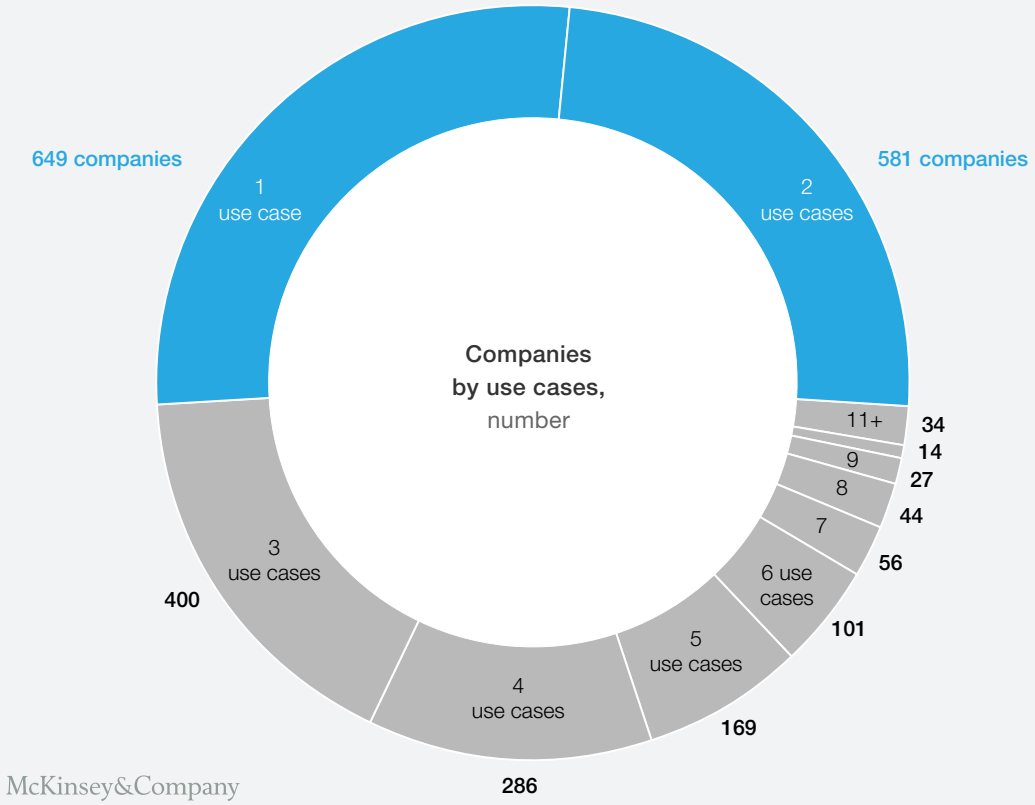
The struggle to find talent

Finding digital talent is a prominent concern for executives across the industry, and it will be critical to digitization: according to research by McKinsey's Digital Academy, investing in talent makes increases the odds of digitization success by 2.5 times. Investing in talent requires balancing the entrepreneurship DNA, industry knowledge, and business acumen to build business unit from scratch—but the talent pool is small when it comes to balancing these three skill sets.

3) How can the industry accelerate its transition to a digital future?

While technology has dramatically advanced in the E&C sector, there is much room for improvement. There are several actions that AEC firms, technology

Exhibit 6



providers, and project owners can take to accelerate construction technology in the coming years.

AEC firms:

Invest in talent and skill building: AEC leaders must begin to expand skill sets among existing employees as well as hire new candidates with technical expertise. To start, AEC firms can explore talent pools in digital native companies, even those outside the E&C industry; a particular focus should be given to candidates in other industries that have undergone a digital transition. These individuals can be paired with the right industry leaders and reach in the organization to integrate new and existing expertise. To upskill current employees, firms should bring in training programs in new technologies—for instance, to train employees in 3-D printing—or set aside funds for capability building.

Actively engage with the start-up ecosystem: This action can take a variety of forms, one of which is investing directly in start-ups through a corporate VC arm. Here, AEC firms may be challenged by entrepreneurs who are hesitant to accept capital from large players, as it compromises their ability to work with a funder's competitor. AEC firms can manage this caution by exploring other, less risky forms of engaging with start-ups: for instance, investing indirectly through a VC fund or partnering selectively for piloting or codeveloping solutions.

Integration plays

We see three types of integration that can materialize over time:

Large software players acquiring point solution start-ups. We see existing software companies acquiring more targeted start-ups in order to offer an integrated software solution, usually across multiple asset classes. Examples of this archetype can be seen in Oracle's 2017 acquisition of Aconex, or Trimble's acquisition of e-Builder and Viewpoint in 2018. These players claim to be a "one-stop shop" for core needs in construction technology.

Platform plays. Companies can become agnostic platforms on which to integrate multiple point solutions, similar to an application programming interface (API). These providers model themselves as a "best-of-breed" solution—analogous to the way Apple markets their iOS ecosystem or platform—upon which various construction needs or applications can sit. This also allows companies to play across multiple asset classes. However, data ownership and related risk (for example, assuming responsibility for negative project outcomes when multiple solutions are deployed) can make end users wary of this type of integration.

Hybrid integrations. While the former two archetypes are asset class–agnostic—that is, their solutions are applicable across asset classes—we also see the potential for integrations of asset class–specific solutions. For example, compared with residential construction, industrial construction requires greater accuracy in reality capture and digital twin models. As such, we have begun to see solutions in this category geared toward specific asset classes (for instance, digital twins for complex oil and gas projects) as well as those geared toward building suites or packages of such solutions. We are also already seeing the rise of vertically integrated contractors who incorporate (by developing, acquiring, or partnering with) the full set of hardware and software solutions for a given asset class—for example, Katerra in residential construction.

Establish conditions of success for piloting and scaling: AEC firms can prime themselves to be early adopters of promising technology by setting aside funding for the purpose of experimentation. As pilot solutions prove their value, AEC firms can use a helpful acid test for evaluating the longer-term use of a technology: whether a project manager is willing to accommodate its cost in their project budget. AEC firms can also bring in outside start-up expertise as needed, as building an in-house development team is often labor intensive and time consuming. Partnering with start-ups that can bring specific capabilities (for example, product development through rapid iteration) can be particularly valuable.

Tech providers:

Listen to the end user and adapt: Solutions in the ecosystem are often developed by looking for a problem. Indeed, we find passionate start-up founders looking for an application of their novel solution in the industry, instead of truly understanding the industry's needs. To that end, start-ups—especially if teams are from outside the AEC industry—must listen closely to the needs of AEC firms and adapt product offerings. This effort will consist of focusing on validated customer needs; in this fragmented landscape, it is imperative to validate the real need (versus a "nice-to-have" application).

Plan for the journey to integration and consolidation: As described above, unlocking real value from the technology ecosystem will require integration across multiple use cases and clusters. As the industry evolves, start-ups must therefore forge a "co-opetition" strategy—that is, how to simultaneously collaborate and compete. This is especially true given the multiple pivots that start-ups undergo (for example, starting with one use case and shifting to a new one). Start-ups in the early stage will need to plan on an evolving go-to-market strategy.

Owners:

Enforce a strong and sharable data foundation: All project participants need to work with one shared data backbone in one system, known as a common data environment (CDE). This data will need to be made available to all project participants, with up-front agreement from all.

Align on supportive contract strategies: Digital participation needs to be part of the bidding contracts for all project participants. Indeed, a digital project should emulate an integrated project delivery (IPD) setup, which can not only improve outcomes and accountability but also circumvent the hostility of an adversarial contractual environment.

Identify and focus on critical use cases: Owners need to focus on understanding their organization's unique economic case for technology. While it may be appealing to pursue the most cutting-edge tools and applications, owners must identify and prioritize the use cases that will have both a long-term impact and a medium- to short-term impact to generate momentum. Only by developing a concrete and customized understanding of the return on investment, as well as the risk and disruption to existing functions, can they ensure that new technology adoption is optimized and sequenced according to pressing needs and their distinct circumstances.

Gone are the days when the construction industry can ignore the burgeoning set of technology solutions across the asset life cycle. We expect investment, competition, and consolidation to continue to accelerate as use cases and start-ups serving the industry proliferate. As predictions come to life and new capabilities infiltrate the field, team, and office, the winners will be the ones that adapt—sooner rather than later.

[1] For more insights on specific use cases of AI in E&C, see "Artificial intelligence: Construction technology's next frontier," April 2018, McKinsey.com.

[2] The caveat is that a rise in late-stage VC can also be driven by price inflation or because companies have chosen to stay private for a longer period (requiring more financing before an exit).

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