Moving Forward:
Findings and Recommendations from the Consultative Council
Introduction
The National Institute of Building Sciences Consultative Council serves a unique role in the building industry. It brings together representatives from leading organizations that represent all aspects of design, construction, operation and regulation to examine important issues before the industry and provide findings and recommendations to the President of the United States and the U.S. Congress on how to effectively address them. In 2017, members of the Consultative Council decided to focus on the future. They wanted to explore how the building industry can and should evolve to meet the changing needs of society and how new technologies and practices can attract a 21st century workforce.

Building The Industry of the Future
Over time, the sectors that drive the economy, the needs and desires of citizens and the metrics of progress change. Buildings and infrastructure serve as important resources that enable such progress to occur. Despite the slow progress the building industry has made implementing internal changes in the past, it continues to provide businesses and communities with the facilities necessary to achieve their missions, and individuals with housing that is comfortable, safe and efficient. However, one question arises as the pace of technology and commerce accelerates and communities face new challenges of resilience and sustainability: Will the building industry be ready?

Populations in the United States (and around the world) continue to move to and expand in urban centers. Whether located along the coasts or other waterways, or in areas prone to drought or earthquakes, many such cities are particularly vulnerable to disasters. To avoid social, economic and environmental disruption, buildings and infrastructure in at-risk locations must be resilient, and will require necessary investment.

At the same time, resources to support the design, construction and operations of buildings, including energy, water and materials, could become increasingly constrained and expensive, advancing the need for sustainable approaches.

The fragmented nature of the building industry, which brings together different groups of small businesses with each project, has resulted in inefficiencies and a slow rate of technology adoption. Technological advances, both from outside and within the industry, present significant opportunities to advance productivity and increase efficiency. Yet, the industry must be primed to swiftly incorporate such technology—which has not been a priority in the past.

Meanwhile, today’s building industry workforce is aging and there is a growing concern that new entrants are not attracted to this market segment. Moving the building industry forward, as discussed in this report, could serve as a catalyst to excite and engage the next generation of building-related workers.

Innovative building owners, designers, contractors, manufacturers, scientists, technology companies and communities already are leading the way in demonstrating how buildings and infrastructure should be
designed, constructed, operated and regulated. To help move the industry ahead, their lessons learned and benefits achieved must be documented, shared and replicated.

The building industry needs a holistic examination, with targeted investment of resources—including personnel, intellectual and financial capital—to meet the growing demand for high-performance buildings. Such an approach must look at all factors that influence the building process—research, development and deployment (RD&D); technology; workforce; procurement; codes and standards; professional, technical and vocational training; design fees, schedules, processes and contracting; performance goals; and building occupants. This report examines some of those key drivers of progress, outlining the challenges and opportunities for moving forward.

**Design, Construction and Operations**

The building industry saw significant advances in the latter half of the 20th century, with an increased focus on life safety through building codes and other guidance; the development and deployment of tools such as computer assisted/aided design (CAD) and building information modeling (BIM) to support increasingly efficient design and construction processes; sustainability through green building rating programs; and building science knowledge around building enclosures, indoor environmental quality and energy and water efficiency. However, the design, construction and operations processes remained focused on optimization within disciplines and components—and the processes, contracts, codes and standards and training to support such an approach.

In the 21st century, the industry is recognizing the need to evolve to meet the new challenges and demands placed on buildings, infrastructure and cities. However, the design, construction and operations processes require a shift in training, contracts, codes and standards to align with integrated teams that are collaboratively co-creating to address a multiplicity of performance-based criteria.

**Project Delivery**

Historically, the project delivery contracting structure primarily governed the relationship between the multiple disciplines involved in the project and their attitude towards the project. In recent years, the contract structures have begun to evolve to meet current needs. Previously, contract types focused on the phases of construction—design, bid, build—and payment terms, including lump sum, cost plus fixed fee and cost plus percentage of cost. Such approaches may still have their place in the industry, but they perpetuate the disjointed processes that hinder collaboration in achieving a high-performance building.

Contracts today include a variety of project delivery methods, including: design-negotiate-build, construction management (CM), CM as owner’s agent, CM at risk, design-build, integrated project delivery and design-build-operate-maintain. These alternative project delivery methods are the industry’s response to improve outcomes associated with traditional 20th century approaches. The resulting procurement reform to accommodate these changes is slow, but underway.

**Allocation of Design Fees**

In addition to new contract structures, the industry also must examine whether the existing allocation of design and construction fees offers the greatest value for the owner and aligns with project priorities and the steps that add to that value. As discussed in this report, BIM provides building owners and operators with information that facilitates efficient operations across the entire life cycle of the facility. Building owners should work with members of the architecture-engineering-construction (AEC) team to identify
the information that should be included in the BIM and then compensate the AEC team appropriately for the additional value provided.¹

Building teams may also wish to examine how members from the design and construction stages can stay involved with the project into the operations stage, which will help owners better realize their long-term project performance goals and provide valuable feedback loops that lead to improved future projects. One example of a successful foray into bridging the gap between design and construction and building operations was the General Services Administration’s performance-based approach used for the design and construction of the Federal Center South building in Seattle, Washington.²

Policies, Codes and Standards
The United States has gained worldwide respect for its inclusive and transparent codes and standards development processes, levels of protection and commitment to enforcement. Yet these processes are perceived as slow to keep pace with technological advances. This perception arises not because the code development process is slow, but largely because many states and local jurisdictions do not have a systematic process in place to regularly adopt newly revised codes. Codes and standards too must evolve to help meet the changing needs of the industry.

Jurisdictions need to have codes and standards development and adoption on a schedule that recognizes the increased pace of development of new materials, products and methods and the expanding need for resilient and resource-efficient communities. This includes assuring that legislators and other decision makers are informed on why codes and standards are regularly updated.

While adoptions occur primarily at a state and local level, the federal government has an increasing interest in assuring such processes occur in a timely manner—out-of-date codes can lead to increased federal costs in disaster recovery, and national energy and water efficiency are served by the provisions incorporated in energy and plumbing codes. The federal government should identify potential mechanisms to incentivize adoption of up-to-date building codes. Such incentives need not be monetary—enforcing current codes can be among the eligibility requirements for relevant grant programs or part of the calculation for disaster recovery funding.

Codes and standards developers, with the engagement of community representatives, should develop criteria to support increased focus on building performance and outcomes rather than prescriptive measures to help meet project- and community-level goals. Performance measures should be formulated with an eye towards ongoing improvements to encourage development of innovative materials, methods, tools and technologies. Policymakers should coordinate policies to address building performance not just during the design and construction process, but throughout the building’s life cycle.

Two emerging opportunities support the evolution of codes to meet current needs. The code official should be recognized as a valuable member of the building team, serving in the role of advisor rather than adversary. Codes and standards developers should identify mechanisms to assure that buildings can

¹ The *National BIM Guide for Owners* helps building owners develop and adopt a documented process and procedure for their design team to follow in order to produce a standard set of BIM documents during the design and construction of the facility, and for maintenance and operations of the facility upon handoff. https://www.nibs.org/?nbgo

remain functional post-disaster in support of economic and social resilience and not just the short-term protection of life safety.\(^3\)

**Off-Site Construction**
Recognizing the increased focus on worker shortages, project quality, speed to market, job-site safety and sustainability, owners and their design teams are increasingly looking at off-site construction as an option to help meet their needs.\(^4\) To realize the potential benefits of off-site construction, the project team should examine its potential utilization early in the design process and deploy it as part of an integrated design and construction process. This requires a shift in thinking by architects, engineers, contractors, code officials and the education and training providers for these disciplines.

**Shifting the Industry**
Due to the size and fragmentation of the building industry, reform is slow. Per the World Economic Forum, “The United States has 710,000 [engineering and construction] companies; only 2% of them have more than 100 workers and 80% have 10 workers or fewer.”\(^5\) Because the industry lacks a major industry player with enough market share or influence to initiate the shift, no single company nor small group of companies are in an overly strong or influential position in the industry. Therefore, government, as a major client, can and must drive the shifts needed.

**Technology**
Meanwhile, the development and deployment of new and enhanced technologies, whether specifically for use by the building industry or in general, has grown significantly. The traditional building industry must be prepared to adopt and utilize such advancements or entities from outside the industry will realize, and then fill, the opportunities to improve current processes. Codes, standards and other guidance must evolve to provide meaningful direction in this increasingly digital environment.

**BIM and Data**
BIM is moving beyond merely a design and construction tool; an increasing number of disciplines, including facility managers, code officials, emergency managers and first responders, are facilitating the widespread and efficient use of building-related information across the building life cycle. Building- and occupant-related data from an increasing network of sensors and controls are further feeding the ability to operate facilities efficiently and inform the design and construction of new or the renovation of existing facilities. Representatives from across the industry should work collaboratively to identify and implement common metrics and support the interoperability of data to further improve facilities and the industry.

**Sensors, Controls and the Internet of Things**
The growing interest in data-supported decision making and the potential to support efficient operations through increased automation are both driving expansion in sensors, controls and the Internet of Things

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\(^3\) NIST has been directed by Congress to support development of an “Immediate Occupancy Code” to address post-earthquake building occupancy. Such an approach should be considered for other hazards as well.

\(^4\) Off-site construction is defined as “the planning, design, fabrication and assembly of building elements at a location other than their final installed location to support the rapid and efficient construction of a permanent structure. Such building elements may be prefabricated at a different location and transported to the site or prefabricated on the construction site and then transported to their final location. Off-site construction is characterized by an integrated planning and supply chain optimization strategy.” Off-Site Construction Council, Glossary of Off-Site Construction Terms, [http://www.nibs.org/resource/resmgr/OSCC/GlossaryOffSiteConstructionT.pdf](http://www.nibs.org/resource/resmgr/OSCC/GlossaryOffSiteConstructionT.pdf)

(IoT). While these advancements provide significant opportunities to advance building performance, the
data they provide and the activities they can facilitate can quickly overwhelm the industry. The building
industry, with the support and engagement of government must develop a strategy for the effective
collection and utilization of building related data—both at a project level and an industry-wide level.
Setting a common set of metrics can help the industry and government to monitor progress towards
established performance goals.

In addition to its use in building operations, IoT serves the construction industry through equipment and
employee tracking devices, such as wearables, drone surveying and other information collected on the
job site. As companies continue to implement cost-saving measures and increase efficiencies, they are
turning to IoT to improve site operations. Wearable devices also have the ability to track workers in the
field and monitor for job-site hazards and whether equipment is in need of repair.

Cybersecurity
Strategic Risk Advisory Troy Carlson wrote in Construction Business Owner, “With the growing use of
digital technology, the construction industry is more vulnerable than ever to cybersecurity threats. With
the amount of work now completed online and on computers or tablets—from BIM to invoices, building
automation services and everyday correspondence about projects—construction companies are opened
up to innumerable cybersecurity threats and liability. If a company is not adequately protected against
exposure, the associated costs can be financially crippling.”

These vulnerabilities are not just on the construction job site; they exist throughout the life of the
building. As building systems and components become increasingly connected through building
automation systems and IoT, they become vulnerable to attack. Policies, procedures, tools and training
must be in place to assure that this risk is addressed.

Virtual and Augmented Reality, Drones and Additive Manufacturing
Virtual and augmented reality technology are emerging as tools to support collaboration among
stakeholders and allow construction teams to detect errors ahead of time and avoid unnecessary project
costs. This technology could also improve job-site safety and allow construction teams to view job-site
conditions without subjecting them to safety hazards. As identified by the Institute’s Science,
Technology, Engineering and Mathematics (STEM) Education Program, integrating BIM and virtual
reality, along with simulated scenarios or decisions, can provide building owners, facility managers,
code officials, first responders and others with a valuable decision support tool before any construction
is undertaken.

Additive manufacturing (commonly called 3D printing) is changing the way structures are being built by
allowing construction teams to “print” structures at high speeds with precision. Project teams also are
using this technology to print the complex structures and objects that make up buildings. Creating these
complex objects by hand and at scale is a massive undertaking, but with 3D printing the task becomes
much more efficient.

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http://www.constructionbusinessowner.com/technology/october-2016-dangers-cybersecurity-construction
7 Further information on building industry-related cyber risks are covered in the Whole Building Design Guide,
http://wbdg.org/resources/cybersecurity.
9 See “Advancing Future Technology while Inspiring the Next Generation.”
http://www.nibs.org/resource/resmgr/stem/STEM_PROGRAM.pdf
Firms are increasingly using drones to monitor site conditions, document the construction progress and even inspect hard-to-reach building features. For example, insurance companies deployed drones to help conduct preliminary damage assessments following Hurricane Harvey.\(^\text{10}\)

**Robotics and Human Augmentation**

In addition to their use in “printing” buildings, robots are being deployed to undertake repetitive processes within the industry, such as bricklaying. In the future, robots could be utilized to support manufacture and placement of off-site building components. Autonomous construction equipment and delivery vehicles will change the job site.

Wearable technology advances also hold promise in creating new jobs in the industry since specialized workers will be needed to manage the technology itself, while at the same time providing new and innovative ways for industry workers to increase their productivity and enhance worksite safety. Exoskeleton technology, for example, which has been increasingly used in health care and military applications, is now making its way into the construction industry. As competition in this market space increases and costs even out, this type of technology—and others yet to be developed—have the potential to increase the skills, scope and training needs of workers entering the industry.\(^\text{11}\)

Privacy concerns and the appropriate use of data will need to be addressed as the use of these technologies grow.

**Workforce**

The changing design, construction and operations processes, coupled with advancements in building-related technologies, make this an exciting time to enter the building industry, particularly when the availability of a future workforce is such a big industry concern. The concerns encompass two main areas: workforce shortages (the lack of workers available to do jobs in the industry) and the workforce skills gap (where employers in large parts of the industry struggle to find workers who are keeping up with technology and code advances).

According to the U.S. Bureau of Labor Statistics, the construction industry lost about 40% of its workforce—around 2.3 million workers—between April 2006 and January 2011. Approximately 6 in 10 of those workers left the industry altogether by 2013.\(^\text{12}\)

This challenge, coupled with the general aging of the U.S. workforce and fewer workers entering the industry, means that the industry is struggling to fill the estimated 500,000 construction jobs that are currently open—as well as the thousands more that will need to be filled in the future. The continual decline in access to trades-related training in high schools, the lack of awareness of fulfilling and successful careers in the building trades and the society-wide definition of success focused on pursuing a four-year degree have exacerbated these challenges.

Today’s building industry workforce requires unprecedented technological, social, cultural, political and economic savvy, and the industry is evolving to address its workforce challenges in a number of ways. Across many parts of the industry, there is strong upward pressure on wages, as employers and developers seek out qualified workers. In addition, more industry employers are actively partnering with labor unions, trade associations, local workforce boards and community colleges to develop and promote trades training programs and specialized coursework in advanced design and construction techniques.\(^\text{13}\)

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\(^\text{11}\) https://www.fastcompany.com/3049042/this-industrial-exoskeleton-helps-workers-carry-their-loads


\(^\text{13}\) http://www.constructormagazine.com/the-workforce-shortage-report/#.WaQbjSiGOM8
Enticing more young U.S. workers into jobs in the industry, and reaching out to “non-traditional” workforce categories, including women and veterans, are the key elements in addressing the current shortage. Reaching younger workers will take a significant effort. As identified by Nicholas Wyman, CEO of the Institute for Workplace Skills and Innovation, “Just a few decades ago, our public education system provided ample opportunities for young people to learn about careers in manufacturing and other vocational trades. Yet, today, high-school students hear barely a whisper about the many doors that the vocational education path can open. The “college-for-everyone” mentality has pushed awareness of other possible career paths to the margins.”

Women continue to be vastly underrepresented in the construction workforce, yet they remain a significant potential source to address worker shortages. Women currently comprise almost half of all U.S. workers, yet account for only 2.6% of workers in the construction industry.

Training programs that provide mentors for women, and access to a broad range of industry trades, are needed in order to address this potential workforce. Likewise, as veterans look to transition into sustainable and successful careers in the private sector, more organizations and employers are looking to train U.S. veterans for jobs in the building industry. “Helmets to Hard Hats” programs are successfully training returning veterans to enter careers in the building industry and should be expanded.

Because of the persistent nature of worker shortages, the building industry is beginning to look at viable workarounds to maintain or increase productivity. Already, off-site construction and prefabrication techniques are helping the industry to streamline the construction process with fewer workers. While significant traditional automation in the industry will take years to develop, many companies are looking to invest in technologies and concepts that hold promise for increasing automation as an option to help them deal with the lack of available workers.

Research
To continually improve, the building industry must focus on research and development (R&D). Unfortunately, because of the disciplinary-focused nature of the industry and the small size of most companies, there has been limited investment in R&D aimed at moving the entire industry forward. Across all segments of the economy, the United States was the largest R&D-performing country in 2013, with total expenditures of $456.1 billion, a 27% share of the global total, and an R&D/GDP ratio of 2.7%. Yet, information on the actual amount of investment in building-related R&D is scarce. A 2014 book from the International Council for Research and Innovation in Building and Construction estimated U.S. investments at 0.25 percent of the value of construction put in place. A 1994 study by the Civil Engineering Research Foundation put the value at 0.5 percent. Many governments around the world, recognizing the invaluable role the built environment plays in their economy and the opportunity to support all segments of the economy through improved buildings and infrastructure, have established building industry research and development programs for their countries. Without a commensurate level

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of investment, the United States risks falling behind other nations—not just in buildings but across the economy.

While discipline-centered programs like architecture, construction management, and engineering are commonplace in the United States, college and university programs focused on building science are almost nonexistent. As a result, it is not always easy to find qualified or interested researchers to perform cross-discipline, systems-focused research. In addition, though there has been a rapid increase in new technologies, there is little research available that addresses the performance, reliability and efficiency of new products, systems and processes. For example, codes require the use of air barriers to prevent air leakage from buildings to conserve energy consumption. However, in some cases unintended consequences result because designers lack an understanding of how air barriers function.

With building codes becoming more complex, jurisdictions implementing new energy conservation measures and weather-related risks changing, the United States needs to invest in research to study the performance of systems that incorporate new technologies. A national effort is needed to coordinate and promote collaboration, prevent duplicated research, utilize economies of scale and provide funding. There is a need to collect data within buildings to gauge building performance. Public/private partnerships can be utilized to provide opportunities to lead innovation and partner in research. As discussed above, new technologies could be used to assist with building code enforcement, understanding code requirements and inspection efficiencies. Increased research focused on buildings as a system rather than a collection of individual components will facilitate further advancements in building codes.

**Recommendations**

- The U.S. Congress should ask the Government Accountability Office (GAO) to conduct a thorough review of the current contracting processes it uses to procure federal facilities, and identify opportunities to implement alternative contracting mechanisms and current barriers to the utilization of such approaches.
- The U.S. Congress should require all federally funded construction projects to adopt and effectively enforce building codes that meet or exceed the latest building codes, including projects provided with federal dollars; all states and localities that receive funding associated with community development, infrastructure, public safety or community governance; and all buildings that house federal employees (whether leased or owned).
- The White House should establish a cross-agency program among the U.S. Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA), U.S. Department of Housing and Urban Development (HUD), National Institute of Standards and Technology (NIST) and U.S. Department of Energy (DOE) that focuses on providing scientific and economic data associated with the effectiveness of building codes and their impacts on communities; education and training for code professionals; technical assistance; and evaluation tools for code department effectiveness.
- Congress, working with FEMA and other federal agencies, should enact incentives for state and local jurisdictions to adopt current codes in order to make communities more resilient in the face of natural disasters and to reduce the cost of federal disaster cleanup and recovery.

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20 Building Science is the analysis and evaluation of issues critical to the development of criteria, standards and practices that yield buildings and structures that respond to the environmental, societal, business and sustainable needs of our nation.
• Industry stakeholders should work to incorporate system-level requirements and operations-focused criteria into baseline codes and other policies to assure long-term performance and focus on diligent design, construction and operations in support of community goals and protection of subsequent owners of projects constructed for short-term investors.

• The building industry, with involvement of representatives from the legal, finance and insurance sectors, should conduct a dialogue on how to evolve the current state of fees, timelines and risk in furtherance of a systems-based approach to realize actual, measured performance results.

• DOE, NIST, the U.S. Department of Transportation and other federal agencies should continue working with the building industry to develop an IoT framework that supports efficient deployment of sensors, controls and IoT-enabled devices in facilities and the achievement of building-, community- and national-level goals.

• The codes and standards development community, including the American National Standards Institute (ANSI) and NIST should work collaboratively to develop protocols and best practices that support the utilization of current and future standards within digital environments, including BIM, additive manufacturing, building automation and robotics.

• Congress, the U.S. Department of Education, U.S. Department of Labor, state and local governments and industry stakeholders should promote technical and trade programs in K-12 and technical schools, emphasizing a good career awaits, not a societal judgment. This is applicable to all students, all genders, all races, all economic backgrounds, to break down preconceived notions of who can choose to go into technical building careers. Specific attention should be directed to training programs that provide mentors for women, and access to a broad range of industry trades.

• The building industry along with federal agencies should develop and fund a national high-performance building research and development strategy that reflects the value of the industry to the US economy, mirroring the 2.7 percent economy-wide investment in R&D.
About the Consultative Council
The Consultative Council assembles high-level building community representatives to make recommendations on behalf of the building community directly to the executive and legislative branches of government to improve our nation’s buildings and infrastructure.

Council Members
ASTM International
American Institute of Architects
American Society of Civil Engineers
ASHRAE
American Society of Plumbing Engineers
Associated General Contractors of America
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RCI, Inc.
Royal Institution of Chartered Surveyors
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For more details on the Council, visit: http://www.nibs.org/CC.