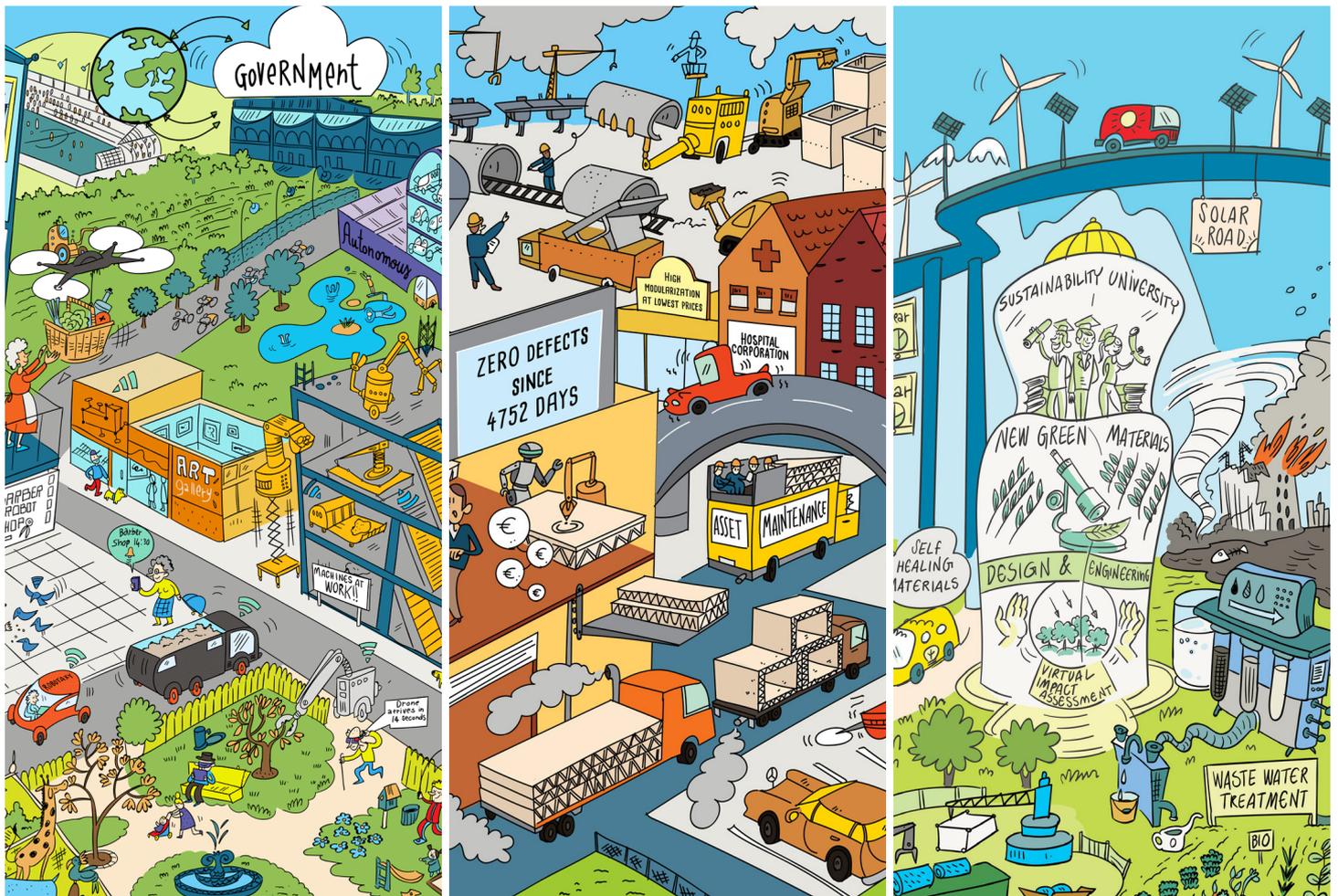


Shaping the Future of Construction

Future Scenarios and Implications for the Industry

Prepared in collaboration with The Boston Consulting Group

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Preface

Olivier Schwab
Managing
Director, Head
of Business
Engagement
World Economic
Forum

**Michael Max
Buehler**
Head of
Infrastructure
and Urban
Development
World Economic
Forum

The world is confronted with many challenges that could impact the well-being and happiness of society. Among the most severe are rapid urbanization, climate change and resource scarcity. The Infrastructure and Urban Development (IU) industry is important in the shaping of a desirable future for our planet. The sector plays a vital role in creating value for society by designing innovative human- and social-centric solutions. Around the world, 200,000 people a day are migrating to urban areas, where they need healthy, affordable, sustainable housing and infrastructure. However, the buildings and infrastructure assets the industry constructs account for a substantial portion of global greenhouse gas emissions, which are a major cause of climate change. On top of that, the industry is the largest consumer of raw materials, further depleting scarce resources.

To address these concerns, the World Economic Forum established the Shaping the Future of Construction project three years ago. Since then, the initiative has successfully served as a platform for Forum Partners, governments, academia and civil society to shape the industry's agenda and find innovative solutions to support the industry's transformation and enhance productivity, sustainability and affordability.

In the initial two-year phase of the project, we prepared a guide for industry transformation and shared lessons learned from leading innovators. At the World Economic Forum Annual Meeting 2017 in Davos-Klosters, the Governors of the Infrastructure and Urban Development community renewed a strong mandate and requested that we analyse how technological change is disrupting the industry and what implications that has for business strategy, organizational design, including talent and skills, financing and risk allocation.

This report is the culmination of that work. During the project's third and final year, we examined what the IU industry could look like in the future and the strategic implications of that for the key stakeholders and broader society. The outlined transformation imperatives should help the IU industry prepare for a prosperous future.

We would like to thank and acknowledge the Forum Partner companies that served on the initiative's steering committee: foremost engineering and construction, chemicals, building materials, real estate, urban services and technology firms, and the many experts who served on the initiative's advisory committee. We hope the strategic dialogues held in the workshops upon which this report is based support stakeholders' efforts to prepare for a challenging but promising future while securing and enhancing the well-being and happiness of society.

Foreword

Sandra Wu Wen-Hsiu

Chairperson and Chief Executive Officer
Kokusai Kogyo, Japan

Co-Chair of the Steering Committee (2017–2018)
Infrastructure and Urban Development Industries
World Economic Forum

Luis Castilla

Chief Executive Officer
ACCIONA Infraestructuras, Spain

Co-Chair of the Steering Committee (2017–2018)
Infrastructure and Urban Development Industries
World Economic Forum

The theme of the World Economic Forum Annual Meeting 2018, “Creating a Shared Future in a Fractured World”, underscored how quickly emerging developments have called into question long-held beliefs. Until recently, greater economic interdependence among countries was presumed to ensure peace and stability. Current events have dramatically changed that. Geostategic fissures have re-emerged on multiple fronts with wide-ranging political, economic and social consequences.

In business, we have experienced a significant reduction in trust, to the point where the 2017 Edelman Trust Barometer reveals that trust is in crisis around the world. The dramatic shift is a wake-up call to the Infrastructure and Urban Development (IU) industry, since trust is the prime enabler of effective collaboration. In addition, the industry’s future has become difficult to predict because of global megatrends such as climate change and shifting demographics, and industry-specific trends, for instance, increasing urbanization and growing talent and infrastructure gaps. Recently, increased volatility and turmoil in world politics have made planning in the IU industry even harder. At the same time, new digital technologies such as building information modelling (BIM), 3D printing, wireless sensors and autonomous equipment are disrupting a range of industries, including IU. Stakeholders can no longer afford to ignore these fundamental changes. Some are beginning to act, but others have put off preparing for a transformation that is bound to happen.

The IU industry lies at the heart of the global economy, directly affecting the quality of our lives and the well-being of society. The industry must, therefore, react quickly and with appropriate action to changing conditions and opportunities for new business to provide society with sustainable, affordable assets that fulfil human needs.

This report should encourage IU decision-makers to think strategically about the future and take preparatory steps sooner rather than later. The World Economic Forum’s Shaping the Future of Construction project created several scenarios of how the IU industry could look in the future based on global trends. These scenarios clearly show that existing capabilities, business models and strategies will not be sufficient to succeed. The scenarios also pinpoint several common no-regret moves that companies should take to remain relevant. Among these transformation imperatives, the chief executives of leading IU companies at the World Economic Forum Annual Meeting 2018 prioritized three: **attracting new talent and improving skills**; **integrating and collaborating across the IU value chain**; and **adopting advanced technology at scale**.

The Future of Construction project will help our industry and individual companies prepare to address challenging issues that could hamper their ability to thrive. Decision-makers can visit our knowledge-sharing platform for additional information.

We would like to acknowledge and thank all members of the steering and advisory committees, as well as the Forum team for their extraordinary engagement, contribution and support. We look forward to continuing this collaboration to transform our industry and better serve our clients and the communities in which we operate.

Executive Summary

Digital technologies have launched the Fourth Industrial Revolution, transforming entire industries. However, the Infrastructure and Urban Development industry (IU) has not kept up. Most companies in the industry's many sectors still use primarily manual methods, offer traditional products and services and operate according to established practices and business models. Productivity has lagged as a result. In addition, while IU's core engineering and construction section alone accounts for more than 6% of global GDP and employs more than 100 million people, a negative perception of the industry makes it difficult to attract the required talent and close a significant talent gap.

The IU industry can no longer afford to stand still. Global megatrends such as climate change, resource scarcity, demographic shifts, and automatization and digitalization are affecting economies, governments and society at large. Players along the IU value chain need to prepare strategically and make the right moves to thrive amid the disruptions these trends could cause.

The World Economic Forum created the Shaping the Future of Construction initiative to help IU companies understand and respond to these trends. The initiative used scenario planning to analyse how multiple present-day megatrends could lead to different versions of a future world. The World Economic Forum and The Boston Consulting Group hosted workshops with representatives from leading IU firms, industry associations, governments and academia to develop the scenarios and the strategic implications based on them. The implications cover changing customer requirements and regulations, processes and technologies, and competition and industry structure.

The scenarios depict three extreme yet plausible versions of the future. In *Building in a virtual world*, virtual reality touches all aspects of life, and intelligent systems and robots run the construction industry. In *Factories run the world*, a corporate-dominated society uses prefabrication and modularization to create cost-efficient structures. In *A green reboot*, a world addressing scarce natural resources and climate change rebuilds using eco-friendly construction methods and sustainable materials. **It is important to keep in mind that the scenarios are not predictions of the future. Rather, they demonstrate a broad spectrum of possible futures. In the real future, the IU industry will most probably include elements of all three.**

The scenarios suggest six common transformation imperatives that IU companies should take to remain relevant. The top three identified by chief executive officers of leading IU companies and ministers of several countries polled at the World Economic Forum Annual Meeting 2018 are: attract new talent and build up required skills; integrate and collaborate across the IU value chain; and adopt advanced technologies at scale. The other three imperatives are: maximize the use of data and digital models throughout processes; review existing product portfolios and embrace new business opportunities; and enable change management and adaptiveness.

A further exploration of each imperative suggests IU companies take specific steps to meet the coming challenges:

- To attract new talent and build up required skills, IU companies must expand where they look for talent, improve the industry's image and establish continuous learning and development practices.
- To increase integration and collaboration across the value chain, they should depend on organic growth or acquire expertise through integrated contracts, joint ventures or mergers and acquisitions.
- To adopt innovative technologies at scale, IU companies must effectively implement new approaches to innovation and integrate new technologies into existing workflows.
- To implement digital models and data usage throughout processes, they should develop suitable use cases, adopt complementary technologies and show that digital models are financially attractive.
- To identify new products and services to sell and segments in which to compete, they should increase the study of market developments, improve flexibility and hedge risks by maintaining a balanced portfolio.
- To react to changing market conditions more quickly, they must embrace comprehensive change-management programmes, flexible organizational structures and agile working methods.

Creating scenarios helps decision-makers understand the differing ways present trends can play out in the future. Industry decision-makers should use scenarios and recommendations based on corresponding transformation imperatives as a foundation from which to create strategies to prepare for the future. As time passes and the direction of future developments becomes clearer, decision-makers can fine-tune their plans accordingly.

1. Introduction

Over the past decade, digital technologies have transformed whole industries, ushering in the Fourth Industrial Revolution. Social media platforms and on-demand streaming services from start-ups such as Facebook, Spotify and Netflix have transformed media and entertainment. E-commerce giants such as Amazon and Alibaba have overtaken brick-and-mortar retailers. Digital-based mobility companies are challenging old-line carmakers. In industry after industry, late adopters have seen market share shrink or disappear completely. Kodak is an extreme example. In the late 1970s, the US photographic equipment maker developed one of the world's first digital cameras. But Kodak opted not to commercialize the device, fearful it would cannibalize existing products. After digital photography drained its livelihood, the company filed for bankruptcy protection in 2012 and remains a shell of its former self.

Digital technologies did not just satisfy consumer demands for better entertainment, shopping and transportation. In those industries and others, innovations improved companies' productivity and sustainability and created new, well-paying and interesting jobs. During that same time, however, the infrastructure and urban development industry continued operating as it has for the past 50 years, with a heavy reliance on manual labour, mechanical technologies and established operating and business models. Productivity stagnated as a result. "The IU industry is not even in the Third Industrial Revolution, let alone in the Fourth," one CEO attending the World Economic Forum Annual Meeting 2016 said. "A step change is required."

Now, digital technologies are seeping into the IU industry, making "a new industrial revolution feasible," the same CEO said. The outcome could be substantial, as the industry's core Engineering and Construction (E&C) sector alone accounts for 6% of global GDP and employs more than 100 million people worldwide. New technologies are changing how infrastructure, real estate and other built assets are being designed, constructed, operated and maintained. Those technologies include building information modeling (BIM), prefabrication, wireless sensors, automated and robotic equipment and 3D printing. In the early phase of this transformation, start-ups have been among the first to experiment. One is DIRTT Environmental Solutions. Since 2005, DIRTT has been paving the way for user-driven digital construction, harnessing video-game technology to design mass-customized building interiors. DIRTT's intelligent 3D models integrate engineering, pricing and manufacturing information that is then used to manufacture customized interiors in off-site prefabrication factories.

All types of IU companies must prepare for the disruption created by widespread use of 3D printing and other new technologies and business models. With the pace of change accelerating, they must act now to identify the right strategic moves to maintain their current business and develop new business models that anticipate coming disruptions. All IU industry members – from building material providers, designers and engineers, to construction companies, operators and service and maintenance companies – need this type of strategic planning.

The World Economic Forum created the Shaping the Future of Construction initiative to guide the industry through this transformation. Strategic planning is difficult because it is impossible to predict exactly how current trends in society, politics, the environment and technology will play out in the future. Increased volatility in world politics has exacerbated planning in the IU industry even further. Preparing for the future is also limited by a tendency to base forecasts on past experiences. The Future of Construction initiative used scenario planning to mitigate these limitations. Scenario planning combines possible outcomes from a number of present-day megatrends to imagine different versions of a future world. Each scenario is extreme, but plausible. The scenarios are not meant to predict the future. Rather, they are an opportunity to foresee the possible outcomes of current trends to be well-prepared for a broad variety of possible futures.

The Future of Construction initiative created three scenarios depicting how the IU industry could look in the future. To develop the scenarios, the World Economic Forum and The Boston Consulting Group hosted a workshop on 27 July 2017 in Berlin. At the workshop, 25 representatives from leading IU firms, industry associations, governments and academia created scenarios using the "Thinking in New Boxes" approach. At a follow-up workshop on 18 October 2017 in London, industry representatives used the scenarios to craft strategic implications and imperatives that IU stakeholders should follow to prepare for the future. At the workshop, 27 participants identified the most important expected changes in customer requirements and regulations, processes and technologies, and competition and industry structure. From there, they sketched out implications and imperatives that IU companies should follow to address these changes.

This report explains the three scenarios and strategic implications for each. It also identifies the transformation imperatives companies should address regardless of which scenarios materialize. The Future of Construction initiative provides this analysis to encourage IU decision-makers to think strategically about the future and take appropriate actions to adopt digital technologies and change business models sooner rather than later – to avoid becoming the next Kodak.

2. Scenarios and implications for the future of the IU industry

To prepare the IU industry for emerging trends that could dramatically impact the industry, the Future of Construction initiative developed three distinct scenarios covering a range of megatrends, including changes in climate, demographics, economics, automation and digitalization (see Illustration 1). In *Building in a virtual world*, virtual reality touches all aspects of life, and intelligent systems and robots run the construction industry. In *Factories run the world*, a corporate-dominated society uses prefabrication and

modularization to create cost-efficient structures. In *A green reboot*, a world concerned with addressing scarce natural resources and climate change rebuilds using eco-friendly construction methods and sustainable materials.

It is important to keep in mind that the scenarios are not meant to predict the future. Rather, they demonstrate a broad spectrum of possible futures. In the real future, the IU industry will most probably include elements of all three.

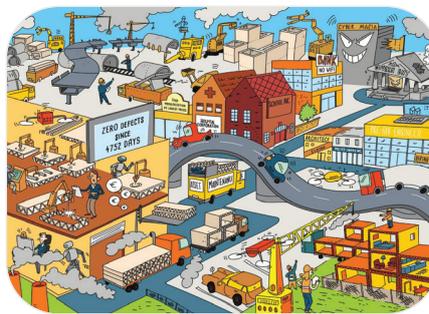
Illustration 1 | Overview of future scenarios

Building in a virtual world



In an era where people are immersed in virtual reality in all aspects of life, intelligent systems and robots run the construction industry

Factories run the world



A corporate-dominated society uses prefabrication and modularization to create cost-efficient structures

A green reboot



A world with increasing conflicts over scarce resources and climate change rebuilds using environmental-friendly construction methods and sustainable materials

2.1 Scenario 1 | Building in a virtual world

Illustration 2 | Building in a virtual world



2.1.1 Global context

In this version of the future, decades of harmonious economic conditions and successful research collaborations between universities, research centres and companies pave the way for major advancements in robotics and artificial intelligence (AI). Automation and robots, connected systems and cloud technology permeate daily life and industries of all kinds. AI applications and other technologies that get smarter the more they are used fuel economic growth. Intelligent systems and robots replace most manual labour.

Strong economies allow governments to offer citizens a comfortable basic income. People shop and go to school virtually. They have abundant free time and spend it on leisure activities, volunteering and travel, creating the need for large passenger transportation hubs. Planes, drones, robot taxis, hyperloops and other autonomous, connected means of transport get people where they need to go. Because society depends on digital systems, governments and private companies funnel enormous resources into cybersecurity to detect security gaps and close them as soon as possible. The environment is much as it has been, with a slight reduction in the amount of natural resources used because of less physical activity and more efficient

processes, which leads to lower emissions per capita. Because country borders play a diminished role in a virtual world, global cooperation is strong and cultures move closer together.

2.1.2 Implications for the IU industry

More residential, recreational and passenger mobility assets are required

In a virtual-focused world, total IU output does not change. Fewer commercial, office and public assets are needed, but there is demand for more residential and recreational buildings. Because so much happens virtually and because more workplaces and other spaces are shared, commerce, government, work and education need fewer buildings. In an economy that primarily runs on automation, people spend more time at home or pursuing leisure activities, increasing the demand for residential assets. More leisure time increases the need for recreational structures and facilities, including swimming pools, fitness centres, theatres and arenas, and large assets such as stadiums and amusement parks. More time for travel leads to an increased demand for passenger transport infrastructure such as airports and cruise terminals, and for infrastructure

that supports personal mobility, including robot taxis, drones and hyperloops. Strong e-commerce also increases the demand for logistics assets and infrastructure such as for parcel delivery.

Not only does the demand for certain assets change, new buildings must live up to new requirements. People want buildings to be as adaptable as their electronic devices, serving numerous purposes. Buildings are designed and constructed to be used 24/7 for multiple purposes, for example, as offices during the day and residential units at night.

Interconnected intelligent systems and robots run IU

Digital technologies replace manual work throughout the IU value chain, and the entire IU value chain is connected through sophisticated data systems. The few people involved are highly skilled experts in areas such as AI, robotics engineering and algorithm programming.

Design and engineering runs on AI with limited human input. AI-based systems propose the best designs for new assets based on customer requirements, key performance indicators and crowdsourced ideas. Connected sensors embedded in comparable existing assets collect usage data and incorporate it into designs for new projects. AI systems optimize building plans by factoring in dimensions such as usability, flexibility, cost and aesthetics, and balance them according to an owner's preferences. AI systems consider the requirements of the robots and automated equipment that build the assets. Early forms of intelligent design automation already exist. The Aditazz design platform incorporates client requirements along with physical constraints, building codes and workflows. An example of a client requirement could be that a nurse needs to be able to walk to a patient's bedside in under a minute. The platform generates numerous designs based on customers' requirements and runs simulations to identify which comes closest to meeting their needs. Output is presented as a building information model (BIM) and a set of metrics, including estimated capital expenditure (CAPEX), operating expenditure (OPEX) and operating performance.

In the virtual-world future, AI-based design and engineering systems will create 7D BIM models with all the information needed later in an asset's life, including 3D object data, scheduling (4D), cost (5D), sustainability (6D), and operations and maintenance (O&M) (7D). During construction, information from 7D BIM models will steer robots and automated construction equipment, including autonomous excavators and trucks, brick-laying robots, 3D printers and drones. Human workers will be needed only to manage and supervise projects, set up robots and perform robot maintenance. Sensors built into asset elements during construction will stream information to an O&M module in the asset's BIM to guide facility management robots that perform O&M tasks.

Software players will gain power

In a construction industry characterized by interconnected intelligent systems and robots, seamless data flows and interoperability across an asset's life span are critical to avoid data and efficiency losses. Activities must be integrated across the IU value chain so that information can be easily shared between project phases. In a connected IU industry, players who can offer integrated services benefit because they control the data and systems used on their projects. Players who are not part of common data systems are at a disadvantage because they cannot process data from upstream activities, and the data they produce is less valuable for downstream activities. Stand-alone contractors and O&M companies are most at risk because the work they once performed is now automated. They could upgrade to managing the robot fleets that take over construction and O&M tasks. However, they will probably compete with original equipment manufacturers (OEM) and fleet managers from other industries entering the business. Subcontractors without highly specialized skills are hit hard by advances in automated construction equipment that lead to such equipment being able to perform many of the same tasks.

Design and engineering firms are the first to see their business disrupted. The current model of employing experts and billing for their work by the hour is replaced by a business model where software produces the required output almost instantly. Design and engineering firms that embrace these changes early and build the required software capabilities stand to gain from this transition. They own the customer interface, AI-based design and engineering algorithms and 7D BIM models with the data needed to steer construction and O&M activities. However, they will have competition from technology companies with AI and software expertise that enter the business. Competition forces incumbents to adopt AI and improve their software know-how.

Large players with the financial means to invest in digital technologies contribute to industry consolidation. These companies can use the economies of scale that data-heavy processes offer. Design and engineering firm consolidation is likely to happen on a global scale, as the virtual nature of this type of work means it does not have to be local. In addition, AI systems would benefit from consolidation because the more data they handle, the smarter they get. Ultimately, IU design and engineering could become an oligopoly with a few specialized companies controlling the business worldwide.

Because IU activities are more transparent, asset owners and investors gain power by having more control over building decisions. By feeding project requirements directly into AI-based design and engineering systems, owners and investors determine the results and are less dependent on intermediaries.

Construction equipment OEMs gain from replacing manual labour with robots and automated equipment. OEMs are key players because their machines produce the operations data that is central to connected data systems on which

construction projects run. However, only the biggest OEMs have the financial muscle to advance their products into a highly automated world.

New businesses will emerge around data and services

Technology advances and changes to the industry's competitive landscape will create new opportunities to sell data and services.

Digitized building objects and data that sensors embedded in assets supply to AI systems to optimize structures could be sold on data marketplaces. One present-day example of this is the BIMobject digital marketplace, which manufacturers can use to promote and deliver products directly to planners for use in their designs.

The large volume of data that will exist in a virtual-world future could be used to create new services and revenue streams from construction equipment and built assets. Construction equipment OEMs could use real-time data from equipment operating in the field to help customers increase equipment uptime. They could also establish pay-per-use models for their equipment, and in doing so, increase their share of the more stable and higher-margin aftermarket business.

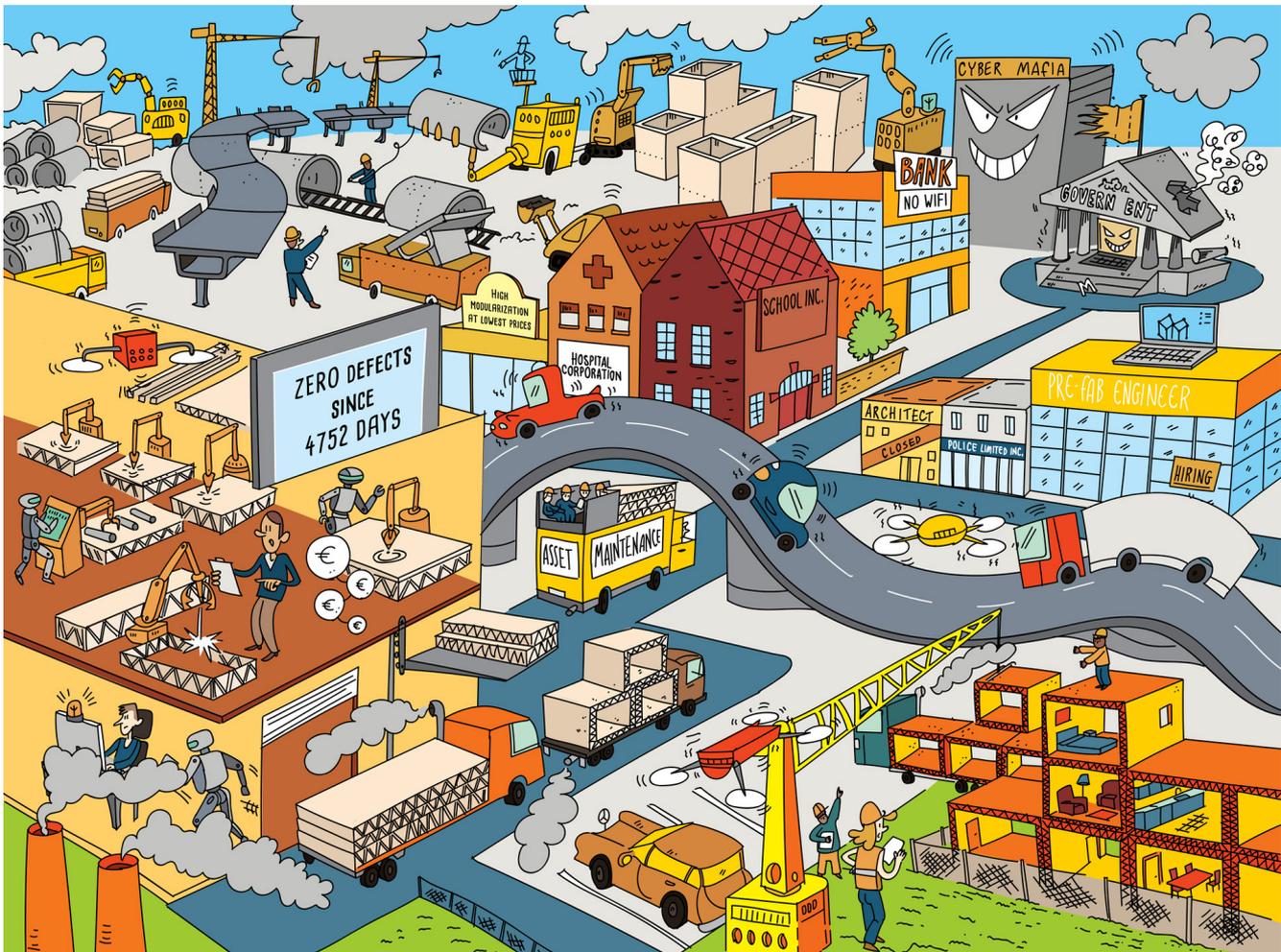
Other industries already use real-time equipment data to offer similar advanced services. In the aerospace industry, Rolls-Royce analyses real-time data from aircraft engines to help customers to increase an engine's run time. Based on this service, Rolls-Royce offers customers the option of paying for aircraft engines by the hour of run time instead of buying the equipment outright. As part of the service, Rolls-Royce maintains engines and replaces any that fail. Such contracts account for about 80% of the engines the company delivers. Construction OEMs should follow suit and sell equipment as a service.

In a similar manner, O&M companies could sell predictive maintenance solutions and other advanced services based on data from sensors embedded in buildings and infrastructure. Among other things, sensors embedded into lights, electrical, sanitation and other building elements are fed into an asset's BIM system to help diagnose conditions that could lead to breakdowns. The system uses the data to steer facility management robots to perform preventive maintenance and minimize asset element downtime. O&M companies could sell maintenance contracts with compensation linked to key performance indicators such as the uptime of specific asset elements.

In the future, integrating activities will ensure data moves seamlessly through a built asset's life span, from design to decommissioning. Making that happen is challenging, especially for small and mid-sized companies without the financial or management resources to cover multiple value-chain steps with sufficient scale. Companies that work in a small segment of the value chain must make sure that their data systems are compatible with the data systems of other parties in a project. The need for collaboration creates an opportunity to provide virtual project management services. The primary function of such services would be integrating project stakeholders' data systems so that all parties have the data they need for their respective roles. Data platform operators and software companies with experience in managing large projects are well-positioned to provide such services. For example, the predictive analytics platform created by Uptake already has such data-integration capabilities. It breaks up the data silos of business units, teams, projects and processes to help construction equipment owners optimize their operations by integrating real-time and historical data from their heavy equipment with information about weather conditions and the environment. Equipment owners can use the data to prevent unscheduled downtime, extend the life of machinery and improve equipment dispatching and planning.

2.2 Scenario 2 | Factories run the world

Illustration 3 | Factories run the world



2.2.1 Global context

Several decades after the 2007–2008 economic downturn, a new global financial crisis hits that is even more devastating. In its wake, governments struggle to cope with the huge debts incurred during the meltdown. Cybercriminals take advantage of the situation to increase the volume and severity of attacks on public and private data networks. The inability of governments to solve debt problems and counter cyberattacks in a timely manner erodes public trust. Private industry gradually assumes tasks that were once the sole purview of the public sector, including providing infrastructure, defence and public education. With the blessing of government agencies, corporations apply business principles to many issues confronting society.

Gradually, fruitful financial times return. Nations' new profit motive spurs the broad adoption of lean principles as well as technology advances, especially in manufacturing. The new social order that prioritizes profits and efficiencies leads to global prosperity, but it has negative implications for the environment and some social groups. Scarce resources are further depleted and unskilled workers lose their jobs to automation or are employed as cheap labour.

To guard against cyberattacks, information is exchanged only through closed data systems that are purposely disconnected from the internet and other online networks. The closed nature of data exchanges limits global cooperation, increasing regional cultural differences.

2.2.2 Implications for the IU industry

Construction booms for industrial and commercial buildings and infrastructure

The flourishing economy creates a boom in industrial, office and commercial building construction, and in erecting transportation and energy infrastructure to satisfy the needs of an economy running at full steam. Businesses also need more physical retail and office space because cyberattacks prevent anything being done online, including e-commerce and remote work. Conversely, demand for public and recreational buildings drops because corporations use their own facilities for tasks once handled by government offices, and society prioritizes work over leisure activities.

Society's new orientation towards business principles makes getting new construction projects designed and built as quickly as possible with the lowest possible total cost of ownership (TCO) a priority. Excellent design and extra features are secondary considerations.

The entire IU value chain adopts prefabrication, lean processes and mass customization

To make construction fast and cost-effective, the IU industry uses both lean principles and advanced manufacturing processes on a large scale to produce assets from prefabricated, mass-customized modules.

Built assets are constructed from a series of modules chosen from design libraries. Building material companies design these modules to be used in a variety of projects. These modules run the gamut of IU industry applications, from bathrooms and office cubicles to parts for bridges and tunnels. They are designed to be as standardized as possible to maximize efficiency in every phase of construction and operation. Advanced manufacturing and mass-customization ensure that even though modules are standardized, they still meet customers' specific requirements. Software helps clients choose modules that come closest to their requirements and then fine-tune them for their specific needs. Individual modules are aggregated into a digital model of the complete asset. In addition to 3D design information, a digital model contains logistics information directing how modules will be transported from the prefabrication factory to the construction site. The model also includes information on an asset's assembly process, cost and O&M requirements. Because of the risk of cyberattacks, stakeholders share digital models physically instead of through open networks. Keeping data in sync across multiple project partners and phases is not a major issue in an industry where construction processes are highly standardized and asset models are unlikely to change once they are created.

Most construction work happens in prefabrication factories that combine conventional production techniques with advanced manufacturing processes, such as 3D printing and mass customization approaches. Factories use high-strength, low-weight construction materials to produce large quantities of mass-customized modules. Once built, modules are shipped to building sites for assembly. Logistics information in an asset's digital model schedules just-in-time shipping so that modules arrive on building sites exactly when they are needed. On-site construction consists primarily of assembling modules. The plug-and-play nature of the work and standardized work practices mean it can be done in a short time by a few workers supported by conventional technologies such as heavy cranes. Reduced on-site labour is partly offset by the need for new blue-collar jobs in prefabrication factories and jobs for production planners, logistic specialists and other experts.

Digital models include everything an asset's O&M provider needs to know about the characteristics and maintenance needs of individual modules and submodules. Because modules are standardized to a large degree, maintenance is efficient and easy to duplicate. Data on repair and replacement costs in an asset's digital model also helps O&M companies decide whether modules that develop problems should be serviced or replaced, with priority given to whatever is most cost-effective.

Suppliers benefit the most from the transition

Large-scale adoption of prefabrication, lean principles and mass-customization tilts the IU industry's focus from building businesses around projects to building businesses around products. The change alters the existing power structure. Suppliers gain the most, and companies that don't offer some type of integrated services are the most likely to struggle. Incumbents are challenged by entrants from other industries with experience in manufacturing large volumes of standardized or mass-customized products. The high degree of standardization makes financing projects less risky, which attracts investors.

Suppliers prosper by expanding from simply selling building materials to marketing complete building modules, and subsequently take over parts of the IU value chain previously controlled by design and engineering companies, contractors and O&M providers. Standardization and mass customization reduce the ability of design and engineering firms to sell assets they create from scratch, limiting their role to that of module selectors. As design and engineering firms lose power, factories that manufacture prefabricated asset modules gain strength. Standalone contractors risk being relegated to low-value, on-site module assembly work. Independent O&M companies also suffer because modules that are largely standardized need only standardized upkeep, turning maintenance into a commodity. Because low-cost modules are as easy to replace as to repair, O&M firms lose business to module manufacturers.

IU companies that offer end-to-end integration – design, manufacturing, logistics, assembly and O&M – rise to dominate the industry. They sell integrated systems and use know-how gained from downstream activities to optimize module and asset designs. They adopt design for manufacture and assembly (DfMA) practices common in industries that choose designs based on how easy it is to manufacture and assemble parts. Carmakers, electronics manufacturers and other companies that use DfMA to produce large quantities of modularized products enter the industry and challenge existing players. In the present day, this type of competition is already appearing. BROADGroup built on experience it gained manufacturing air-conditioning systems to enter the construction sector. In 2009, the Chinese company opened a subsidiary to prefabricate and assemble high-rise buildings. The company shifted 90% of construction work to factories run by its BROAD Sustainable Building Co. Ltd (BSB) subsidiary, which makes components and then assembles them on-site, calling the process "as easy and fast as playing Lego".

In addition to offering integrated services, IU players consolidate. Large-scale operations make design, production and marketing activities more cost-effective as in other product-focused industries. High-volume operations position IU companies to amortize the sizeable initial investments needed to develop platforms and set up large-scale production factories.

The combination of standardized processes and reliable cost and scheduling information reduces risks and makes cash flow more predictable. The circumstances make it easier for investors to raise money, which spurs construction activity.

New business opportunities through integrated system offerings and logistics requirements

A world run by factories creates opportunities to sell platform-based integrated systems, franchises, new technologies and logistics services.

In an environment where construction is based on modularization and prefabrication, IU companies can use platform strategies to expand from selling structural elements to selling integrated systems. Those systems could also include subsystems such as plumbing, electronics, lighting and mechanical equipment. BSB is already implementing this approach. It sells standardized floor plates, steel frames pre-fitted with pipes and wires, and tile and laminate flooring. Clients use a simple menu to customize floor plates based on their needs.

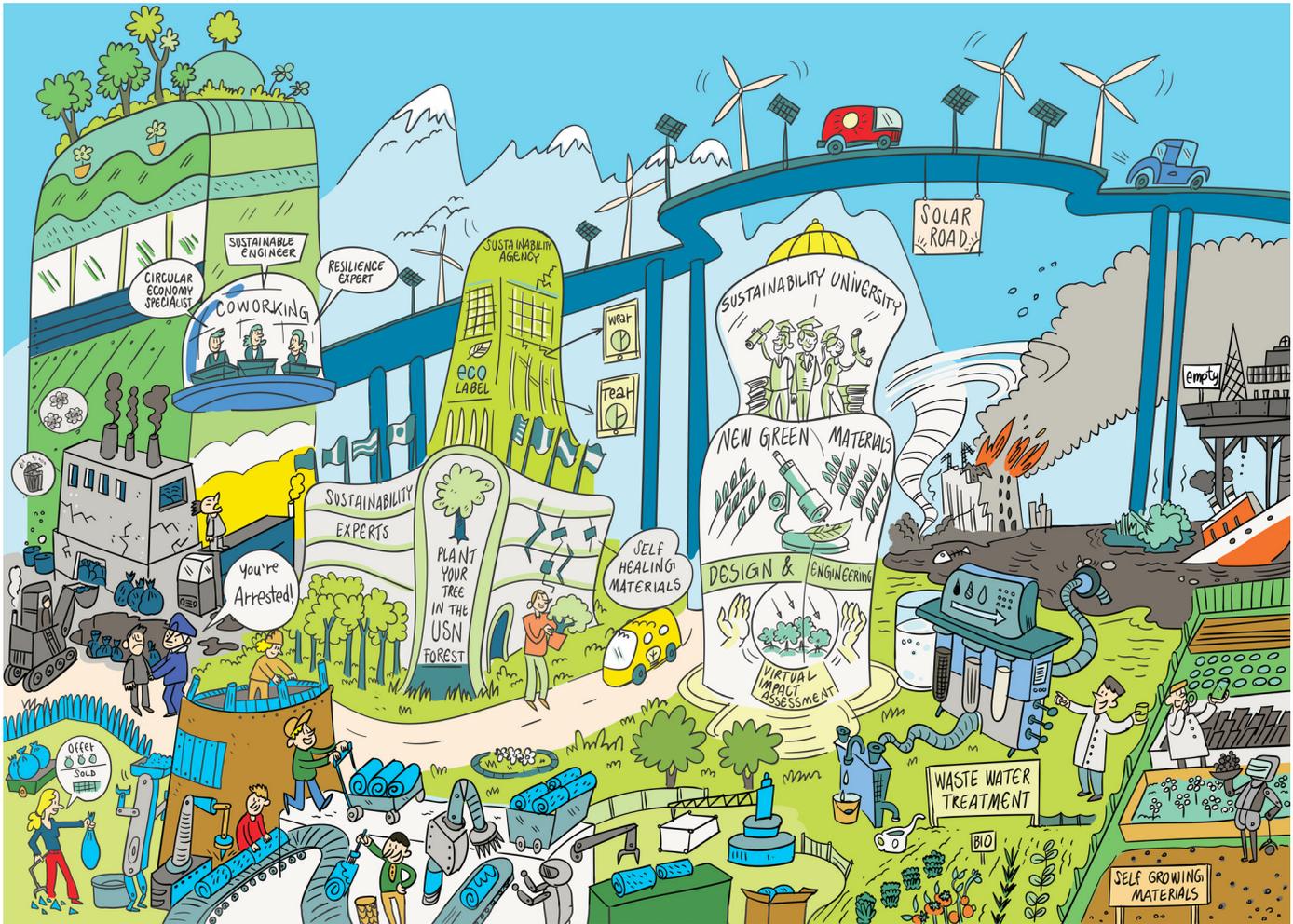
BSB is an example of how module suppliers can cope with the logistical limitations inherent in their business and still create new revenue streams. Because it is not financially feasible to transport large building modules over long distances, BSB expanded by franchising. Under the company's business model, franchisees pay BSB a fixed fee upfront that is tied to the population size of the country they are entering, plus royalties based on a project's floor space, measured in square metres.

Construction equipment firms could take a hit in an IU industry where most construction activity shifts from work sites to factories. Factory-based prefabrication makes conventional construction equipment such as formworks irrelevant while increasing the need for others such as cranes. OEMs could counter the shift by building on their construction technology experience to start new businesses offering construction equipment that can be used in factories, for construction logistics or for on-site assembly.

By contrast, construction logistics plays an important part in a factory-run world. A major portion of IU industry transportation activity shifts from primarily providing low-value logistics transporting commodity-type items, such as bricks and lumber, to high-value work moving large prefabricated parts to project sites. In addition to moving heavy loads, logistics companies must deliver modules exactly when they are needed, as construction sites cannot afford to take delivery of them in advance since it would eat up capital and depress profits. Logistics providers have the added task of sequencing module deliveries to a construction site not just from one source but from multiple factories. Rigorous project management is required to coordinate activities of parties that have not yet become integrated. Logistics companies are well positioned to take on such project management roles to coordinate between prefabrication factories and construction sites. The additional requirements lead to higher margins for construction logistics players and stimulate specialists from other industries to enter the business.

2.3 Scenario 3 | A green reboot

Illustration 4 | A green reboot



2.3.1 Global context

In this future world, decades-long neglect of climate change and dwindling natural resources devastate the planet. A group of powerful countries takes action after recognizing that any further deterioration of natural resources threatens humanity. They form the United Sustainable Nations (USN) to halt overuse of scarce resources, stop natural catastrophes triggered by climate change and revitalize the environment. The group establishes a global fund to finance sustainability research and education, and passes strict global environmental regulations. The push to save the environment leads to innovations in materials and new production methods in construction and other industries. To reinforce sustainable practices, the USN imposes new taxes on high CO₂ emissions, waste and other industrial byproducts that harm the environment.

Society adopts more eco-friendly practices, moving closer to a circular environment model. People and companies reuse as much as possible. Recycling is mandatory. A strong sharing economy emerges from efforts to reduce consumption. Online platforms let people share housing, workspaces, vehicles and other necessities. Technology breakthroughs in e-mobility and battery storage ensure that energy and transportation become increasingly greener.

Conserving limited resources and reducing consumption is good for the planet, but the economy stagnates as a result. Nevertheless, the USN and its citizens are pleased with the trade-off when they see that the environment improves from their efforts.

2.3.2 Implications for the IU industry

Sustainability is the new main decision criterion

In a green world, construction of new infrastructure and buildings declines. Demand shrinks for new commercial, office and industrial buildings because of the strong circular and sharing economy, reduced consumption and less industrial activity. As local production increases, the need for freight transportation drops, reducing the construction of new cargo infrastructure. Likewise, the environmentally focused culture and high prices for transportation based on fossil fuels cut the need for new private passenger transportation infrastructure. At the same time, demand soars for the construction of green-powered rail systems and other public transportation with minimal impact on the environment.

Demand also rises for decentralized, renewable energy sources such as wind and solar farms, and for recycling infrastructure, including waste-water treatment plants. New construction is regarded as a last resort, and space for new projects is prohibitively expensive, so the IU industry concentrates on refurbishing, revitalizing and upgrading existing assets, not least to make them more sustainable.

Governments impose strict environmental regulations on construction, including tough limits on waste production and energy and material consumption. IU players must adhere to stringent requirements to make assets resilient and able to withstand extreme weather conditions. Public and private investors use environmental impact as the primary measurement for evaluating proposals for new assets. They also prioritize flexibility and reusability, helping make sure assets last for as long as possible.

Innovative technologies, new materials and sensor-based surveillance ensure low environmental impacts

To comply with tough environmental regulations and meet demand for sustainable assets, IU stakeholders adopt innovative technologies and new materials created through substantial investment in public and private research and development (R&D).

Design and engineering companies run complex simulations to design new assets to have the lowest possible impact on the environment over their lifetime. Designs must be eco-friendly to avoid the stiff fines that USN levies on projects that miss environmental-impact targets. Designs that meet or exceed stated goals receive lucrative tax incentives. Although design and engineering companies rely on simulations and other new technologies for this work, they also employ workers well trained in sustainable planning. Expert employees include resource-efficiency engineers, resilience experts and circular economy specialists. Aside from design work, these employees' chief responsibility is to choose materials for new assets. This is an important job given that the materials they select determine to a large extent an asset's impact on the environment across its lifetime, and the USN tax system factors that impact into material costs. Materials are taxed based on origin, recycling share and required life cycle maintenance. To minimize taxes, design and engineering personnel specify the use of locally sourced and recycled materials whenever possible. Some of these materials are traditional renewables such as wood. Others are innovative bioengineered materials created from fast-growing organisms such as bacteria, or materials that copy functions found in nature, such as a plant's ability to heal itself, which makes it more durable.

On construction sites, human workers use new technologies only if the techniques or tools enhance the sustainability of the construction process or the asset being built. For example, 3D-printing robots are used to print building elements out of new materials, minimizing construction waste. Site crews wear augmented-reality glasses to see real-time instructions on the most environmentally efficient way to complete tasks. Virtual reality and mobile-collaboration applications minimize travel and the moving of materials and equipment.

Sensors play an important role during and after construction. When an asset is built, sensors deliver real-time information on the project's environmental impact to USN sustainability agencies. Once construction is finished, O&M companies monitor sensors embedded in various asset elements to make sure their environmental impact stays within acceptable limits. O&M companies manage software systems connected to sensors embedded in all the assets they manage. The systems track live data from the sensors to determine when maintenance or repairs are needed, optimizing the timing of replacements. Personnel analyse sensor data to control lighting, heat and building equipment such as elevators to minimize energy consumption. USN uses the same sensor data to enforce environmental regulations. Sustainability agencies check it to verify that an asset's environmental impact during and after construction matches projections created by design-stage simulations.

Players with deep knowledge of materials and local brownfield portfolios thrive

IU companies with extensive knowledge of sustainable practices and materials thrive in a green future where the most important buying criterion is an asset's impact on the environment. In particular, the importance of sustainability plays to the strengths of material providers and design and engineering companies. Because materials used to build an asset largely determine its overall impact on the environment, material suppliers that provide innovative materials are rewarded with high profit margins. Established material suppliers do not have the market to themselves, though. They are challenged by industry newcomers, particularly biotechnology companies with experience in making innovative substances, such as self-healing materials.

Today, design and engineering companies' environmental competencies are more advanced than those of any other IU industry player, allowing them to benefit from these developments. In addition, those companies see their business increase because of the more complex planning procedures required to minimize new assets' environmental impact and to allow refurbishment and new uses for existing assets.

In addition to the right know-how, successful players offer products for brownfield projects and existing assets. Existing assets are used for as long as possible, and as a result, require retrofits and other work to extend their useful lives. By contrast, greenfield projects are rare because of the severe impact constructing new assets has on the environment and related regulations that limit new building. In a green world, running decentralized or local operations is more advantageous than gaining scale through consolidation. Operating in this manner lets players benefit from matching processes to local requirements, and meets requirements to source materials locally. Even so, IU stakeholders gain from deep knowledge across the value chain. Minimizing an asset's environmental impact requires an integrated offering, from design and construction to operations and maintenance.

Asset operators benefit from a larger sharing economy that feeds the demand for relevant services. However, increased demand for those services is partially offset by a fall in demand for maintenance, since self-healing materials and optimized schedules based on sensor data result in less need for servicing.

New business opportunities around environmental-focused services and material recycling

A culture and regulations that put the environment first create opportunities for service-oriented businesses, including environmental and decommissioning planning, environmental impact auditing and platforms for sharing construction equipment. Significant opportunities also emerge for companies to recycle and sell local building materials.

Design and engineering companies have a major opportunity to capitalize on their experience and capabilities by providing comprehensive, up-front plans of an asset's impact on the environment over its lifetime. Such services reach beyond conventional planning, which focuses primarily on construction, to include an asset's commissioning, operations and decommissioning. Design and engineering companies can apply their skills to performing environmental audits and assessing opportunities to reuse assets at the end of their life cycle as an alternative to a complete decommissioning.

A strong sharing-economy culture paves the way for highly efficient sharing-economy platforms. Construction-equipment sharing platforms gain a foothold because they reduce total equipment demand, which in turn reduces the construction equipment industry's footprint.

The new system of material taxes promotes use of locally sourced recycled materials, and serves as the basis for new, local enterprises created to recycle building materials.

3. Imperatives to adapt to new realities

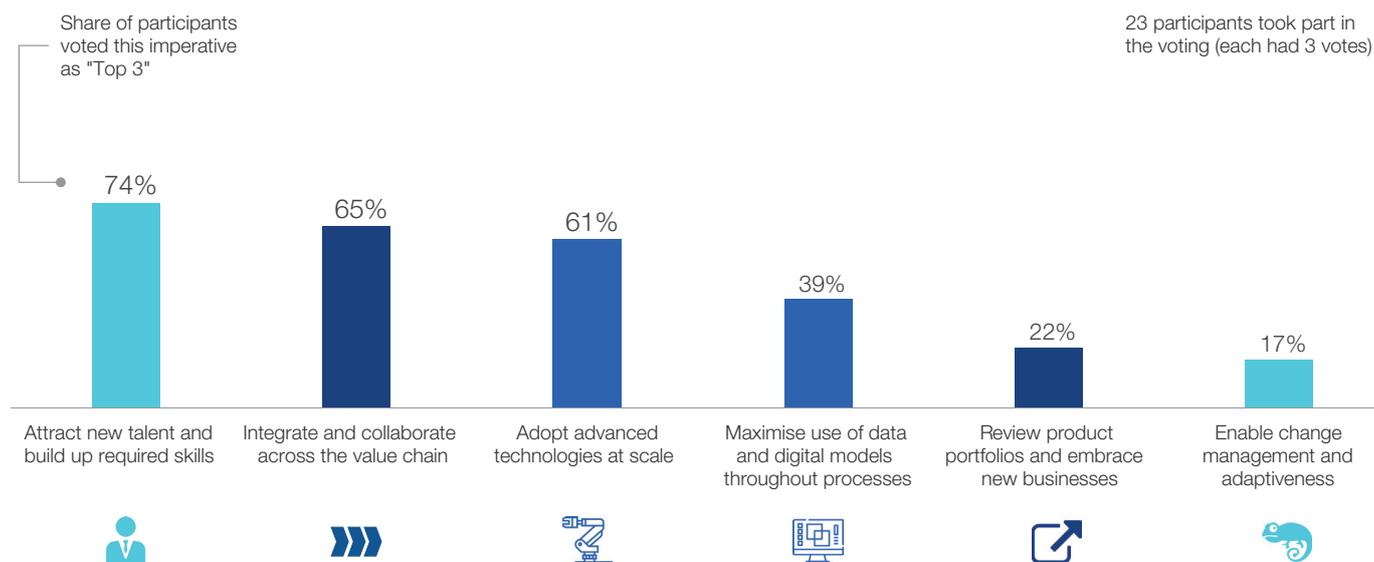
As the three scenarios illustrate, the IU industry could look quite different in the future. Current business models, strategies and capabilities will not be sufficient in any of these future worlds. Players along the IU value chain need to prepare strategically to thrive in the face of anticipated disruptions to their businesses. Many actions relate to a specific scenario. However, analysing all three reveals a set of common transformation imperatives or “no-regret moves” relevant in any possible future, especially since it is likely that in the future the real world will include elements of all three

(see Illustration 5). The actions organizations take to prepare for the future should include finding and retaining talent with the right skills, and increasing flexibility and adaptiveness. Actions should also include embracing digitalization to foster rigorous use of data and digital models, as well as adopting other advanced technologies at scale. Finally, companies must pursue new opportunities through integration and collaboration across the value chain, and constantly review and update product portfolios and business opportunities.

Illustration 5 | Common transformation imperatives



Illustration 6 | CEOs and ministers' priorities for imperatives to transform the industry



At the World Economic Forum Annual Meeting 2018, leading IU company CEOs and ministers of several countries were asked which IU industry transformation imperatives were most important. Their top three imperatives are: 1) Attract new talent and build up required skills; 2) Integrate and collaborate across the value chain; and 3) Adopt advanced technologies at large scale (see Illustration 6).

In addition to acting on recommendations outlined in the previous chapter, corporate decision-makers should use the common transformation imperatives as a foundation for future strategies. As time progresses and the direction of future developments becomes clearer, transformation imperatives can be fine-tuned accordingly.

3.1 Enable the organization

3.1.1 Attract new talent and build up required skills

The future requires new skills

An ongoing shortage of qualified workers is a major reason why the IU industry is not innovating quickly and is facing stagnating productivity as a result. In all three scenarios, new technologies require talent with substantially different skills from those the IU workforce possesses today, exacerbating the existing talent gap. The version of the future described in *Building in a virtual world* requires experts with skills in artificial intelligence, data analysis and programming. In this virtual world, demand is also strong for experts with robotics and engineering skills who can train, supervise and maintain construction and maintenance robots. In *Factories run the world*, the IU industry needs experts with modular design and engineering skills, production planners with lean process skills and logistics specialists. In *A green reboot*, sought-after experts include resource efficiency engineers, resilience experts and circular economy specialists.

Today's IU industry does not have enough people with the necessary skills for the future, and processes to help workers acquire suitable capabilities are not in place. Almost three-quarters (74%) of leading IU company CEOs at the World Economic Forum Annual Meeting 2018 recognized this issue as important, and rated attracting new talent and building up required skills as one of three top transformation imperatives for the industry.

Actions required to attract new talent and increase required skills

To attract new talent and retain their existing workforce, IU companies must expand the areas in which they source and recruit talent, improve the industry's image and establish continuous learning and development practices.

To find workers with the required skills, IU companies must look beyond traditional sources of talent. One possibility is the gaming industry. Digital skills from the gaming industry could be transferred to construction applications such as building information modeling (BIM) or virtual and augmented reality. The kind of modular thinking and lean process and manufacturing skills used in the car industry could be applied to future IU jobs. Women are another untapped source of new talent, as they currently comprise only about 13% of the IU industry workforce. New job profiles and sought-after skills could help to bring more women into the industry and to close the talent gap. At CCC, the Consolidated Contractors Company, for example, most BIM engineers are women.

However, the industry has an image problem that could deter high-potential, in-demand candidates from considering it. Two-thirds of participants in a YouGov poll said they would never consider a career in the construction industry, and large portions of graduating civil engineering students take jobs in other industries. Many blue-collar workers think IU jobs are dirty and dangerous, while white-collar workers feel jobs in the industry lack innovation and challenge. To improve the public perception, IU companies, together with industry associations, governments and academia, should run image campaigns promoting the IU industry's relevance

to society, for example, as builders of critical transportation and utility infrastructure. Campaigns should play up the industry's role in solving key global challenges, such as reducing carbon emissions. They could also emphasize the challenges and rewards of IU careers.

To make industry jobs more attractive, companies should adopt innovative technologies, more modern workplaces, attractive career paths and forward-looking corporate cultures. For high-potential job candidates, a top contributor to a company's attractiveness as a place to work is the opportunity for learning and development. IU companies must improve development opportunities. To do that, they can use technology-based training, institutionalize knowledge sharing, and establish career programmes that recognize learning and development achievements. ACCIONA, for example, established a collaborative learning platform with employee-specific training content. The social media-type platform lets people share work-related content to improve engagement and connect with co-workers.

3.1.2 Enable change management and adaptiveness

Companies must become capable to adapt to new realities and act quickly

The IU industry has changed only a little in decades. The industry has held on to old ways of doing things, and organizations and individuals are not accustomed to reacting quickly to change. Based on the scenarios of how current trends could play out, profound changes are on the horizon. In one, *Building in a virtual world*, powerful software systems and robots change processes throughout the value chain. In *Factories run the world*, prefabrication and modularization transform industry practices. In *A green reboot*, an environmentally conscious society and tough regulations lead industry practices to become more eco-friendly. Because future developments in the IU industry are ambiguous and unknown, it is imperative that companies prepare themselves now to adapt to new realities and act quickly regardless of which one unfolds.

Actions required to enable change management and adaptiveness

For IU companies to react more quickly, they must embrace comprehensive change-management programmes, flexible organizational structures, and agile working methods.

Widespread resistance to change can hinder an organization's efforts to adapt quickly to evolving environments. If individuals do not see why change benefits their jobs and careers, they may be reluctant to accept the need for new skills and work habits. Organizations instituting changes to address evolving environments often err by restricting their efforts to adjusting technologies and processes while ignoring crucial human and cultural components. To deal with potential resistance, change management must be comprehensive. Change management-programmes should share the value of intended changes with employees and the risks they face if the required changes do not take place. Programmes must train employees on the required skills. As part of that, companies must cultivate environments where mistakes

are considered part of the learning process and failure is tolerated. Organizations should find high-profile role models to promote new work habits and reward employees who adopt those habits. Successful programmes should change the context of work in a way that makes employees want to take desired actions without needing to be instructed to do so.

In addition to adopting a change mindset, IU companies must adopt flexible organizational structures to be able to adjust quickly to new customer requirements, technologies and laws. Corporate decision-makers should revise organizational structures to prioritize adaptability and agility. Organizations should embrace agile ways of working to react faster to daily challenges. Agile working methods emphasize performance and outcomes. One method is establishing cross-functional teams that work across corporate silos to shorten feedback loops and speed up information sharing. Agile methods also empower employees to accelerate processes by giving them power to make decisions without needing prior approval. AECOM's allegiance to agile ways of working motivated the company to locate a new office hub in the Greater London area that was specifically designed to eliminate department-based silos, encouraging instead creativity and innovation across the organization.

3.2 Digitalize processes

3.2.1 Maximize the use of data and digital models throughout processes

In the future, data and digital models will become even more important

Companies have begun using digital models, most notably BIM models. Most existing BIM applications, however, cover only design, engineering and construction activities, and have not significantly changed operation and maintenance processes. In fact, O&M applications account for only 10 out of 206 commercial applications listed in an industry database of open-source BIM applications. Likewise, many current BIM applications address just one phase of an asset's life rather than functioning as a comprehensive application over an asset's entire life. As a result, as they are designed today, BIM models usually need significant revisions to become useful as-built models. As the three scenarios show, digital models that cover end-to-end processes will play a critical role in the future. Such models are the backbone for digital technologies such as 3D printing, autonomous equipment and prefabrication, which work only if they have accurate, consistent information from project stakeholders along the value chain and if information is not lost between steps.

It is obvious from the scenarios that IU stakeholders all need access to data. Applied digital models and other new technologies need and generate significant amounts of data. Data from sensors embedded in existing assets is needed to optimize the design of new assets. Project data helps craft more competitive bids and anticipate potential project risks. IU companies can monetize data by selling it on data marketplaces or by using data analytics to offer advanced services.

In *Building in a virtual world*, 7D BIM models are the core operating system. They store designs, steer robots and autonomous construction equipment, and monitor O&M work. Processes are automated, and doing business would be impossible without access to interoperable data. In *Factories run the world*, digital models plan how modules are manufactured, schedule just-in-sequence deliveries from multiple factories to construction sites, and track and document asset wear and tear to schedule maintenance or order replacement units. In *A green reboot*, digital models are integral to the large-scale adoption of environmentally friendly technologies and procedures such as 3D printing and mobile-collaboration tools. Initially, design companies use real-time data collected from built-in sensors to create the best asset design; before, during and after construction, real-time data is monitored to assess an asset's impact on the environment.

From the *Factories run the world* scenario, in which cyberattacks pose a constant, serious threat, it is evident that while unencumbered data sharing is an elementary part of data accessibility, it cannot be taken for granted. As IU companies become more interconnected through digital technologies, they too face increased cybersecurity threats. According to UK government statistics, one in six construction businesses experienced some type of online crime in 2015, or about 15%. Cybercrime threats will increase as the industry becomes more digitalized, as is already the case in other industries.

Actions required to exploit data and digital models

To implement digital models, IU companies should develop suitable use cases, employ complementary technologies and prove that digital models lead to sustainable solutions and are financially attractive.

Adopting digital models is not an end in itself. Rather, IU companies must develop use cases that illustrate the advantages of digital models. One example of a use case could be determining how data from digital models could be used to check the status of asset components to schedule preventive maintenance. The full potential of digital models can be unleashed only if they are used in combination with other technologies that use model data. Digital models should be implemented along with complementary technologies, such as mobile collaboration or augmented-reality tools. The large investments in software, technology, infrastructure, consultants and training needed to set up digital models often lead companies to resist implementing them. To help convince sceptics to commit to implementing models, companies should conduct a transparent long-term return on investment (ROI) assessment and detail the strategic importance of intended use cases.

To create the data that digital models and other new technologies need, IU companies must develop data lakes and related data governance structures. The goal is providing consistent access to the same data pool to all company digital applications. In addition to gathering data from embedded sensors and other sources, this requires structuring and preparing data so that applications can use it. To increase the availability of data beyond their own

sources, IU companies should form data partnerships or trade data on data marketplaces. Examples of this are a data exchange between a contractor and construction equipment OEM, or buying digitized building objects or existing assets' operations data from data marketplaces. An important step towards enhancing data interoperability between different systems and stakeholders is adopting international standards, such as the International Construction Measurement Standards.

IU stakeholders must also actively strengthen cybersecurity to respond to the rising threat levels. Companies must keep abreast of cybersecurity threat reports and use the strongest possible mechanisms to protect data systems. They must also monitor attacks on data systems, share observations, and collaborate on strong anti-cybercrime alliances. Such alliances already exist in other industries. The banking industry created the Cyber Defence Alliance in 2015 to exchange information on cyber threats and inform law enforcement agencies of problems. The World Economic Forum and BCG have worked together to distil leading practices into a framework and a set of tools that decision-makers can use to integrate cybersecurity and resilience into business strategy so that organizations can innovate and grow securely and sustainably.

3.2.2 Adopt advanced technologies at scale

The industry must accelerate technology adoption

The IU industry has been slow to create and adopt new technologies. IU companies spend less than other industries on R&D, about 1% of total industry revenue. The investment is small relative to other industries' R&D spending, including 3% in manufacturing, and double-digit investments in high-technology industries such as aerospace (10%) and pharmaceuticals (13%). The spectrum of possible changes to come underscores why IU stakeholders must embrace new technologies. In *Building in a virtual world*, new technologies consist mainly of AI-programs and other software, as well as construction and maintenance robots. The future depicted in *Factories run the world* depends on advanced manufacturing technologies to prefabricate modules and on advanced logistics technologies. Innovative high-strength, low-weight materials also play an important role. IU players in *A green reboot* adopt advanced sustainable materials and sustainable construction methods. At the World Economic Forum Annual Meeting 2018, 61% of CEOs and ministers said adopting advanced technologies on a large scale is important, and ranked it among the top three transformation imperatives that will drive the IU industry to success in the future.

Actions required to adopt advanced technologies at scale

To develop and adopt innovative technologies, IU companies must complement internal R&D capabilities with capabilities from outside the own organization, implement new approaches to innovation, and integrate new technologies into existing workflows. Companies should decide whether they have the capabilities to develop new technologies on their own and

if such developments would give them a lasting competitive advantage. Otherwise, they could decide that a better course of action would be sourcing new technologies from established suppliers or start-ups in or outside the IU industry. If companies determine they do not have the internal resources necessary to develop new technologies, they should evaluate partnering with enterprises that have complementary capabilities. In 2017, the French contractor Vinci opted to develop 3D-printing technology by buying a stake in 3D-printing technology start-up XtreeE.

IU companies must find new ways to develop and test innovative technologies. That includes collaborating on R&D with customers, start-ups and universities, and using crowdsourcing platforms to create a more open R&D environment to source more ideas from outside the company. They could also establish technology accelerators, corporate venturing capital units or other types of innovation units. In one example, ACCIONA launched a start-up accelerator to fund and mentor new companies, which pilot their technologies on ACCIONA projects. Start-ups in the programme are identified through challenges the company's business development and R&D staff formulate, and are chosen by 50 ACCIONA executive directors involved in the mentoring phase. Start-ups benefit from receiving fast-tracked procurement and testing their services in a real-world setting, and establishing a commercial relationship with ACCIONA.

Integrating new technologies into existing workflows is just as important as developing it in the first place. IU companies need to move away from a conservative, risk-averse mindset and be proactive about testing and integrating new technologies into existing workflows. More reliable testing procedures, especially for new materials, could mitigate implementation risks. Optimizing the interfaces people will use to interact with the technologies should be just as important as making sure applied systems can work together properly.

3.3 Capture new opportunities

3.3.1 Integrate and collaborate across the value chain

A disintegrated IU value chain hampers productivity

The IU industry is characterized by a disintegrated, fragmented value chain with many players, including architects, designers, engineers, building material suppliers, contractors and operations and maintenance companies. Too often, players concentrate exclusively on their own work without considering how it affects other stakeholders or overall project performance. However, the future scenarios make clear the benefits to be had from controlling a larger portion of the value chain or from more intense collaborations with a larger group of stakeholders. In *Building in a virtual world*, data systems throughout the IU value chain and asset life cycles must be connected and coordinated to ensure seamless data flows. Integrated players benefit from controlling systems and data on their

projects. In *Factories run the world*, vertically integrated players use knowledge gained in downstream activities to optimize module design for manufacturing, logistics, assembly, and operations and maintenance. Vertically integrated players could also better synchronize activities along the value chain. In *A green reboot*, players either integrate design, construction and O&M activities or collaborate on them to fine-tune assets' lifetime impact on the environment. At the World Economic Forum Annual Meeting 2018, 65% of CEOs and ministers said better integration and collaboration across the value chain is a priority, and picked it as one of their three primary transformation imperatives for advancing the IU industry.

Actions required to integrate and collaborate across the value chain

To increase integration and collaboration across the value chain, IU companies should enter new activities organically, or acquire expertise through integrated contracts, joint ventures or mergers and acquisitions (M&A).

It can be difficult for companies to expand to other parts of the IU value chain on their own because they lack the necessary resources, or the time needed to be successful is too long. Given such challenges, IU players may find it easier to expand by working with outside parties through integrated contracts, such as design build (DB) contracts, integrated project delivery (IPD) contracts and public-private partnerships (PPP). BIM and other new technologies could facilitate collaboration across stakeholders in these settings. Integrated contracts work best on a project-by-project basis. For stable, long-term integrations, IU companies may need to pursue joint ventures or M&A. The industry is already seeing such vertical integrations. AECOM is an example of an organization developing capabilities across the asset life cycle, with acquisitions such as that of Shimmick Construction giving them construction capability in the US infrastructure market to sit alongside their existing design and O&M capabilities.

IU companies could also use joint ventures and M&A to acquire skills necessary in the future that have yet to become widespread in the IU industry. In the world described in *Building in a Virtual World*, design and engineering companies and software firms with AI expertise could form joint ventures. In *Factories run the World*, mergers with logistics players or manufacturers from other industries could help companies gain required knowledge and sufficient scale. IU companies have already begun buying software firms. In early 2018, the Dutch design and engineering firm Arcadis bought SEAMS, a UK-based software and analytics firm. Because of the acquisition, Arcadis now offers clients its technical and asset knowledge along with SEAMS' advanced analytics capabilities.

3.3.2 Review product portfolios and embrace new businesses

The volume of potential future demands poses an enormous challenge for IU companies

Depending on the future scenario, demand for certain types of buildings and infrastructure will go up or down. The ambiguity makes clear that the only certainty about future demand is that it will be different from what it is today. As IU industry practices shift, established players could find themselves with less demand for current core businesses and see demand swing in new directions.

In the future depicted in *Building in a virtual world*, demand for physical buildings drops as society embraces e-commerce and virtual ways to work, go to school and to govern. Instead, construction centres on residential and recreational assets. At the same time, highly automated processes take over part of the work previously done by construction and O&M companies, causing them to lose value. In *Factories run the world*, a flourishing economy creates a construction boom for industrial, office and commercial buildings and transportation infrastructure. Standalone design and engineering companies lose out in this scenario, downgraded to working as simple module selectors and, in the case of construction players, on-site assemblers. In *A green reboot*, decentralized renewable energy assets and recycling infrastructure emerge as key market segments. Most work happens on brownfield projects, as new construction is too wasteful. In this future world, maintenance players may be hit hard because self-healing materials and sensor-data optimized schedules reduce required maintenance. The range of possibilities is an enormous challenge for IU companies determining how to capitalize on new opportunities to offset potential dips in demand for current offerings while at the same time building a foundation for future growth.

Actions required to review product portfolios and embrace new businesses

To identify new products and services to sell and segments in which to compete, IU companies should increase how much they track market developments and improve flexibility. They should also hedge risks by maintaining a balanced portfolio and explore new ways to find game-changing business models.

Reviewing product and service portfolios on a regular basis can detect shifts in customer demand and broader market trends. Reviews should be based on thorough market analyses to determine whether foreseeable disruptive trends could threaten current business offerings or provide opportunities to branch out. For example, if self-driving cars become commonplace, it could reduce the number of car parks cities must build or maintain, freeing up space for other, more complex urban assets. IU companies active in this area should be tracking such developments to be prepared to take advantage of them. Companies can also use scenario analysis and other planning tools regularly to identify relevant developments as well as implementing agile ways of working to speed up the time it gets new ideas to market.

Companies cannot rely solely on agile ways of working to keep product and segment portfolios updated. Their workforce must also have skills that are general enough to be useful across multiple segments. This flexibility gives IU players the speed necessary to quickly roll out new offerings or move into new segments and bridges any talent gaps that could arise until they can develop talent with specialized skills. Aside from growing organically, companies could pursue joint ventures or M&A as a shortcut into new markets.

In uncertain times, focusing on a single product or market segment could increase the possibility of future developments threatening the entire business. Instead, IU companies should hedge risks by maintaining a balanced portfolio of products and segments that require similar core competencies to operate but that potential future developments would not affect in the same way.

To find game-changing new business opportunities, IU companies should broaden their search for innovations beyond internal R&D efforts and M&A activities, both of which frequently focus on the core business. Instead, companies should explore new ways to grow, including creating dedicated innovation units, business incubators and accelerators, and corporate venturing initiatives. Initiatives should uncover new ideas that companies would not find internally, and that yield strategic and financial benefits. One example of such an initiative is Leonard, a platform for innovation, foresight and inventing future businesses created by VINCI, the French construction group. VINCI taps Leonard to detect emerging trends within its businesses and markets. Based on the trends, foresight groups pinpoint opportunities for changes in VINCI's businesses and organizational structures to identify new growth drivers. VINCI also uses Leonard as a project incubator and to accelerate projects created by employees and start-ups. In another example, in 2017 building materials giant CEMEX created a corporate venture capital arm to use its industry knowledge and connections to expand beyond its core business. CEMEX Ventures plans to work with start-ups, entrepreneurs, universities and other IU players to look at opportunities in urban development, construction value-chain connectivity, and new construction trends and technologies.

Regardless of which path they take IU companies must strive to create a culture of cooperation rather than rivalry with the new innovation centres. Established players should capitalize on existing relationships, access to large customer networks, intellectual property and other strengths to support start-ups that spring from their own initiatives and defend against competing start-ups that are particularly agile or innovative.

Conclusion

For IU companies, megatrends such as climate change, shifting demographics, urbanization and automatization and digitalization create ambiguity and uncertainty about the future, as do the industry's persistent talent and infrastructure gaps.

Creating scenarios of what the future could look like helps reveal the myriad ways the IU industry could change over time, allowing IU players to better map out the steps to take now to prepare for change. All three scenarios presented in this report are extreme, making them useful to prepare for potentially radical changes. As the real future might hold elements of all three, companies should consider using the six common transformation imperatives to future-proof themselves against any possible developments.

Delaying this work is not an option. IU decision-makers must act now, using the changes within their industry the scenarios describe as a wake-up call to think strategically about the future. They must closely monitor industry and global developments to understand where IU trends are heading. Understanding trends is an important prerequisite to preparing for the strategic implications mapped out in the scenarios and implementing scenario-based actions as soon as it is appropriate.

Governments should use their standing as regulators and the IU industry's biggest customers to support companies' efforts to implement recommendations. They can sponsor initiatives to spur innovation, require that new technologies be included in public projects, and revise building codes to promote innovative industry practices.

All IU stakeholders should use the recommendations to prepare themselves and set a base to fulfil their calling to promote economic growth, social progress and environmental responsibility today and in the years to come. Aligned with this purpose, the World Economic Forum started to work with leading companies, industry associations and governments to create the Infrastructure and Urban Development Industry Vision 2050. The chief goal of IU Industry Vision 2050 is to bring the industry together to work towards common goals, planting the seeds of change now by creating a shared vision of the future. That vision is built on nine pillars, which describe an IU industry that is: collaborative and fair; performance-based; human-centred; holistic and systemic; smart and connected; sustainable and affordable; safe and secure; long term; and responsive and responsible. IU industry CEOs discussed the IU Industry Vision 2050 at the World Economic Forum Annual Meeting 2018 and acknowledged the change imperative and need to start implementing it today.

Appendices

Workshop participants

25 individuals from 18 organizations participated at the scenario-generation workshop held in Berlin on 27 July 2017

Organizers

The World Economic Forum
The Boston Consulting Group

Participants

Abertis
ACCIONA
AECOM
Arcadis
Arup
Atkins
Consolidated Contractors Company
Danfoss
Dubailand
Institute for Computational Design and Construction
International Institute for Sustainable Development
PLP Architecture
Royal Institution of Chartered Surveyors
Saudi Aramco
TG International Manager
UN-Habitat

27 individuals from 20 organizations participated at the strategic implications workshop held in London on 18 October 2017

Organizers

The World Economic Forum
The Boston Consulting Group

Participants

ACCIONA
AECOM
Arup
Consolidated Contractors Company
Deltares
DIRTT Environmental Solutions
École polytechnique fédérale de Lausanne
Institute for Computational Design and Construction
Kier Group
PLP Architecture
Project Management Institute
Royal Institute of Chartered Surveyors
Salini Impregilo
Secco Sistemi
SNC-Lavalin Group Inc.
TG International Manager
The Bartlett School of Construction & Project Management
University College London

Contributors to the Future of Construction Initiative

Project Team

World Economic Forum

Till Zupancic, Project Manager, Future of Construction
Michael Buehler, Head, Infrastructure and Urban Development Industries
Isidora Kosta, Community Lead, Infrastructure and Urban Development Industries
Hani Dakhil, Community Lead, Infrastructure and Urban Development Industries

The Boston Consulting Group (Adviser and Knowledge Partner)

Santiago Castagnino, Partner and Managing Director, Head of Engineering and Construction Sector
Alan Iny, Associate Director, Senior Global Specialist for Creativity and Scenarios
Christoph Rothballer, Principal, Global Infrastructure Expert

Steering Committee, Future of Construction Initiative

Abertis

Francisco Reynés, Chief Executive Officer, Abertis Infraestructuras, Spain
Marc Ribo Pedragosa, Senior Economist, Abertis Infraestructuras, Spain

ACCIONA

Luis Castilla, Chief Executive Officer, ACCIONA Infraestructuras, Spain
Pierre Patrick Buffet, Strategy Officer, ACCIONA, Spain

AECOM

Michael S. Burke, Chairman and Chief Executive Officer, AECOM, USA
Matt Forbes, Chief Operating Officer, Operational Excellence, AECOM, USA

Aecon

John M. Beck, President and Chief Executive Officer, Aecon Group, Canada
Mathew Kattapuram, Senior Vice President, Strategic Business Development, Aecon Group, Canada

Arcadis

Peter Oosterveer, Chief Executive Officer, Arcadis, Netherlands
Bianca Nijhof, Global Sustainability Program Manager, Arcadis, Netherlands

ArcelorMittal

Lakshmi N. Mittal, Chairman and Chief Executive Officer, ArcelorMittal, United Kingdom
Patrick Le Pense, Manager of Flat Products; Business Development Construction – Infrastructure, ArcelorMittal, Luxembourg

Arup

Gregory Hodkinson, Chairman, Arup Group, United Kingdom
Tim Chapman, Leader – Infrastructure London Group, Arup Group, United Kingdom

BASF

Kurt Bock, Chairman of the Board of Executive Directors, BASF, Germany
Ulrich Baum, General Manager LUWOGÉ consult GmbH, Germany

Consolidated Contractors Company

Samer S. Khoury, President, Engineering and Construction, Consolidated Contractors Company, Greece
Amr El-Sersy, Manager Learning & Innovation, Consolidated Contractors Company, Greece
Aref Boualwan, Manager, MIS and BPR, Consolidated Contractors Company, Greece

Construction Products Holding Company

Mu'taz Sawwaf, Vice-Chairman of the Board and Chair of the Executive Committee, Construction Products Holding Company, Saudi Arabia
Raja Nahas, Assistant, Construction Products Holding Company, Saudi Arabia

Danfoss

Kim Fausing, President and Chief Executive Officer, Danfoss, Denmark
Nis Jessen, Vice-President Strategy and Business Development, Danfoss, Denmark

The Durst Organization

Douglas Durst, Chairman, Durst Organization, USA

Fluor

David T. Seaton, Chairman and Chief Executive Officer, Fluor Corporation, USA
Mark Brown, Vice President – Construction & Fabrication, Fluor Corporation, USA

HCC

Ajit Gulabchand, Chairman and Managing Director, HCC, India
Arjun Dhawan, Group Chief Executive Officer, HCC, India

IC Holding

Firat Çeçen, Chairman of the Board, IC Holding, Turkey
Murat Sogancioglu, Chief Executive Officer Investment Group, IC Holding, Turkey

Kokusai Kogyo Co

Sandra Wu Wen-Hsiu, Chairperson and Chief Executive Officer, Kokusai Kogyo, Japan

Link Real Estate Investment Trust

George Kwok Lung Hongchoy, Executive Director and Chief Executive Officer, Link Real Estate Investment Trust, Hong Kong SAR
Max HK Wong, Co-Head, Co-Head of Project and Development, Link Real Estate Investment Trust, Hong Kong SAR

OVG Real Estate

Coen van Oostrom, Chief Executive Officer, OVG Real Estate, Netherlands
Cees J. van der Spek, Director, Sustainability and Marketing, OVG Real Estate, Netherlands

Perot Group

Henry Ross Perot Jr, Chairman of the Board, Perot Companies, USA
Todd Platt, Chief Executive Officer, Hillwood, USA

RMZ Corp

Manoj Menda, Corporate Chairman, RMZ Corp., India
Jayakumar K., Associate Director Projects, RMZ Corp., India

Saudi Aramco

Amin H. Nasser, President and Chief Executive Officer, Saudi Aramco, Saudi Arabia
Fahad E. Al-Helal, Vice-President Project Management, Saudi Aramco, Saudi Arabia
Abdirahman Abdi, Supervisor, Value Practices Unit, Project Optimization Division (PMOD), Saudi Arabia

Siemens

Joe Kaeser, President and Chief Executive Officer, Siemens, Germany
Roland Busch, Member of the Managing Board and Chief Technology Officer, Siemens, Germany
Alexander Stuebler, Head of Executive Office of Dr Roland Busch, Siemens, Germany

Skanska

Anders Danielsson, President and Chief Executive Officer, Skanska, Sweden
Roger Bayliss, Senior Vice-President, Operational Efficiency, Skanska, Sweden

SNC-Lavalin

Neil Alexander Bruce, President and Chief Executive Officer, SNC-Lavalin Group, Canada
Ian Leslie Edwards, President, Infrastructure, SNC-Lavalin Group, Canada

Tarkett

Glen Morrison, Chief Executive Officer, Tarkett, France
Gilles Lebret, VP Customer Operations and Group CIO, Tarkett, France

Advisory Committee, Future of Construction Initiative

Monica A. Altamirano, Specialist, Public-Private Partnerships and Climate Finance, Deltares, Netherlands

John Atkins, Director Buildings, Arcadis, Germany

Camilo Andrés Benítez Ávila, Department of Construction Management and Engineering, Twente University, Netherlands

Ron Bakker, Founding Partner, PLP Architecture, United Kingdom

Mark Bew, MBE, Chairman, PCSG Limited, United Kingdom

Johnny Clemmons, Global Industry Director and Chief Engineer, SAP, USA

André Dorée, Head, Department of Construction Management and Engineering, Twente University, Netherlands

Mahmoud Hesham El Burai, Chief Executive Officer, Dubai Real Estate Institute, DubaiLand, United Arab Emirates

Tarek A. El-Sheikh, Director, UN-Habitat, Kuwait

Thomas Ermacora, Founder, Architect and Curator, LimeWharf, United Kingdom

Danielle Grossenbacher, World President (2015-2016), FIABCI International Real Estate Federation, USA

Tiago Guerra, Founder and Managing Partner, TG International Manager, Lda, Portugal

Carl T. Haas, Professor of Civil and Environmental Engineering and Interim Chair, Canada Research Chair, University of Waterloo, Canada

Lars Hesselgren, Senior Associate, PLP Architecture and Visiting Professor, Chalmers University of Technology, United Kingdom

Arjan Hijdra, Senior Adviser, Network Performance, Ministry of Infrastructure and Environment, Netherlands

Sherena Hussain, Assistant Professor, Brookfield Centre in Real Estate and Infrastructure, Schulich School of Business, Canada

Iván Jiménez, Visiting Researcher, Alexander von Humboldt German Chancellor Fellow, Germany

Richard Koss, Director of the Global Housing Watch, International Monetary Fund, Washington DC, USA
Monetary Fund, Washington DC, USA

Alex Lubbock, Head of Digital Construction, Infrastructure and Projects Authority, United Kingdom

Jeffrey Matsu, Senior Economist, Royal Institution of Chartered Surveyors (RICS), United Kingdom

David Mosey, Director of the Centre of Construction Law and Dispute Resolution, King's College London, United Kingdom

Milagros Mostaza, Managing Director – EMEA, Project Management Institute (PMI), USA

Alan Muse, Global Director of Built Environment Standards, Royal Institution of Chartered Surveyors (RICS), United Kingdom

Ibrahim Odeh, Founding Director, Global Leaders in Construction Management – Research Group, Department of Civil Engineering and Engineering Mechanics, Columbia University, USA

Alastair Parvin, Co-Founder, WikiHouse Foundation, United Kingdom

Oshani Perera, Director, Public Procurement and Infrastructure Finance, International Institute for Sustainable Development (IISD), Switzerland

David Philp, EMIA BIM Director, AECOM, USA

Spiro Pollalis, Professor of Design, Technology and Management, Harvard Design School, USA

Bob Prieto, Chairman and Chief Executive Officer, Strategic Program Management, USA

Michael Ramage, Director, Centre for Natural Material Innovation, University of Cambridge, United Kingdom

Craig Ross, Partner, Head of Project and Building Consultancy, Cavendish Maxwell, United Arab Emirates

Claudia Schachenmann, Director, Bureaux Schachenmann, Switzerland

Prakash Senghani, Digital Project Delivery Lead, Construction Services, AECOM, USA

Sam Spata, Owner, Principal, Method Lean, USA

Marc Tkach, Director, Infrastructure, Millennium Challenge Corporation, USA

Jennifer Whyte, Laing O'Rourke/Royal Academy of Engineering Professor of Systems Integration, Imperial College London, United Kingdom

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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744

contact@weforum.org
www.weforum.org