The digital future of construction

Rajat Agarwal, Shankar Chandrasekaran, and Mukund Sridhar

The industry needs to change; here’s how to manage it.

Although the construction industry suffers from sluggish productivity growth and relatively low financial returns, it has been slow to embrace the process and technology innovations that could help it to do better, with respect to both profitability and performance (Exhibit 1).

In general, R&D spending in construction runs well behind that of other industries: it accounts for less than 1.0 percent of revenues, versus 3.5 to 4.5 percent for the automotive and aerospace sectors. Ditto for spending on information technology.

Traditionally, the sector has tended to focus on making incremental improvements. But this will no longer do. Projects are ever larger and more complex. The growing demand
for environmentally sensitive construction means traditional practices must change. And the shortage of skilled labor and supervisory staff will only get worse. These are deep issues that require new ways of thinking and working.

Here are five ways the industry could transform itself over the next few years.

**Higher-definition surveying and geolocation**

Geological surprises are a major reason that projects are delayed and go over budget. New techniques that integrate high-definition photography, 3-D laser scanning, and geographic information systems, enabled by drone and unmanned-aerial-vehicle technology, can dramatically improve accuracy and speed. And they are more accessible than ever because costs have come down substantially.
Large capital projects typically take 20% longer to finish...

...and are up to 80% over budget,

and R&D spending in construction runs well behind other industries.

<1% Construction

3.5% Auto

4.5% Aerospace

Note: Figure represents average percent of revenues
5 big ideas are poised to disrupt construction

1. Higher definition surveying and geolocation

2. 5-D Building Information Modeling

3. Digital collaboration and mobility

4. The internet of things and advanced analytics

5. Future-proof design and construction

For the industry to do better it needs to embrace 4 principles

1. Transparency and risk sharing in contracts
2. Return-on-investment orientation
3. Simplicity and intuitiveness in the design of new solutions
4. Change management

To learn more visit: www.mckinsey.com/industries/infrastructure
Photogrammetry, for example, provides high-quality, high-definition images of survey areas. Light-detection-and-ranging (lidar) technology is much faster than conventional technologies and provides high-quality 3-D images that can be integrated with project-planning tools, such as building information modeling (BIM), as Exhibit 2 shows.

Exhibit 2

McKinsey Global Institute industry digitization index; 2015 or latest available data

The construction industry is among the least digitized.

<table>
<thead>
<tr>
<th>Relatively high digitization</th>
<th>Relatively low digitization</th>
<th>Digital leaders within relatively undigitized sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall digitization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT(^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Media</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance and insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale trade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil and gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals and pharmaceuticals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic goods manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real estate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation and warehousing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail trade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entertainment and recreation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal and local services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthcare</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture and hunting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Based on a set of metrics to assess digitization of assets (8 metrics), usage (11 metrics), and labor (8 metrics).
2Information and communications technology.

Source: AppBrain; Bluewolf; Computer Economics; eMarketer; Gartner; IDC Research; LiveChat; US Bureau of Economic Analysis; US Bureau of Labor Statistics; US Census Bureau; McKinsey Global Institute analysis

McKinsey&Company
Used in conjunction with ground-penetrating radar, magnetometers, and other equipment, lidar can generate above-ground and underground 3-D images of project sites. This is particularly important in dense, environmentally sensitive, or historical project sites, where disturbance needs to be minimized.

These advanced survey techniques are complemented by geographic information systems that allow maps, images, distance measurements, and GPS positions to be overlaid. This information can then be uploaded to other analytical and visualization systems for use in project planning and construction.

**Next-generation 5-D building information modeling**

The construction industry lacks an integrated platform that spans project planning, design, construction, operations, and maintenance. Instead, it still relies on bespoke software tools. In addition, project owners and contractors often use different platforms that do not sync with one another.

Next-generation 5-D BIM is a five-dimensional representation of the physical and functional characteristics of any project. It considers a project’s cost and schedule in addition to the standard spatial design parameters in 3-D. It also includes details such as geometry, specifications, aesthetics, thermal, and acoustic properties. A 5-D BIM platform allows owners and contractors to identify, analyze, and record the impact of changes on project costs and scheduling (Exhibit 3). The intuitive, visual nature of 5-D BIM gives contractors a chance to identify risks earlier and thus to make better decisions. For example, project planners can visualize and estimate the impact of a proposed change in design on project costs and schedule.

The use of 5-D BIM technology can be further enhanced through augmented-reality technology via tablets or wearable devices. A wearable, self-contained device with a see-through, holographic display and advanced sensors can map the physical environment, for instance. Companies are developing BIM-like design and construction solutions for these platforms. In this “mixed reality” environment, users can pin holograms to physical objects and interact with data using gesture, gaze, and voice commands.

**Digital collaboration and mobility**

One reason for the industry’s poor productivity record (Exhibit 4) is that it still relies on paper to manage its processes and deliverables such as blueprints, design drawings, procurement and supply-chain orders, equipment logs, daily progress reports, and punch lists.

Now owners and contractors are beginning to deploy digital-collaboration and field-mobility solutions. A large global construction firm recently announced it was working with a software provider to develop a cloud-based, mobile-enabled field-supervision platform that integrates project planning, engineering, physical control, budgeting, and document management for large projects. Several large-project developers have already successfully digitized their project-management work flows.
In an American tunnel project that involved almost 600 vendors, the contractor developed a single platform solution for bidding, tendering, and contract management. This saved the team more than 20 hours of staff time per week, cut down the time to generate reports by 75 percent, and sped up document transmittals by 90 percent. In another case, a $5 billion rail project saved more than $110 million and boosted productivity by using automated work flows for reviews and approvals.

It’s long been difficult for central planning teams and on-site construction teams to connect and share information about progress in real time. Now the availability of low-cost mobile connectivity, including via tablets and handheld devices, has ushered in a new generation of cloud-based crew-mobility apps. These can be deployed even on remote construction sites and could change the way the industry does everything from work- and change-order management to time and material tracking, dispatching, scheduling, productivity measurement, and incident reporting.

The Internet of Things and advanced analytics

Project sites generate vast amounts of data, but little of this is captured, let alone measured and processed. The Internet of Things—sensors and wireless technologies

Exhibit 3

Lidar represents an evolution in surveying; added mobility from drones and handheld technology is a breakthrough.

Overview of technology commonly used in site surveys

<table>
<thead>
<tr>
<th>Electronic distance measurement</th>
<th>GPS</th>
<th>Photogrammetry</th>
<th>Light detection and ranging (lidar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most commonly deployed</td>
<td>Uses GPS coordinates</td>
<td>Uses high-resolution images</td>
<td>Uses optical lasers to detect thousands of points per second, with native 3-D output</td>
</tr>
<tr>
<td>Requires on-site personnel</td>
<td>Ineffective when blocked (e.g., by tall buildings or clouds)</td>
<td>Requires postprocessing time to convert to usable data</td>
<td>May have issues with some terrain, such as steep slopes</td>
</tr>
<tr>
<td>Best used for on-site rechecks prior to work</td>
<td>Best used when there’s a need for high accuracy in small open sites</td>
<td>Best used when there’s a need for high accuracy in large sites</td>
<td></td>
</tr>
</tbody>
</table>

While lidar has existed for some time, there has been a breakthrough in its use via drones/unmanned aerial vehicles (UAVs) and handheld platforms

- Handheld 3-D laser scanners
- Mounted on mobile platforms
- Some lidar systems are now under 10 kg and can be deployed with drones/UAVs

Source: McKinsey analysis

Exhibit 3
that enable equipment and assets to become “intelligent” by connecting them with one another—could change that. On a construction site, the Internet of Things would allow construction machinery, equipment, materials, structures, and even formwork to “talk” to a central IT platform to capture critical performance parameters. Sensors, near-field-communication devices, and other technologies can help monitor productivity and reliability. Potential uses include equipment monitoring and repair, inventory management, quality assessment, energy efficiency, and safety.

One popular form of near-field-communication technology is radio-frequency identification (RFID). This is used extensively in logistics, retail, and manufacturing environments to collect precise information about a product, place, time, and transaction. Since the 1990s, construction has used RFID to track materials and equipment and to develop automated time sheets. Costs of RFID equipment—including scanners, receivers, and tags—are falling, and new applications are emerging. Soon, tags will be able to include information on specifications, dates, defects, vendors and original-equipment manufacturers, maintenance records, operating parameters, and other applications.

In addition to the opportunities from the Internet of Things, digitization could enable construction firms to capture data. Then advanced analytics can help to improve efficiency, timelines, and risk management.

Insights from advanced analytics helped one oil and gas giant improve the productivity of its engineering function by 20 to 25 percent by pairing the right teams, appointing...
appropriate team leads, and modifying their work flows to minimize waste and improve efficiency. In another case, a large Middle Eastern construction firm used a predictive-analytics engine to prevent equipment breakdowns on-site for its fleet of construction vehicles. This saved millions of dollars in downtime, fuel costs, and maintenance expenses.

**Future-proof design and construction**

New building materials and construction approaches can lower costs and speed up construction while improving quality and safety.

**Building materials**

These usually account for more than half the total cost of projects. Traditional materials such as concrete, cement, and asphalt make up most of this demand. But there has been a wave of innovation in construction materials over the past few decades; a number of products have been developed with specific uses in mind. Here are a few that are particularly interesting:

- **Self-healing concrete.** This uses bacteria as a healing agent to close cracks on concrete; it is currently at the proof-of-concept stage.

- **Concrete canvas.** Take a layer of “concrete cloth,” then add water and allow it to set. This innovation typically is used for drains, channels, and passages, and it is now available commercially.

- **Topmix permeable.** This is a cement alternative that can absorb 4,000 liters of water a minute. It is in the early-adoption stage.

- **Aerogel.** This supertransparent, superinsulator material is 99.98 percent air; it is available commercially.

- **Nanomaterials.** These superstrong, ultralightweight materials may eventually be a substitute for steel reinforcement in structures and foundations, though they are still in the research stage.

Adoption of these “materials of the future” has been slow due to a lack of awareness, a limited supply chain, a lack of availability at scale, and risk aversion. Despite being available for more than 30 years, for example, ethylene tetrafluoroethylene (ETFE) gained widespread adoption only after it was used to build part of the aquatic building for the Beijing Olympics in 2008. ETFE weighs less than 1 percent of an equivalent glass panel and costs 24 to 70 percent less.

**Construction approaches**

About 80 percent of all construction work is still done on-site, but project developers and contractors are deploying new approaches that show promise. Among them:
Preassembly. Relatively simple structures, such as factories and covered yards, can use in-factory or in-yard assembly for a complete building envelope. This technique can also be adapted for modular buildings, such as hotels and budget condominiums. Complete submodules of a larger building are put together in a factory or nearby yard before final assembly at the construction site.

Techniques such as prefabricated, prefinished volumetric construction integrate off-site capabilities to transform the construction site into a manufacturing system (Exhibit 5).

The result: greater efficiency, less waste, and improved safety. In addition, materials such as cross-laminated timber are emerging in response to the need for greener construction options. In the United Kingdom, an 80-story timber skyscraper recently received preliminary approval.

3-D printing. Printing submodules or complete concrete structures before assembly and internal work could transform the industry with respect to design, cost, and time. However, 3-D printing is still in the early stages of its development and cannot yet be deployed at the scale and speed required for large projects.

Robot-assembled construction. Construction projects are inherently unstructured and often unpredictable; they can also be sited in difficult terrains and environments.
For these reasons, the use of robots has been limited so far. However, robots are now being selectively used for repetitive and predictable activities, such as tiling, bricklaying, welding and spool fabrication, demolition, and concrete recycling.

Recommendations for action

It’s time for a new mind-set. Owners often believe that their responsibility ends when they award contracts, forgetting that they pay the economic costs of delay. For their part, contractors often do only the minimum required to meet contractual terms, leaving substantial value on the table. For the industry to do better, it needs to embrace four principles:

- **Transparency and risk sharing in contracts.** Habits are tough to change, and one habit is to see contracts as adversarial opportunities to hand off risks. Instead, contracts need to be seen as tools that allow fair sharing of risks and rewards and that help both sides succeed. This will happen if contracts clearly outline responsibilities and allow owners and contractors to share the benefits that arise from the adoption of technological and process innovations.

- **A return-on-investment orientation.** Measuring and communicating how new technology will improve construction—for example, through the positive effects on cost, schedule, and risk optimization—is the surest way to build a compelling case for adoption. One oil and gas major measures, documents, and communicates productivity-related savings as a result of the deployment of an advanced-analytics and visualization solution for its deepwater platforms.

- **Simplicity and intuitiveness in the design of new solutions.** At the front end, user interfaces need to be “foreman friendly” to encourage usage. At the back end, building in compatibility with existing enterprise solutions mitigates the need to spend more on upgrading existing platforms.

- **Change management.** To move away from business as usual, organizations need a clear direction. Top management needs to communicate why these changes are important and what they mean for organizational structure, capabilities, and resourcing. Organizations that do not invest in change management will face pushback and are more likely to fail.
Other industries have shown that first movers can build a sustainable competitive advantage. In the construction sector, this is also likely to be the case. Over the next decade, these winners of tomorrow will take the lead in technology innovation and digitization. Resisting change is no longer an option.

Rajat Agarwal is an associate partner in McKinsey’s Singapore office, where Mukund Sridhar is a partner; Shankar Chandrasekaran is an associate partner in the Mumbai office.