Building Design 2020

ARUP

About Arup
Arup is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Through our work, we aim to make a positive difference to different communities. We shape a better world.

Founded in 1946 with an initial focus on structural engineering, Arup first came to the world's attention with the structural design of the Sydney Opera House, followed by i ts work on the Centre Pompidou in Paris. Arup has since grown into a multi-disciplinary organisation. Its work, such as the National Aquatics Center for the 2008 Olympics in Beijing has reaffirmed its reputation for delivering innovative and sustainable designs that reinvent the built environment.

Arup Foresight + Research + Innovation
Foresight + Research + Innovation is Arup's internal think-tank and consultancy which deals with the future of the built environment and society at large. We serve Arup's global business as well as external clients from a broad range of regions and sectors. We help our organisations understand trends, explore new ideas, and radically rethink the future of their businesses. We developed the concept of 'foresight by design', which uses innovative design tools and techniques to bring new ideas to life and engage clients and stakeholders in meaningful conversations about change.

Contacts

Tristam Carfrae
Arup Fellow and Deputy Chairman
tristram.carfrae@arup.com

Chris Luebkeman
Arup Fellow and Global Director, Foresight + Research + Innovation
chris.luebkeman@arup.com

Released December 2014

ARUP

13 Fitzroy Street
London W1T 4BQ
arup.com

Contents

Click on section title to navigate

>

Introduction

In the past half century, Arup has accomplished astounding feats. Through our partnerships, fortitude and innovative spirit, we have dotted the earth with iconic beauty, pushed the boundaries of physics to touch the sky, and provided unparalleled value to clients around the globe. We take pride in our commitment to shape a better world. Each year, Arup invests in a wide range of research to ensure the continued success of this mission.

Part of that research is the document you are currently reading, the Arup Foresight, Research & Innovation team's global study on the future of Building Design. Funded by the Buildings Practice Executive, this investigation took the form of a series of over 300 conversations across Arup's five regions, aimed at identifying vectors of change affecting building design over the next half-decade. We interviewed internal subject matter experts and external stakeholders involved at every stage of the building design process to identify the biggest trends in the sector and to develop an understanding of how these trends will impact Arup's daily practice.

In the following pages, you will find a distillation of the insights that emerged from this research. These findings around the future of building design indicate areas of particular interest to Arup and our partners, as well as highlighting some of the most exciting new ideas from our investigation. We hope that this report will serve as a starting point for deep, regionally-specific conversations on how to best leverage trends relevant to the future of building design in order to improve our work, deliver more value for our clients, and remain a leading provider of cutting-edge solutions.

Welcome to Building Design 2020.

Left: Guangdong Museum, Guangzhou, China

People

"When I joined Arup I was brand new, I didn't know anybody – but I could walk into a room in a joint venture and pick out who the Arup people were, because the Arup people were saying 'Let's try this,' and the other people would be saying 'No, no, we didn't do it that way on the last project, so why do it that way now?'"

—Jim Quiter, Principle, Fire Engineering

Building design starts with building designers. Both day-to-day and over the long term, people are where changes in the industry will be felt first. Over the next decade, changing skillsets, new approaches to relationships and a shifting recruitment landscape will all transform the traditional roles of people in building design.

1.1 Skills

Building designers at all stages of their careers are increasingly required to master specialised skills.

A basic suite of technology-focused skills are considered a fundamental component of new building designers' toolsets; ensuring that these skills are effectively disseminated to veteran staff as well can help build organisational resiliency. Similarly, specialism-related skills and certifications in areas such as sustainability, product design and advanced manufacturing techniques add considerable value across teams.

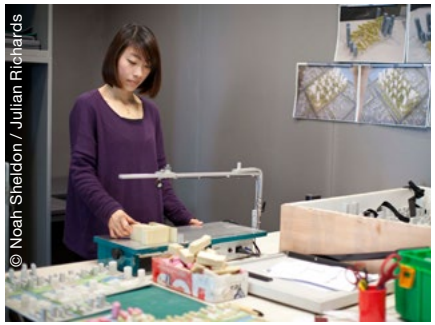
Integrating across disciplines and between project phases is increasingly necessary to ensure consistent project management from inception to completion. Identifying and leveraging opportunities for ongoing formal and informal learning are critical for AEC firms to retain well-rounded skill portfolios across generations of staff into the near future.

Specialisation & Fragmentation

Trends of skill specialisation and fragmentation continue across the engineering and building professions. Programming and software development are critical areas for skill growth across the field, and can provide meaningful advantages for prototyping, visualisation and collaboration. Materials science, design integration, and client interface skills are all important components of the modern building designer's toolkit, as is fluency with recent developments in fabrication and construction technologies.

Left: Penguin Pool, Arup New York, 2012

Case Study: Massive Open Online Courses



Massive Open Online Courses, or MOOCs, allow anyone with an internet connection to take university courses over the internet for free, watching lectures onx streaming video, using interactive online materials and cooperatively marking assignments via social networks.

MOOCs represent a transformative development in skill-building and cross-specialism for the AEC industry, allowing workers to acquire new skills and prepare for heavily specialised or culturally-dependent projects with minimal overhead compared to traditional learning approaches. The 'open' aspects of MOOCs are a double-edged sword for the industry, as the same technologies that enable rapid skill acquisition for staff also enable fiercer competition from designers and firms in developing markets without previous access to similar educational resources.

Location / Business: Mountain View, CA. Coursera for public use.

Generation Gap

The increasing specialisation of building designers' skillsets raises the risk of established designers falling behind a technological adaptation curve. The implications of this generation gap were particularly apparent during the recent global recession; the downsizing of medium- and larger-sised firms to core, often senior designers meant losing a generation of new skills and talent. Ensuring that mastery of both the theoretical and technical aspects of building design is evenly distributed across all generations of staff will be critical to the competitiveness and resiliency of the profession.

Continuing Education

The pace of technological and regulatory advancement within building design as a field underlines the necessity of continuing education. A flexible, relevant and competitive design team will encompass material, technological and process specialties, possess some degree of interoperability and be able to synthesise data from multiple collaborative platforms. Emphasizing holistic programs of continuing education can both ensure that designers maintain a

Case Study: Interactive Learning

Codecademy offers free online courses in programming languages such as Javascript, Python and Ruby. The site is modeled on a social network, and users are encouraged to support one another, create their own courses and organise meet-ups.

Codecademy has grown to millions of registered members in under five years, with meet-ups held in 360 cities worldwide and over 100,000 lessons created. The service's popularity reflects the reality of coding becoming a critical skill set across a wide variety of professions, AEC included. Codecademy's platform increasingly serves not merely as an educational resource but also as a repository for open source code modules, allowing students to build on one another's knowledge to execute increasingly complex projects.

Location / Business: New York, NY. Codecademy for commercial use.

fundamental level of technical currency and help mitigate the effects of increasing specialisation while encouraging independent pursuit of new skillsets.

1.2 Relationships

Building design teams are undergoing a shift in traditional understandings of both structure and leadership. In contrast to the traditional model of a designer employed by a single firm over the duration of a career, talent is increasingly nimble.

Changes in project procurement and a shift toward methodologies such as Public-Private Partnerships, Private Finance Initiatives and Design-Build project delivery all require contractors to assume a greater share of project risk, and therefore a greater role in design team leadership.

Academic-Industrial and business-to-business partnerships will play an increasingly important role in the development, delivery and commercialisation of new technologies and processes.

Case Study: Co-Working Spaces

Co-working spaces such as PARISOMA are shared office facilities, providing productive, creative workspace and amenities to corporations or individuals for a monthly fee.

As more and more companies move to cloud-based remote file access, portable hardware and distributed communications, workers need no longer be tethered to one office location. Co-working spaces provide an office environment for a monthly fee, including workspace, wifi, storage, and discounts on shared tool platforms. Co-working spaces can function as informal R&D or incubator labs, allowing staff to discover and engage with fresh ideas they might not encounter in an industry-specific office.

Location / Business: San Francisco, CA. PARISOMA for commercial use.

Case Study: Digital Networks of Licensed Professionals

Uber is a ridesharing service that connects registered drivers with passengers in need of a ride. Drivers are insured and certified by the organizing network; riders request, track and pay for rides using a smartphone app, choosing on the fly between several service tiers.

Uber (and similar ridesharing firms) stand to substantively alter the transportation landscape, with serious implications for both design and construction of new urban infrastructure and the development of urban mobility regulation. The company's business model is emblematic of the value being created in cities by a new crop of technological innovators enabled by mobile, digital networks utilizing and generating nearly limitless data.

Location / Business: San Francisco, CA. Uber for commercial use.

Networks of Affiliation

As the traditional model of "one designer, one firm, one career" is increasingly replaced by a generation of less allegiant, more mobile specialists, the near future of building design is one of increasing ad-hoc project-by-project collaboration involving teams of highly specialised consultants. The design firm, rather than serving as a top-to-bottom clearinghouse for an entire project, assumes the role of a management hub, linking and facilitating a web of fluid connections between specialists. Firms must consider adapting strategies for employee recruitment, development and investment to accommodate this new, highly mobile and specialised workforce.

New Kinds of Clients

Shifts in market, spatial and environmental contexts will come to define new types of client. A growing trend of public-private partnerships in certain regions will cause shifts not only in design team makeup by also client type. Simultaneously, the growing popularity and feasibility of crowd-funded projects will require consideration of contracting and management strategies for this new client base.

New Kinds of Partnerships

Partnerships between businesses, and between academia and industry, will increasingly define the practice of building design. Academic-industrial collaboration will continue as a critical research stream, developing innovative new tools and processes and refining them into commercial feasibility.

1.3 Talent

As the skill sets relevant to building design continue to evolve, and as the relationships between designers, firms, and non-commercial partners become increasingly complex, the development and retention of talent is of increasing importance in the practice of design.

Talent recruitment is undergoing seismic shifts, from changing employee expectations of work-life balance to the the inception of innovative methods such as team-based hires, which carefully consider the dynamics of a group of collaborators beyond traditional skill sets. Efforts to improve the diversity of the design workforce are successful only when attention is also applied to the retention and professional

Case Study: Competiton-Sourced Talent

Kaggle is a predictive modelling and analytics platform, allowing companies and individuals to host "modelling competitions", submitting project datasets for competitive crowd-sourced analysis; winning analyses become the perpetual intellectual property of the competition host.

Competitive crowdsourcing allows a vastly broader number of approaches to be applied to modelling and analysis tasks, leveraging the collective brainpower of Kaggle's 200,000 member data scientists. Kaggle competitions have resulted in significant advancements in HIV research, traffic forecasting and game theory; the implications for the AEC industry of this sort of crowdsourcing are enormous. In addition to promoting thinking "outside the box", competitive modelling invites project solutions from subject area experts and local specialists inaccessible through traditional team-building methods.

Location / Business: San Francisco, CA. Kaggle for commercial use.

development of future senior leaders for the duration of their professional career. Specification of talent is evolving alongside new paradigms for performance measurement; mechanisms such as value-driven design put a heightened emphasis on product rather than process, potentially altering the mix of working styles involved in successful design projects.

Team-Based Hires

Advancements in cloud-based file storage and real-time communications technologies make it easier than ever for personnel with complementary skills and personalities to form highly functional teams regardless of disciplinary or geographic separation. Companies are leveraging these abilities with the adoption of team-based hiring, a process where staff are either acquired as a team or identified as a potential team via group interviews and activities designed to assess group cohesion. Team-based hiring is particularly relevant for the AEC industry, due to the intensively collaborative nature of our work.

Case Study: Self-Selected Teams

Salesforce's all-day "Build Your Own Dream Team" recruiting event was designed to identify top-performing self-selected teams rather than single job candidates, betting on collaboration over individual experience.

This unique approach to corporate recruitment emphasises the value of agile, creative team-based solution finding when combined with traditional foundational training and deep professional skillsets. The generative capabilities of a smoothly functioning team, and the attendant cross-pollenisation across specialisms and interests, can be a powerful asset in the near future of the building design landscape.

Location / Business: Portland, OR. Salesforce for internal use.

Talent Retention

Design firms are redefining their expectations and processes for talent retention, as an industry-wide shift towards project-based talent curation continues. As individual designers' skillsets become more specialised and career-long institutional allegiance becomes rarer, an opportunity space arises in the AEC industry for the rapid assembly of purpose-built teams. Advocating for diversity among incoming talent will ensure that future building design teams possess the breadth of experience necessary to engage the broadest possible range of clients; with regard to outgoing talent, alumni networks have become increasingly relevant for maximizing value of departed employees.

Value-Driven Design

Design processes that foreground performance, rather than the mechanisms for achieving said performance, are increasingly commonplace within the AEC industry. Value-driven design of this sort encourages firms to both explore progressive team-building and recruitment processes and incorporate both talent and design solutions from historically unrelated industries.

Technologies

"Look at the number of people the banking industry used to have just typing numbers in computers. They've all gone, because what they were doing is a very automatable thing. The architect has now got a computer model, with everything he wants in it, and it's not a huge leap for someone to say, add a button that can do the structural design."

—Michael Willford, Arup Fellow, Advanced Technology and Research

Dynamic, capable design tools requiring complex skillsets; smart, sustainable materials facilitating concepts as bold as they are efficient; construction processes increasingly enabled by automation and novel fabrication methods. The near future of building design technologies is full of opportunities and potentially transformative innovation.

2.1 Materials

Materials science involved in building design is responding to two sets of market pressures. Materials are increasingly considered as component elements of smart, interactive, self-regulating systems, where the ability to support embedded information and track lifetime usage statistics are of considerable value; simultaneously, there is more demand than ever for materials whose simplicity, reusability and low carbon intensity are manifest through their entire cycle of manufacture and use.

This emerging integration of high-performance and low-impact materials is enabling increasingly complex and highly functional structural, mechanical and façade solutions, where ambitious aesthetic aims go hand in hand with smarter, safer, more sustainable projects.

High-Performance Materials

"High-Performance" as relates to material science is coming to be understood as a description of a material's ability to increase operational performance, reduce energy expenditure, and contribute new potential functionalities to building design. A growing trend is the development of materials that couple traditional structural and aesthetic functions with a growing range of dynamic, responsive physical and environmental behaviours enabled by embedded sensing technologies.

Left: Marina Bay Sands, Singapore

Case Study: Phase Change Materials from Automotive Industry

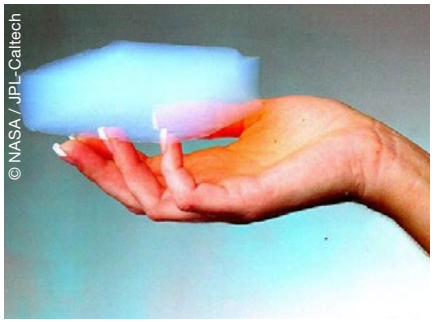
Phase Change Materials store and release waste heat when changing state from liquid to solid at certain temperatures; used extensively to enhance the performance of automotive batteries, the technology has significant implications for the AEC industry.

PCMs are used throughout the building industry for effective passive reduction of heating and cooling loads. Their ductile and reconfigurable nature make them a natural fit for building design applications, allowing designers to create structures where waste heat management is built into the fundamental elements of a design. PCM technology is starting to appear in a number of products marketed to the AEC industry, among them BioPCM mats, GlassX glazing, and ThermalCORE drywall.

Location / Business: Oberhausen, Germany. Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT for commercial use.

One area of particular innovation is façade design, where electrochromic and thermochromic glass, building-integrated photovoltaics and specialised coatings are enabling innovative solutions for the generation, storage and transfer of energy. The growing prevalence of microelectronics and synthetic composites indicates a shift in the way the industry conceives of materials and their function; increasingly, ‘materials’ are highly complex systems of miniaturised or responsive elements, functioning at ever smaller scales and with an ever-increasing degree of seamlessness.

Case Study: Low Emissivity Insulation



Aerogels are a synthetic porous material which replace the liquid components of a gel with an inert gas. The resulting solid, 96% air, is among the lightest, most soundproof, least thermally conductive materials in existence.

Windows present a problem for building designers; they provide critical natural light but can be the weak link with regards to heat loss, solar gain and acoustics. Aerogel-insulated glazing could be a transformative technology for building design, allowing unprecedented façade and window arrangements and significant improvements in emissions control.

Location / Business: Richmond, CA. Thermalux for commercial use.

Processes and technologies from other industries continue to drive innovation in building design. One example is phase-change material, first developed for the automotive industry, which stands to revolutionise thermal energy handling in buildings. As ‘smart’ technologies become ubiquitous, data-driven intelligence and high physical performance will align in the development of increasingly connected, information-rich, and efficient materials.

Case Study: Microalgae Façade

The 200 square metre façade of this residential apartment tower is composed of glass "bioreactor" panels, each containing microalgae plants, continuously supplied with liquid nutrients and carbon dioxide via a water circuit. Catalyzed by sunlight, the continuously generated biomass from the panels is harvested, converted into a biofuel and used to heat

BIQ's microalgae façade is an important pilot project, demonstrating the feasibility of such living-system façades and pointing the way to a future in which the contained biomass could be used for C02 sequestration and air quality monitoring as well as heat production. BIQ's designers anticipate a day when the biomass generated in such structures can provide 100% of a building's power requirements.

Location / Business: Hamburg, Germany. Splitterwerk/Arup for International Building Exhibition.

Case Study: Timber Tower Research

Timber Tower Research Project is an initiative to develop a safe, structurally viable, 42-story building framed with mass timber, employing reinforced concrete only in high-stress areas.

As environmental impact measurements shift from energy intensity to carbon intensity, construction materials take on added importance as contributors to a building's embodied carbon footprint. SOM's Timber Tower has a carbon footprint 60-75% smaller than a comparably sised building constructed from traditional reinforced concrete and steel structural elements.

Location / Business: Chicago, IL. Skidmore, Owings and Merrill LLP and Softwood Lumber Board for private use.

Sustainable Materials

Current areas of sustainable material development include low-carbon materials, materials from renewable sources, and products that are recyclable at both the material and component level. Façade design continues to play a critical role in sustainable building, with strides being made both in façade materials and control systems, allowing dynamic, responsive designs that can help mitigate solar gain and emissions at the systemic level.

Structural materials are another area of innovation, in both the development of new material categories and the innovative application of existing materials via projects that push the boundaries of engineering science. The development of low-C02 cement-free concrete and the popularity of timber construction points to an ongoing renaissance of low-tech sustainability solutions.

The ability to track the material content (and by extension, projected performance) of recyclable materials has greatly expanded their potential for commercial applications. Materials continue to become smarter, with embedded indicators of content makeup and lifetime strain enabling new categories of reuse. Resource scarcity continues to place significance on designing for reusability at the material, component, and building scale. Upfront investments in designing more adaptable materials, structural and façade elements, and building systems will need to be incentivised in order to attain the longer-term benefit of resilience and flexibility.

Case Study: Liquid Desiccant Air Conditioning

Liquid desiccant air conditioning (LDAC) systems pass air through a brine solution, removing particulates and odors along with heat and moisture with similar upfront costs to traditional technologies and a 30-50% reduction in energy expenditure.

LDAC systems can provide meaningful improvements in indoor air quality, resulting in improved worker productivity and reduced mold and mildew remediation costs. Given that 75% of the world has a humid climate, affordable, durable liquid desiccants can potentially have a large-scale impact on operational energy savings versus conventional air conditioning technologies.

Location / Business: North Miami Beach, FL. Advantix for commercial use.

Materials in Systems

Constructability, adaptability, and flexibility continue to be the key criteria for sustainable building design. The ability of buildings to respond to real-time environmental data through systems designed into both the façade and the interior will become increasingly important. Innovative mechanical shading systems relying on high-performing materials will grow in significance in extreme and temperate climates alike.

Resilient building technology will be essential to ensuring longer-term relevance of structures under development today. Drivers for innovation include lower energy intensity, resource management, and increasingly sophisticated building management systems.

Pressure for increased building performance, alongside reduced operational and embodied carbon, will continue to drive systems innovation and technology adoption trends at all scales, including lighting, HVAC implementation and water management.

Case Study: Dynamic Shading

The dynamic adaptive façade of the Al Bahar towers opens and closes in response to solar movement, dramatically reducing solar gain, cooling load and carbon emissions.

The twin 29-story Al Bahar towers share a common lobby area and a unique innovation: a computer-controlled dynamic curtain wall of triangular PTFE panels pre-programmed to fold open and closed as the sun moves around the buildings. The geometric screen calls to mind a futuristic mashrabiya, a traditional element of Arab architecture intended to provide both cooling and privacy. The 1,000 mobile elements of each façade allow a solar gain reductions 50% over a comparable structure, saving 1750 tons of CO2 emissions annually. Sensors integrated into the façade allow it to close autonomously to shield the building from winds and sandstorm activity, and a percentage of the façades' own power is derived from roof-integrated solar cells.

Location / Business: Abu Dhabi, UAE. Aedas / Arup for Abu Dhabi Investment Council.

As a growing number of cities establish plans for reduced and zero carbon schemes, smart and sustainable materials and systems will come to define the future of building design. Building technology will become increasingly integrated into design at the systemic level, driven by advances in data analysis and automated adaptation functions.

2.2 Tools

The tools and technologies that will define building design in the near future will be characterised by the collective improvement of building and system performance, minimisation of waste and environmental impact, and the presence of increasingly streamlined mechanisms for collaboration and integration of information across platforms, disciplines, and projects.

Ideation and process management software developed for other design-centric industries holds the potential to meaningfully improve the workflow of future building projects. Advancements in these related sectors include the

Case Study: Augmented Reality

Meta's Spaceglasses add a third dimension to the Augmented Reality interface made popular by Google Glass, enabling users wearing proprietary goggles to view and to manipulate virtual 3D objects in real time using simple gestures.

Augmented reality, immersive environments, and visualisation techniques adapted from gaming all have an increasing role to play in building design, particularly in how spatial information is communicated to stakeholders and clients. As systems integration and performance metrics assume more and more critical roles within the design and construction process, comprehensive visualisation platforms will be a competitive advantage for AEC industry firms.

Location / Business: Portola, CA. Meta for commercial use.

Case Study: Academic-Industrial Design Hubs

The Royal Melbourne Institute of Technology (RMIT) Design hub is a purpose-built space where students, researchers and industry experts can collaborate on discussions, presentations and events aimed at promoting industry-specific exploration and enabling connections between pure research projects and commercial implementation.

As technological innovation continues to be a critical competitive differentiator among AEC industry firms, collaborative research programmes and spaces like RMIT's Design Hub provide a valuable forum for working engineers and designers to invigorate their practice with fresh ideas from a range of generations and disciplines. Industrial-academic partnerships of this sort can allow for unparalleled cross-pollination of ideas, provide rigorous technical critique, and serve as a valuable recruitment pool for talent.

Location / Business: Melbourne, Australia. RMIT for public use.

use of sophisticated forms of data visualisation and digital mockup in the aerospace industry, and the iterative, process-driven design paradigms of the automotive industry. Design and construction of buildings, as well as communications and management of those processes, will continue to benefit from cross-pollination from related industries and an influx of data-driven tools from nontraditional sources.

Integrated Design

Over the past decade, Building Design-related software products have focussed on leveraging increased computational power for the purpose of analysis and simulation. In the near future, with the centre of gravity in area-specific software development will shift to integration; highly mobile, easily accessible, clearly visualised data will be available to more building project stakeholders, across more platforms and devices, than ever before, allowing new efficiencies from design to operation.

The continued development and standardisation of Building Information Modeling (BIM) technology will enable designers from different disciplines and phases of involvement in the design process to work together in an increasingly seamless manner. Hard datasets and lessons learned from successful projects will be increasingly available for adaptation to future work through these trends in digital workflow and collaboration.

The modeling capacity of BIM will be supplemented by a greater degree of integration amongst disciplines and design phases in the next ten years. Cloud-based information storage and subscription-based software will transform the way that design teams work across geographies and project phases. Distributed, near-realtime communication between design team members, clients and stakeholders, as well as the prevalence of comprehensive data visualisation technologies and highly portable system models will streamline the design, construction and operation stages of future projects.

Case Study: Innovation Model: Design for Business

LEGO's Design for Business (D4B) management process tightly couples innovation, creativity and business goals, ensuring that marketing, product development and production are mutually-supporting endeavors.

Why it's important: While the building design industry is focusing on BIM and software at large as the primary tool for streamlining and advancing the design process, LEGO has rethought the design process itself, with impressive results. LEGO's Design For Business (D4B) has cut the company's design cycle in half and allowed the firm to concentrate on projects likely to generate the most impact. The initiative includes developing an innovation model, a foundation overview, and a roadmap that together help articulate objectives, anticipate required skills and resources, and assess results.

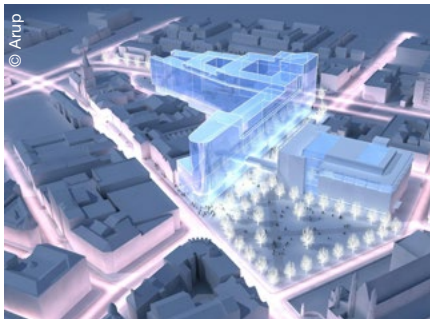
Location / Business: Billund, Denmark. Lego Group for internal use.

Cross-Industry Technologies

A trend that became apparent in the last decade was the increasing utility of computational technologies from other industries to enable an ever-expanding degree of design complexity in buildings. Tools from related industries will continue to alter the landscape of building design, and different disciplines' toolsets will become less segregated. This will be due in large part to the increasing necessity of integration between design phases as designers are required to communicate and collaborate across specialisms in a digital and real-time design environment.

Expanded relationships between software developers and cloud computing providers will enable a more advanced integration of computation and BIM workflow into building design and related disciplines. The growing prevalence of cloud-based data storage, increasing industry engagement with open-source design strategies, and availability of rich and extensive data sets are fueling an awareness of the potential for the commoditisation of design information.

Case Study: Multi-Stakeholder Cloud Collaboration



Box OneCloud integrates a building design content platform with a suite of mobile apps, centralizing project information and allowing designers, contractors and clients to interact with BIM data without specialised tools.

Collaboration and centralisation has been the weak link in many current BIM implementations. The OneCloud suite of data-access tools allows every participant on a given project, from owners to designers to contractors, to view and comment on blueprints, schedules and revisions from any mobile device. The partnership between Gehry Technologies and Box points the way to a near future where all stakeholders across the breadth of a project will have real-time, device and software-independent access to drawings, photos and models at any phase of construction.

Location / Business: Los Altos, CA. Box / Gehry Technologies for internal use.

In addition to the expanding prevalence of cross-industry software, cross-platform workflow and most particularly communication technologies will be vitally important to building design in the coming decade. While designers can be expected to use many of the same design techniques as they have in years past, workflow will be impacted by expanded capabilities of communications platforms, design software and fabrication hardware. Software applications from related industries will increasingly support designers in visualizing and communicating ideas at each stage of the design process.

Case Study: Building Information Management (BIM) in the UK

BIM implementation in the Manchester Town Hall Complex refurbishment project enhanced communication between stakeholders, improved approvals turnaround and identified crucial workflows in simulated works and demolition processes.

The use of BIM techniques in the Manchester Town Hall Complex project is credited with reducing construction timelines by nine months. As the UK e Government scales up to mandatory BIM use, this pilot project will provide crucial data regarding the utility of BIM-based processes in Facilities Management (FM) tasks beyond basic design and construction.

Location / Business: Manchester, UK. Ian Simpson Architects for Manchester City Council for private use.

Governmental Uptake

Building Information Modeling (BIM) has been the subject of widespread discussion in the building design industry over the past decade. To date, however, the benefits of BIM have been limited, as adoption of the standard has been scattershot. This is changing, as BIM uptake by public authorities both at the local and national level is expected to accelerate considerably over the next decade. At present, BIM is mandated at the national level in various countries around the world, including the Australia, Singapore and the United Kingdom.

HM Government Report of the United Kingdom notes that "by 2016 all [UK] Government construction projects will be using BIM at level 2, irrespective of project size," and that "between 2016 and 2025 it is expected that the UK Government and industry will move to Level 3 BIM."

Australia's National BIM Initiative forecasts a $7.6b improvement in the national economy over the next decade, and stipulates that remaining at the forefront of BIM development is a critical component of the nation's continued strategic competitiveness in the built environment sector.

Case Study: BIM in Singapore

The Singapore Building and Construction Authority has developed a roadmap designed to encourage and enable full BIM adoption across all Singaporean construction projects by 2015, including collaboration guidelines, submission templates, and the establishment of a national fund for training and consultancy assistance.

The Singapore government has thrown its full weight behind standardizing BIM adoption across all of the nation's building projects. The establishment of a $6M fund to help Singaporean design firms transition to BIM from CAD and the unilateral promotion of BIM as a specialty in Singaporean universities speak to the seriousness of the nationwide effort. The government expects as much as a 25% improvement in construction productivity as a result of the initiative.

Location / Business: Singapore. Singapore Building and Construction Authority for public use.

2.3 Construction

New construction methodologies and requirements for regulatory compliance are transforming building design at the material, component and systemic levels. Building design professionals' workflow will increasingly require a familiarity with both sophisticated materials and newly developed processes of automated and digital fabrication. Process optimisation and prefabrication will offer the possibility of reducing both project timelines and environmental impact during the construction phase.

Unconventional and crossover skills, such as computer science, industrial design and robotics will become as important to construction projects as traditional architecture and engineering experience. Construction, like all components of building design, will benefit from open data programmes and advanced collaboration tools. Ultimately, new construction approaches will not only impact the processes and skills involved in building design, but may enable entirely new types of projects.

Case Study: Reduced Construction Schedules in China

Broad Group, a Chinese contractor specialising in modular construction, has built a 30-story hotel in 15 days and a 15-story in only 6 days, and has announced plans to build a 220-floor tower of modular components in 90 days.

Broad Group's demonstration of the advantages of modular construction for reducing development time and costs sent waves through the building design world. Despite claims that the group's 15-story Ark Hotel is thermally efficient, sustainably powered and designed to resist damage from severe earthquakes, the construction technique raises questions regarding quality assurance, long-term operations and the culture of disposability surrounding such projects.

Location / Business: Changsha, China. Broad Group for commercial use.

Case Study: Specialty Robotics

Rethink Robotics' Baxter is a safe, economical, intuitive factory robot designed to collaborate with rather than replace human workers; SynTouch's BioTac robot hand mimcs the sensory capbilities of a human fingertip. At the large and fine scales, potential for robotic technology for highly complex specialty applications is advancing.

Baxter represents a new generation of working robots that prioritise intuition, flexibility and ease of training over raw speed, strength or precision; SynTouch's technology indicates a quantum leap in machine handling sensitivity. The combination of the two robotics technologies has the potential to meaningfully transform automation in a variety of AEC industry applications, from design through construction to operations and maintenance tasks.

Location / Business: Boston, MA and Los Angeles, CA. Rethink Robotics & SynTouch for commerical use.

Off-Site and Modular

Advancements in both software design and construction technologies have transformed our understanding of prefabrication. A process that once conjured images of boxy, unimaginative building units has become an area of critical design innovation, where material and cost efficiencies can be realised in complex, striking aesthetic and structural forms. Production of highly complex building components in a controlled factory environment can produce considerable gains in worker safety and unit quality while compressing production schedules, reducing construction traffic and eliminating worksite waste streams.

Over the next decade, modular construction will continue to evolve, integrating new fabrication techniques such as CNC machining and additive manufacturing. As modular units become more sophisticated, a greater emphasis will be placed on the inclusion of plug-and-play systems and services.

The building design process will demand equal attention paid to fabrication and construction, requiring extensive collaboration amongst a varied project team within virtual construction models.

Case Study: Contour Crafting

Contour Crafting is a rapid prototyping technology which uses a quick-setting concrete-like material to rapidly build structures with included structural components, plumbing, wiring and fixtures, achieving significant reductions in both material waste and construction process emissions.

Koshnevis' adaptation of computer-controlled mold printing has significant implications for the AEC industry as a whole, particularly with regard to climate resilience, as the technology could be used for affordable housing or automated rebuilding in the wake of natural disasters. Early evaluations by NASA indicate potential applications for contour crafting in lunar or exoplanetary base construction.

Location / Business: Behrokh Koshnevis / University of Southern California for public use.

New methods of fabrication

The trend of design for digital fabrication presents opportunities not to merely execute traditional designs more efficiently, but to experiment with new design paradigms and structural forms unimaginable using traditional approaches. Design for digital fabrication has natural affinities for BIM and parametric design methods, allowing advanced geometries to be explored and modified to suit a given project. Novel methods of additive and subtractive fabrication unlock the potential for new geometries impossible with traditional methods of design and fabrication.

Case Study: Digital Timber Construction

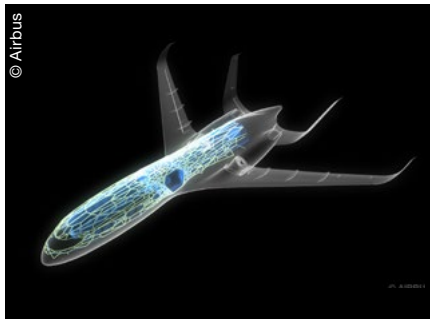
This wooden roof structure for a university architecture lab would be impossible to build by hand. Gramazio & Kohler's design consists of more than 45,000 individual timber elements, woven into a complex, free-form design via automated digital fabrication.

The combination of cutting-edge digital fabrication technology with a local, sustainable resource points the way to a near future where simple, renewable materials are given new aesthetic and structural possibilities through intricate assembly methods. The project showcases an end-to-end digital planning process, connecting design, structural analysis and construction processes.

Location / Business: Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zurich. The Sequential Roof, Zurich, 2010-2015 **Client:** ETH Zurich Building and Constructions Infrastructure Division

A combination of smart and sustainable materials, new software and advanced tooling techniques will allow construction methodologies such as prefabrication to become an increasingly interesting design possibility. As off-site construction is engaged in a larger proportion of projects, design paradigms will evolve to enable this process, reducing waste and increasing efficiency. Building-scale fabrication will come to be characterised by an increasing departure from traditional, labor-intensive on-site processes.

Case Study: Aerospace Industry Use of Digital Mock Up



During new product development at Airbus, a digital mockup (DMU) not only models every physical component of new airframes, but also contains comprehensive information regarding assembly, operation and maintenance of the aircraft. All engineers, suppliers and project partners have access to the DMU throughout the project and on into the product's lifecycle.

As the specialisms required of building design increasingly overlap with those involved in creating high-performance systems such as aircraft, the concept of integrated, comprehensive digital mockups is of obvious vlaue. The integrated lifecycle model reflected in the DMU points the way to advanced applications of BIM (Building Information Model) approaches currently gaining traction in the industry, where each specialist can access and modify performance data relevant to their specialty across the project's entire scope.

Location / Business: Blagnac, France. Airbus for internal use.

Construction Methodologies from Other Industries

Construction methodologies will continue to incorporate product and process advancements from related industries. Prime candidates for best practice transfer include the automotive and aerospace industries, whose understanding of physical machining and digital tooling for complex geometries have natural potential for the AEC sector. Building design can also benefit from examination of the iterative process design, widespread application of digital mockup tools and integrated, collaborative workflow common in automotive and aerospace projects.

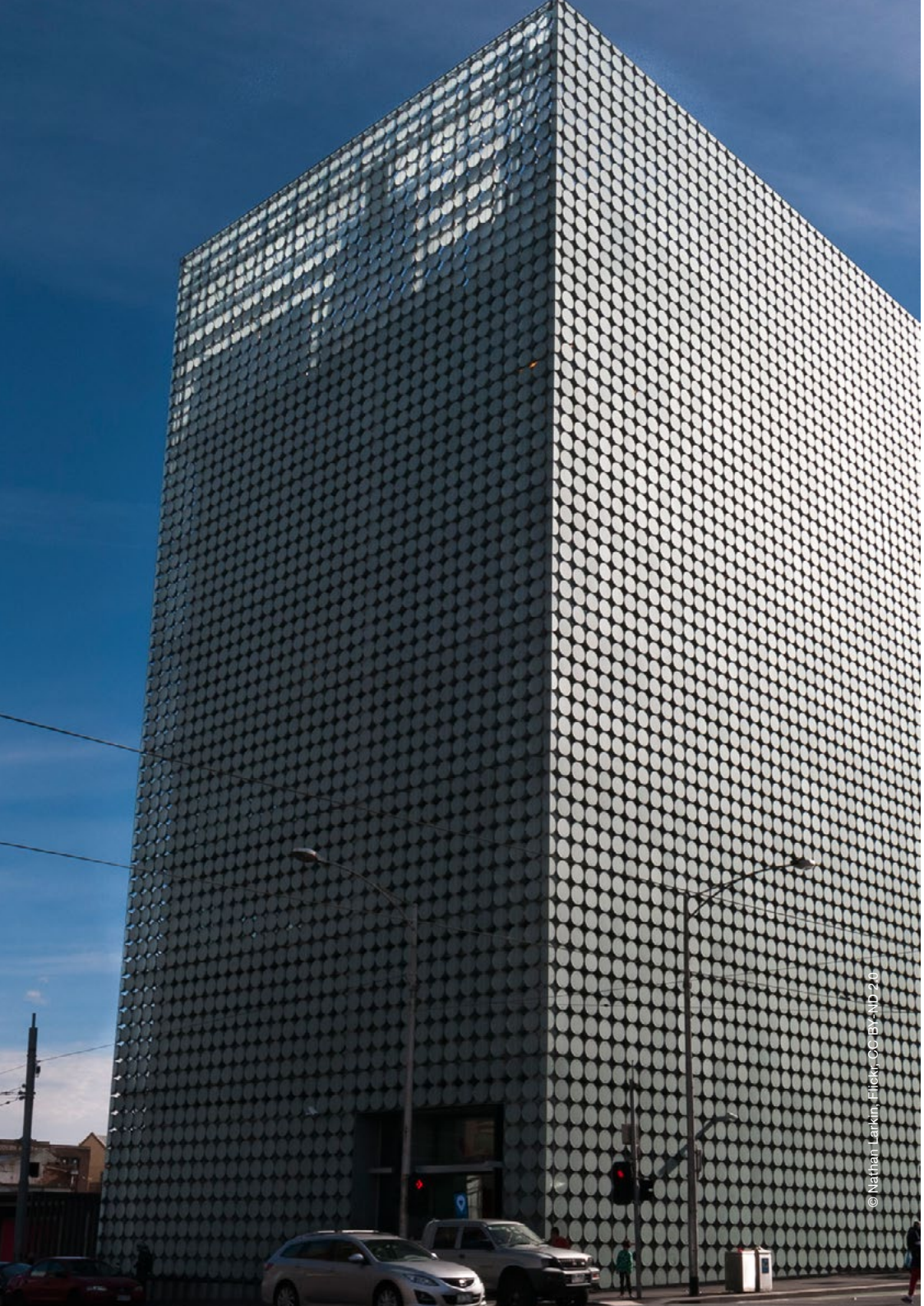
Case Study: Ergonomic Optimisation Through Selective Laser Sintering

Nike's new Vapor Laser Talon cleats make extensive use of 3D printing through the product's entire development cycle, from rapid 3D prototyping during design to the selective laser sintering used to fabricate complex part geometries impossible to achieve via traditional manufacturing methods.

Demonstrated reliability of structural strength in new rapid-fabrication technologies such as laser sintering stands to add powerful new capabilities to the building designer's toolkit. Rapid prototyping of ideas can generate startling efficiencies in the planning and ideation process, allowing stakeholders to quickly and clearly understand design and assembly solutions. The technology holds the promise of one day including additive manufacturing as an integral part of building construction, yielding previously unimaginable combinations of structural efficiency and aesthetic freedom.

Location / Business: Beaverton, OR. Nike for internal use.

User customisation at a variety of scales will become a fundamental element of building design in the near future. Groundbreaking fabrication and assembly technologies hold the potential to refine and streamline construction. As the field of building design incorporates greater numbers of cutting-edge fabrication and construction techniques, academic-industry partnerships will be particularly valuable in developing commercially viable applications for cutting-edge processes.



Systems

"At the moment there's an enthusiasm for all things smart, how we're going to capture all this data… but to what end? In several years you'll have a lot of sites where no systems are talking, and then you'll have the exemplars of data collection shining out, where the data is open and operable in as many systems as possible."

—Damien McCloud, IT & Comms Systems

3.1 Growth

Current drivers in building design include urbanisation at the global scale, and an expanding constellation of resources for collecting and processing design and performance data at the building and systemic levels.

Urbanisation in the developed and developing world alike will pose design challenges requiring unprecedented levels of cross-project integration, as well as heightening pressure for resource efficiency in construction and operation.
While the necessity to design buildings for long-term relevance is becomingly increasingly apparent, the retrofit of existing building stock will be an equally critical workstream for a resource-limited future.

Emerging economies will come to represent a greater proportion of global design work, both in terms of design and labor capacity as well as in terms of the quantity, scale, and type of building projects taking place in countries with growing populations, rising middle classes, and expanding connectivity to the developed world.

Left: The Royal Melbourne Institute of Technology (RMIT) Design Hub

Case Study: Sustainable Urban Civic Buildings

Seattle's Bullitt Center was touted as the "greenest commercial building in the world" upon its opening in 2012. Energy and carbon neutral, the building includes independent water and sewage processing facilities and was constructed entirely without the use of toxic substances.

The 52,000 sqft Bullitt Center is energy and carbon neutral and includes independent water and sewage processing facilities, rainwater collection and geothermal wells. All of the building's lumber is certified to Forest Stewardship Council standards, and all of the sealants, coatings and materials used in construction are certified nontoxic. The project raised the bar for the performance of urban office buildings through a synthesis of passive design principles and technologies aimed to reduce loads, recycle waste streams, generate energy, and create a beautiful and healthy work environment.

Location / Business: Seattle, WA.
The Miller Hull Partnership for commercial use.

Urbanisation

Urbanisation and development in India and China will come to define much of the new-build market, providing opportunities for continued research into masterplanning and eco-district schemes. Existing building retrofit, as well as the development of sustainable and smart materials and components, will take on a heightened priority as resource shortages make themselves felt. The joint implications of densification as well as project requirements in regions without established industrial and regulatory paradigms for formal construction will pose new challenges in terms of design, construction, and resource usage for building designers and project stakeholders.

Case Study: Vacant Cities

In 2007, one hundred invited architects submitted entries to a masterplan project designed to build a 300,000-resident city from scratch in Inner Mongolia. After seven years and $1B of investment, Ordos is a ghost town where 28,000 residents wander through a collection of vacant buildings and incomplete luxury developments.

Ordos represents a particular challenge to the building design industry, namely to create achievable, scalable masterplans with an eye to minimizing waste and maximizing utility in emerging economies where growth pressure is considerable. A future defined by rapid urbanisation will require planners and building designers who can pair efficiency and enthusiasm with sensitivity and nuance, ensuring that designs are truly reflective of social needs, demographic changes and environmental contexts.

Location / Business: Ordos, China.
Government of China for Public Use.

The benefits of big data, such as performance analysis at the building and greater systemic level, will be increasingly available to influence the design of buildings and urban resource plans. These trends will also highlight the development of eco-districts as progressively more commercially viable design solutions. Simultaneous trends in resource shortages, availability of performance data, increasing urban density, and investment in the reuse of materials will enable a transformation from zero net energy building design to net-positive design.

Case Study: Whole-Building Retrofit

Whole Building Retrofit is an integrated and systemic approach to building modification focused on driving greater building efficiency and larger financial returns. Applied to New York City's iconic 2.1m sqft Empire State Building, a whole building retrofit programme achieved 38% energy savings, well above the 15-20% possible using traditional, system-by-system methodologies.

Integrated, systemic planning for building modification can result in significant cost and schedule savings over piecemeal approaches to such projects. In the case of the Empire State Building retrofit, the project included window replacement, chiller plant retrofit, more efficient lighting, a radiative barrier, variable air volume handling units, and tenant demand-controlled ventilation among other improvements. These modifications are credited with lowering annual utility costs per square foot from $4.00 to $2.50, a dramatic reduction.

Location / Business: New York, NY. Anthony Malkin for ESBC.

Existing buildings

Any conversation on urban growth, sustainability, and carbon reduction necessarily involves the potential benefits of retrofitting existing buildings. Given that achievable energy savings in the world's existing buildings stock are estimated between 20% and 40%, national, regional and municipal energy resilience and carbon reduction initiatives must include retrofit as a core concern.

While there are several examples of extensive building retrofits that have drastically improved energy performance, the World Economic Forum has identified the following financial barriers preventing such retrofits in commercial real estate. Firstly, capital costs influence the feasibility of obtaining funding for retrofit projects, as financing mechanisms do not account for reduced operational cost. Since financial institutions may lack the information to determine if an energy efficient retrofit can pay for itself, they either do not participate or are conservative when

Case Study: Existing Building Performance Legislation

New York City's Local Laws 84 and 87 specifically target existing buildings for Energy Star performance reporting, requiring disclosure of annual energy use, water use and building information; this data represents a considerable retrofit market, currently constrained due

While New York's efforts to post building performance data on an annual basis are laudable, the utility of such frameworks are compromised by a reluctance to match performance legislation of this sort with policy efforts designed to facilitate retrofit financing. Building owners lack access to the capital required for large retrofit projects, causing ongoing constraint in the retrofit market.

Location / Business: New York, NY. City of New York for public use.

underwriting. Governments can assist by establishing third-party institutions that provide loan guarantees, discounted loans or credit enhancements to minimise risk and establish a track record of financial viability. They can incentivise participation through tax structure, establish industry-specific targets to increase resource efficiency, and establish a cap and trade scheme for trading energy efficiency obligations. Changing procurement and project finance structures in favor of private funding will enable larger up-front investments in certain contexts. Scaling up energy efficiency building retrofits will require leadership from government and close collaboration between designers and professionals in the planning and finance sectors. This integration has the capability to catalyze action through policy and new financing mechanism.

Case Study: Top Six Emerging Economies in 2013

Leading research organisations project significant changes in the location and constitution of world markets over the next decade, with an array of smaller, technologically-advanced developing nations joining the traditionally largest emerging markets as important opportunity spaces for client development.

In 2010, the CEO of HSBC articulated a vision of a future no longer exclusively dominated by BRIC countries (Brazil, Russia, India, and China), but heavily influenced as well by CIVETS nations (Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa). The McKinsey Global Institute predicts that the percentage of Fortune Global 500 companies located in emerging markets will increase from 17% in 2010 to 46% in 2025. This shifting market balance towards emerging economies opens the opportunity for new processes and designs that maximise efficiency and minimise cost.

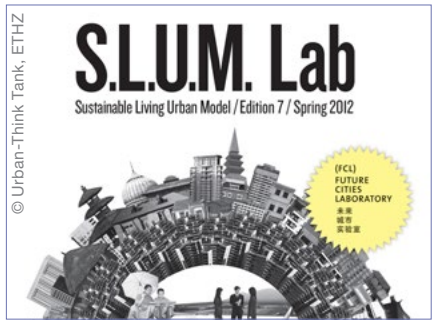
Location / Business: New York, NY. McKinsey Global Institute for commercial use.

Emerging Economies

Urbanisation, population growth, and rising middle classes in emerging economies will each play a role in a substantial growth in the proportion of building and infrastructure projects taking place in the developing world. The UK government forecasts that the population of Africa is likely to double in the next 40 years, and that the population in India is anticipated surpass that of any other country, with over 1.5 billion residents.

The population of urban dwellers in Sub-Saharan Africa, for example, is expected to grow by 70% by 2025. Meeting the needs of residents for housing, workplaces, schools, healthcare, transit, retail, and access to basic amenities will require a large quantity of new build projects in a comparatively compressed timeframe. Urban development projects in emerging economies require significantly different design decisions than those in more developed regions, and may present the opportunity to leapfrog over existing infrastructure and design paradigms.

Case Study: Urban-Think Tank



The Sustainable Living Urban Model (SLUM) Lab is a design and research project combining traditional architectural and design education with sociology, economics and natural science, with the aim of producing politically engaged architects skilled navigating the complex sociological, political and health demands of urban development.

Columbia University and Urban-Think Tank's SLUM lab turns urban planning on its head, injecting considerations of poverty alleviation, sustainability and political action into the earliest phases of high-density development. As an increasingly greater share of potential client work involves densely urbanised contexts in emerging economies, cultivating building designers with a deep understanding of the social and political ramifications of formal and informal built environments will be a key competitive differentiator.

Location / Business: Caracas, Venezuela. Urban-Think Tank for Columbia University

Urbanisation and district-level development will represent a larger proportion of building projects in emerging economies in the coming decades. Countries such as China are already pioneering the production of urban masterplans, and critical lessons are being learned regarding the best practices of designing whole cities. Although substantial benefits of sustainability and economy can be realised at the masterplan scale, such projects must consider the intangible, social elements of city design.

The developing world presents an enormous opportunity to both surpass the conventional paradigms of building design and urban planning and realise enormous social and climatological benefits from holistic planning on a grand scale.

Case Study: User-Controlled and Behavior-Responsive Systems

Nest Labs' smartphone controllable thermostats and smoke alarms can track temperature trends, adjust to occupancy patterns and modify their own behaviour to optimise efficiency, eliciting considerable interest from both the technology and AEC sectors.

Google's $3.2 billion acquisition of Nest's sensor hardware and responsive algorithms indicates the importance of user-responsive systems to a truly integrated future. Behaviour-response technologies have broad applications to the AEC sector, from dynamically increasing energy efficiency to allowing long-term usage pattern observation and logistics planning.

Location / Business: San Francisco, CA. Nest / Google for commercial use.

3.2 Data

In an urbanizing, warming, and increasingly interconnected world, a critical element of design will be robust, efficient tools for analyzing and applying a wealth of progressively more sophisticated data. The current explosion of sensing technology at the building performance level, widespread distributed monitoring systems at larger environmental scales, and increasingly advanced capacities for data analysis in the design process will define the practice of building design in the coming decade and beyond.

Currently, designers are making fast progress in aggregating and analyzing such data. Tools such as Building Information Modeling (BIM) and related practices hold the potential to organise this ever-growing amount of information across specialised design teams throughout the building's construction and operational phases. Whereas past application of data-gathering and processing advancements was largely exemplified by the design of highly complex

Case Study: Networked Environmental Sensors

The Copenhagen Wheel is a sensor platform easily mounted to most standard bicycle frames. The smartphone-controlled unit records and transmits data about weather, pollution levels, road conditions and traffic loads, allowing users to plan healthier bike routes and city officials to better understand the complex interactions of the built environment.

Networked environmental sensors of this sort have immediate value to users, allowing them a fine-grained understanding of their personal environment, commute logistics and health trends. The implications for building design are enormous; distributed sensing programmes provide a wealth of data that can be leveraged across the design, construction and operations phases to minimise traffic disruptions, improve energy performance and modify structures to accommodate usage patterns.

Location / Business: Copenhagen, Denmark. MIT for United Nations Climate Conference.

geometrical forms, future use of such information and analysis will enable designed forms of all types to be built with greater efficiency, adaptability, and resilience.

Sensing and Monitoring

Currently, forward-looking building design projects are laying the foundation for advancements in sustainable design and more comprehensive data analysis. In many countries, legal policy work is being addressed to enable financing for future retrofit projects that take into account long-term operational savings in addition to upfront capital expenditure. Performance monitoring at the building level in current projects can be expected to allow for increasingly advanced data to be gathered at the systemic level in the coming decade.

Data collection and analysis will become increasingly ubiquitous in building design. Collection will occur at a broader scale throughout cities, enabling efficiencies of design and operation impossible when data gathering is limited to the discrete building level. Successful design projects will both

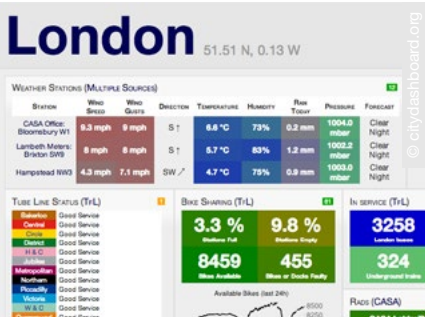
Case Study: Office Realtime

Office Realtime is a data visualisation tool that uses realtime data to guide sustainability-related behaviour change.

Office Realtime displays sustainability and resource consumption data for a wide variety of typical office activities, from energy and water use to copying and printing resources to business travel. The tool displays information in a simple, engaging form that makes it easy for individual staff to see how small changes to their daily workflow can meaningfully affect the organisation's carbon footprint. Implementation of Office Realtime has resulted in measurable positive impact on office resource use and energy consumption reduction.

Location / Business: Melbourne, Australia. Arup for Internal Use.

Case Study: City Dashboard



City Dashboard is a website displaying real-time visual data gathered from a variety of free and open sources throughout London. The user-configurable site presents weather, traffic and news, but can be used to monitor granular climatological, transit and sociological indicators such as pollutant levels, traffic loads and aggregate citywide mood.

One of a number of similar "heads-up displays" that leverage open-source and crowdsourced data to allow urban residents new perspective on their surroundings, City Dashboard speaks to the wealth of data available to users and a desire for its meaningful presentation. "Citizen reporting" open-source aggregation platforms of this type allow urban residents to be better informed about a range of issues affecting their city, potentially improving transit choices, health outcomes, and the urban experience as a whole.

Location / Business: London, UK. Oliver O'Brien / JISC for public use.

use external data to inform the daily functionality of buildings and enable real-time, responsive connectivity with the broader urban social and environmental context.

Equally, processes of data collection will become more automated and embedded into building materials and operations. The design of buildings must respond to the increasing quantity and complexity of data at the building and systemic levels by incorporating advanced control mechanisms that can adapt to dynamic environments in real time. The ubiquity of not only the data and data collection will allow expanded applications of responsive systems, such as automated shading and operational tuning

Big Data

Through a combination of advanced design software, embedded sensing technologies, and building management systems, designers are increasingly equipped to monitor and analyze design, construction, and operational performance data relating to building projects. This wealth of data can be used to positively influence operational performance across the life of the building as well as improve the design decisions and specifications for future projects.

In the design stage, these datasets provide invaluable performance insights, allowing comparative modeling across projected climate and occupancy conditions. The standardisation of building performance collection and reporting methods will gain significance as datasets from past projects are used to benchmark future design. In the operational stage, datasets must be accessible and understandable to facilities managers and occupants alike.

A fundamental trend in building design is the expansion of design considerations beyond the building level. The increasing availability of construction and operational data for buildings of all types in a range of environmental

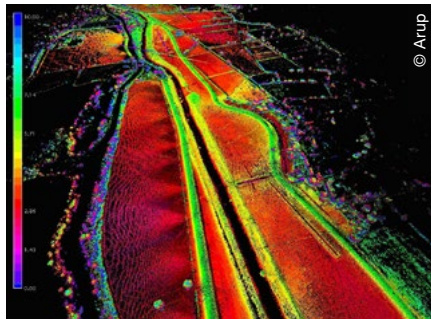
Case Study: Zero Carbon Buildings Plan

Australian think-tank Beyond Zero Emissions partnered with the University of Melbourne's Energy Institute to release a report detailing how existing buildings can be retrofitted to reduce their energy use by half, potentially reaching net zero carbon emissions by 2020.

The Zero Carbon Buildings plan focuses on whole-building retrofit, touching on insulation, draft proofing, window glazing, shading, roof paint, cooling systems and air handling units as key areas for energy reduction. Released in parallel with a report demonstrating how Australia can generate 100% of its electricity from renewable sources by 2020, these ambitious public planning documents reflect the critical interest in climate adaptation and sustainability across the traditional building design client base.

Location / Business: Melbourne, Australia. University of Melbourne / Beyond Zero Emissions for public use.

Case Study: Climate Shifted Energy Modeling



City Dashboard is a website displaying real-time visual data gathered from a variety of free and open sources throughout London. The user-configurable site presents weather, traffic and news, but can be used to monitor granular climatological, transit and sociological indicators such as pollutant levels, traffic loads and aggregate citywide mood.

One of a number of similar "heads-up displays" that leverage open-source and crowdsourced data to allow urban residents new perspective on their surroundings, City Dashboard speaks to the wealth of data available to users and a desire for its meaningful presentation. "Citizen reporting" open-source aggregation platforms of this type allow urban residents to be better informed about a range of issues affecting their city, potentially improving transit choices, health outcomes, and the urban experience as a whole.

Location / Business: London, UK. Oliver O'Brien / JISC for public use.

and usage contexts is enabling the application of big data to entire systems. City-scale operations, such as resource management, energy production and distribution, as well as infrastructure and transit functions, will play a proportionately larger role in the work of designers in the coming decades.

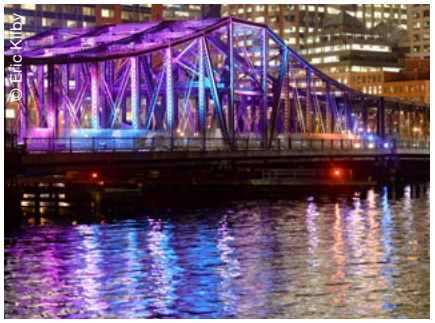
Climate Data and Adaptation Planning

Building design is more than a matter of designing for optimal performance in ideal conditions; successful designs must withstand unforeseeable circumstances that may limit their functionality. Designing resilient buildings requires careful selection of building sites and design schemes to enhance survivability, ensure continued functionality and reduce risk.

Beyond climate-related resilience, adaptation planning includes designing spaces for physical flexibility in the longer-term future. Solutions for adaptable buildings and infrastructure exist at every scale, ranging from responsive shading systems that adjust dynamically throughout the day, to flexibility at the programmatic level, effectively designing for the ability to retrofit existing spaces to reflect future changes in user specifications with minimal cost and energy expenditure.

Increased awareness and availability of environmental, demographic, and building performance data will enable designers and operations specialists to effectively anticipate future trends and adapt accordingly.

Case Study: City Innovation Districts



Boston's Innovation District pilot program allocated 1000 acres of underdeveloped waterfront land to attract high-tech investment with mixture of live-work and collaborative spaces, extensive bike-friendly infrastructure and LEED certification for all structures over 50,000 sqft.

The innovation district is designed to explore the intersection of entrepreneurship and environmental sustainability. The area is a model for sustainable development, having added 4,000 jobs and 200 new companies to the region over a several-year period. Waste reduction and transportation management programs are being fielded to gain further efficiencies from the program.

Location / Business: Boston, MA. Boston Redevelopment Authority for City of Boston.

3.3 Connectivity

Data-informed design holds the promise of high-performing, livable buildings, neighbourhoods and cities with an increased level of built-in resilience to social, economic and climate change. As embedded sensing systems become commonplace, data analysis, currently implemented within individual building projects, will scale to the neighbourhood and city levels, allowing planning professionals, public officials and the community at large more extensive involvement with the design process.

Urbanisation will drive an increased degree of connectivity between buildings, city systems, and the people that inhabit and use them; the rich streams of resultant data will need to be synthesised and communicated in a manner accessible to a diverse range of stakeholders. A general trend of increased intra-project coordination and inter-project connectivity has considerable implications for waste reduction, project timelines, and the ultimate desirability and habitability of new designs.

Case Study: Eco-Towns in the United Kingdom

Bicester's 5,000-home development includes an energy centre, a community centre, a primary school and "eco-pub"; every building in the town includes efficient insulation, rainwater harvesting and an integrated solar array.

Of the four cities designated "eco-towns" in 2009, Bicester is the only municipality that has held itself to the government's original planning criteria for renewable energy, public transport, and efficient and affordable homes. The eco-town project is an important testbed for integration of meaningful sustainability and renewability measures across entire communities.

Location / Business: Bicester, UK. A2Dominion for Cherwell District Council.

Urban Connectivity

Holistic, regional-scale design plans offer considerable potential benefits alongside the challenges of scale and project management. Shifts in scaled procurement methodologies, seamless resource integration, and operational savings will continue to make large public projects a vital part of the AEC sector. The design process itself is evolving along with finance and management strategies, with alternate procurement methods and the increasing use of Design-Build placing an increasing amount of design control at the contractor level.

Considered from a climate mitigation standpoint, urban connectivity and regional-scale design offers considerable operational efficiencies. Connectivity beyond buildings empowers a shift towards measuring emissions, rather than energy use, as a relevant metric of sustainability. Informational connectivity between building and infrastructure projects paves the way for the development of district energy systems, centralised fuel sources, and productive reuse of waste products such as water, heat and energy.

Case Study: Wiki House

WikiHouse is an open-source construction platform from which people can freely download and modify building plans, send files to a local CNC router, and then assemble the pieces to build a house without any prior construction knowledge.

The open-source paradigm may allow designers to rethink the way that the design of buildings has traditionally been attributed to singular designers or firms, and transition into an environment that places less value on brand recognition for high-end projects. The industry's place may evolve into more of an advisory role in open-sourced projects, providing expertise to establish mechanisms for ensuring the relative originality of the ultimate design and accuracy of calculations.

Location / Business: London, UK.
00 / WikiHouse for public use.

Open-Source Design

Open-source design, or the practice of making design elements freely available for use or adaptation by others, has rapidly transitioned from a curiosity to a valuable component of professional practice. A concept originating in software development, open-source practices have made considerable inroads in the AEC sector, with significant implications for building design in the coming decades.

Case Study: Open Architecture Network

The Open Architecture Network is a free, open-source online community where designers, architects and engineers share ideas, designs and plans, commenting, building upon, and refining one another's work to improve living conditions around the world.

Using an open-source model, the OAN makes the world-shaping power of architecture and design available for free, raising the standard of the built environment in new markets. Initially conceived by Architecture for Humanity, the project is a collaboration, dissemination and project management platform that is open to all. OAN makes it easier for individuals and firms to collaboratively contribute to global development, but may also pose challenges to firms who currently compete for work in this area.

Location / Business: San Francisco, CA.
Architecture for Humanity for public use.

The challenges facing open-source design for building projects include issues of standardisation, originality and accuracy. The the open-source paradigm requires a reexamination of traditional brand strategy, systems attribution, and teambuilding. The role of the engineer in an open-source context may evolve into more of an advisory capability, providing expertise to non-traditional or non-technical aggregators of open-source components. The AEC sector stands to realise efficiencies from the internal use of open-source processes, but must remain aware of the competitive advantages open source approaches lend to nontraditional firms.

Case Study: Prodigy Network in Colombia

Prodigy Network's real-estate crowdfunding platform combined $172m in funding from 3,100 small-scale investors to design and develop Colombia' tallest skyscraper, the 66-story BD Bacatá.

Prodigy Network's successful backing of the downtown Bogota BD Bacata not only proves the concept of crowdsourced real estate but adds ongoing value for participants. Once a property is constructed using crowdsourced funds, the investors can buy and sell shares of the building through a resale program. The combination of crowdfunding and co-ownership may shift real estate power dynamics, enabling ever-more ambitious and innovative building design.

Location / Business: New York, NY. Prodigy Network for commercial use.

Crowd-sourcing and crowd-funding

The influence of startup culture upon building design includes the consideration of innovative social mechanisms to initiate large-scale projects and engage new sources of private funding. The implications of crowd-sourced catalyzing in the AEC sector are substantial, particularly for building design. Whereas building-scale projects have traditionally been funded by a small minority of the total population, crowd-sourced initiation and funding of projects presents the opportunity for new use cases and entirely new client bases to emerge.

Challenges for designers of crowd-sourced projects include the incorporation of a larger number of opinions into the design, but opportunities include the development of new usage paradigms that, when coupled with advancements in data analytics, can be both designed and operated in a highly efficient manner.

Case Study: Fundrise in the United States

Fundrise's real estate crowdfunding platform allows individuals to invest sums as small as $100 in professionally-developed local building projects, potentially transforming a market long dominated by accredited private equity investors making million-dollar bids.

While the United States will likely soon lift current legislation requiring developers to market their projects to accredited investors with a minimum net worth of $1 million, Fundrise has successfully been able to crowdfund projects in America through an exception that allows unaccredited investors to fund local projects that they themselves can use. Fundrise has successfully crowdfunded projects often through large numbers of small-dollar investments from locals in a movement that not only promotes social power but localised, shared profit.

Location / Business: Washington, DC. Fundrise for commercial use.

Although the popularity of crowd- sourced and crowd-funded projects may never fully replace traditional methods of procurement, financing, and design, trends such as this present designers with the opportunity to think critically about the end user of building design projects and to adapt lessons into traditional management structures.

Conclusion

Building design stands on the precipice of great and subtle change, enabled by the confluence of increasingly democratised design tools and advanced fabrication technologies, catalyzed by emerging economies and urgently needed to house a rapidly expanding human population.

Emerging economies and hyperdense urbanisation are changing the makeup of our traditional client base; new models of investment, project procurement and collaboration may well alter project workflows; accessible software tools and collaborative workplace arrangements are blurring the definitions of traditional specialties.

Workforce composition and skillsets remain the core of building design. Highly mobile, technically adept architects and engineers are adapting disruptive concepts from the tech sector to enhance every phase of building design; ensuring that this new generation of workers can collaborate with and learn from the experience of legacy staff will create a potent mix of talent.

New developments in materials technology and fabrication processes are enabling previously inconceivable formal and aesthetic solutions, while allowing increasingly sensitive, efficient structures to be built more quickly and safely than once imagined possible.

Technological change continues to drive opportunity. The rise of algorithm-driven design and automation-assisted construction means that firms must carefully consider their processes and value proposition to clients; conversely, the amounts of data and connectivity available to today's designer mean that "smart" and "green" solutions can now be effectively applied at neighborhood and regional scales.

As the industry moves towards 2020, building design will become increasingly dynamic, sustainable and competitive. Arup's responsiveness to the areas of focus outlined in this report can help ensure our fitness for purpose as we lead, innovate and excel in designing the buildings that will define the next decade and beyond.

Arup Interviewees

UK

London
Adam Alexander
Paul Andrew
Francesco Anselmo
Giulio Antonutto
Francis Archer
Mark Arkinstall
Rob Baldock
Alice Blair
Darren Briggs
James Canaan
Chris Carroll
Andrea Charlson
Ed Clark
Toby Clark
Jeremy Edwards
Ken Enright
Lee Franck
David Gilpin
Mike Gosling
Alisdair Guthrie
Stephen Hill
Paul Jeffries
Florence Lam
Joanne Larmour
Damien McCloud
Robert Mitchell
John Moss
Roger Olsen
Stuart Smith
Becci Taylor
Michael Trousdell
Chris Twinn
Felix Weber
Richard Wheal
Steve Walker

MEA

Dubai
Peter Evans
Kubilay Kicyilmaz
Chouaib Lekmiti
Tony Lovell
Stefen MacAskill
Neil Walmsley

Europe

Amsterdam
Alexander Boogers
Paul Coughlan
Salome Galjaard
Kathy Gibbs
Michiel Hagenouw
Anastasios Kokkos
Sean McGinn
Joop Paul
Sheela Sankaram
Roel van de Straat
Laurens Tait

Berlin
Matthias Effinger
Andreas Ewert
Nicolo Guariento
Carsten Hein
Ewan McLeod
Alexander Rotsch
Frank Walter
Jan Wurm

Dusseldorf
Karsten Jurkait
Christian Wrede

Frankfurt
Karsten Spengler

Americas

Los Angeles
Bruce Danziger
Paul Devereux
Russell Fortmeyer
Martin Howell
Murat Karakas
Erin McConahey
Bruce McKinlay
Patrick Noll
Douglas Nordham
Julie Root
Roel Schierbeek
Bill Scrantom
Elizabeth Valmont
Teena Videriksen
Atila Zekioglu

Americas cont.

New York
Leo Argiris
Dan Brodkin
Zak Kostura
Ashok Raiji

San Francisco
Kyle Adams
Ibbi Almufti
Shakeel Ahmed
Ignacio Barandiaran
Ingrid Chaires
Joseph Collins
Joshua Cushner
Raj Daswani
Tatjana Dzambazova
Alexej Goehring
Rob Henderson
Jacob Johnston
Amit Khanna
Eric Ko
Jan-Peter Koppitz
Shaun Landman
Alex Lofting
Bill Maddex
Brian Mathews
Alisdar McGregor
Priscilla Mensah
Shane Myrbeck
Greg Nielsen
Frank Palermo
Brian Pene
Raj Patel
Jim Quiter
Cole Roberts
Larry Tedford
Andy Thompson
Michael Willford
John Worley
Frances Yang
Robert Young

Australasia

Melbourne
Michael Alder
Phil Alexander-Pye
Matthew Francis
Frank Gargano
Gerard Healey
Martin Holt
Peter Johnson
Nik Killis
Andrew Maher
James O'Donnell
Matthew Wash
John Legge-Wilkinson

Sydney
Andrew Beazley
Ben Cooper-Woolley
Cameron Dymond
Steven Downing
Alex Edwards
Tim Elgood
Richard Hough
Andrew Johnson
Alexander Kobler
Johnathan Lindsay
Peter MacDonald
Chris Mawson
Tania Milinkovich
Xavier Nuttall
Deirdre O'Neill
Andrew Pettifer
Ricci Piper
Claire Pomroy
Alex Rosenthal
Haico Schepers
Tim Womack

Singapore
Dion Anandityo
Ricky-C Chan
Russell Cole
Chris Deakin
Henry Jeens
Samantha Peart
Steve Pennell
Benjamin Sitler
Rohan Bridgland
Lee Yeung

Arup Interviewees

East Asia

Shanghai
Wei Bai
Anthony Buckley-Thorp
Vickie Chen
Francesca Galeazzi
Andrew Luong
Jeff Tsai
Frederick Wong
Lu Wu
Tony Chan Yong-Wei

Hong Kong
Argoon Chuang
Iris Hwang
Stefen MacAskill
Andrew Mole
Simon Ng
Tommy Tang
Kevin Wan
Jia-Jin Wang

With Advisory Input from the Arup Global Buildings Practice Executive
Peter Bowtell
Tristram Carfrae
Mark Chown
Joseph Correnza
Justin Evans
Peter Hartigan
Andy Lee
Anthony McCauley
Rory McGowan
Antonio Ng
Declan O'Carroll
David Richards
Rudi Scheuermann
Paul Sloman
Paul Tsang
Matt Williams
Atila Zekioglu

External Interviewees

Americas

Atlanta, GA
Vikram Sami
ZGF Architects

Berkeley, CA
Stephen Selkowitz
Cindy Regnier

Boulder, CO
John Bacus
Trimble Navigation

Chicago, IL
Rand Ekman
Cannon Design

Los Angeles, CA
Alex McDowell,
USC 5D Institute
Mehrdad Yazdani
Yazdani Studio, Cannon Design

Minneapolis, MI
Jim Bradburn
Mortenson
Derek Cunz
Mortenson
Julianne Laue
Mortenson

New York, NY
Jim Barrett
Turner Construction
Michael Deane
Turner Construction
Paul Logan
Jones Lang Lasalle

San Francisco, CA
Andrew Arnold
DPR Construction
Tatjana Dzambazova
Autodesk
Mark Hatch
TechShop

Americas cont.

Don Horn
GSA
Brian Mathews
Autodesk
Brian Pene
Autodesk
Robert Plummer
Gensler
Phil Williams
Webcor Builders

Seattle, WA
John Coster
Skanska
Rob Pena
UW & Bullitt Foundation

St. Louis, MI
Mary Ann Lazarus
HOK + AIA

Washington, DC
Elizabeth Heider
Skanska
Ann Kosmal
GSA High Performance Building Group
Amir Roth
Dept. of Energy

Australasia

Melbourne
Frank McMahon
Brookfield Multiplex
Tim Black
BKK
Geoffrey London
Dept of Premier and Cabinet, Victoria
Miro Miletic
Memko
Sean Sweeney
Grocon
Stefan Mee
John Wardle Architects
Alan Pert
University of Melbourne

Acknowledgements

Author
Katherine Prater

Graphic Design
Mark Pearsall

Editor
William Newton

Research
Katherine Prater
Meng Sun
Mike Norris

Image Credits

Images from Flickr
p 20 NASA, CC BY 2.0
p 24 Woodley Wonder Works, CC BY 2.0
p 28 Forgemind Archimedia, CC BY 2.0
p 29 Steve Juvetson, CC BY 2.0
p 30 Drummond Masterton, CC BY-NC-ND 2.0
p 34 Nathan Larkin, CC BY-ND 2.0
p 38 Paul Stocker, CC BY 2.0
p 39 Jeffrey Zeldman, CC BY 2.0
p 40 Pedro Szekely, CC BY-SA 2.0
p 43 Sujal Shah, CC BY-ND 2.0
p 46 Oregon DOT, CC BY 2.0
p 48 Eric Kilby, CC BY-SA 2.0
p 49 Shelleylyn, CC BY-SA 2.0
p 50 Javier Leiva, CC BY 2.0
p 53 Payton Chung, CC BY 2.0

This report highlights key challenges and opportunities the building design industry will face in the coming decade. Below, we have identified overarching trends affecting the industry as a whole, as well as case studies of current solutions and innovations

We found that rather than being a simple question of the latest technological or material advancements, the future of building design requires a careful consideration of how tools, practice and their integration fit into an evolving local and global context. In the coming decade, building design will be shaped by developments in the key areas of people, technologies and systems.

An increasingly networked, specialised, and fluid workforce is reshaping our internal and external relationships.

Technologies from other industries in both the design and construction of buildings are changing the processes and projects we undertake.

Urbanisation and connectivity will transform the broader landscape of the built environment in the developed and developing world alike.

ARUP

13 Fitzroy Street
London W1T 4BQ
arup.com