Research Directions
For the Built Environment

DesignIntelligence Quarterly

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In this menu of strategic responses to IT-related challenges, two global experts offer opportunities for action by data-enabled firms.

Rapid Technical Change Offers Opportunity

The AEC industry is ready for technical change but has been slow to seize technical, legal, and contractual opportunities for reasons such as inadequate staffing and limited resources. Like most industries, AEC has had opportunities to use technology developed over the past few years to address a variety of problems. But if the pace of innovation is led by current AEC players, some fear that change will be driven from the outside, and current players will be bypassed. Firms that focus on innovating new and creative technology rather than leveraging existing technology may miss the opportunity to act in the most efficient, effective way with fewer resources. To avoid being bypassed, we must focus on measuring outcomes, the intersection of IoT and 5G, and machine learning, while weighing the opportunities and dangers of these technologies.

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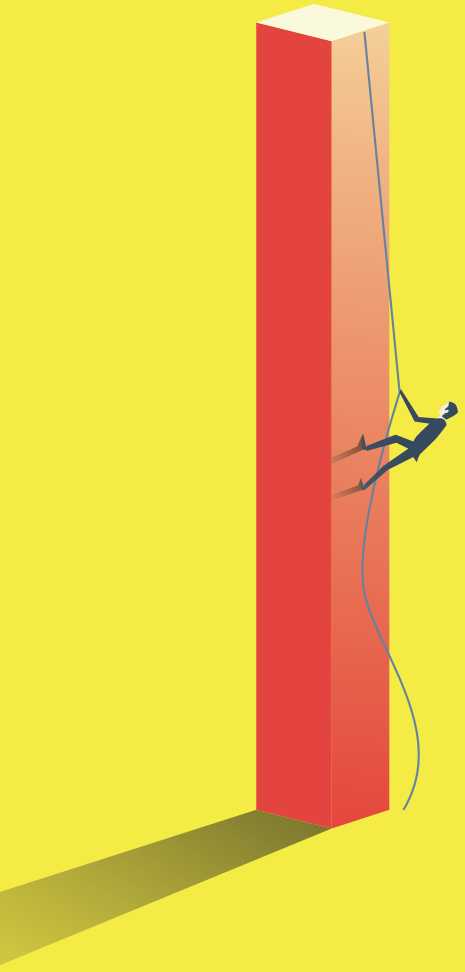

Challenges

Industry challenges abound. Among them are:

1. How can companies find enough resources to develop software/hardware products and take them to market to move the industry forward?
2. Can we use custom hardware/software to make 5G and IoT more secure or do we have to live with what AT&T, Verizon, Microsoft, Cisco, et al. give us? For example:
   - Can we use software/routers to make it harder to hack companies I.T. infrastructure?
   - Can we make it harder for a hacker to hack an apartment dweller's Nest or Alexa's IoT devices?
3. Can we design buildings and civic structures that are secure from malicious attacks?
4. Can AEC firms develop and market design software which improves sustainability?
5. How can the built environment help with disease prevention and epidemics?
6. The current pace of change seems already too much for designers, builders, and owners. Can we collaborate to identify better methods of responding to exponentially rapid change?
7. Unlike other industries, designers, engineers, building trades, building managers and owners lack good feedback on the performance of buildings and structures.
   - Can we develop hardware/software tools that measure the performance of new and existing structures and buildings?
   - Can we develop better ways of standardizing, sharing, validating, and organizing data?
   - Can Machine Learning (ML) and other forms of AI be useful?
   - Do we need to look past the limitations of today's common design tools?

Paths Forward

The AEC industry can respond to these challenges in three ways:

1. Respond to technical challenges and opportunities on a company-by-company basis. That is necessary, but more is possible.
2. Limit initiatives to those sponsored by Google, Microsoft, Amazon, IBM, and other leaders. Those and similar companies will offer some opportunities but may find it difficult to hold on to traditional values among designers, architects, and engineers unless more independent paths are developed.
3. Form collaborative projects between design, architectural, engineering, building trade, building management, and building ownership firms. These collaborations may take financial, skills, problem/opportunity identification, and other forms.

Opportunities

Based on the paths above, we offer the below menu of considered choices for firms to consider.

Beyond Generic

Problem: Generic hardware is not always appropriate.

Google made a major leap in adoption 20 years ago largely because they standardized commodity hardware. Most computer companies followed this path. Pressure from the gaming community led to an arms race in specialized chips (GPUs), for 3D graphics processing. Later, against the advice of most programmers, Google engineers harnessed GPUs for Machine Learning (ML) — a task for which they were not designed. The success was so great that Google then developed its own type of processing unit called a Tensor Processing Unit (TPU). Tensor is the name of a data structure valuable for ML. Today, Google depends on their own chips, as Apple and other market leaders depend on theirs. Can a consortium of small players (compared to Google et al.) follow a similar path in a search of more secure IoT and 5G?

We are not proposing to have hardware 'hackathons' at Design Futures Council meetings. Rather, firms may find a way to collaborate in a search for innovation with an aim for security in IoT, especially in combination with 5G. For many problems, environmental sensors, or custom chip security as a key design goal are examples of reasonable undertakings for companies smaller than Apple, Google, Microsoft, Facebook, or Amazon. Specialized software to enhance router security and off the shelf products from Cisco and their competitors are other possible innovation paths.

Built Environment Reloaded

Problem: The character of the built environment is changing radically.

1. Considered broadly, the FitBits and Apple watches people wear are part of the built environment. They represent the heart of our concerns: the built environment of 2020 is the work product of diverse players, not just architects, engineers, contractors and manufacturers.

2. The introduction of smart devices and rich data acquisition devices such as Alexa, smart phones, watches, HVAC controls, and local routers — devices which can collaborate over Bluetooth, WiFi, and (potentially) other channels -- offers potential diagnostic and active care services.

3. Smart devices, wired and wireless, can engage in new levels of environmental monitoring. Are all the new

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plants really improving air quality? The hall temperature is 72 °F. But how hot is the living room getting? There is a construction across the street, but how much of that dust are we breathing?

On-Site, Automated and Modular Construction

Problem: onsite construction is less efficient than offsite

WikiHouse is an open source construction system aiming to use digital manufacturing to simplify the building process. It allows anyone to affordably design, download, 3D print, and assemble structures without the need for traditional construction skills and tools. WikiHouse harnesses three main ideas: digital design, local fabrication, and rapid assembly. Can these any of these ideas be extended to more mainstream AEC aspects?

Retrofitting

Problem: We need to reuse/adapt our buildings rather than build anew to conserve resources.

We need to make an engineering science out of retrofitting existing buildings for energy efficiency, environmental quality, and energy production. California made a quantum leap in earthquake safety by rethinking building codes and retrofitting everything from single car garages to bridges. Similar things can be done from energy efficiency, sustainability, residential and office security concerns.

For example: Changing municipal codes e.g. you are not allowed to cover an entire roof of a house with solar panels in San Francisco because neighbors think it looks 'ugly'. This does not involve any technical progress but requires changes to building codes and zoning. Many problems fit this pattern.

Data Integrity

Problem: Data should be shared across projects and companies, but current data management practices make that difficult technically.

There may be valuable technical progress which can facilitate this, but the starting point should be to make use of existing computer science by reverting to basic principles. Many, probably most, AEC firms will benefit by evaluating current practice without the time pressure of a specific project. Possible topics for review include rigorous use of relational algebra, strongly typed languages, data encoding designed to cross hardware and software boundaries, encryption, possible read-only shared ledgers, and data pipelines to ensure integrity and usability of data as it flows across diverse systems.

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Construction Data and Market

Problem: Many current construction cost estimates are based on phone surveys. Their data sources are limited.

Use blockchain and/or more conventional cryptography to share construction and maintenance costs between trades and BPMs and create a market for construction data based on real world events, not surveys. Can this information be used to lower the cost of building materials for the building trades and owners? Can it be used by BPMs to optimize their R&D spending?

Rather than a pure technical approach, we recommend that creating new markets for data be considered.

Data Organization

Problem: As it stands, the industry does not have the right tools or skill sets to organize data in a scalable manner.

We need to organize data in a way that can be compared across projects. The poster child for dealing with unstructured data may be the Panama papers. A few terabytes of unstructured stolen data were essentially useless until graph algorithms were applied. In addition to widely used deep learning, probabilistic reasoning and strongly typed functional languages may play a role. The problem is far too deep to simply have everyone try to adopt the same standards. If that could have worked, it would have been done last century.

We can do more by exploring the combining technology and health care institutions while considering the goals and objectives of those who occupy the built environment.

Data and Models as IP

Problem: Generate income from data and models of data.

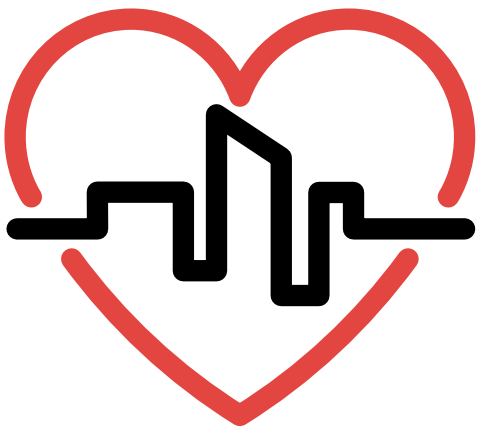
Aggregated data and stats on data are products in themselves (e.g. being able to rent out data and machine learning models built from the data to other firms to maximize efficiency.

AEC firms consider data and associated models to be their IP. Do we want to share the data or sell the Machine Learning systems based on the data? Would something stemming from the cryptography be appropriate? Oasis Labs treats data as private property — this approach is based on custom hardware coupled with a design that starts with scalability and security, contrasting widely adopted approaches to blockchain.

Healthy Offices and Buildings

Problem: The design of buildings and the materials used in their construction often leads to unhealthy living and working conditions.

As we rethink the built environment as suggested in the section named Built Environment Reloaded, it's possible to rethink the relationship between homes, offices, and the health care system. 5g and IoT offer amazing possibilities to facilitate collaboration between medical providers, public health organization, and the structures themselves. Some companies have already developed sensor networks which can be easily installed and monitored for measurements of well-being such as temperature and humidity. [One such effort inspired this article.] We can do more by exploring the combining technology and health care institutions while considering the goals and objectives of those who occupy the built environment.



Covid-19 Looms Large (and Other Directions?)

These opportunities and responses offer a host of strategies and actions in forms interested in developing responses to research opportunities for practice. The challenge will be to find those best suited to your values and capabilities.

As we finish this article, global pandemic Covid-19 is running out of control in Italy and much of Europe. The San Francisco Bay Area, where we live, is under 'shelter in place' orders. The world is concerned that as China returns to work, they may experience a Covid-19 resurgence. This sharpens but does not change the basic value of collaboration across firms, civic, and professional organizations to improve the sustainability, safety, and utility of the built environment. Because technology is changing so rapidly, the opportunities and dangers are increasing exponentially. If any of these research directions interest you, please write to us at DesignIntelligence Quarterly. If you have other, possibly much better ideas, please tell us about those as well.