The Future of the Built Environment

Prepared for: CII

By: The University of Houston Foresight Program

January 2019

TABLE OF CONTENTS

UNIVERSITY of HOUSTON
COLLEGE of TECHNOLOGY
Foresight

Figure 1. Domain map

EXECUTIVE SUMMARY: OVERVIEW & KEY FINDINGS

Overview

CII sought to expand its portfolio of research topics by identifying and proactively studying potentially disruptive strategic issues. Scenario planning was used to map the potential futures of the built environment. The scenarios were analyzed to identify potentially disruptive strategic issues and thus craft a portfolio of future-based research topics.

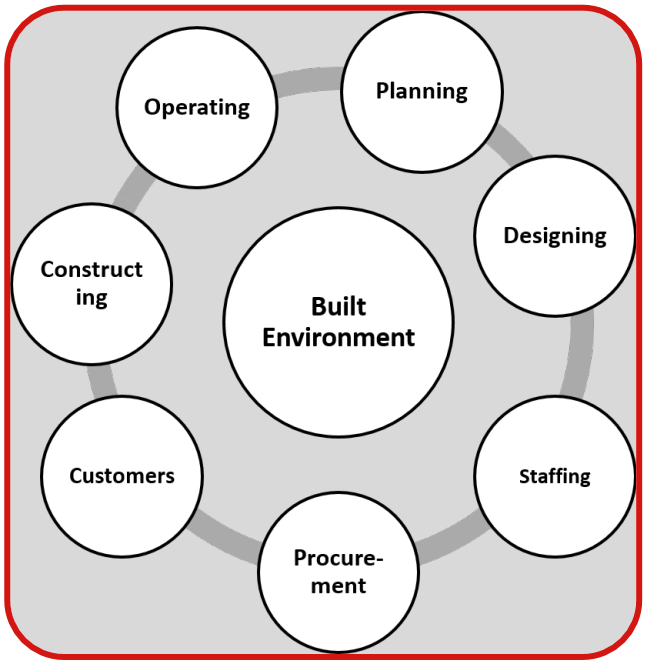
The project used the 2x2 uncertainty scenario planning approach that frames the scenarios around the two most important and uncertain elements regarding the future of the topic. The logic is to spend time thinking about the factors that are crucial to the future, especially those with least clarity or vision of how they might play out. The resulting scenarios create a landscape of plausible future developments or outcomes, which provides organizations the ability to anticipate potentially disruptive strategic emerging issues, whether they be threats or opportunities.

Key Findings

1. Mapping The Built Environment

The domain map is a visual representation of the built environment topic organized by categories and sub-categories. It provides a guide for the research to ensure that key aspects of the topic are adequately covered. The seven primary domain categories are:

- ***Planning*** focuses on factors relating to business and project planning.
- ***Designing*** focuses design-related factors such as BIM, materials choice, landscaping, architecture, safety and integration with surroundings.
- ***Staffing*** focuses on workers, automation, and



related factors such as training, unions, safety.

- ***Procurement*** focuses on the acquisition of equipment, materials, logistics, and transport.
- ***Customers*** focuses on needs related to commercial, government, and residential clients.
- ***Constructing*** focuses on the approaches and techniques for making structures, including factory-built, site-built, modular, and 3D printing.
- ***Operating*** focuses on factors important to operations, such as power, maintenance, waste management, "smartness" and landscaping.

2. 16 Drivers Of Change

Drivers are the key themes shaping the future of the topic. A driver is a thematic cluster of related changes identified from the research and horizon scanning that is driving or shaping significant change in domain. The drivers encompass cross-cutting changes that should be central considerations in developing strategy. They are organized into three types:

- The *Pull of the Future* drivers are more future-oriented and represent *aspirations* or images of how the future could be different, thus they tend to pull the topic toward the future.
- The *Push of the Present* drivers are components of the current landscape providing *momentum* for the future continue in this direction.
- The *Weight of the Past* drivers are the key barriers providing *inertia* to the change we might wish to see

Drivers Explained

Pull of the future
1. **Automation and Labor**: intensifying debate on the "right" relationship between machine and human labor.
2. **Prefab Approach**: move to more of construction working being done offsite and shipped to and assembled onsite.
3. **Shifting Sense of Place**: growing ability to "virtualize" nearly everything raises questions about the role of physical spaces.
4. **Smartness**: the growing capability to add intelligence to any item and link into connected networks and make use of resulting data.
5. **Net Plus**: evolution of social responsibility from being "bad" to neutral to becoming a net benefit
6. **3D Printing**: emerging paradigm shift to manufacturing from the "bottom-up" influences construction.

Push from the present
7. **Integration with Surroundings**: growing demands on buildings to customize fit with particular local conditions.
8. **Mixed-use Development**: move away from single-purpose building to flexible design that can accommodate new and varied uses.
9. **Off-the-grid**: increasing desire and capabilities to make buildings self-sufficient.
10. **Personalization**: increasing expectation among users that their specific needs will be addressed.
11. **Sharing**: increased willingness to share resources over owning increases the demands and options for using space**.**
12. **Voluntary Simplicity**: growing and influential value shift to choosing to less over more.
Weight from the past
13. **Impacts of Climate Change**: perceptions of ongoing shifts in climate contributing to extreme weather events and disasters drive demand for proactive building and infrastructure approaches.
14. **More, and More Varied, Regulation**: increasing efforts to meet complexity of demands with a mix of formal laws and informal nudges (incentives and disincentives).
15. **Transparency and Integration**: growing move away from adversarial approach to working together more openly and effectively.
16. **Trade Power**: increasing impact of the global geopolitical shifts on the supply chain.

3. Interview Findings

Twenty-three interviews were conducted with a mix of selected stakeholders and workshop participants. The interview discussions provided insight into the types of questions important to the future of the built environment that ought to be explored in the scenario workshop:

Workforce Management

- How can we address the workforce resource and skills gap?
- Is the construction industry an ideal career option for the younger generation?
- How can we improve the worker's safety and health?

Productivity/Way of Working

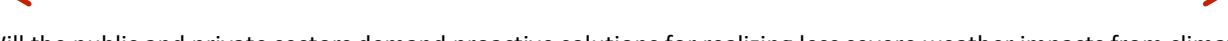
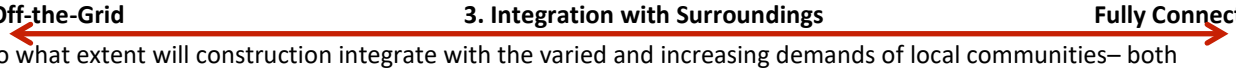
- How can we improve our productivity and delivery of the project on budget, on time?
- How can we break down silos and conflicts between stakeholders? And build more collaborative and seamless integration of teams?
- What will the business model look like in the future?

Technology

- What role will technology play?
- Are we going to be too dependent on technology and lose the fundamentals?
- In an increasingly demanding and resource-constraint environment, how can we optimize the use of data?
- How are people's lives going to be different? What will they care about? Will we face difficulties accessing materials?

4. Key Uncertainties

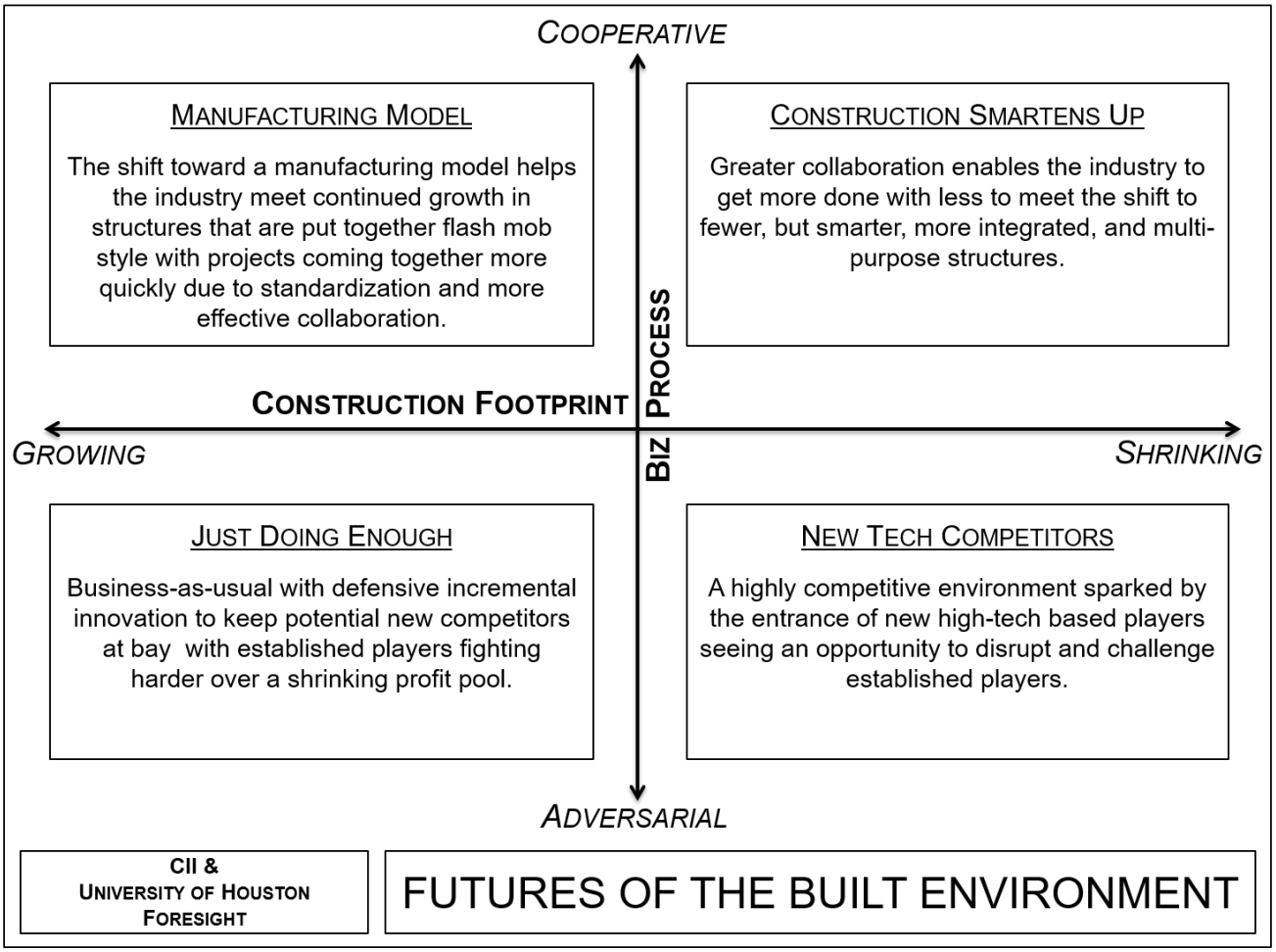
The scenario planning technique used in the project relies on identifying key uncertainties for the future of the topic. Uncertainties have a high level of importance to the topic and a high degree of uncertainty as to how they will unfold in the future. Seven candidate uncertainties were identified for the team to prioritize in the scenario development workshop, and an eighth was added during the workshop.

Candidate Key Uncertainties
Replace — **1. Automation & Labor** — **Augment**  Will automation be used to deal with the labor shortage by replacing humans or to augment human performance as part of a renewed emphasis on workforce development?
Reactive — **2. Climate Change Response** — **Proactive**  Will the public and private sectors demand proactive solutions for realizing less severe weather impacts from climate change, or will a reactive disaster clean-up approach prevail?
Off-the-Grid — **3. Integration with Surroundings** — **Fully Connected**  To what extent will construction integrate with the varied and increasing demands of local communities– both regulatory and incentives/disincentives – such as livable and smart cities, or will the momentum shift to self-sufficiency?
Physical First — **4. Shifting Sense of Place** — **Virtual First**  As virtual capabilities improve such that virtual office and technology-enabled environment can increasingly replace physical facilities, to what extent will decisions about building physical structures be influenced by the potential for

virtual substitution?
Adversarial **5. Biz Process Integration** **Cooperative**  Will contracting and business processes become more open and cooperative as technology tools enable greater integration of systems, data and analytics or remain stuck in adversarial conflict-based approach?
Site-Based **6. Distributed Construction** **Factory**  Will the move toward pre-fabbed, modular, and automated 3D printed components accelerate and increasingly replace site-built, or will the slow pace of change and the craft aspect enable site-built to maintain its share of the building process?
Nice-to-Have **7. Circular Economy** **The Norm**  Will the move toward circular economy principles gain traction as the new guiding philosophy for the design and building of structures and use of materials, including a greater emphasis on retrofitting, or will it remain largely an afterthought or aspiration?
Decentralized **8. Movement of Resources** **Centralized**  Will the movement of equipment, materials, and components to the job site be more centrally coordinated or continue to be ad hoc and haphazard?

5. Scenarios of the Built Environment 2028

The 2x2 uncertainty techniques frames the scenarios around the two most important and uncertain elements regarding the future of the topic. These uncertainties frame the matrix, providing boundaries and focus for the set of four scenarios. The poles of each uncertainty are combined to create four different boundary conditions.



6. Recommended Research Portfolio

The first scenario workshop set the stage for crafting a research portfolio by creating a scenario landscape of the built environment. The second implications workshop is focused on developing potential strategic responses or options for preparing for this landscape. For this project, attention was focused on identifying potentially disruptive strategic issues, which could be topics for funded research. The objective in identifying future challenges is proactively understand and develop potential responses – before they hit. They steps taken to develop the research portfolio were:

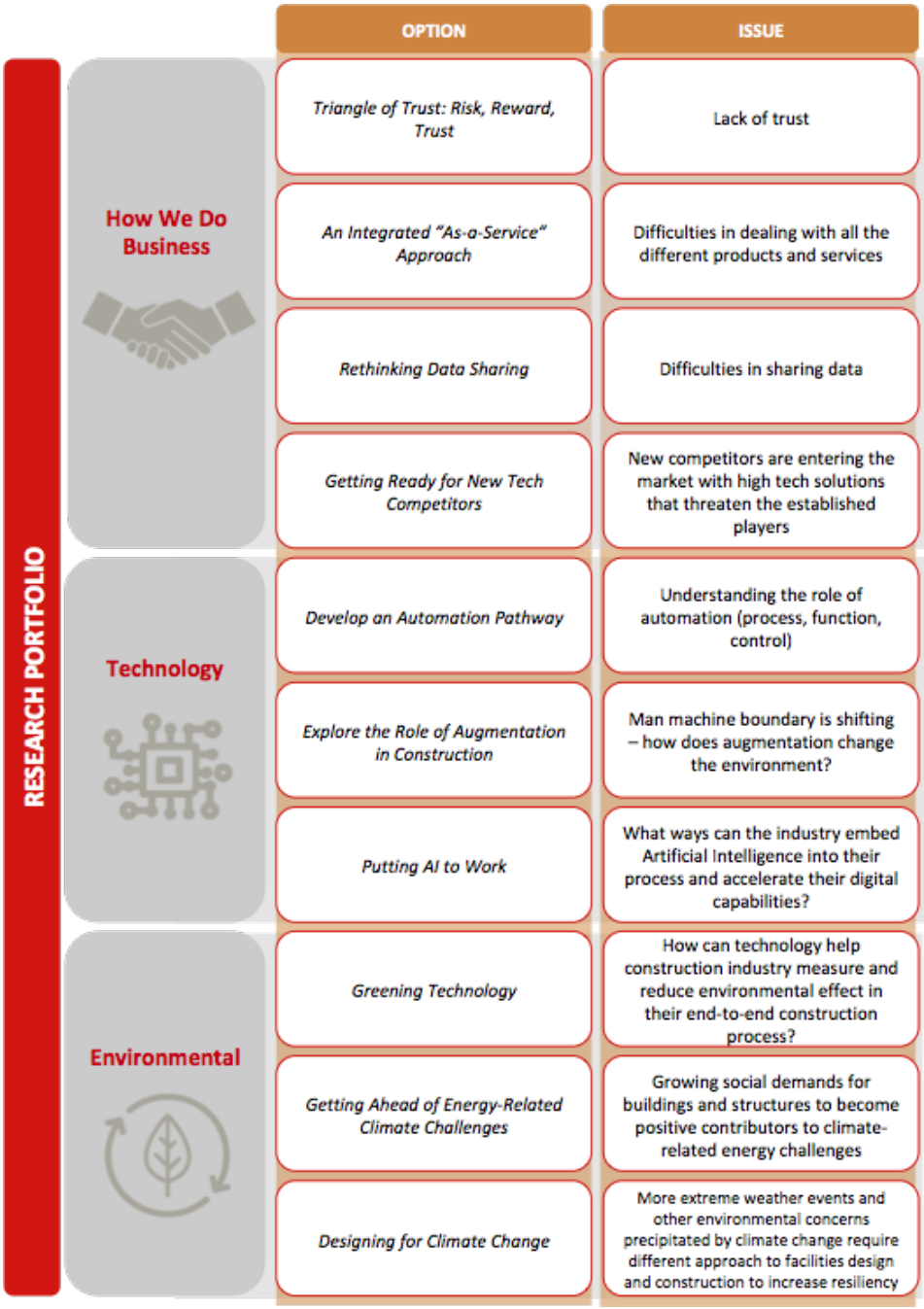
- Brainstorm potential implications or impacts of each scenario
- Identify disruptive strategic issues from the implications

- Develop an option or strategic response to each issue
- Synthesize the output into the research portfolio

These options provide a robust list of potential research projects for CII to consider. They are grouped into three themes.

- How we do business: these options/issues revolve around the business of doing construction, how it's done, and who it's done with.
- Technology: these options/issues centered on potentially disruptive emerging technology with a particular focus on how they might be applied within the construction industry.
- Environmental: these options/issues consider how environmentally-related issues could have a disruptive effect on the industry.

While they are listed separately, there is overlap and connections among these three areas. Business operations, for instance, will be affected by technology and the environment.



7. Getting Started

Returning to the framing question of the project -- **What are the potentially big disruptions ahead in the next ten years for the built environment?** – How might CII get started?

1. Choose initial issues. It is often useful to pick an a small number of issues and have teams do a "quick-and-dirty" initial scoping in a relatively brief time and report back findings and then make a decision on which to select for full study.

2. Revisit each planning cycle. A key consideration is that it is not necessary to go through the full scenario process each year. Assuming the work was done well, the list of issues should be robust for at least a few years if not longer.

3. At some point, refresh the list. The rule of thumb is to let circumstances dictate whether it is time for a new look, not some specific number of years. If there have been significant shifts in the landscape, then a new scenario project may be launched. If there haven't been significant shifts, they will not.

4. Ongoing horizon scanning. Horizon scanning provides a continuous view of the emerging future. Horizon scanning will not only provide insight into which of the scenarios appears to be emerging, but will also alert the organizations to new developments.

5. Other Uses. The scenarios, and the scanning, trends, drivers, and uncertainties that were used to generate them, were used by this project to identify strategic issues to study. But all of this material can be useful in several others ways, such as:

- Strategic planning. Member organizations can use this material as stimulus for developing their individual strategic plans.
- Innovation sessions. The e scenarios, or the individual trends or drivers, could be used in ideation to to develop new product or service offerings.
- Deep dives. Influential individual drivers or scenarios that are especially significant studied separately can be explored more comprehensively through a Deep Dive.

INTRODUCTION

CII asked Houston Foresight to use scenario planning to help explore the future of the built environment. The focus of the project was to use scenarios to identify strategic issues influencing the future of the industry so that CII could proactively study them before they "hit." The objective was to develop a portfolio of potentially disruptive strategic issues over the next decade that would be candidates for CII to study.

This project used the 2x2 uncertainty scenario planning approach. The Houston Foresight program leader Andy Hines led the research, assisted by alum Maria Romero and a team of four graduate students (bios appended). The 2x2 uncertainty approach frames the scenarios around the two most important and uncertain elements regarding the future of the topic. The logic is to spend time thinking about the factors that are crucial to the future, especially those with least clarity or vision of how they might play out. The resulting scenarios create a landscape of plausible future developments or outcomes. This in turn gives organizations the ability to anticipate emerging issues, whether they be threats or opportunities. This approach enables the organization to feel confident that it is prepared for the future, as it has considered a full range of future possibilities.

The principal components of the projects are:

- Framing and Scanning
- Research: Trends, Drivers, Interviews, Knowledge Base, and Uncertainties
- Scenarios: Built Environment 2028
- Recommended Research Portfolio

FRAMING & SCANNING

The first step is to develop a **focal question** to guide and focus the project. A scenario planning study is framed around a focal issue. The team chose: **What are the potentially big disruptions ahead in the next ten years for the built environment?**

> What are the potentially big disruptions ahead in the next ten years for the built environment?

During the project and in the report, we use the term strategic issue to capture the key outputs. It should be kept in mind that we are in particular looking for strategic issues with significant disruptive potential.

While we focused primarily on North America, we drew examples globally where applicable. Many useful examples from abroad were found that may be bellwethers of what is ahead for the North American built environment.

The timeframe was set as the next ten years, with a recognition that it would be useful to consider what's over that horizon.

DOMAIN MAP

With the focal question and timeframe set, the team then created the **domain map** of the key categories. The domain map is a visual representation of the built environment topic organized by categories and sub-categories. It provides a guide for the research to ensure that key aspects of the topic are adequately covered. The seven primary domain categories are:

- ***Planning*** focuses on factors relating to business and project planning.
- ***Designing*** focuses design-related factors such as BIM, materials choice, landscaping, architecture, safety and integration with surroundings.
- ***Staffing*** focuses on workers, automation, and related factors such as training, unions, safety.
- ***Procurement*** focuses on the acquisition of equipment, materials, logistics, and transport.
- ***Customers*** focuses on needs related to commercial, government, and residential clients.
- ***Constructing*** focuses on the approaches and techniques for making structures, including factory-built, site-built, modular, and 3D printing.
- ***Operating*** focuses on factors important to operations, such as power, maintenance, waste management, "smartness" and landscaping.

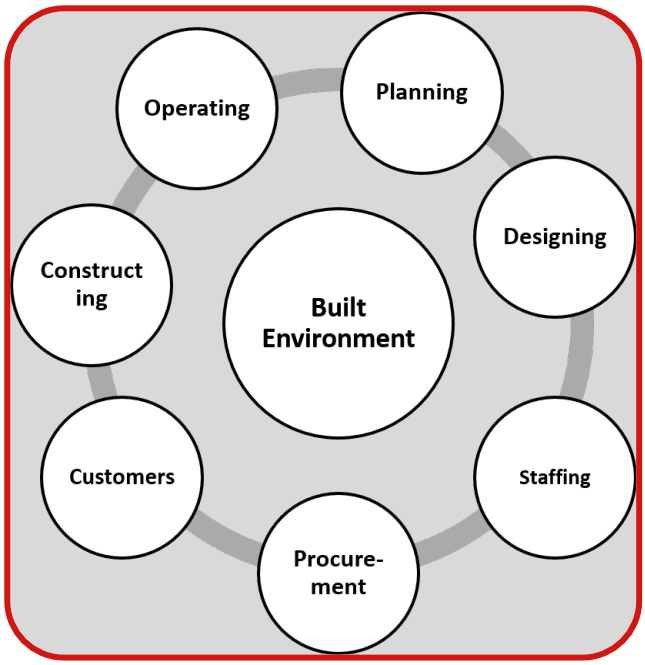


Figure 1. Domain map

STEEP focuses on the social, technological, economic, environmental, and political context influencing the built environment. Futurists use STEEP as a shorthand for considering factors outside of an industry – in this case construction -- that may influence its future. Our experience as futurists suggests that many times the most significant changes or disruptions to an industry come from outside, such as an economic boom or bust, a regulatory swing, design or style shifts, or a new technological development in another industry that could be adapted.

The domain map provides a framework for organizing and guiding the horizon scanning, which is the process of identifying, collecting, and analyzing the "signals of change" in the built environment space. Individual team members were assigned responsibility for scanning for changes using categories above as a guide. More than 300 scanning hits, which included articles, blog posts, videos, reports, etc., were collected into a cloud-based library for annotation. The scanning hits provided useful ideas about how the future could be different that are important for developing the set of scenarios.

HORIZON SCANNING

Horizon scanning involves the identification, collection, and analysis that capture the "signals of change." A "scan hit" is an individual piece of information that captures a signal of change. They may be news or journal articles, blog posts, videos, reports, etc. The signals have varying degrees of evidence to back them, that is, strong signals of change are supported by multiple and credible sources. In contrast weak signals have less support, and there are typically lots of them. A well-rounded horizon scanning process includes both.

We strove for breadth and depth in our scanning to access a wide range of sources, from specialized outlets like Science Daily, Business Insider, and Fast Company to international and local media websites like Reuters, AP, Northeast Valley News, and The Berkshire Eagle. We also indicated which of three time horizons that the suggested change was likely to take place in.

We also strove to ensure a balanced search across the next decade. We used the Three Horizons model, shown in the figure 2 below, to organize the search:

- Horizon One: the short-term future of roughly the next five years in which the current system or way of doing things in an industry largely prevails

- Horizon Two: the mid-term future of transition from five to ten years out in which the existing system is breaking drown and a new approaches are making inroads.
- Horizon Three: the long-term future from the next ten years and beyond in which a new system will eventually take root

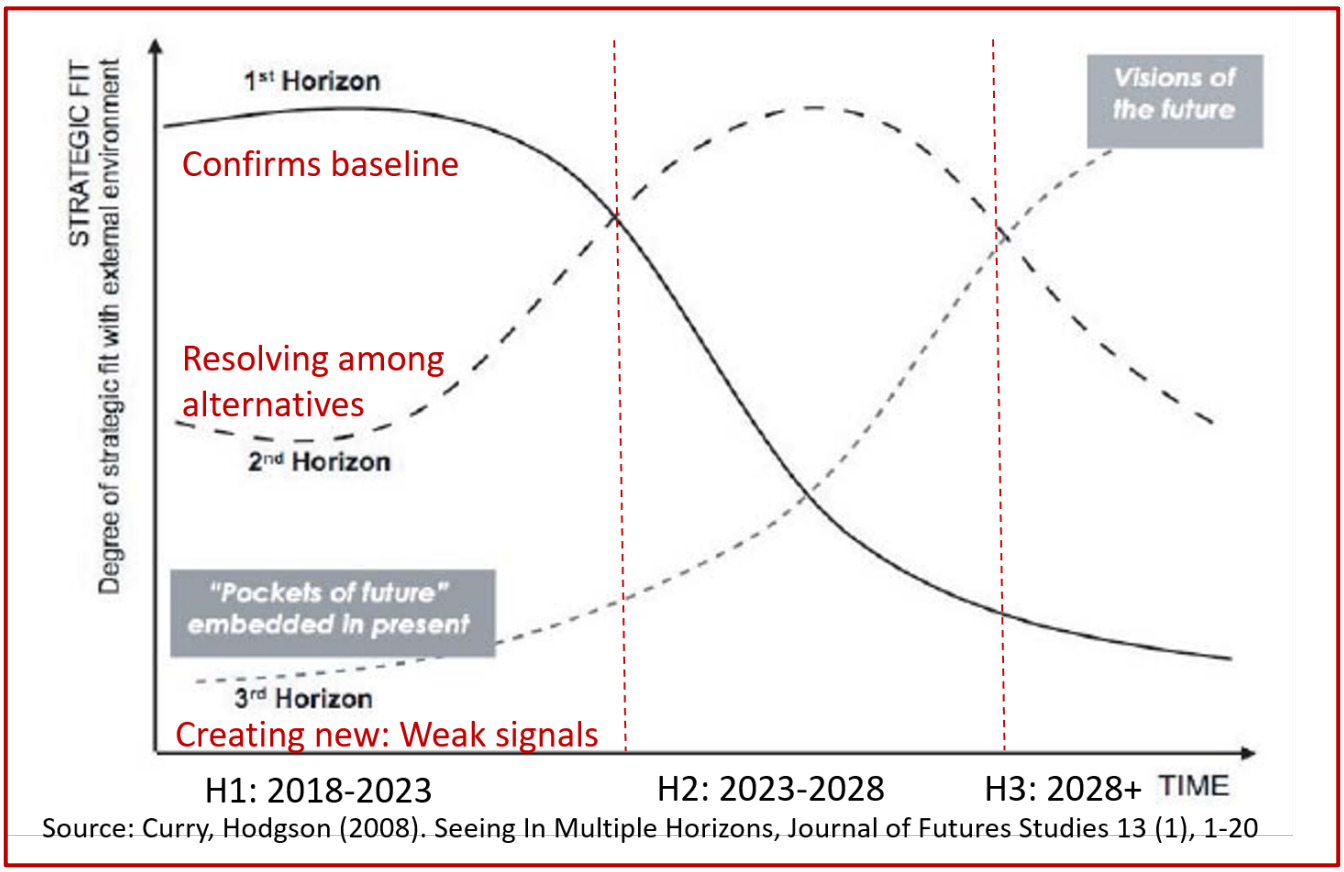


Figure 2. Three Horizons model graphic representation

The team met regularly to discuss and probe more deeply into their potential implications. In our age of abundant information, it's less about finding a piece of information that no one else can find and more about understanding the implications, so that the information can be acted upon in a timely and strategic manner. The Houston Foresight horizon uses three basic steps in scanning.

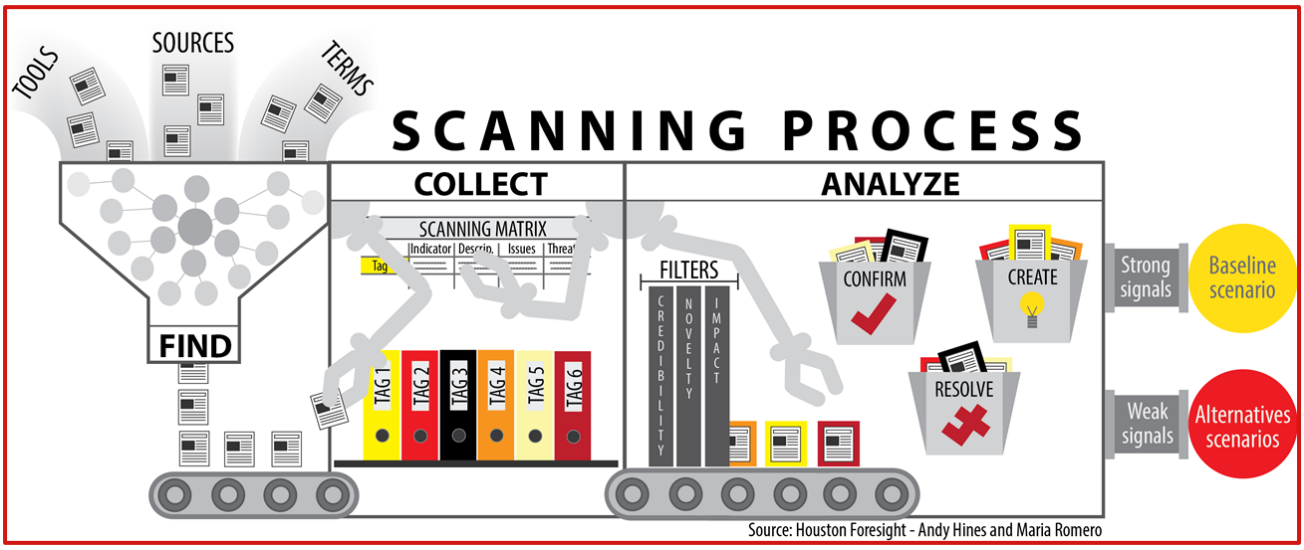


Figure 3. Scanning process graphic representation

- The first, **FIND**, is the process of searching for and identifying potential scanning hits. It uses the domain map categories as jumping-off points to organize the search.
- The second, **COLLECT**, is the process of capturing the resulting scan hits. We use an online, cloud-based bookmarking website or library called Diigo, which captures files or website links in a common location with annotations. Each entry is also tagged based on the domain map categories to ease the retrieval of information.
- The third, **ANALYZE**, uses a simple triage to decide whether to include a scanning hit in the library. When included, the scanner includes a brief commentary on why they thought it was interesting and relevant. A more detailed evaluation of the hits takes place in crafting the drivers.

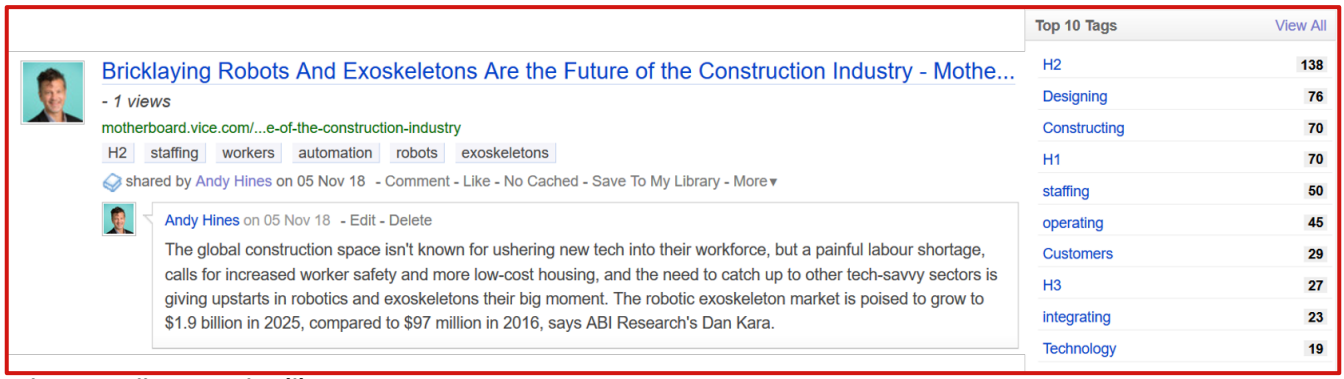


Figure 4. Diigo scanning library

More than 243 scanning hits were collected into our Diigo library. Figure 4 shows a scanning hit and the top 10 tags revealed popular topics from the scanning. As we would hope, the tags reflect a mix of domain map categories, suggesting a balanced approach covering key topics.

RESEARCH

The team conducted research to identify relevant trends and drivers, as well as interviews alongside the horizon scanning. We also reviewed the CII Knowledge Base. The primary objective of the research was identify the candidate uncertainties to explore at the scenario development workshop. The secondary objective was to develop provide inputs or ingredients that would be used to build the scenario stories.

TRENDS

Trends are statements about a change and the direction it is moving. The scanning process will sometimes uncover trends, but more commonly it suggests topical areas in which to look for trends. A team member was given an explicit task to identify and research relevant trends in addition to those coming from the scanning process. The resulting 76 trends (See separate Excel spreadsheet file) were reflective of the domain map, that is, the trend identification used the domain map categories as a guide. These trends in turn helped us to identify the drivers, as well as providing support for the scenario stories. Some of the key trends identified for the future of the construction industry are summarized below:

Labor and staffing challenges. As the workforce ages, it will put additional pressure the staffing and labor shortages already affecting the industry. A recent survey conducted by the Associated General Contractors of America (AGC) found that ~80% of companies currently experience staffing challenges and expect it to continue over the next several years, especially as demand for new construction grows.

More technology applications. Technology-enabled solutions are increasingly used in the construction industry for inspections, staff training, off-site construction of modular components, to automate repetitive tasks, and to augment worker capability on the job site. Facilities design, construction, and maintenance now frequently employ systems such as building information modeling (BIM) that use artificial intelligence (AI) and machine learning computational methods and thus require greater access to big data. As a result, data collection activity – both at construction sites and in completed facilities – is rising.

Jobsite inspections using drones have increased rapidly over the past several years; as more inspections are performed remotely, travel time to sites is reduced and problem resolution can be accelerated. Remote inspections also provide data that integrates with modeling and design software for measuring progress to

plan. In addition, augmented reality (AR) and virtual reality (VR) tools are gaining traction in safety and situational training, allowing workers to experience difficult situations in a realistic but virtual setting.

Prefab growing. Activity in off-site construction and prefabrication continues to grow, with start-ups such as Katerra and FullStack Modular leading the trend. While much attention has been focused on the residential and hotel construction markets in the past, this trend is also increasingly seen in the industrial construction market; UK firm, Bryden Wood, has initiated a project for pharmaceutical company, GSK, with a 'factory in a box' that can be shipped worldwide and assembled on-site according to local standards. Greater use of prefabrication is anticipated as BIM platforms allow more complexity in modularized design elements.

More automation. The trend toward greater use of automation in the construction industry has the potential to increase efficiency and safety as well as reduce costs as robotics-driven solutions are able to perform tasks that were once carried out manually, such as bricklaying, welding, grading and site preparation work, and lifting operations. Automation is closely linked to the prefabrication, as many of the market leaders use robotic systems in the manufacturing process.

Augmentation making inroads. Assistance for workers wearing exoskeleton devices is one example of tech augmentation in the construction industry. Market research firm, ABI Research, projects growth in this market to rise to $1.9 billion in 2025, up from $97 million in 2016. In addition to augmenting workers' physical ability and reducing fatigue, use of exoskeleton robots in the industrial construction setting is expected to improve safety and increase productivity, as well.

Data integration. The trend toward greater integration of data and analytics along the full spectrum of the construction process from design through facility operations will continue. The internet-of-things (IoT) and trend towards greater connectivity and 'always on' monitoring of systems will continue to provide data required by BIM systems for facilities, as well as system control for industrial processes. In addition to data collected on-site, from project documents and specifications, and from proprietary systems, shared data and commercial data assets will continue to fuel AI and machine learning technologies that provide context-specific analysis and insights to quickly solve problems. Design and architecture are areas with growing potential for AI, as well.

DRIVERS

The results from the scanning, trends, and interviews were synthesized into two central inputs to the scenario development workshop: drivers and uncertainties.

Drivers are the key themes shaping the future of the topic. A driver is a thematic cluster of related changes identified from the research and horizon scanning that is driving or shaping significant change in domain. The

thematic changes captured as drivers may come from a combination of scanning hits, trends, or any other insights derived from the research. The drivers encompass cross-cutting changes that should be central considerations in developing strategy. In some foresight projects, the identification of drivers is the key deliverable of the project. Scenario planning goes a step further in exploring how these drivers could plausible interact to create different alternative futures. The scenario planning activity described in the next section explored the degrees of uncertainty around these drivers.

The team developed a list of 16 drivers of change influencing the future of the built environment. They were organized using a tool called the Futures Triangle developed by futurist Sohail Inayatullah (link). It sorts drivers into three categories:

- The *Pull of the Future* drivers are more future-oriented and represent *aspirations* or images of how the future could be different, thus they tend to pull the topic toward the future.
- The *Push of the Present* drivers are components of the current landscape providing *momentum* for the future continue in this direction.
- The *Weight of the Past* drivers are the key barriers providing *inertia* to the change we might wish to see

Each driver is defined in the table below.

Table 1 Drivers Explained

Pull of the future
12. **Automation and Labor**: intensifying debate on the "right" relationship between machine and human labor.
13. **Prefab Approach**: move to more of construction working being done offsite and shipped to and assembled onsite.
14. **Shifting Sense of Place**: growing ability to "virtualize" nearly everything raises questions about the role of physical spaces.
15. **Smartness**: the growing capability to add intelligence to any item and link into connected networks and make use of resulting data.
16. **Net Plus**: evolution of social responsibility from being "bad" to neutral to becoming a net benefit
17. **3D Printing**: emerging paradigm shift to manufacturing from the "bottom-up" influences construction.
Push from the present
18. **Integration with Surroundings**: growing demands on buildings to customize fit with particular local conditions.
19. **Mixed-use Development**: move away from single-purpose building to flexible design that can accommodate new and varied uses.

20. **Off-the-grid**: increasing desire and capabilities to make buildings self-sufficient.
21. **Personalization**: increasing expectation among users that their specific needs will be addressed.
22. **Sharing**: increased willingness to share resources over owning increases the demands and options for using space**.**
12. **Voluntary Simplicity**: growing and influential value shift to choosing to less over more.
Weight from the past
17. **Impacts of Climate Change**: perceptions of ongoing shifts in climate contributing to extreme weather events and disasters drive demand for proactive building and infrastructure approaches.
18. **More, and More Varied, Regulation**: increasing efforts to meet complexity of demands with a mix of formal laws and informal nudges (incentives and disincentives).
19. **Transparency and Integration**: growing move away from adversarial approach to working together more openly and effectively.
20. **Trade Power**: increasing impact of the global geopolitical shifts on the supply chain.

Figure 5. Drivers of change

Figure 5 helps clarify the conflicting currents of change that characterize most landscapes of the future, that is, there are forces of inertia, momentum, and aspiration competing against one another. Scenario planning involves exploring how these various drivers might come together into larger patterns or scenario logics or plot lines.

INTERVIEWS

The interviews are designed to complement desk research. If a piece of information can easily be found on the web, we don't need to ask interviewees about it. The twenty-three interviews were drawn from a mix of selected stakeholders and workshop participants. They responded to a series of open-ended questions designed to encourage strategic thinking about built environment that would be useful to incorporate into the scenario planning workshop. Interviews with selected industry leaders, workshop participants, and external experts are key inputs for the scenario workshops. The questions are open-ended and designed to encourage respondents to reflect and think strategically. There are no "correct" answers. Instead, the responses reveal the hopes and concerns of the respondent that provide valuable input for framing the topics that should be central to the scenario workshops.

The interview discussions provided insight into the types of questions that ought to be explored in the scenario workshop. Most interviewees, for example, mentioned the issue of the labor shortage in the Built Environment and the role of technologies such as AI,

Scenario interview questions

1. If I could answer any question about the future for you, what would it be?

2. What are 1 or 2 critical strategic decisions regarding the construction space are on the horizon? What are your current strategic priorities?

3. What should the construction space need to forget/stop doing?

4. What are the top 2 or 3 trends driving the future of the construction space?

5. If you looked back from 10 years hence and told the triumph in the construction space, what would it be?

6. If you looked back from 10 years hence and told the failure in the construction space, what would it be?

7. What kind of obstacles should we anticipate?

8. What should I have asked that I did not?

BIM, 3D printing, modularization, etc. Also, the interviews revealed current concerns about the adversarial relationship among the stakeholders and the need for more integrated business models. To summarize, the key questions raised by the interviewees are sorted by overarching theme.

Workforce Management

- How can we address the workforce resource and skills gap?
- Is the construction industry an ideal career option for the younger generation?
- How can we improve the worker's safety and health?

Productivity/Way of Working

- How can we improve our productivity and delivery of the project on budget, on time?
- How can we break down silos and conflicts between stakeholders? And build more collaborative and seamless integration of teams?
- What will the business model look like in the future?

Technology

- What role will technology play?
- Are we going to be too dependent on technology and lose the fundamentals?
- In an increasingly demanding and resource-constraint environment, how can we optimize the use of data?
- How are people's lives going to be different? What will they care about? Will we face difficulties accessing materials?

A summary transcript of responses to each question is appended.

CII'S KNOWLEDGE BASE

The CII Knowledge Base was reviewed in detail to calibrate our futures research. We reviewed the project phases and project functions roles to best understand the current day built environment operations, focus and issues.

We also verified our approach to researching the future of the built environment was not counter to or overlapped with existing or recent research. The research topics found in the Knowledge Base are largely current day, operational and tactical items – risk management, project management, safety, etc. - with an emphasis on identifying recommendations for operational improvements to address current day challenges

rather than an exploration of how trends or activities adjacent to or even fully outside the built environment could impact the industry. Even the most recent research areas in the knowledge base - improved integration of the supply chain, improving US workforce development, productivity improvement programs and project planning – did not overlap with what future issues we're seeing around automation, 3D printing and other advanced technologies, and trends to counter the skills shortage or impacts on climate change/environment.

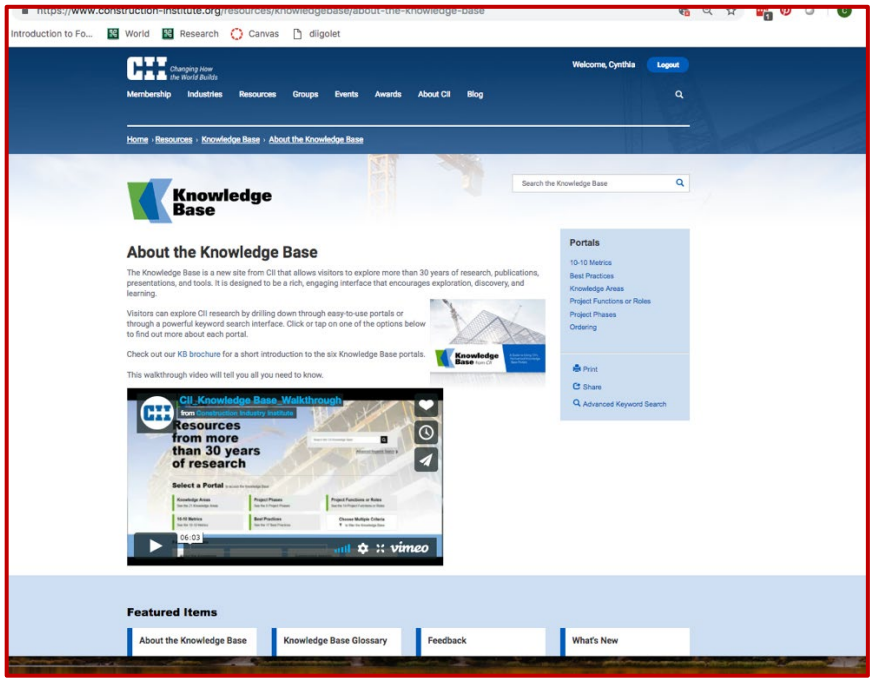


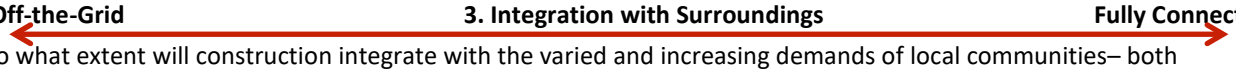
Figure 6. CII Knowledge Base interface

As such, we are confident we have identified several trends and drivers with potential to impact the industry that have not yet been explored within the exiting research, and present exciting opportunities for CII to explore.

UNCERTAINTIES

Uncertainties are at the heart of the of 2x2 uncertainty approach to scenario planning. These are drivers that have a high level of importance to the topic and a high degree of uncertainty as to how they will unfold in the future. Seven candidate uncertainties were identified for the team to prioritize in the scenario development workshop, and an eighth was added during the workshop.

Table 2 Candidate Key Uncertainties

Candidate Key Uncertainties
Replace — **1. Automation & Labor** — **Augment** 
Will automation be used to deal with the labor shortage by replacing humans or to augment human performance as part of a renewed emphasis on workforce development?
Reactive — **2. Climate Change Response** — **Proactive** 
Will the public and private sectors demand proactive solutions for realizing less severe weather impacts from climate change, or will a reactive disaster clean-up approach prevail?
Off-the-Grid — **3. Integration with Surroundings** — **Fully Connected** 
To what extent will construction integrate with the varied and increasing demands of local communities– both regulatory and incentives/disincentives – such as livable and smart cities, or will the momentum shift to self-sufficiency?
Physical First — **4. Shifting Sense of Place** — **Virtual First** 
As virtual capabilities improve such that virtual office and technology-enabled environment can increasingly replace physical facilities, to what extent will decisions about building physical structures be influenced by the potential for virtual substitution?
Adversarial — **5. Biz Process Integration** — **Cooperative** 
Will contracting and business processes become more open and cooperative as technology tools enable greater integration of systems, data and analytics or remain stuck in adversarial conflict-based approach?
Site-Based — **6. Distributed Construction** — **Factory** 
Will the move toward pre-fabbed, modular, and automated 3D printed components accelerate and increasingly replace site-built, or will the slow pace of change and the craft aspect enable site-built to maintain its share of the building process?
Nice-to-Have — **7. Circular Economy** — **The Norm** 
Will the move toward circular economy principles gain traction as the new guiding philosophy for the design and building of structures and use of materials, including a greater emphasis on retrofitting, or will it remain largely an afterthought or aspiration?
Decentralized — **8. Movement of Resources** — **Centralized** 
Will the movement of equipment, materials, and components to the job site be more centrally coordinated or continue to be ad hoc and haphazard?

Uncertainties are at the heart of the of 2x2 uncertainty approach to scenario planning. These are drivers that have high level of importance to the topic and a high degree of uncertainty of how it will play out in the future. Sometimes a team will agree that a driver is highly uncertain and other times there will be strong arguments that it will play out in one direction or another. The team generated a list of nine candidate uncertainties to be discussed and prioritized at the scenario development workshop.

Workshop participants went through three prioritization exercises to reduce the number of uncertainties from nine to the two needed to frame the 2x2 matrix.

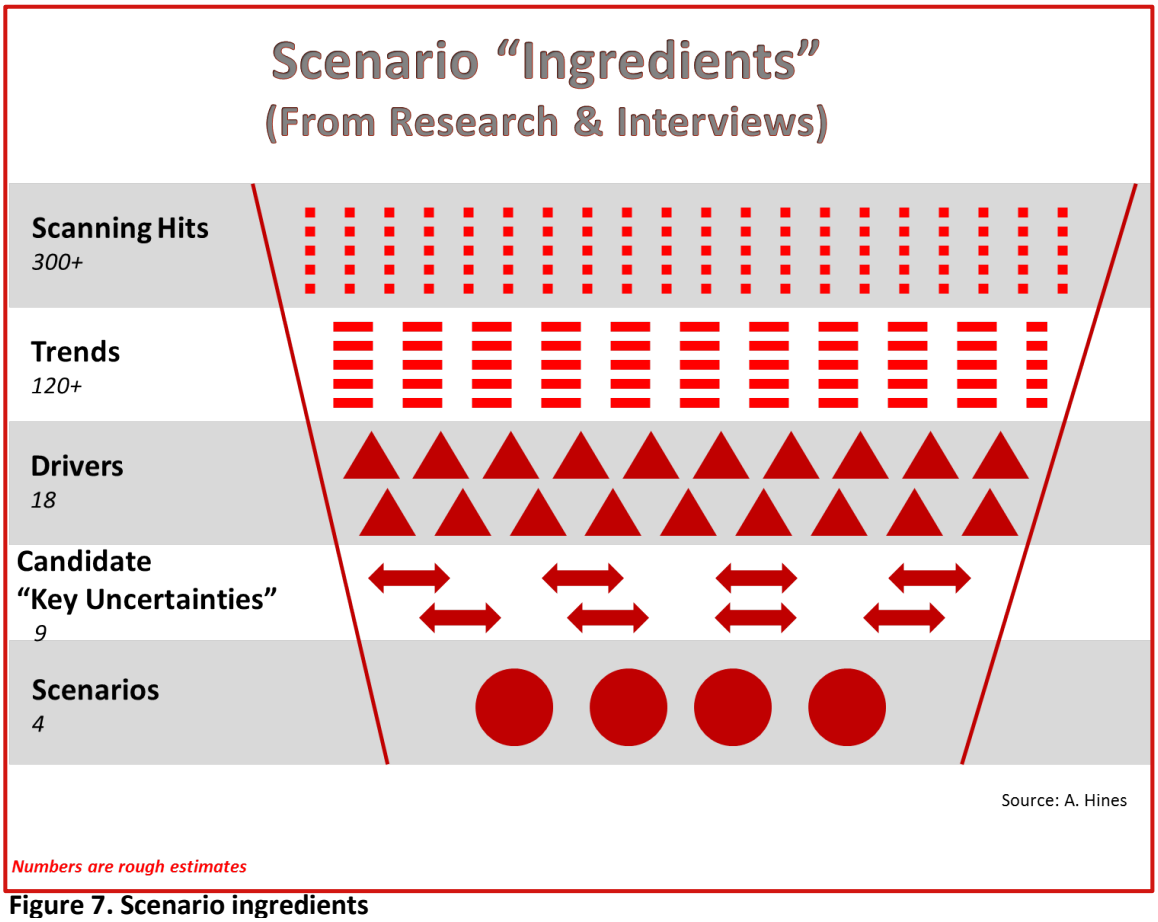


Figure 7. Scenario ingredients

The research for scenario planning is designed to provide inputs into the two scenario planning workshops. It comes from desk research from the team as well as the internal and external interviews. It involves an iterative process of gathering and synthesis. Figure 8 summarizes the key inputs and shows the flow of how each ingredient is largely a synthesis of its predecessor.

SCENARIOS: BUILT ENVIRONMENT 2028

The 2x2 uncertainty approach was developed by the Global Business Network, which was founded by ex-Shell scenario practitioners and colleagues in 1987 (the technique is described in Peter Schwartz, The Art of the Long View, Doubleday, 1991, link). For roughly twenty years, it was the dominant scenario technique and is still popular today. It frames the scenarios around the two most important and uncertain elements regarding the future of the topic. These uncertainties frame the matrix, providing boundaries and focus for the set of four scenarios. The poles of each uncertainty are combined to create four different boundary conditions.
The logic is to spend time thinking about the factors that are crucial to the future, especially those with least clarity or vision of how they might play out. This gives the organization the ability to design strategies, plans, and tactics that will enable it to strategically respond to whatever way the uncertainties unfold. This enables organization to feel confident that it is prepared for a full range of future possibilities.

The scanning, research (trends, drivers, uncertainties), and interviews provide the foundation for developing scenarios. The central focus of the 2x2 uncertainty technique for scenario planning is two workshops: the first to create the scenarios and the second to explore the implications. In this project, the workshops were conducted weeks apart in October and December 2018.

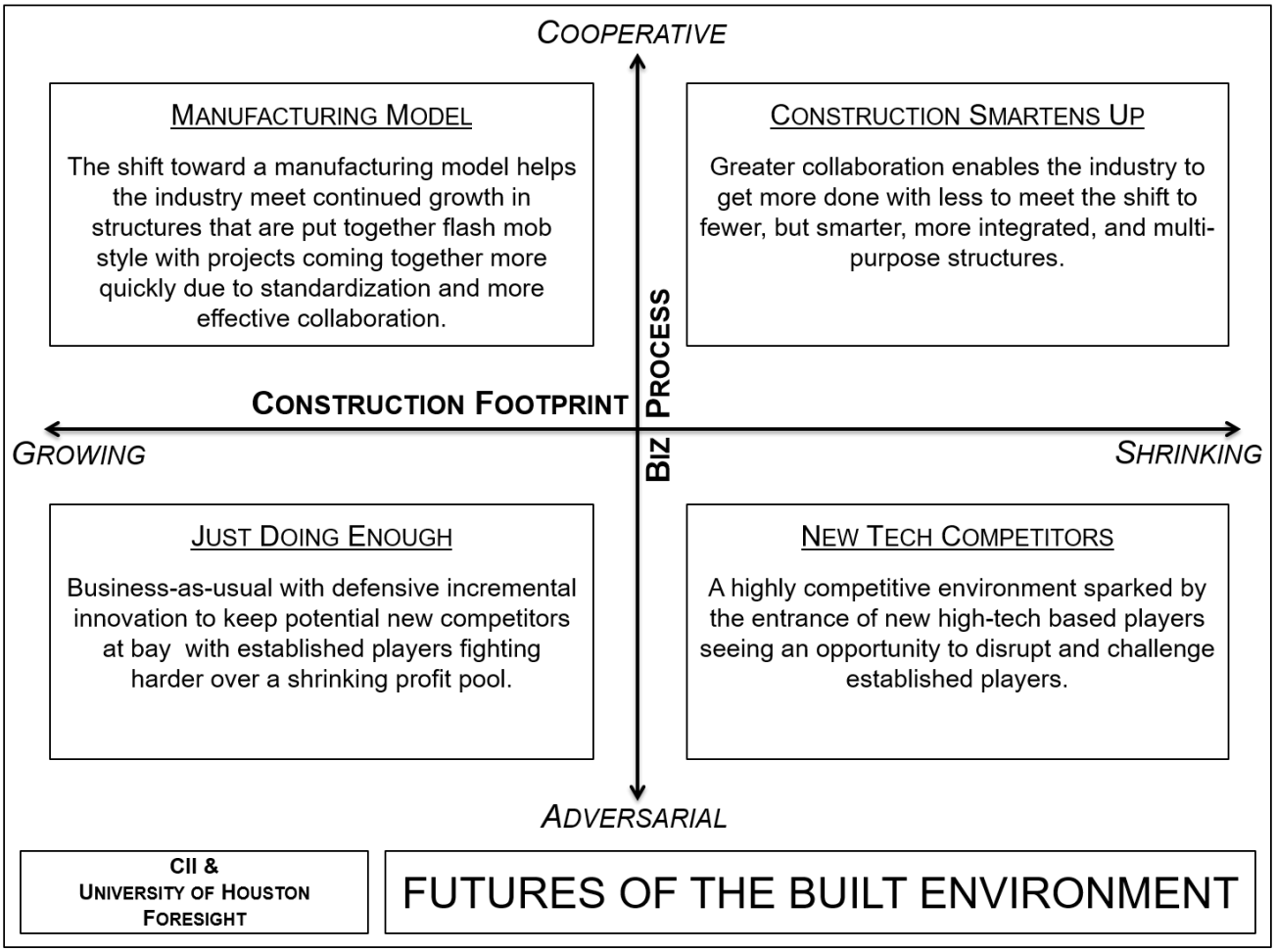


Figure 8. BUILT ENVIRONMENT 2030 Scenario matrix

Each scenario was fleshed out with the following items:

- Summary of the scenario at a glance, including key differences from today
- How the other uncertainties play out in the scenario ("other" refers to those candidate uncertainties not chosen for the scenario axes)
- Key drivers (each workshop team selected what it felt were the most relevant drivers for its scenario
- Headlines, which provide a sense of the pathway to the future by imagining hypothetical events along the way

- Scanning hit sampler provides actual headlines from the research team's scanning that suggest how the future might be different (the full piece is available in the Diigo scanning library)

A common exercise in scenario workshops it to do a "quick and dirty" evaluation of the participants views on how the scenarios compare to one another in terms of how much strategies attention they merit. The goal of this exercise is to see if any scenario is especially important or relatively unimportant. Each team rated the four scenarios on two dimensions:

- How likely is the scenario on a scale of 1-9 (9 is high)
- How unprepared is the organization for that scenario on a scale of 1-9 (9 is high)

Most times, the evaluations reveal a relatively close evaluation, but occasionally there is a scenario that presents a huge threat or opportunity that suggests it merits greater attention. For instance if a scenario is ranked high on likelihood and the organization is not prepared for it – that suggests urgent attention. At the other extreme, sometimes a scenario is judged to not be very likely and the organization is prepared for it – that suggests no further work needed. In our case, the scores turned out to be relatively even.

The scoring is from each team: the first number is the probably score and the second is unpreparedness. The score are close. Participants felt the industry was most ready for "Doing Just Enough," Green Tides, which they felt was the scenario most like today, and equally prepared/unprepared for the other three scenarios

Manufacturing Model	Construction Smartens Up
6+7=13 6+5=11 24	6+8=14 4+7=11 25
Doing Just Enough	**New Tech Competitors**
7+3=10 9+1=10 20	5+8=13 4+8=12 25

Figure 9. Scenario evaluations

Below is an expanded treatment of each scenario. The format includes:

- Summary statement and key facts and stats - to provide an at-a-glance view that frame the scenario
- Scenario description - including key differences from today, captured as "what's changing"
- Scanning hit sampler - provides actual headlines from the research team's scanning that suggest how the future might be different (the full scanning library will be provided in a separate file)
- How the other uncertainties play out in the scenario - refers to those candidate uncertainties considered by the team that were not chosen as the scenario axes, but are nonetheless important
- Top drivers - are the top 3 most influential drivers for each scenario
- Other important drivers - include what each workshop team selected as the most relevant drivers for their scenario after the top 3
- Pathway headlines - provide a sense of the pathway to the future by imagining hypothetical future events likely to occur along the way; they are not intended as precise predictions, but as representative of the kind of changes that would happen in that scenario

DOING JUST ENOUGH

Business-as-usual with defensive incremental innovation to keep potential new competitors at bay. Established players in the industry are fighting harder over a shrinking profit pool with limited workforces.

Key facts and stats

BIM
"Widespread use of BIM faces additional hurdles. As a rule, many firms are involved in a project, each with its own software tools and computer-aided design"
[SMART INDUSTRY]

4.5% projected growth rate over the next several years.

Will cause construction to lead industry in wage & employment growth, but also limit profit margins.
[Tradesmen International]

Training
Construction is "most successful when led or supported by companies invested in training their workforce."
[Entrepreneur]

Scenario Description

Entrenched traditional companies are focused on protecting their domain rather than expanding or innovating. Lack of creativity reduces the talent brought into the field, leading to higher wages to be competitive with workers. Profit margins are lower, but are decent and consistent as well as pretty evenly distributed. Automation 3d printing, modularization, smart buildings all happen, but not particularly quickly. Companies are paranoid about being disrupted but also aren't particularly interested in innovation, possible but seems a strange combination. Maybe they aren't disrupted due to barriers to entry of the industry? Hard to come by large amounts of capital to enter an industry that's already competitive. Also large amounts of complicated regulation could make it hard to disrupt the industry even if the ideas are good. Climate change steps are retroactive only take place after being demanded by government/the people.

What's Changing?

- Environment will not be pleasant or engaging for attracting and retaining talent.
- Cyber security is an even bigger concern than today.
- Fewer traditional companies are doing this work and more upstart companies are trying to enter the industry.
- Cost of doing business will increase due to less industry competition, but due to wages it doesn't translate to much improved profits.
- Retroactive, any focus on sustainability or circular economy comes from public/government.

Scanning Hit Sampler

- Construction is booming now but without new workers and tech its future is uncertain
- Bubble? What bubble? Apartment and condo construction simply can't keep up with demand
- Internet of things smart building: smart building: the future of construction catching up
- Construction sector needs foreign labor
- Blog: constructing a more secure digital future
- 3 tech trends shaping the future of logistics
- Automation puts supply chain workers at high risk for exploitation
- 80% of construction contractors report difficulty finding qualified craft workers
- UK construction industry will need to reskill over 600,000 employees over the next two decades
- Managing building information in large building and infrastructure projects

How "other" Uncertainties Play Out

Uncertainty	How it Plays Out
1. Labor /Automation	• Incremental improvements but not groundbreaking • Lack of skilled labor will become more of an issue • Stifling innovation so cannot attract best and brightest to the industry • Safety and quality deterioration
2. Climate Change Response	• Less proactive • Push for change would have to come from public to government
3. Integration with surroundings	• No interest unless incentivized/regulated • Government and owner push on social responsibility
6. Distributed construction	• In some industries modularization is well-established • Some industries will not want to manage the risk • Early decisions are required, but may not work for the risk-averse industry
7. Circular Economy	• Lack of interest • Will need push from public/government for any action
8. Movement of resources	• Just-in-time approach is not achievable, as it requires trust and cooperation and is too risky

Top Drivers

AUTOMATION AND LABOR

Incremental improvements, nothing groundbreaking. Lack of skilled labor will become more of an issue.

Stifling innovation so cannot attract best and brightest to the industry. Safety and quality improvements limited

MORE, AND MORE VARIED , REGULATION

Government voices the public concern on the environment, however it doesn't translate to any serious action. The constant distrust on each other keeps the checks and balances in place

TRANSPARENCY AND INTEGRATION

Too risky to even consider. Lack of trust in other stakeholders. Privacy is king

Other Important Drivers

Driver	How it Plays Out
Smartness	• Cybersecurity is a huge concern • Just-in-time is considered too risky due to lack of trust, so still require large warehouse/laydown yards • Culture is not open to change, globally • Limited by imagination
Net Plus	• Most companies doing parts of this, but don't see motivation for doing more • Some push from public/government
3D Printing	• Incremental progress will probably be ready for "prime time" in manufacturing by then; some applications in construction, but not broadly used
Prefab Approach	• Incremental improvements, but not ground-breaking • Not open to methods such as miniaturization – seen as too risky

Pathway Headlines

2019	2021	2023	2026	2028
Construction industry continues sluggish productivity growth despite other industries booming Low recruitment drives construction wages up	IT departments develop secure private networks for construction designs and tech New tech deemed "Not there yet" by execs despite popular interest	Polls show growing support for climate change regulation….but industry drags its feet Construction continues consistent low growth for 6th straight year	Procurement dep artments cut costs via IoT & AI Customizable 3d printed/modular structures are [still] just around the corner (as they always seem to be)	Big companies setting up a Climate departments are accused of "climate-washing" Is the focus on cybersecurity paying dividends, or are we just paying through the nose?

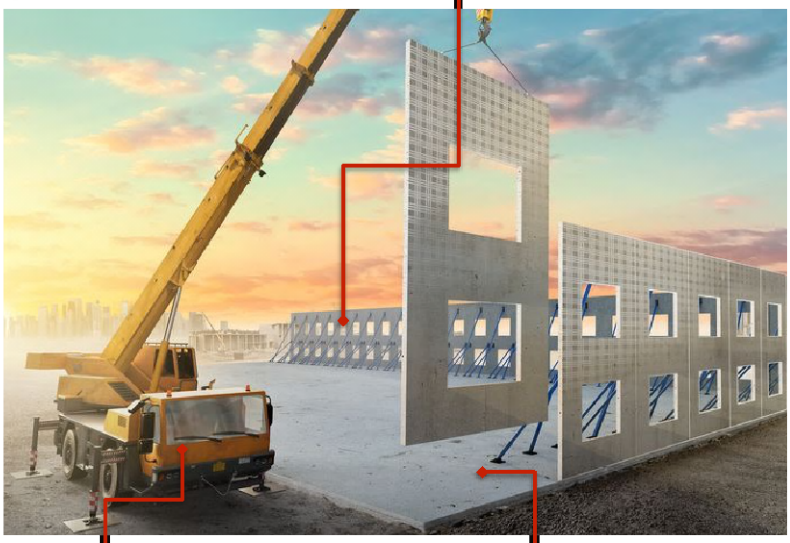
MANUFACTURING MODEL

The shift toward a manufacturing model helps the industry meet continued growth in structures that are put together flash mob style with projects coming together more quickly due to standardization and more effective collaboration.

Key facts and stats

91 %
Reported having a difficult or moderately difficult time finding skilled workers.

[Commercial Construction Index]



7%
Projected growth rate of modular construction market from USD 92 billion in 2018 to USD 130 billion by 2023

[PR Newswire]

BIM
Introduces efficiencies by allowing architects, engineers, and builders to work as teams, sharing information and harnessing the power of the cloud
[SMART INDUSTRY]

Scenario Description

Trusted networks flourish in which all stakeholders collaborate seamlessly and effectively. Networks comprised of pre-certified contractors that are selected based on ratings to put together structures in a flash mob style. Skilled craftspeople post their availability online and firms will search for workers based on their scores from former employers and clients.

Growth in structures continues, and the industry adopts a manufacturing model to standardize the design and process to build prefabricated facilities. As facilities are built, progress information is updated real-time and can be accessed by all stakeholders involved at their fingertips. Ongoing and transparent crowd-sourced assessment of the building progress pushes for operational excellence to minimize the risk and bottlenecks and complete structures much faster and safer.

What's Changing?

- Increased congestion.
- Continued innovation in design and overall performance aimed at standardization.
- Digitally networked workforce.
- Greater use of pre-certification to enable rapid collaboration.
- Improved collaboration and more seamlessly transactional processes (e.g. invoicing) greatly facilitates team-building and alliances.
- Darwinian evolution of infrastructure
- Increased pressure on resources (labor, materials, etc.)

Scanning Hit Sampler

- "Next Generation" Biomanufacturing plant will be the first of its kind in the U.S.
- Global Pharmaceutical/Biotechnology Modular Facilities Market
- Company breaks ground on industrial fabrication shop
- Construction is Booming Now but Without New Workers and Tech
- The Future of Self-Employment in the Construction Industry
- Construction Labor Shortage to Worsen
- Future of Construction is Manufacturing Buildings
- How Technology is Transforming Manufacturing
- Firms Enticing Workers to Get Into Construction with More Education, Higher Pay
- Exoskeletons for Constructions Workers are Marching on-Site

How "other" Uncertainties Play Out

Uncertainty	How it Plays Out
1. Labor /Automation	• Automated processes drive partnership with craft labor • Higher value work in fully employed environment • Continuous/incremental improvement driven by augmented productivity and predictable outcomes
2. Climate Change Response	• Darwinian approach of only doing what is absolutely necessary • If structures are destroyed, simply rebuild them
3. Integration with surroundings	• More innovation to allow easier exchange of data and information with islands of independence
6. Distributed construction	• Moving toward factory/prefabrication to support "one design-build many"
7. Circular Economy	• Rising awareness of increasing scarcity and cost of resources in overbuilt environment leading some to taking circular economy more seriously
8. Movement of resources	• Coordinated material supply chain in open data real time environment

Top Drivers

AUTOMATION AND LABOR

Automated processes drive partnership with craft labor. Higher value work in fully employed environment. Single truth. Continuous and incremental improvement driven by augmented productivity and predictable outcomes

PREFAB APPROACH

The industry moves toward factory/prefabrication to support "one design-build many"

NET PLUS

Increasing scarcity and cost of resources in overbuilt environment will drive reuse and repurposing

Other Important Drivers

Driver	How it Plays Out
Smartness	• AI earlier warning of problems • Insight into project performance root causes and corrective action plans • Computational design leaps to unique and optimum infrastructure
Personalization	• Maker spaces become valuable recruiting grounds for creative and innovative talent needed by industry. • Craftsmanship is flourishing under the radar as an alternative to move to standardized designs
More, and more varied, regulation	• Increased regulation being discussed as a trend to overbuilding and population density, but making little headway within ten year time

Pathway Headlines

2019	2021	2023	2026	2028
Workers fatalities at infrastructure construction site increase by 15% Construction industry sees profit dip as rising cost of raw materials continues	A factory that makes manufacturing facilities It's coming to North Carolina Safety training is pushed back due to insufficient funding	Construction workers get "uber star ratings" 30% of jobs will be automated in the next 5 years	Company leverage crowdsourcing platform to advance prefabrication capabilities Department of labor reports productivity gains in construction industry	HR hosts a celebration for zero-injury quarter Hitachi and general electric co partnership commercializes the next-generation modular reactors

CONSTRUCTION SMARTENS UP

Greater collaboration enables the industry to get more done with less to meet the shift to fewer, but smarter, more integrated, and multi-purpose structures.

Key facts and stats

73 %
Of BIM users cite improved quality/ performance of final building
[Project Delivery]

34 %
The global smart building market is expected to exhibit a CAGR of more than 34% between 2017 and 2024.
[SbWire]

37%
Of construction positions could be automated by 2040
[Mace Group]

Scenario Description

Fewer new facilities are needed, and they are generally smaller, as I/T and smart technologies enable more efficient and effective use of space. Mega-structures in some cases reduce the number of structures needed. Companies in the construction industry collaborate regardless of physical location to deliver either retrofits of existing facilities or deliver new facilities with a multi-purpose intention - facilities that can be used for various purposes simultaneously as well as be easily reconfigured for different purposes as future needs change. Information sharing combines with 3D printing, Internet of Things, and other automation technologies that augment human work, enabling the satisfaction of competing needs simultaneously with transparent decision-making. While the physical footprint is down, the higher value-add of the structures that are built does not adversely affect economic returns.

What's Changing?

- Widespread and deeper integration
- Step changes in innovation and integration
- Optimizing the whole rather than the parts
- Business metrics – better sharing of risk enabled by trust, which in turn enables breaking away from existing economic limitations and boundaries
- Future needs and benefits trump current operating circumstances

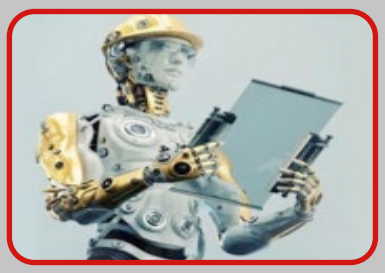
Scanning Hit Sampler

- Walmart trims growth to focus on remodels, e-commerce
- Future facilities to demonstrate virtual prototyping of edge data centers
- Building the next generation of energy from waste facilities
- An Italian winery hidden in the Tuscan hills
- Roadmap for change: the flexible industrial distribution facilities network of the future
- The power plant of the future is your home
- Parking garages are getting a second life as places for people
- The plug-in house built in Boston to demonstrate potential for use in us backyards
- W industrial assets might be in the future for dense us cities
- NBM to present making room: housing for a changing America

How "other" Uncertainties Play Out

Uncertainty	How it Plays Out
1. Labor /Automation	• Greater use of augmentation to improve labor productivity, e.g., delivery labor using tech to delivery (machine learning, AI) • Most replacement is unskilled labor; need for highly trained labor to take advantage of augmentation; e.g., virtual repair and maintenance for facility operations
2. Climate Change Response	• Proactive assessment of environmental impacts, e.g., carbon footprint • More energy-efficient • Fewer structures leads to less waste
3. Integration with surroundings	• Trending towards fully connected, with highly tech-enabled • Increased data collection from people and objects (IOT) • Flexible facilities with multi-function capabilities
6. Distributed construction	• Modularization and prefab increase; made easier with transparency of design info • More work done in factory
7. Circular Economy	• Retrofitting is challenging as existing structures are not flexible • Flexibility designed into new structures so they can adapt and be reused/redeployed, etc. • Designed for longer life means less waste
8. Movement of resources	• Infrastructure more integrated via "smart city" approaches

Top Drivers



AUTOMATION AND LABOR

Automated processes drive partnership with craft labor. Higher value work in fully employed environment. Single truth. Continuous and incremental improvement driven by augmented productivity and predictable outcomes

SMARTNESS

Fundamental driver behind the seamless integration of virtual and physical infrastructures. The efficiency resulting from smarting up the industry pays off

TRANSPARENCY AND INTEGRATION

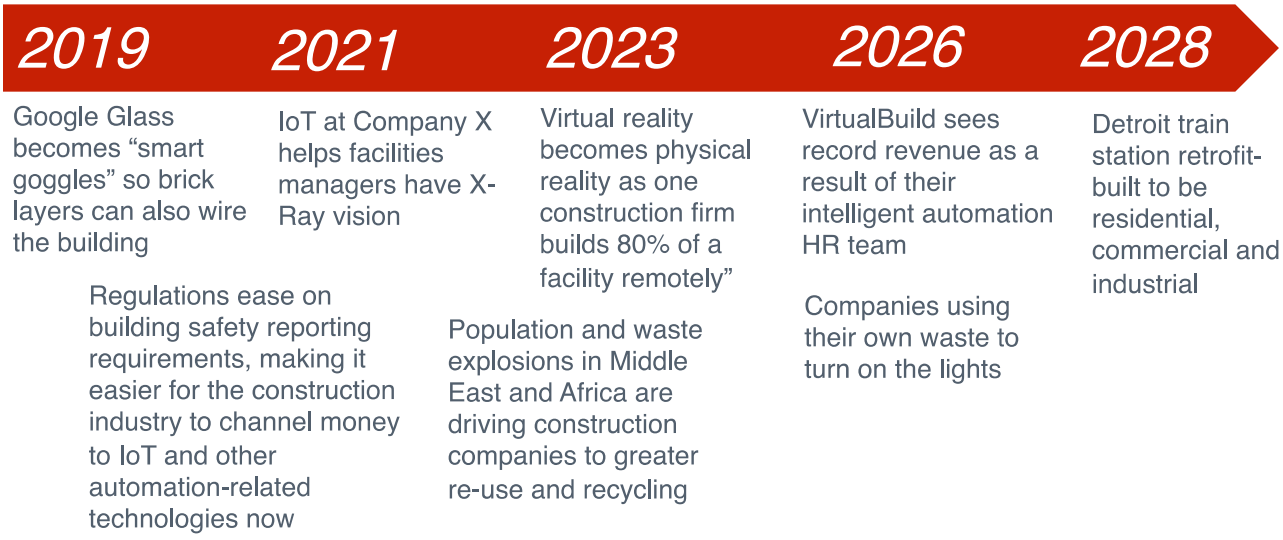
More communication and better coordination. Open data exchange increases innovation. High levels of trust develop between participants

Other Important Drivers

Driver	How it Plays Out
Prefab Approach	• As automation increases, factory-built components are more prevalent • Supply-chain visibility, control, predictability enables more pre-fab • Earlier design completion facilitates prefab
3-D Printing	• Very effective for prefab/modularization • Quicker and cheaper prototyping • Improves maintenance and operations, e.g., fix problems quickly for less downtime
Transparency and Integration	• Greater trust leads to more communication, more open data exchange, and better coordination • Collaborative delivery systems are the norm, e.g., increased operator and sub-contractor input

	• Significant boost in innovation enabled by greater collaboration • Better (more effective) sharing of risk
Smartness	• Smarter facilities • Work is augmented by technology • Infrastructure is more integrated and efficient
Mixed-use Development	• There are fewer but more flexible and multi-purpose structures that demand less infrastructure • Includes more affordable housing and co-working, co-living collectives • Livable communities and new urbanism
Personalization	• Millennial generation living through the phone and apps will influence design (how)
Sharing	• Sharing economy continues to increase for consumers and business

Pathway Headlines



NEW TECH COMPETITORS

A highly competitive environment sparked by the entrance of new high-tech based players seeing an opportunity to disrupt and challenge established players.

Key facts and stats

$1.83 BILLION IN 2023
AI in construction market projected to grow at 35% by 2023; cloud-based solutions are expected to have greatest efficiencies

[AI in Construction Market by Technology and Industry Type]

GROWTH IN ROBOT LABOR
Global construction and demolition robots increasingly used for basic tasks in building construction – 9.5% growth to 2022 forecasted

[Global Construction and Demo Robots Market 2018-2022]

7.1% CAGR
Modular construction market projected to grow to $129.7 billion by 2023

[Research and Markets report]

Scenario Description

As industry players continue their adversarial approach, they focus technology development on cybersecurity to protect innovation and proprietary data sources which leads to greater IT/security costs for every enterprise. Redundancies and lack of cooperation among established companies help create opportunities for new high-tech players. Small, agile technology companies with integrated high-tech design, planning, operations, and maintenance systems take advantage and seek disruptive openings. These new players come from outside the industry and are able to leverage their global experience to leapfrog to high-tech approaches that challenge competitive dynamics - such as greater use of augmented reality (AR), artificial intelligence (AI) and machine learning, prefab manufacturing approaches, and 3D printing.

What's Changing?

- Maintaining competitive advantage requires increasing investment in technology, including AI, machine learning and big data assets
- Reduced facility footprint includes self-contained, on-site utilities and services
- Greater use of multi-use, multi-functional facilities, flexible operations, and shared space
- More tech-enabled design, construction, operations, and facilities maintenance

Scanning Hit Sampler

- Odico launches 'Factory-On-The-Fly' robot system to custom fabricate formwork, insulation, reinforcement, or tiles
- Why Fortune 500 companies use virtual reality to train workers of the future
- Bay Area start-ups see big opportunity in construction technology
- Katerra to integrate Kinestral's Halio smart tinting glass into its smart buildings
- World's first 3D printed reinforced concrete bridge opened
- Autodesk's BIM360 Project IQ uses connected data and AI for risk prediction and prioritization
- Six paths to the automated construction site
- The future of facilities is digital
- Amazon invests in prefab building start-up

How "other" Uncertainties Play Out

Uncertainty	How it Plays Out
1. Labor /Automation	• Established players automating to cut costs • New players reducing some, but more focused on pioneering augmented approach with highly skilled labor
2. Climate Change Response	• Subset of new players attempting to use proactive climate approach as competitive differentiator
3. Integration with surroundings	• Competitive ethos generally discourages cooperative approaches, though some new players promote an integration approach for their competitive differentiation
6. Distributed construction	• Some use of factory-based and modular using standard designs for interchangeable components • New players rely more heavily on distributed as basis of competitive advantage
7. Circular Economy	• Nice to have but difficult to achieve with closed data systems in place
8. Movement of resources	• Fragmented, but supply chain focus on local resources, where feasible

Top Drivers

AUTOMATION AND LABOR

Reducing and augmenting human workforce reduces labor costs and bypasses labor shortage for new competitors, but cost of data analytics and automation offsets savings as closed data systems require high rate of collection and commercial data assets

PREFAB APPROACH

Greater uptake of factory-based and modular construction of facilities use standard designs for interchangeable components

3D PRINTING

Designs are proprietary, centralized in integrated CAD/BIM systems so only authorized contractors can print on-site. 3D printing is cost-effective for smaller companies with distributed equipment and modular design approaches

Other Important Drivers

Driver	How it Plays Out
Automation & Labor	• Competitive pressure on established players push them to reduce labor costs • Automation to improve cybersecurity, data collection, warehousing, protection, processing for use in design, planning, construction, and maintenance
Transparency & Integration	• Lack of transparency and competitive pressures reinforce silos as companies seek to use technology for their advantage
Shifting Sense of Place	• New players drive shift to more work being done in virtual environment and within shared space in facilities
Smartness	• Greater emphasis on data collection and curation and protection to enabled competitive advantage; larger players purchase commercial datasets to help with AI and data analytics • Smart buildings integrate only with other organizations with high cybersecurity

	standards
Net Plus	• Subset of new players ○ Promoting locally sourced and sustainable materials for competitive advantage ○ Promoting recycling move to cradle-to-cradle practices as part of sustainable waste management
3D Printing	• New players pioneering virtual approaches that can be designed centrally then printed on-site or in manufacturing facility in any location
Integration with Surroundings	• Hyper-competitive environment pushes players toward self-contained, stand-alone structures over integrated – for IP and competitive edge • Subset of new players pushing healthy building for competitive edge

Pathway Headlines

COMPARING THE SCENARIOS

After viewing the individual scenarios, it can be useful to look across the set and see how the uncertainties and drivers play out differently. A useful set of scenarios presents four contrasting views of how the future of the topic might evolve. This is not meant to suggest that the future will necessarily follow one scenario or another. Indeed, the future will likely involve a mix of the scenarios to some degree. Rather than get the future precisely right, one hopes to understand the major plot lines while the particular details might be different. In looking across the uncertainties and drivers across the scenarios, one gets a deeper understanding of how the major plot lines of each scenario are different. The comparisons should also instill a sense of confidence that a wide range of options have been considered. It removes the pressure to guess right or predict how the future will turn out, rather one considers the range of plausible outcomes and then monitors how the future actually unfolds.

The table below compares how the uncertainties play out differently in each scenario.

Table 3 Comparing Uncertainties

	Doing Just Enough	**Manufacturing Model**	**Construction Smartens Up**	**New Tech Competitors**
1. Labor /Automation	Incremental but not groundbreaking productivity improvements Lack of skilled labor more of an issue Challenges in attracting talent beginning to affect safety and quality	Automated processes drive partnership with craft labor Higher value work Continuous improvement driven by predictable outcomes and some augmentation	Greater use of technology (AI machine learning, augmentation) improves labor productivity and drives demand for highly-trained labor Unskilled labor increasingly replaced	Established players automating to cut costs New players reducing some labor, but more focused on pioneering augmented approach with highly skilled labor
2. Climate Change Response	Reactive approach Push for change would have to come from public/ government	Darwinian approach of only doing what is absolutely necessary If structures are destroyed, simply rebuild	Proactive assessment of environmental impacts, e.g., carbon footprint More energy-efficient Fewer structures leads to less waste	Subset of new players attempting to use proactive climate approach as competitive differentiator
3. Integration	No interest unless	More innovation to	More use of data from	Competitive ethos

	Doing Just Enough	Manufacturing Model	Construction Smartens Up	New Tech Competitors
with surroundings	incentivized or forced by government or owners	allow easier exchange of data and information with islands of independence	people and IoT trending towards fully connected Flexible facilities with multi-function capabilities	generally discourages cooperative approaches, though some new players promote an integration approach for their competitive differentiation
6. Distributed construction	In some industries modularization is well-established; others don't want to manage risk	Significant move toward factory/ prefabrication to support "one design-build many"	Modularization, prefab & factory built increase, made easier with transparency of design info	New players rely more heavily on distributed as basis of competitive advantage vis-à-vis established players
7. Circular Economy	Lack of interest Needs push from public/government	Rising awareness of increasing scarcity and cost of resources in overbuilt environment leading some to taking it more seriously	More retrofitting, but it is challenging as existing structures are not flexible Flexibility and longer life increasingly designed into new structures	Nice to have but difficult to achieve with closed data systems in this highly competitive environment
8. Movement of resources	Just-in-time approach is not achievable, as it requires trust and cooperation Seen as too risky	Coordinated material supply chain in open data real time environment a key enabler of success	Infrastructure is more integrated via "smart/smart city" approaches	Fragmented, but supply chain focus on local resources, where feasible

During the scenario workshop, teams were asked to identify what they felt were the top three drivers for their scenario out of the sixteen developed for the workshop. To help contextualize these top drivers, the outcomes of the two scenario axes were added above them. It is interesting but not surprising that each team had a top driver in common; this is a typical pattern in foresight work. There is usually some degree of consensus on a few key factors that quickly dissipates as the teams dig deeper. Automation and labor was a key driver in each and transparency & integration in three of four.

Table 4 Top 3 Drivers by Scenario

	Doing Just Enough	Manufacturing Model	Construction Smartens Up	New Tech Competitors
Biz Process Axis	Adversarial	Cooperative	Cooperative	Adversarial
Footprint Axis	Growing	Growing	Shrinking	Shrinking
Top 3 Drivers	**Automation and Labor**	**Automation and Labor**	**Automation and Labor**	**Automation and Labor**
	More, and More Varied, Regulation	**Prefab Approach**	**Smartness**	**Prefab Approach**
	Transparency and Integration	**Net Plus**	**Transparency and Integration**	**3D Printing**
				Transparency and Integration

In table 5 below we compared the rest of the drivers by scenario.

Table 5 Driver Summary Comparison

Scenario / Driver	Doing Just Enough	Manufacturing Model	Construction Smartens Up	New Tech Competitors
Shifting Sense of Place	Continued slow adoption of virtual; construction slowing increasing	Virtual makes less of an impact; more construction.	Most use of virtual to replace physical; less construction.	More use of virtual to replace physical; somewhat less construction.
Smartness	Cybersecurity is a primary concern; other applications lag.	Greater use of technologies to improve project performance, but still limited application in the structures.	Fundamental driver behind the seamless integration of virtual and physical infrastructures improves efficiency.	New competitors create smarter systems but the lack of integration with other systems limits overall efficiency.

Scenario Driver	Doing Just Enough	Manufacturing Model	Construction Smartens Up	New Tech Competitors
Net Plus	Lack of interest with a focus on meeting existing requirements.	Growing concern about increasing scarcity and cost of resources in overbuilt environment has not yet translated into significant action	Movement towards, as new flexible facilities easier to reuse and adapt and materials choices favor efficiency and longer life cycle.	Greener facilities, materials, and resources utilization are a niche market for visionaries, but established players lag.
3D Printing	Slow, steady increase in limited application areas.	Growing as a specialized area, with actual value coming from the intricate and precise design more than the printing itself.	More investment and use leads to quicker and cheaper turnaround via shared designs printed in real time; primarily focused on repairing and quick fixes on site.	Additive manufacturing is cost-effective alternative for small companies able to exploit distributed equipment and modular design approaches.
Integration with Surroundings	Not a factor; build wherever one can get a permit.	Greater coordination with externals not a priority, but improved exchange of data in projects.	More attention to impacts on community, in part enabled by digital design tools facilitating planning.	Closed data systems make it challenging to build external relationships, though some smaller companies moving ahead.
Mixed-use Development	More focus on prototyping the concept than implementation.	Not a focus as facilities are built fast and on-demand.	Flexible multi-functional facilities are increasingly the norm.	Some focus, particularly on interchangeable components within each system to add flexibility
Off-the-grid	Lack of trust in the traditional system encourages facilities to explore more self-sustained infrastructures.	Small movement resisting the "one size fits all model" is pioneering off-the-grid facilities	The trend toward integration is much stronger; few signs of off-the-grid behaviors.	Niche movement to alternative energy grids and other localized utility service networks lead to some redundancies, but also greater self-sufficiency
Personalization	Limited by practicality and lack of trust and standards between adversarial stakeholders.	Maker spaces for sharing access to sophisticated devices, helps to expand craftsmanship as niche market alternative to the industry.	Flexible designs and apps to personalize facilities a selling point.	Personalization is limited by costs but is accomplished through unique combinations of modular components.

Scenario Driver	Doing Just Enough	Manufacturing Model	Construction Smartens Up	New Tech Competitors
Sharing	Security concerns inhibit sharing, but some users are inclined to share whenever there is a monetary benefit in the short term.	Sharing application for streamlined process is vital, but limited to trusted or certified network partners.	A steady increasing trend of consumers and businesses supporting the sharing business model is making inroads in construction.	Rental economics predominate in construction equipment sector; competitive dynamics inhibit sharing except on small scale.
Voluntary Simplicity	No clear movement towards simplicity, unless it is tied to cost-effectiveness.	The environmentally conscious support voluntary simplicity but they are still a minority.	Flexible nature of facilities lets users adapt to their preferred level of simplicity.	Move towards virtual and shared facilities drive younger generations to embrace simplicity.
Impacts of Climate Change	Wait-and-see approach.	Largely reactive; rather than strengthen, just rebuild.	Most proactive as technology is used to address climate impacts in structures and is a selling point.	Some proactive preventative efforts in most vulnerable markets and locations.
More, and More Varied, Regulation	Growing public concern on the environment doesn't translate to any serious action.	Increased discussion about need for regulation to address overbuilding.	Working more closely with regulators; some advantage in using digitally testing and simulation to get ahead of the curve.	. Due to a lack of standardization at federal level, local governments enact regulations as needed.
Trade Power	Just-in-time approach is not achievable, as required trust and cooperation missing.	Coordinated material supply chain in open data real time environment	Maximized efficiency decreases the pressure on global supply chains.	Fragmented but supply chain focuses on local resources where feasible.
Transparency & Integration	Transparency and integration are too risky to even consider in adversarial environment.	More seamlessly transactional processes and greater collaboration among trusted partners.	More communication, better coordination, and open data exchange increases trust and boosts innovation.	Increasing specialization makes standardization across industry challenging, but some competitors doing it are gaining market share of market.

RECOMMENDED RESEARCH PORTFOLIO

The first scenario workshop set the stage for crafting a research portfolio by creating a scenario landscape of the built environment. The second implications workshop is focused on developing potential strategic response or options for preparing for this landscape. It is sometimes referred to as the "so what" workshop – we have a sense of the future from the future, so what can we do about it? In the case of this project, attention was focused on identifying potentially disruptive strategic issues, which could be topics for funded research. The objective in identifying future challenges is proactively understand and develop potential responses – before they hit. They steps taken to develop the research portfolio were:

- Brainstorm potential implications or impacts of each scenario
- Identify disruptive strategic issues from the implications
- Develop an option or strategic response to each issue
- Synthesize the output into the research portfolio

IMPLICATIONS

After reviewing the scenarios, participants in the implications workshop begin by identifying implications or impacts that each individual scenario might present to the industry. They must assume that the scenario "comes true" and consider what that would mean for the industry – even if they don't necessarily believe in a particular scenario. It is important to consider the impact of a scenario that may not seem likely. Futurists have a wealth of experience in witnessing many cases where a scenario favored by a client didn't happen; and the flip side where a scenario deemed unlikely actually came to pass. We often pay special attention to a scenario that a client has an almost visceral or emotion response against, as that is often a clue that this future could present a big challenge that they would rather not deal with.

We used a tool called "Third Order Impacts," which uses a branching approach such that for each implications identified, the teams considers downstream impacts. The goal is not to do an exhaustive analysis of all the possibilities, but to brainstorm a wide range of possibilities. A sample Third Order Impact worksheet is below.

The teams generated a few hundred or so implications by doing several rounds of third-order impact identification.

Table 6 Sample Third Order Impact Worksheet

Key Change Suggested by Scenario	1st order impact	2nd Order Impacts (for each 1st order impact)	3rd Order Impacts (for each 2nd order impact)
Adopt 'fast follower' strategy	Reduced risk of failure b/c criteria for success established by others but requires flexibility for changing market conditions	Directed investment to piloting new technologies & processes	Establish 'skunkworks' teams dedicated to innovation
			Longer lead time allows greater focus on building infrastructure for new paradigms
		Potential for friction, especially in organizations reluctant to write off sunk costs of 'traditional approach'	Active change management campaigns may be required in organizations with high inertia
			Lack of flexibility and agility in decision making may lead to missed opportunities
Acquire competitors when innovation is fairly mature	Potential for culture conflict between established organization and newly acquired teams	Conflict and disruption reduce effectiveness of leadership, productivity of staff	Organizational chaos limits continued innovation, leads to high attrition
			Silos become more entrenched – 'us' vs. 'them' mentality
		Opportunity to improve communication, break down organizational silos	New methods for measuring performance established
			Multidisciplinary teams become new norm
Streamline current processes to become more future-ready	Evaluate current processes to identify vulnerabilities, strengths	Do not value identifying opportunities for process improvement	Churn due to constant 'reinvention of wheel' w/ new learning curve for each project
			Maintaining multiple systems preserves process inefficiencies, knowledge silos
		Open approach to process improvement creates transparency and greater stakeholder collaboration ('we' > 'me')	Reward knowledge sharing among owners, builders, contractors
			Shared data assets allow faster identification of issues and leverage points for improvement

STRATEGIC ISSUES & OPTIONS

The implications provided idea or raw material from which to construct strategic issues, with particular consideration given to those with a potentially disruptive effect – whether a threat or an opportunity. The teams considered the implications generated for each scenario and were asked to identify three to six issues. The combined lists off issues were then discussed in plenary with the intent of selecting balanced coverage of the top two to three issues for each scenario. The bolded issues were the ones selected for the development of options or strategic responses, some of which were developed during the workshop and some after.

1. **Trust**
2. Inertia/resistance to change
3. **Risk/Reward Balance**
4. Unconventional financial commitments
5. **New technology adoption (including augmentation, and AI)**
6. Organizational culture adoption
7. Training new technical skills
8. Business Model
9. **Different product/process [transition to "as a service]**
10. Supply Model
11. Management Structure & Decision-making
12. **Sharing Data**
13. Changes in contracting
14. **Automation (process, function, control)**
15. Speed

It is not unusual in a workshop to focus on some themes at the expense of others. It is often true that participants will focus on those issues closest to the current way of doing things. One of the obligations of futurists in working with clients is to ensure that potential future changes outside of the current way of doing things get due consideration. After the workshop, the core team reviewed the list generated in the workshop and felt that environmentally-related issues could be potentially disruptive, particular as move toward the latter half of the ten-year timeframe. So, the core team did a brainstorming event to identify environmentally-related challenges and added three more issues to the list (outlined below).

Our experience as futurists suggests that while identifying strategic issues is a good and useful activity, its value is greatly enhanced by exploring what can be done about them, which we refer to as options. Options are high-level strategic responses to the strategic issues. A useful tool for capturing the high-level responses at the workshop – and afterwards – is the elevator speech tool. We used a version of the elevator speech tool employed by the Houston Foresight program that was adapted from Strategos, the former company of business guru Gary Hamel. The goal is to capture the essence of how the client might develop a longer-term strategy for responding to the issue as well as first steps in the present. The particular version of the elevator

speech tool used for this project was customized to capture information most useful to outlining a potential research project for CII.

DRAFT RESEARCH PORTFOLIO

After reviewing the issues and options from the workshop, the team reviewed all the research to ensure a robust portfolio of recommendations. As mentioned above, in a workshop setting there is often not enough time to fully explore all the relevant issues. Thus three environmentally-related issues and options were added. The options listed below to address the strategic issues are intended as potential research areas. It should be noted that some of the options/issues developed during the workshop were slight modified or re-named by the core team after the workshop.

Obviously, more work will need to be done to full flesh these options out, but they should provide a robust list of potential research projects for CII to consider. They are grouped into three themes.

- How we do business: these options/issues revolve around the business of doing construction, how it's done, and who it's done with.
- Technology: these options/issues centered on potentially disruptive emerging technology with a particular focus on how they might be applied within the construction industry.
- Environmental: these options/issues consider how environmentally-related issues could have a disruptive effect on the industry.

While they are listed separately, there is overlap and connections among these three areas. Business operations, for instance, will be affected by technology and the environment.

RESEARCH PORTFOLIO

	OPTION	ISSUE
How We Do Business	***Triangle of Trust: Risk, Reward, Trust***	Lack of trust
	An Integrated "As-a-Service" Approach	Difficulties in dealing with all the different products and services
	Rethinking Data Sharing	Difficulties in sharing data
	Getting Ready for New Tech Competitors	New competitors are entering the market with high tech solutions that threaten the established players
Technology	***Develop an Automation Pathway***	Understanding the role of automation (process, function, control)
	Explore the Role of Augmentation in Construction	Man machine boundary is shifting – how does augmentation change the environment?
	Putting AI to Work	What ways can the industry embed Artificial Intelligence into their process and accelerate their digital capabilities?
Environmental	***Greening Technology***	How can technology help construction industry measure and reduce environmental effect in their end-to-end construction process?
	Getting Ahead of Energy-Related Climate Challenges	Growing social demands for buildings and structures to become positive contributors to climate-related energy challenges
	Designing for Climate Change	More extreme weather events and other environmental concerns precipitated by climate change require different approach to facilities design and construction to increase resiliency

The ten options/issues are described in the elevator speech format below.

HOW WE DO BUSINESS

Lack of trust - ***Triangle of Trust: Risk, Reward, Trust***

Category	Description	
What is the issue? And the title of your response?	Issue: Lack of trust Response: ***Triangle of Trust: Risk, Reward, Trust***	
Why is it important?	Lack of trust costs money and underpins a lot of industry problems Leads to waste (spending on lawyers and insurance instead of for owners Biggest brake on adoption of innovation/new approaches Risk and reward are aligned to contribution Applies to OPEX and APEX	
What are the key areas to study? Key research questions?	How can we deal with mentality of "need someone to blame?" What can we learn from other industries, military IT hardware (Sematech)? How can we improve team structure + collaboration within and across organizations? How can we develop the different skillsets required in team mgmt vs project mgmt.? Should we adopt waterfall and scrum approaches? How do we embrace that notion that "conflict can be good?" How can we develop and adopt trust structures, including responses to breaches of trust? Can the impacts of lack of trust be quantified? How can we reconcile different definitions of success between owners and service providers?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Wide net and wide bridge Softer stuff is harder to study Should be useful examples of other industries	Impact Dealing with view that resolving trust issue "will never happen" Lots of dollars being wasted It's the elephant in the room

HOW WE DO BUSINESS

Difficulties in dealing with different products and services - ***An Integrated "As-a-Service" Approach***

Category	Description	
What is the issue? And the title of your response?	Issue: Difficulties in dealing with all the different products and services Response: ***An Integrated "As-a-Service" Approach***	
Why is it important?	It would revolutionize the ecosystem and its dynamics. Key steps to standardization. Allows focus on core business.	
What are the key areas to study? Key research questions?	What are the nuances between sectors? What standards are required to create "services"? Who creates the standards? How would a complete transition to "as a service" environment impact capital deployment? The deployment of capital isn't executed/delivered to the end-user. How to transform the supply chain from product to service? Would it incentivize a shorter-term market?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility We are not equipped to execute this project.	Impact Owners: Alter the decision-making process (Commitment and risk) Service providers: Risk assessment and investment decisions. Need to compensate for owners.

HOW WE DO BUSINESS

Difficulties in sharing data - ***Rethinking Data Sharing***

Category	Description	
What is the issue? And the title of your response?	Issue: Difficulties in sharing data Response: ***Rethinking Data Sharing***	
Why is it important?	Info is siloed, which impedes decision making Can't get our arms around the issues/problems Sharing would improve project delivery; having it being open facilitates analysis and action and promotes learning opportunities Will likely find cases where "what we thought was true, isn't" Should be using data to make decision rather than making assumptions	
What are the key areas to study? Key research questions?	What data is valuable to share? Should we just share everything? And with whom, e.g., stakeholders? What are the barriers to sharing? (Evaluate the current approaches of what data is or is not shared); What info is needed and how do we get it? What data is useful and what is not? What tools can help gather and share it AI? Who should owns that versus accessing it? What is the proper relationship between single and ongoing use? What are the key liability issues? What are the key security issues? What is the right level of normatlization, i.e., classification structure, tagging and naming What can we learn from adjacent markets, e.g., airlines?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Very feasible in bite size? (Some of the issues are already studied)I Interview project participants and the develop surveys and case studies Survey/case studies	Impact Would provide lens into "the waste" Huge opportunity and threat, but might have believability issues Bring in BI and AI and visualization process into the industry

HOW WE DO BUSINESS

New competitors are entering the market with high tech solutions that threaten the established players - ***Getting Ready for New Tech Competitors***

Category	Description	
What is the issue? And the title of your response?	Issue: New competitors are entering the market with high tech solutions that threaten the established players. Response: ***Getting Ready for New Tech Competitors***	
Why is it important?	Efficiencies and advantages can be gained for future-ready companies employing data analytics solutions in the construction industry Several new competitors have already gained a foothold with high-tech capabilities; understanding the potential impact will help CII members create proactive change and reduce disruption	
What are the key areas to study? Key research questions?	Competitive landscape analysis to identify new high-tech competitors and understand service offerings in this niche Structuring of strategic partnerships among consortium members to share data and technologies for greater efficiency Evaluate which new competitors may be appropriate targets for acquisition Identify data acquisition methods and commercial data assets that will be required for high tech solutions in future	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Research and market analysis reports Incorporate full spectrum of member companies' expertise Include other market segments (municipal infrastructure, residential construction) to identify parallels and effective responses	Impact Understanding the potential entry points and competitors' use of technology to improve processes can help CII member companies prepare for future disruptions in the market

TECHNOLOGY

Understanding the role of automation - ***Develop an Automation Pathway***

Category	Description	
What is the issue? And the title of your response?	Issue: Understanding the role of automation (process, function, control) Response: ***Develop an Automation Pathway***	
Why is it important?	Potential to increase productivity and predictability by reducing variability. Ability to control or replace something.	
What are the key areas to study? Key research questions?	What controls or functions in the capital deployment world can be automated? Understanding automation as "convert to an automatic procedure (not pneumatic or electronic) What would have more impact in the industry if it was automated? Who develops, operates and owns the machines?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Yes, but the information is fragmented.	Impact The industry could agree on data collected and processed by automated tools.

TECHNOLOGY

Man machine boundary is shifting – how does augmentation change the environment? - ***Explore the Role of Augmentation in Construction***

Category	Description	
What is the issue? And the title of your response?	Issue: Man machine boundary is shifting – how does augmentation change the environment? Response: ***Explore the Role of Augmentation in Construction***	
Why is it important?	Automation that augments human capability is being inserted in construction That automation doesn't replace the human, but changes the skills necessary in the built environment (have to understand how to program a machine to lift without causing an accident) – have to learn how to operate a different type of machine than before. Automation is progressing quickly and with a labor intensive industry there is pressure to insert technology. Has the potential to change the financial exposure due to cyclical nature of built environment	
What are the key areas to study? Key research questions?	What are the impacts on economic models (lease/rent s. own) Impacts of new economic models on traditional built environment – in capital expenditures and in wages/employment. Training/simulation capabilities – how to implement Quality assurance is currently unclear – how do you validate the work is accurate when you can't always see the in-process work in stages? How do you fix or re-do work that is automated? Can you? Can the machine be hacked? How do you handle security of leased machines operated remotely? Operated with remote options? Integration of IT security with built environment. Safety issues/consistency issues of man/machine automation combinations	
Feasibility & Impact Is the research obtainable? Impact of addressing for CII members?	Feasibility Feasible to do research but must have interim reporting/results delivery to avoid scope creep relative to tech advancements. Would provide members with recommendations and guidance on how to steer future projects and where to invest in 'built environment tech infrastructure' so they can prepare for future	Impact Could demonstrate where to embrace man/machine integration for best case outcome in industry. Could identify where quality and safety need to be refined or perfected before the man/machine integration can be fully embraced Help progressives get funding to get ahead

TECHNOLOGY

What ways can the industry embed Artificial Intelligence into their process and accelerate their digital capabilities? - ***Putting AI to Work***

Category	Description	
What is the issue? And the title of your response?	Issue: What ways can the industry embed Artificial Intelligence into their process and accelerate their digital capabilities? Response: ***Putting AI to Work***	
Why is it important?	Currently, the end-to-end built environment process fluxes from project to project. The industry often faces delays with their overall process due to unpredictable circumstances. As the industry become more competitive and data-driven, the industry will first need to standardize the overall process and accelerate their AI capabilities	
What are the key areas to study? Key research questions?	What will the new business model look like with AI? What kind of workforce and capabilities are required to accelerate AI driven process? What regulations and process need to be implemented to ensure human workers and AI are working effectively? What level of cyber-security measures should be implemented? How to ensure right data feeds into AI? What ways to develop AI capability? Acquisition? Develop internal skills? Partnership?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Require expertise in AI	Impact There is a tremendous amount of hype around AI,but great uncertainty about how it could usefully implement in construction

ENVIRONMENTAL

How can technology help construction industry measure and reduce environmental effect in their end-to-end construction process? - ***Greening Technology***

Category	Description	
What is the issue? And the title of your response?	Issue: How can technology help construction industry measure and reduce environmental effect in their end-to-end construction process? Response: ***Greening Technology***	
Why is it important?	Every stage of construction projects have a measurable impact on our environment. With continued pressure to consider environmental issue, the industry standard may be forced to raise beyond green building and recyclable materials. Artificial intelligence and connected network infrastructure will eventually drive the industry to track and be transparent how the projects are impacting the environment.	
What are the key areas to study? Key research questions?	What standards and regulations should the industry anticipate? How will data management accelerate the industry's green practice? How can green investment benefit the industry? What environmental effect information are required to inform the stakeholders?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility highly feasible with connected network infrastructure, increasing pressure to address environmental issue	Impact Members will be informed to better understand how green investment will impact the construction industry. With real-time accessible data, industry will be able to make more environment-friendly decisions.

ENVIRONMENTAL

Growing social demands for buildings and structures to become positive contributors to climate-related energy challenges - ***Getting Ahead of Energy-Related Climate Challenges***

Category	Description	
What is the issue? And the title of your response?	Issue: Growing social demands for buildings and structures to become positive contributors to climate-related energy challenges Response: ***Getting Ahead of Energy-Related Climate Challenges***	
Why is it important?	Climate change is driving alternative power options globally If investors/building owners create power generating buildings they will want to benefit financially, and that will drive attention from regulators and legislators; this, in turn could completely change the traditional economic model of the built environment Quality, security and safety are still undecided	
What are the key areas to study? Key research questions?	What are the impacts on economic models when a building can sell back power reliably and consistently? How do other industries address this model change? What are the potential regulatory impacts to this type of building industry? Are there additional or different safety issues to be address with a power positive building whose primary purpose isn't power generation – only its secondary purpose? Is this feasible for any type of primary facility or are there instances where this can't work?	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Might be difficult to identify a large enough sample to consider second and 3rd order impacts Should be considered in multiple climate options depending on the type or source of the power generation	Impact Could demonstrate whether this could be financially viable enough to repeat Could identify where quality and safety need to be refined or perfected as well as clearly identify the regulatory challenges of this approach at large scale Help to convince skeptics of climate change that the built environment can positively impact the environment Help people think out of the box about traditional built environment

ENVIRONMENTAL

More extreme weather events and other environmental concerns precipitated by climate change require different approach to facilities design and construction to increase resiliency - ***Designing for Climate Change***

Category	Description	
What is the issue? And the title of your response?	Issue: More extreme weather events and other environmental concerns precipitated by climate change require different approach to facilities design and construction to increase resiliency Response: ***Designing for Climate Change***	
Why is it important?	Indices of global climate change are trending toward greater impacts of extreme weather events in future CII members can better prepare for future climate-related business disruptions and increased regulatory requirements by anticipating future environmental changes	
What are the key areas to study? Key research questions?	Methods to 'build-in' resiliency such as low profile design, structural enhancements, and self-contained utilities within facilities to provide greater location-appropriate readiness for weather impacts Future trajectory of regulatory ecosystem to anticipate how environmental legislation/regulation may impact building codes, materials selection, carbon reduction of building processes, or design standards in future Identify best practices in sustainable construction methods - including ways to reuse and recycle building materials, adapt to potential scarcity of resources needed for construction (such as water, sand)	
Feasibility & Impact **Is the research obtainable?** **Impact of addressing for CII members?**	Feasibility Consider industry- and location-specific parameters Reuse/recycling of building materials topic may have overlap in waste disposal research projects	Impact Identify potential areas of disruption to help prepare for new climate conditions and regulatory requirements Plan construction and deconstruction projects to optimize materials availability

GETTING STARTED

Returning to the framing question of the project -- **What are the potentially big disruptions ahead in the next ten years for the built environment?** – how might CII get started?

1. Choose initial issues
2. Revisit each planning cycle
3. At some point, refresh the list of issues
4. Ongoing horizon scanning
5. Other uses of the project material

1. Choose initial issues. It would be presumptuous for the Houston team to suggest how CII should go about its business. We can offer the observation that we have recommended to clients in the past that it is often useful to pick an a small number of issues and have teams do a "quick-and-dirty" initial scoping in a relatively brief time and report back findings and then make a decision on which to select for full study.

2. Revisit each planning cycle. Once the initial issue(s) have been studied, and it is time to choose again, other candidates that did not make the cut the first time can be reconsidered. It may be that developments over the previous cycle will suggest a candidate that may not have garnered much attention in the initial cycle. A key consideration is that it is not necessary to go through the full scenario process each year. Assuming the work was done well, the list of issues should be robust for at least a few years if not longer.

3. At some point, refresh the list. At some point, however, it is time to revisit the future landscape. The most successful user of scenario planning in our view, Shell, will consider revising scenarios between three and five years. If there have been significant shifts in the landscape, then a new scenario project may be launched. If there haven't been significant shifts, they will not. The rule of thumb is to let circumstances dictate whether it is time for a new look, not some specific number of years.

4. Ongoing horizon scanning. A set of scenarios is a snapshot of the future at a point in time. To really deepen the organization's insight and understanding of the future, horizon scanning provides a continuous view of the emerging future. Horizon scanning will not only provide insight into which of the scenarios appears to be emerging, but will also alert the organizations to new developments. The scenarios provide a framework or mental model of future possibilities against which new developments can be compared. Does a new

development fit with a particular scenario, or does it suggest that something new may be emerging. Having the mental model provides the organization with a rich context to evaluate and make sense of new developments.

5. Other Uses. The scenarios, and the scanning, trends, drivers, and uncertainties that were used to generate them, were used by this project to identify strategic issues to study. But all of this material can be useful in several others ways, such as:

- Strategic planning. Member organizations can use this material as stimulus for developing their individual strategic plans.
- Innovation sessions. The e scenarios, or the individual trends or drivers, could be used in ideation to to develop new product or service offerings.
- Deep dives. Influential individual drivers or scenarios that are especially significant studied separately can be explored more comprehensively through a Deep Dive.

In addition, the drivers, trends, and supporting research can be the foundation of building an ongoing futures inventory or knowledge base that can be added to with each project, as well as provide a starting point for new projects.

APPENDICES

APPENDIX 1. PROJECT TEAM

CII Core Team
Dr. Daniel Oliveira
Dr. Michael P. Pappas, P.E.
Ms. Kristi L. Delaney

CII Project Team
Dr. John D. Borcherding
Mr. Keith B. Critzer
Mr. Danny Daoust
Mr. Chad Dorgan, Ph.D.
Ms. Karen Furlani
Mr. Thomas C. Glasscock
Dr. Carl T. Haas
Mr. David R. Halicks
Dr. Keith R. Molenaar
Mr. Brian Rhoades
Mr. Harvey C. Swift
Dr. John E. Taylor
Ms. Tricia G. Thibodeaux, PE
Mr. Brian Welsey
Mr. Paul Wicker

Houston Foresight team
Dr. Andy Hines – Principal Investigator
Maria Romero – Project Leader
Bes Baldwin – Student Researcher
Hannah Kim – Student Researcher
Collin Sledge – Student Researcher
Cindi Stuebner – Student Researcher

APPENDIX 2. ABOUT THE HOUSTON FORESIGHT PROGRAM

The Houston Foresight program is the world's longest-running graduate program solely focused on foresight. It offers education and training in futures thinking and methodologies in a variety of formats that are customized for different learners with different needs – from a week-long "boot camp" to a four-course graduate certificate to a full Master's degree. It also performs research on futures-oriented projects to benefit the community and business, government, education, and non-profit organizations.

Our vision is to be widely recognized as the premier training ground for professional futurists and for those seeking to futurize their lives and their organizations.

Our mission is to serve aspiring professional futurists and the world by providing high-quality foresight training to help individuals and organizations in business, government, education, and non-profits realize their preferred futures.

For more information, visit http://houstonfutures.org/

APPENDIX 3. INTERVIEW RESPONSES

Question 1 If I could answer any question about the future for you, what would it be?	Question 2 What are 1 or 2 critical strategic decisions regarding the construction space on the horizon? What are your current strategic priorities?	Question 3 What should the construction space need to forget/stop doing?	Question 4 What are the top 2 or 3 trends driving the future of the construction space?	Question 5 If you looked back from 10 years hence and told the triumph in the construction space, what would it be?	Question 6 If you looked back from 10 years hence and told the failure in the construction space, what would it be?	Question 7 What kind of obstacles should we anticipate?	Question 8 What should I have asked that I not?
How can we overcome the resource gap? How can the industry get past just small incremental productivity change to large gradual productivity change?	How do we plan and execute our work more consistently? How can team collaborate and make sure that all stakeholders have a good experience through the project?	The way we do design - it's a very repetitive, cyclical, laborious process - there are many challenges of getting the design to where we can build it. Building silos vs.	Technology affects how we approach construction Robotics augmented/labor-assisted devices Virtualization of teams - we can no longer	Seamless teams that is more collaborative Construction is going to become more immersive in augmented reality We use tech to see what we build as we build	Skill gap in design and construction - people are not learning the same way they used to - people don't know how to build or work	How can we better identify the underlying problem?	NA

		breaking down silos	assume teams will be in one location – Construction with pre-fab	it vs. deciphering models or plans as we go - a Lego approach			
what does builder of engineering, construction site, manufacture look like in future?	The industry is catching up on digitization, leveraging technology Roles of people are changing, skillsets, stakeholder collaboration	The old mentality of everyone must protect themselves against others, "I blame you."	Automation of workforce New players such as Amazon, Google, Elon Musk Technology disruption - changing in the business model (i.e., Keterra)	Automation of processes that are dangerous, mundane, physically challenging Miniaturization, modularization, Materials using different ways, Integrated stakeholders	Conflicts between the stakeholders Not thinking of new business models,	Old mindset Lack of thinking beyond US-centric viewpoint (Europe, Asia, etc.)	NA
How can we best use technology?	Big data analysis, Visualization of workflow Worker safety	Overemphasizing technology	Better access to data and information Worker's safety & health	Improved front planning, construction phases with better data analysis More open to sharing the data, communication	Lack of materials Unable to keep up with the population growth	The industry is seniority level focused, less open to change among senior levels ,	NA
Would we still need human beings to do the manual labor? How do we bring more diverse leadership (generational, race, ethnicities gap) into the construction industry?	Adopt innovative technologies and mindset especially among larger companies Advance R&D in-house; the current model is to let the startup do it all	Stop under-investing in early stages of the project; need to spend finalizing layouts and evaluating constructability	Investment in becoming cost effectiveness Use of data - IoT Automation to replace physical labor	Adoption of big data	Failure due to in-action Productivity stalls due to lack of data systems Not embracing automation; still using humans for labor	Aging workforce	Construction workforce tends to be regionally focused. Loss of knowledge transfer between generations

How can construction industry overcome constraints that are becoming tougher? (i.e., regulation, shortage jobs, budget constraint).	Address contracting models for increasing success for all stakeholders. Workforce trends- who is the future workforce and how do we attract them? Adoption of application of technology advancement	Dwelling on what we are not good at. Ignoring fundamentals	Application of technology Artificial intelligence, automation	Better financial result The industry is a lucrative career choice, Embrace technology	Companies going out of business Less high-quality talents	The industry is ignoring the fundamental- built on judgment	NA
How can we address the gap for qualified craft people?	Adopting technology into the field Digitize the processes	Most work on customized work so loses efficiencies, standardization	Modularization Labor automation	Reinventing work processes, Efficient upfront work and less administrative action	Struggling to adopt technology	The industry has trouble looking out future.	Some of the job sites are middle of nowhere (mining site in Peru)
Will there be disruptive technology companies such as Uber-Taxi industry example?	Visualization of the data	Much work is manual. Data management	Robotic type devices. 3D printers	Transparency to the end-to-end status of the project	Lack of transparency. Insurance companies driving Misused of data.	Lack of tech-savvy capabilities at the leadership level	Are we getting good representation from new and old career people?
What is the new business environment or a new way of contracting between owners and contractors be?	How can we work together collaboratively What is the role of AI in design space?	Adversarial contracting must learn how to trust each other Focused on cost-driven or schedule-driven are often competing priorities; The belief that tech will solve all problems	Automation and technology to augment humans or replace the workforce Shift to more manufacturing	New business approaches, new ownership models, financing and contracting structures Successful integration of technology	Reacting too slow to change Risk avoidance and tactical risk Low-profit margins dampen innovation	Construction needs to rethink how the industry operates	NA

What will the world look like in future with the melding of man and machine?	Labor cliff in the construction industry, hard time recruiting, safety is a concern. Using offsite fabrication then assembled on-site. Remove human from the process Research in technology applied to construction; 3D modeling, visualization	Hard to automate because of the unique features of each project. Find generalities at a lower level of the project; interoperability of systems issue is a big barrier Industry fragmentation is a huge barrier, need greater integration within the industry	Using technologies for data collection, Better job of making sense of data. More complexity in projects, the pressure to deliver faster – need to expand beyond silos and work with other functional groups	Seamless integration of software and technology – More modularization	High resistance to change may prevent uptake of automation and robotics	Different levels of implementation of digitization, challenge for the fragmented industry Change is slow to occur, and construction is complex	NA
What is the role of AI IoT Robotics electric/automated vehicles and their implications on the rest of the world?	Ability to gather share and make sense of data to inform decision making. Infrastructure failure in the US as well as around the world, complicated by Climate Change. Public-Private Partnership	A clear understanding of our role. There is an issue of diffusion of responsibility	Vertical integration, Continued adoption and expansion of BIM More mature risk discussion and responsibility between stakeholders.	Good rewarding career choice for both blue- and white-collar workers, Sustainable infrastructure	Become adversarial, not collaborative, No technology adoption, continue to play hot potato with risk.	Talent gap- People think it's a dirty low potential work. The false dichotomy between minimum wage and university.	NA
How will advances in technology play a role in planning, designing, building and using facilities for Industrial, infrastructure?	Help different organizations even sectors work together.	Not a lot of transfer of knowledge from project to project.	Mechanization, automation do more work offsite, Be more productive like an assembly line. Modularization	Improve safety, quality, productivity and therefore cost and performance.	Failure to improve productivity improve performance on budgeting and scheduling.	The industry is very resistant to change, Contractual and legal even adversarial challenges prevent collaboration. Motivate young people to come to the industry.	Think more about technical, operational level from working parts.

Will my business improve because of the projects that I have done? How can we improve business value?	Be serious about data. Silos. Interoperability for decades, Labor constraints Prefabricate and standardization	Move toward integration. Forget the silos.	Prefabrication. Modularization Integrated project delivery. Big data and data analysis.	Closer to a catalog of projects and preassemble — faster turn-around.	Struggling with decision-making and uncertainty.	People and culture are challenges	NA
How technology is adapting to the construction industry	HR. People. A big issue on A&E and the contractor side. Adapt to new technology Financing for Project	All projects end in legal issues.	Automation. Seamless, more integrated with the construction. Narrow down into smaller projects. Construction with robots.	Safety. Prefabrication Modularization Lifecycle management of the construction. Consider maintenance	We might not have people to work on construction. Not calculating the resources. Resistance to adapt.	NA	Know everyone's biased. Environmental. A&E perspective.
Will the industry ever be able to overcome the challenges of data exchange and flow?	From fragmented supply chain and data exchange process. Understand the new execution model to improve productivity.	Little trust between partners. Excepting new technology implementation.	Automation and robotics. How to make the industry more acceptable as a career path	Machine and AI helping us do the job. Upgrading the reputation of the industry	We keep talking about the changes instead of piloting and testing them.	Bridge the gap between the ones at the top (old folks) and the new generations (tech savvy).	Make us that are breaking down the barriers more visible.
How can we execute very large projects in demanding environments well?	Capital efficiency Solve the productivity problem	Overreliance on data gathering and reporting. Lots of designs are very conservative to avoid lawsuits.	Technology, automation, robotics	No human injury & impact on the environment	Forgetting the basics in favor of overreliance on technology.	Overregulation Close minded to new ideas, Construction viewed as a lower tier	Could we turn project management into something that's repeatable, as an assembly line where projects didn't have to be unique each time? (Standard-ization)
What does it take to make people stop doing inefficient work?	Standardization, Modular construction, less specialization; design side;	Have more generalist approach, fewer specialists Augmented intelligence, rule-based data-centric design. Include automation (exoskeletons)	Augmented intelligence, reality, voice recognition, exoskeletons, sensors for safety; 3D printing	Laser scanning and electronic access to documents, integrated information management systems will be base for innovation	Contracts awarded strictly on price. A slow rate of change in compliance and regulations	Industry margins are too slim and not enough resources for tech and training	Transportation-centric society will change in the next decade – will impact many domains; need to think holistically (society level)

Are we going to continue to be the high-cost US vs. low-cost Asia?	Leverage technology, tools to better manage data AWP: planning and executing work more effectively.	Stop doing the old ways and embrace new technologies and tools	Data-centric technology	Use technology to enable less engineering, non-field related labors A metric centric approach will improve labor productivity.	Builders can't build in the US due to cost restriction. Modular pieces are built in chemical plants offshores low quality.	NA	Don't design future for future mega-projects that affects mega companies and not take account smaller size.
What is the industry going to do solve workforce issues?	Workforce shortage, Leverage technologies Different supply chains and contracting relationships to do work differently	Stop managing through individual contracts and Stop being transactional type industry	Increasing autonomy of technology-minimal human interface, more relational supply chain- due to a human shortage	Increase and use of design contracting-integrated method- being more relational base, A better understanding of uncertainties via risk analysis	Inability to recruit and retain people under the trades.	Lack of investment in VC and long-term public financing. Traditional investors may stop us from integrating moving forward being relational based	The industry is heavily influenced by government spending, federal/state/local - which can be very challenging.
How are we capturing the benefits of automation/ while still elevating the industry?	Data-management	Stop print plans. Use 3d models.	Connected workforce and connected building.	Projects will be on budget/on time.	Over-reliance on technology, becoming complacent/lacking diligence.	Regulatory risk,	NA
How will automation, technology will replace physical elements of constructions?	Manage data from design to work front stages	Stop thinking that productivity can be improved and everything's will be taken care of just by technology	Labor shortage, lack of resources Modularization Access to improved materials	Data-centric environment Crafts can translate to physical work	Lack of training and promote inclusion, career advancement	Craft labor shortage Material supply especially with recent government and their tariff plans Interest from professionals have been minimized	Customers in the future may be different! Minimize projects upfront to get the product to market quicker An integrated build will become more important
Will we be able to hire anybody to do construction in 10-20 years?	Circular economy Renovation more than industrial or new build. Recycling, reusing, cycling through of buildings Re-construction. Planning,	Stop respecting and promoting the loud voice in the room.	Working remotely. Not driving not needing to be there physically. The world cares about green now,	Digital twin. Print exactly how you want it. Massive revolution. Landscaping, complex, facilities. 3D Models. More efficient time and resources.	Parts of the industry that are disintegrated. Inefficient. Financial layers. Hurts innovation — broken supply chain.	NA	NA

	visualization, architecture. Health of workers. Motion suits. Biomechanical analysis. Real-time fab control with 3D printing						
How can we address the skilled labor gap?	Quality of labor, establishing a contract/ dispute, productivity - integrated projects, safety, technology/ robotics	NA	Continued improvement in safety Simpler to use materials Increased modularization	Modularization, More integrated project delivery Continued improvement of safety and less shortage of labor	Skeptical of robotics, productivity may not improve much, labor, training	NA	NA
Will we always be so dependent on market forces out of our control? (i.e., availability of capital, a stock market, etc.)	Expanded use of tech in the construction industry.	Stop fearing technology	Tech will drive construction trends 3D printing materials, or replacement parts, etc.	Construction market would capitalize on labor resources that exist.	Failure of labor productivity in construction.	Top to bottom integration of technology, there is a hesitancy to incorporate new technology at every level	NA

APPENDIX 4. GLOSSARY

Scanning hit	an article, blog post, video or other piece of information describing or signaling a potential change
Trend	A statement describing a change and its future direction: increasing, decreasing, or holding steady
Driver	A thematic cluster of trends, scan hits, or other research information that describes an influential change; these are the fundamental building blocks of scenarios
Uncertainty	A driver that is both highly important to the topic and whose outcome is highly uncertain; in the 2x2 scenario approach, the team prioritizes two uncertainties to frame the scenarios
Scenario	A plausible plot line or story of how combinations of uncertainties and drivers might play out in the future; the 2x2 approach produces four scenarios
Implication	A potential consequence for the organization if a particular scenario plays out
Issue	A strategic question emerging from the scenarios for the organization, typically based on clusters of related implications
Option	A proposed response by the organization to a strategic issue