CONNECTED BIM FOR BUILDING DESIGN

IMPROVED PROJECT INSIGHT WITH THE CLOUD

Image courtesy of HKS Inc.

Foreword

In a 2013 lecture at the Canadian Center for Architecture, Stan Allen drew an important distinction between the "computational" and the "digital."

At Princeton, we've been trained very well to refer not to the digital but to computation when we're talking about the computer in architectural terms… The digital is a kind of state of being. It's a condition. When you talk about computation, you're talking about active processes.[1]

He observed that, while the building industry has been moving toward the digital for many years as information was generated with computers, we are only now fully engaged in the computational: using the computer to not just create data but to manage, manipulate and create ideas themselves. While both digital and computational tools once seemed novel, no capable firm would now consider abandoning them as the AEC industry moves fully into the Information Age.

In this report, we look at how trends in technology have evolved in the sector to deliver a better built environment. From the earliest days of Computer-Aided Design (CAD) through to Building Information Modeling (BIM), cloud computing and generative design, we take you on a journey through the ages – the Eras of Documentation, Optimization and Connection – and present our vision for the future of the building design industry.

Image courtesy of HKS Inc.

THE ERA OF DOCUMENTATION

Since the emergence of computers in academia in the 1950s, CAD software has had a significant impact on the architecture industry. This grew exponentially in the 1980s, following the introduction of personal computing. In the earliest days of CAD, tools like AutoCAD spurred the “Era of Documentation.”

Although early researchers predicted an exciting future interaction between machines and human designers, the first computer tools to be widely adopted by architectural designers were computerized versions of traditional drafting and rendering tools. Software, data, and plotters replaced plastic and lead sheets of mylar and drawing boards, for example. While they allowed designers to produce technical drawings much faster than with traditional methods, they did not fundamentally change the process of design.

Because of this, the industry started to realize that CAD drawings were not necessarily the best way to share, correct, or store manufacturing files. Instead, engineers and architects looked for ways to combine the models they were creating with technical drawings based on 3D forms; thus marking the transition from CAD to 3D modeling.

Fast forward two decades, and we’ve seen widespread adoption of a new technology, BIM, where computation is applied to represent built artifacts as three dimensional, behaviorally simulative predecessors of their physical counterparts. It provides a critical foundation to help designers, builders, and owners gain a competitive advantage with the ability to access, share, and make use of enormous amounts of information throughout the lifecycle of buildings and infrastructure.

BIM is blurring the lines between digital processing and physical systems, causing the design and build phases of projects to move closer together. That said, the transition from CAD to BIM has been difficult, aided only in part by accelerating capabilities of machines themselves in storage capabilities, processor power, and graphics resolution. The bigger challenge: BIM represents an inversion of a several-thousand-year-old tradition of building workflows – representation and communication through 2D drawings giving way to databases where the drawings are a result, rather than the purpose itself, of the tools. Those databases, rich in accessible information, make it possible to both represent and analyze a design as it develops, enabling architects and engineers to evaluate and optimize project components like area, structure, or the movement of air. Insights available from a robust digital model are supported by analytical tools that evaluated the design in process.

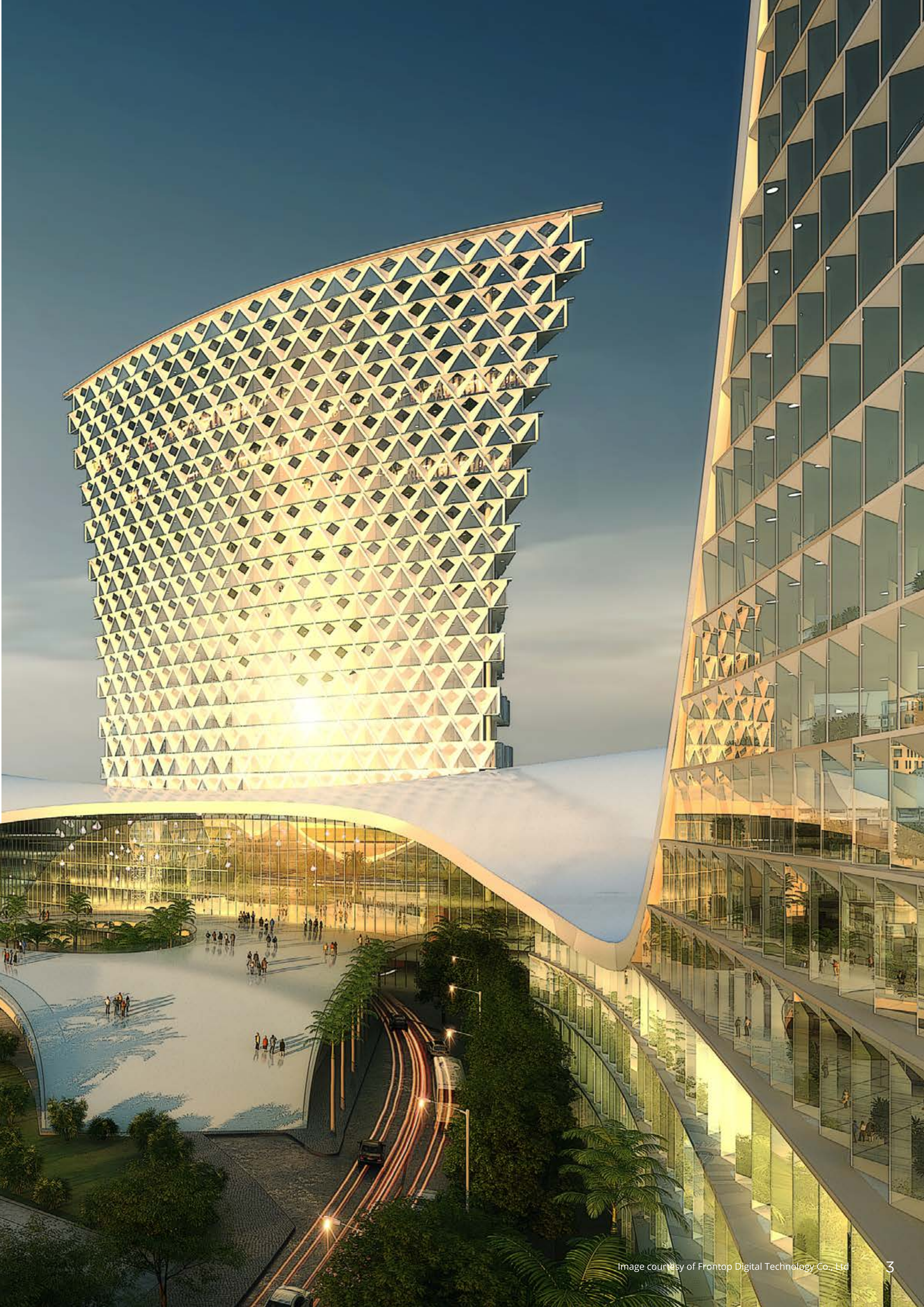


Image courtesy of Frontop Digital Technology Co., Ltd

THE ERA OF OPTIMIZATION

The emergence of BIM in the 1990s ushered in the "Era of Optimization," and simultaneously made computation as important as digital information.

The computational challenges of this change were born by both software providers and their customers. BIM tools are not just supercharged drafting platforms but rather specific, encoded knowledge systems based on semantic representations of their intended built objects.

A CAD tool (like AutoCAD) can draw just about anything, as it is essentially oblivious to the result; it's rather optimized to provide sophisticated drawing capabilities. But a BIM tool needs to understand "what" a road or building "is," including a way to represent its constituent parts (doors, walls, windows or substrate, surface, curbing) and proper parameters and relationships. It's essentially a sophisticated database design problem, where the resulting software can simultaneously create the data and generate "reports" about it, in the form of drawings. After establishing these platforms, capabilities grew, and it became possible to differentiate discipline-specific "views" of the model and a wider array of designers (structural and mechanical) came into the BIM fold. The industry is widely understood to now be moving toward BIM as both work processes and technologies have matured.

As vendors produced increasingly capable BIM tools, building professionals worked to leverage the new-found advantages of technology, adopt new work approaches, and align their new capabilities with the realities of building production, standards, and project delivery. Where CAD-based project management wasn't dramatically different from its analog predecessor (just substitute "file folder on server" for "flat file drawer"), BIM-enabled teams have new ways to connect models, improve technical outcomes, coordinate information in the field, create high-resolution renderings, and speed document production. As the internet became first ubiquitous and then rapid, digital data moved quickly between offices and project sites. But what comes after speedier desktops connected by the internet?

Cloud computing is already transforming building processes and workflows in ways that make the disruption of the BIM transition seem tame in comparison. Representing very large things like buildings or bridges has always been demanding—and BIM made this more so. But cloud-enabled BIM destroys this constraint with essentially unlimited computation and storage capabilities available to any device, whether an engineer's workstation or a job superintendent's tablet in the field. The implications here are profound, since virtually any piece of representation or complex computational process can simultaneously be available to any member of a project team, in any location, with readily available hardware and software. Availability of the information created in the designer's office, job trailer, or sub-contractor's fabrication shop is unconstrained, rendering its originating location no longer relevant. Both that information and related insight—building data and the ability to use it—becomes ubiquitous. And the computational thus catches up with the digital.

Adoption of cloud-based collaboration in building design projects

(Source: Leading the Future of Building: Connecting Teams)

98%

respondents report using some type of a cloud-based collaboration solution on their BIM projects

63%

are using a cloud-based collaboration solution

82%

of those who made a significant investment in collaboration solutions cited a positive ROI

Collaborative solutions reduce the need for co-location and associated costs:

Architects	50%
Engineers	47%
Trade Contractors	44%
General Contractors	22%

Architectural benefits of using collaboration solutions on BIM projects:

56%
Quicker communication, workflows and decision

54%
More advanced implementation of BIM

50%
Less need for co-location and associated costs

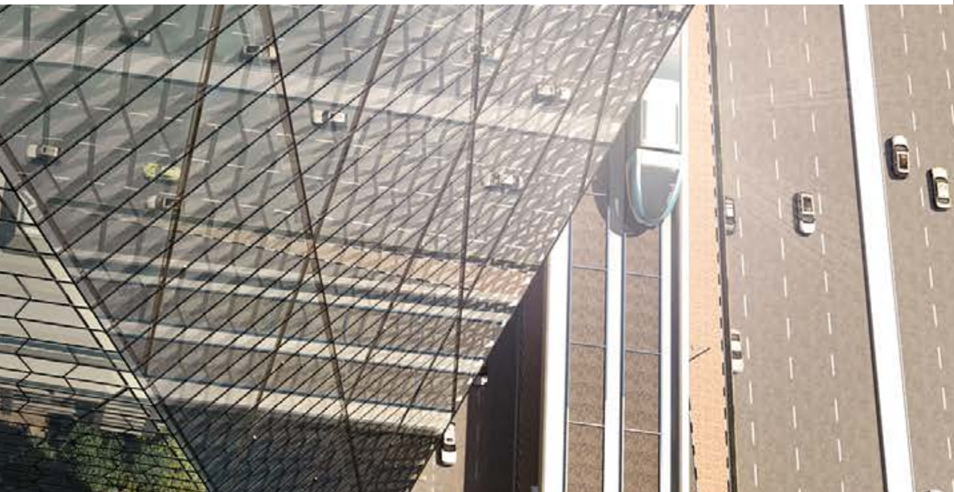


Image courtesy of PTAH

THE ERA OF CONNECTION

So, we can see the transition from the “Era of Optimization” and the advent of a new generation of tools and processes to a new "Era of Connection” in a convergence of robust representation (BIM) and ubiquitous computing power (the cloud). While historically, the focus has been on the “M” of BIM (modeling), we’re now seeing a rapid shift to focus on the “I” (information). This focus on information and the increasing ability to share it more easily is enabling project teams to work together in ways never before possible.

Cloud-enabled, interconnected BIM process, or “Connected BIM,” is beginning to displace “interoperable CAD” as the platform for managing and optimizing design to construction. And while drawings will likely never disappear entirely from the design and construction process—at least in our lifetimes—a Connected BIM process generates drawings of greatly improved projects as an outcome of an integrated schema of models, analytical tools, big data, and collaborative infrastructure. This interconnected constellation of computational technologies brings with it a new set of workflows and capabilities.

At the center of the Connected BIM proposition are cloud-enabled authoring tools, enhanced (unlike their desktop-bound counterparts) by accelerated computation power, far greater storage capacity, and connected work in a multi-disciplinary environment.

What is Connected BIM?

Connected BIM is BIM, plus the power of the cloud.

By leveraging the capabilities of the cloud for BIM processes, AEC professionals can benefit in the following ways:

Image courtesy of Fentress Architects and Hennebery Eddy Architects

Connected BIM streamlines collaboration for the new PDX Terminal

The Portland International Airport (PDX) Terminal project was delivered as a collaborative design partnership between Fentress Architects, headquartered in Denver, Colorado, and Hennebery Eddy Architects, based in Portland, Oregon[3]. Fentress and Hennebery Eddy worked together as a single design team, enabled by Autodesk® BIM 360, to deliver the complex public infrastructure project. Not only were the two firms geographically separated, but there were a number of different stakeholders involved – consultants, engineers, and architects, as well as the owner and owner representatives. They worked together by using BIM 360 to centralize their two design teams in the cloud. Communication, design reviews, file sharing, version history tracking, and model coordination was all done using BIM 360, eliminating the need to physically co-locate the two offices.

Image courtesy of Autodesk

Designers and consultants can operate both separately and simultaneously, synchronizing complex disciplinary models as needed. The "reference space" of the design process – the environment within which decisions are connected and inform each other – is enlarged. Assisted by powerful authoring tools, those designers can create, assess, select, and refine alternative solutions more rapidly, expanding the solution space for any given problem.

The range of exploration can be further expanded by adding an additional layer of computation to the toolset: scripts, which are digital instructions that automate the generation of design alternatives, altering any parameter in a digital model. Rather than directly choose, for example, the size of a set of windows in a facade, an architect can experiment with a series of options by writing a script that adjusts the width and height of each opening while the model reports the implications for the construction of the facade, admitted light, energy loads, and construction cost. Testing each and every combination of width and height manually would be tedious and complex, and these are just two of the hundreds of parametric variables as the design develops. Any such parameter of the design can be manipulated in this way with an algorithm, bringing direct computation to the Connected BIM representation in a methodology known as generative design, a technique that augments (rather than replaces) the designer's ability to define, explore, and choose alternatives[2].

Automating design exploration substantially increases the designer's ability to evaluate, sort, and select an option. Cloud-enabled simulation and analysis tools, in combination with BIM representations, make this process rapid and accurate. The architect designing the facade in the example above can connect her work with a cloud-based analysis engine that evaluates, in real time, the implications of changes in daylight, heating and cooling loads, systems sizes, and air distribution

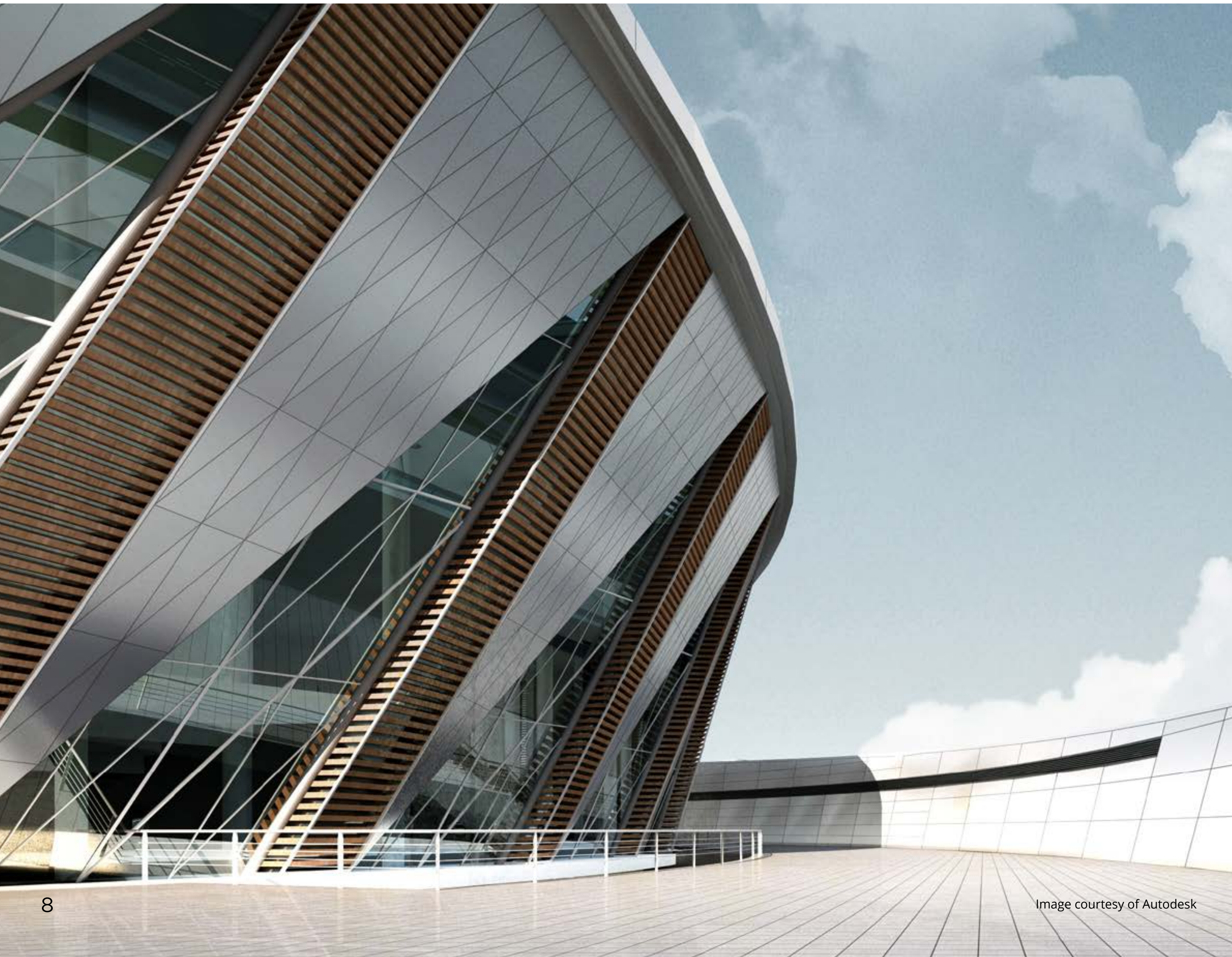


Image courtesy of Autodesk

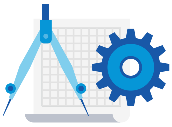
Connected BIM technology adoption

Generative design

46%

are aware of generative design tools and practices, and over one third (37%) of those are currently using them

Impact of generative design on production, construction and operation:



62%

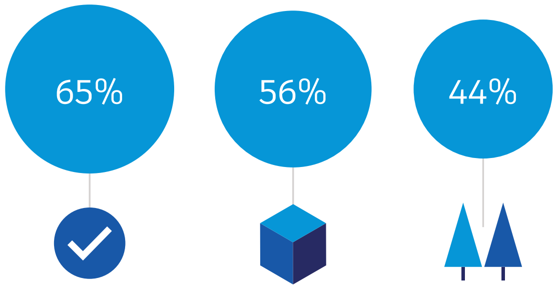
Increased coordination between architectural and engineering design documentation

59%

Improved contractor understanding of design intent

(Source: Leading the Future of Building: Connecting Design Insight)

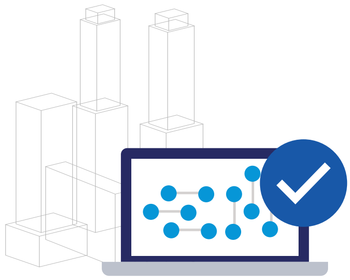
Impact of generative design on design solutions:



Quality control | Constructability | Increased sustainability

75%

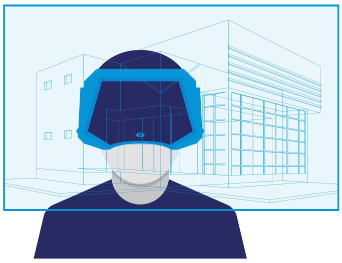
Architects (75%) lead in producing better solutions within budget because of generative design



VR

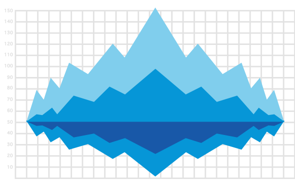
80%

of architecture professionals who have already adopted VR are using it on multiple projects



(Source: 2017 Architectural visualisation technology report)

Cloud collaboration



68%

of architects and engineers consider cloud-based and connected technologies to be critical

60%

of architects and engineers are aware of performance analyses in the cloud, and nearly two thirds (64%) of those who are aware are currently using it

(Source: Leading the Future of Building: Connecting Design Insight

Reality capture

48%

of architects and engineers are aware of reality capture capabilities

75%

of those that are aware, are incorporating reality capture to document existing conditions more accurately

(Source: Leading the Future of Building: Connecting Design Insight)

Data analytics

42%

of AEC CIOs say big data and analytics would give their company a better business advantage

(Source: Autodesk)

(for example). These data provide immediate feedback on the ramifications of the design strategy. Simulative analysis provides simultaneous advice to the designer as the work progresses; this role had previously been played exclusively by outside consultants. Simulation is further augmented by cloud-based rendering, eliminating the need for hours-long desktop generation of high resolution images of the design as it unfolds, and returning those images in minutes. High-resolution renderings in a Connected BIM environment are further enlivened with the capabilities of virtual reality projection (VR) where real-time walkthroughs and interaction with digitally rendered elements of the design are available. A designer can quickly understand both how her design looks and works with these tools.

Information and insight from Connected BIM workflows extend both to and from the construction site. Coordinated digital information from centrally-located cloud-based data can be directed to the project trailer, the fabrication floor, the supplier's procurement system, or mobile devices directly in the field without any intermediate translation to paper or otherwise. Model-based asset information integrates with builder schedules, LEAN strategies, and project control systems. Before construction begins, detailed three-dimensional models of existing conditions (ground plane, buildings, and other physical constraints) can be captured via LIDAR or photographs and integrated in the Connected BIM data structure via reality capture technologies. As construction is increasingly automated through digitally controlled processes like robotics and machine-controlled fabrication, coordination tools move data smoothly from design studio to job site. Those same techniques, where job site data is collected via drones, provides detailed feedback to the building team on construction progress. Reality capture methods like these align the aspirations of the design process with the physical realities of building while creating rich datasets that can be referenced for future work.

The utility of digital information leveraged computationally through BIM extends to the operating asset as well, made possible by sensors and other data inputs enabled by the "Internet of Things" (IoT). Modern building and transportation system design requires such infrastructure to control systems, traffic flow, and other performance characteristics with real-time data flow. The design of the "digital nervous system" of an asset thus becomes as important as its physical characteristics, both made possible by the design power of connected BIM workflows, and the resulting feedback from these inputs that is made available for reference to improve the next design.

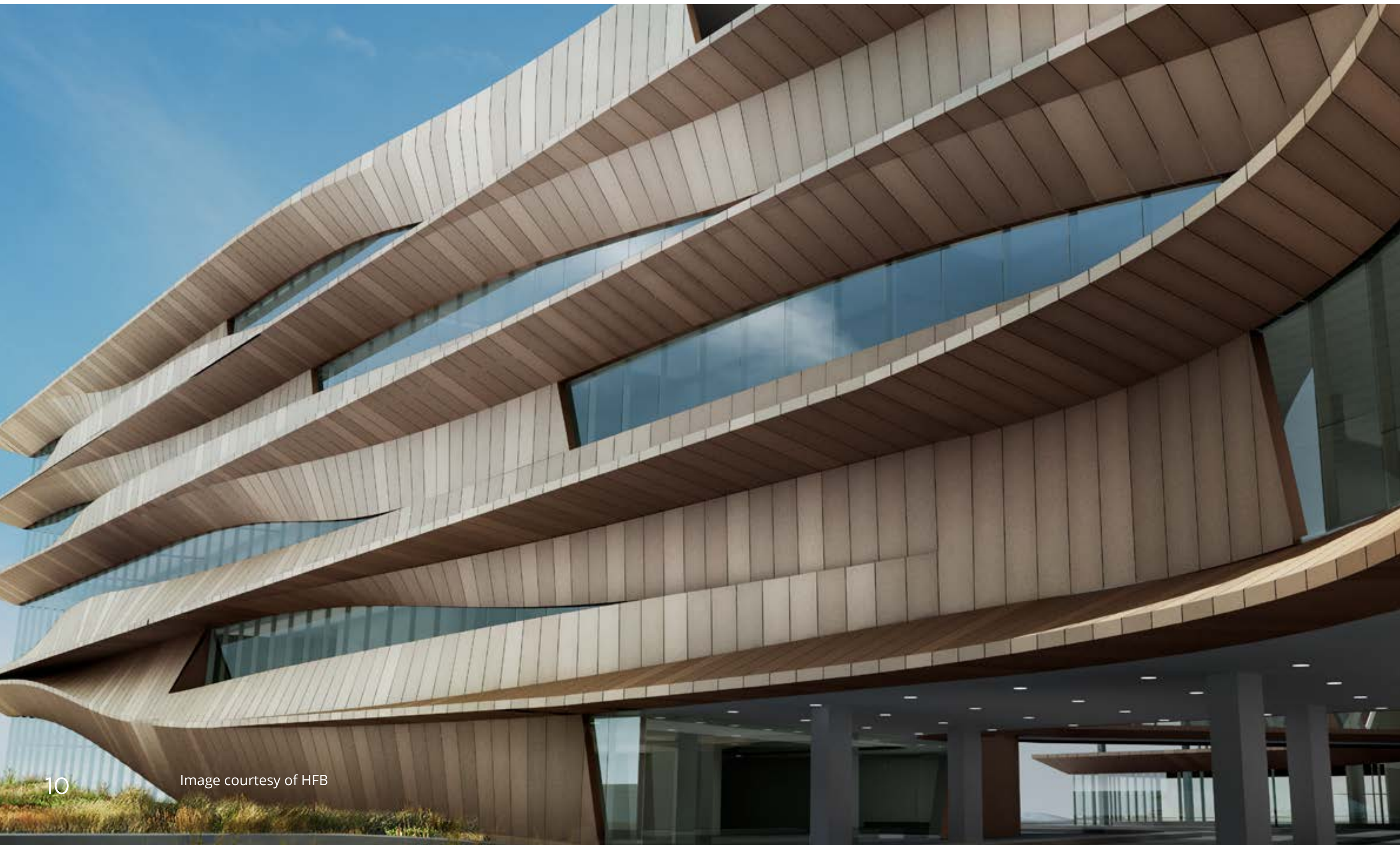


Image courtesy of HFB

Benefits of Connected BIM

(Source: Leading the Future of Building: Connecting Design Insight)

68% of architects and engineers consider cloud-based and connected technologies to be critical

91% believe more valuable industry information is available and want it to be accessible digitally to improve design insight

74% say the insight derived from BIM improves performance predictability of completed buildings

Image courtesy of Starbucks

Starbucks Coffee Japan uses BIM and VR to improve design of coffeehouses

The coffeehouse design department of Starbucks Coffee Japan, known as the Japan Design Studio, is one of the leading 18 Starbucks design studios in the world[4]. Amongst its 30 staff members, almost 80% are interior designers or architects. They design more than 100 coffeehouses for new store openings and remodel 150 existing coffee houses each year.

In 2016, when designing a new coffeehouse for its Ark Hills Store, the team started creating VR experiences from BIM data by using the Autodesk® Revit® Live service. Revit Live can revert Revit files to VR experiences in just one click, without any complicated conversion work. The visualizations can be used for presentations and information sharing. Before adding Revit Live to their workflow, various departments in the company were asked to experience the Ark Hills store that had just been remodeled through VR, with the HTC VIVE head-mounted display. 60 staff members from various departments experienced the model in VR and the feedback was incredibly positive. The VR experience in Revit Live provides sufficient quality for in-house verification processes, helping the team to create even more detailed visuals and make an even more realistic VR experience possible.

The cloud is the computational infrastructure that makes these processes possible, inverting the traditional relationship between local and consolidated information storage. Where once digital information lived on specific machines or within local area networks, cloud-based collaboration consolidates that data, putting the project information, rather than applications, at the center of project workflows. Where once data exchange was transactional—swapping files at pre-determined moments much like drawings were distributed in the analog age—cloud-based collaboration is integrated, where everyone on a project team knows where data resides, how to find it, its status, its originator, and its intended use. Up-to-date information, where project data is at the center of the process and delivered to the point of work, makes building workflows more efficient and effective, especially combined with the representational, analytic, and reality capture capabilities described above.

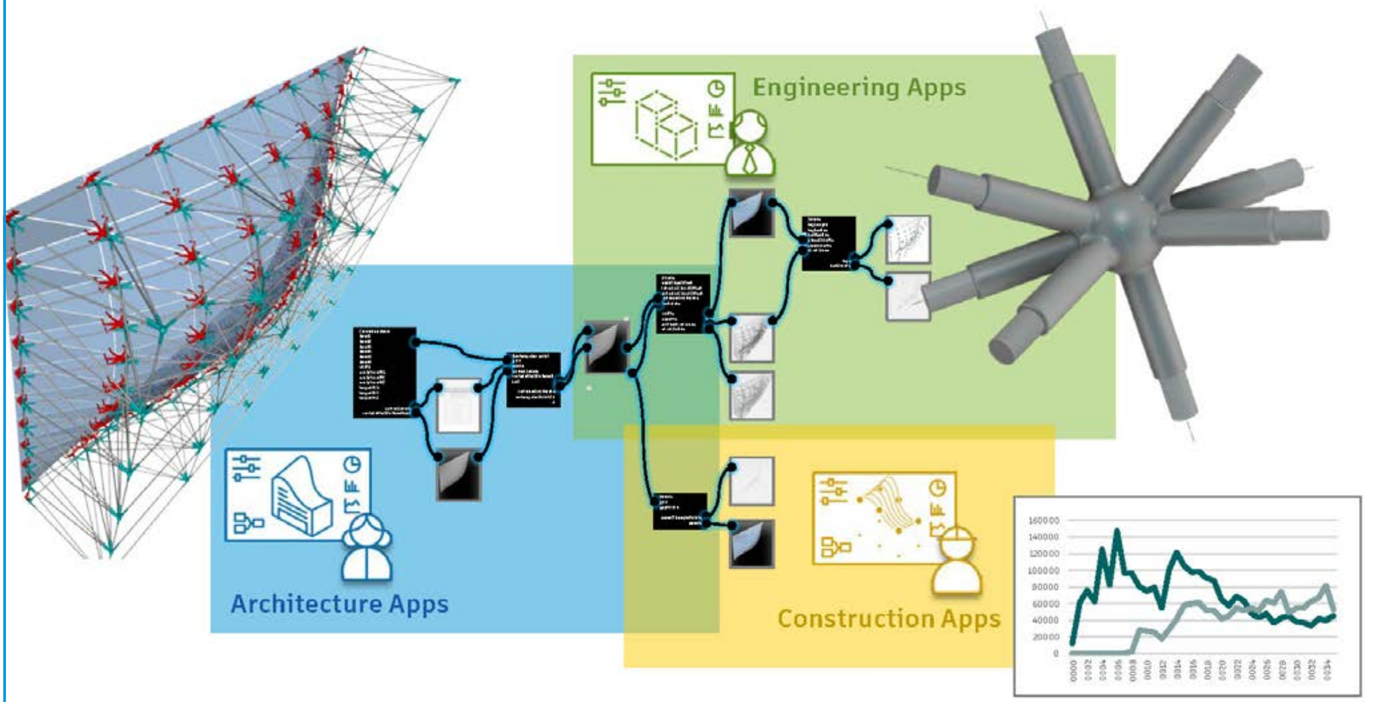


Image courtesy of Autodesk

Project Quantum aims to improve information sharing and collaboration

Autodesk is developing Project Quantum to serve as a system for sharing targeted project information within teams. Architects, engineers, and contractors will use Quantum's cloud-based common data environment to create and automate a seamless workflow among applications and services so that each collaborator can focus on just the parts that matter most to them.

For example, an architect could be in the process of designing a signature curtain wall – and all of the components that require coordination – like the attachment spider clip. The architect, engineer, and contractor all have different responsibilities – aesthetic, structural integrity, quantity, and cost options. Each of these disciplines are referring to common data – enabling them to remain in sync and collaborate while using their industry standard applications.

Image courtesy of Ryan Companies US, Inc.

The Living, an architectural research team within Autodesk, carried out studies to define the best way to meet conceptual objectives in the new building area.

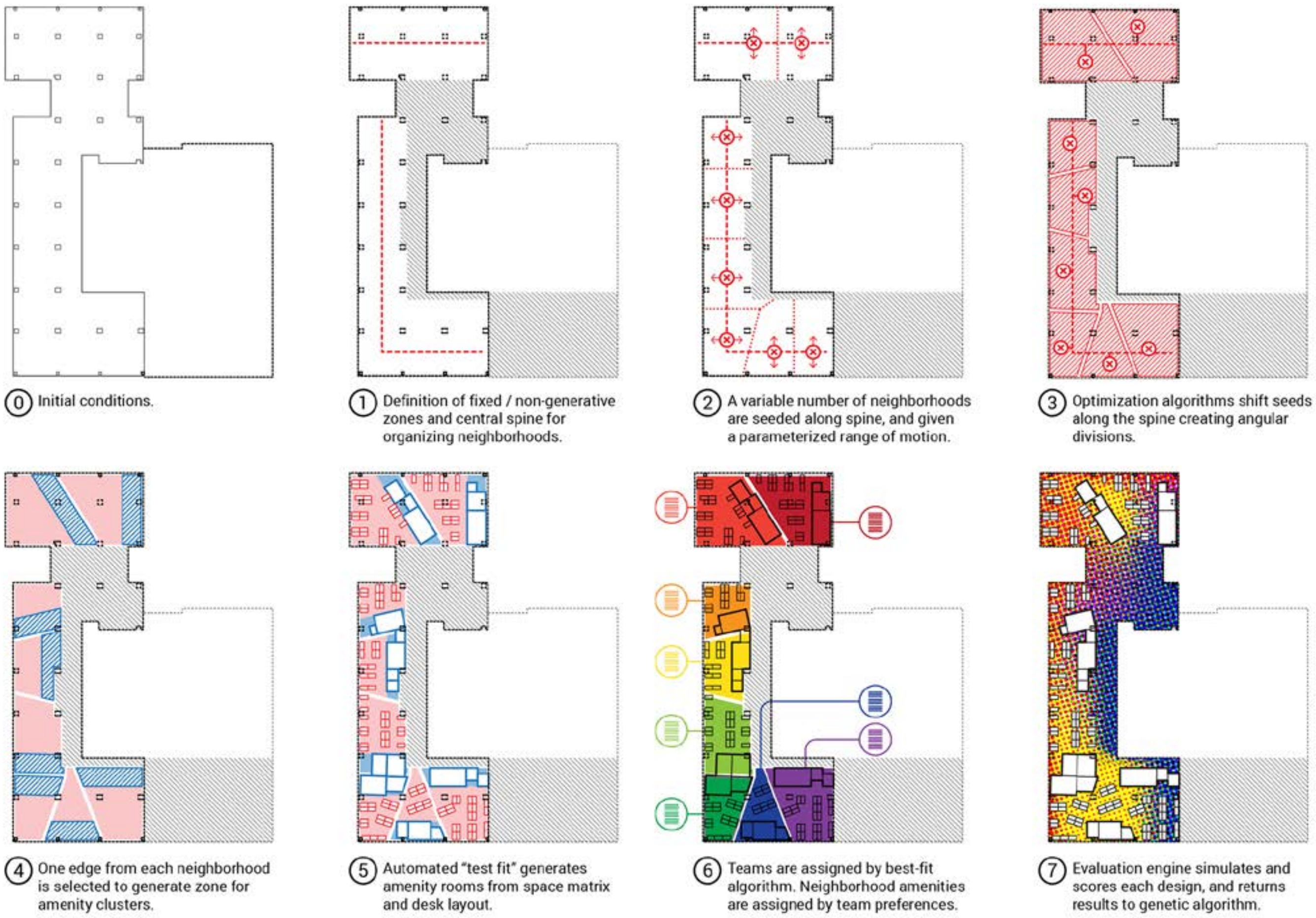


Image courtesy of The Living

Autodesk evaluates 10,000 design options using its own generative design solution

For the design and planning of a new Autodesk office and research space in the MaRS Innovation District of Toronto, we pushed the limits of generative design for architecture in a workflow known as Project Discover[5]. We started with high-level goals and constraints, collecting data from employees and managers about work styles and location preferences. We then developed six primary and measurable goals: work style preference, adjacency preference, low distraction, interconnectivity, daylight, and views of the outside. We created a geometric system with multiple configurations of work neighborhoods, amenities, circulation, and staked private offices. Finally, we used the power of cloud-based computation to generate, evaluate, and evolve 10,000 different design options that would not have been possible to create without this approach.

This methodology offers many benefits for designing office space – including managing complexity, optimizing for specific criteria, and augmenting human creativity and intuition, navigating trade-offs based on real data and structuring discussion amongst stakeholders about design features and project objectives.

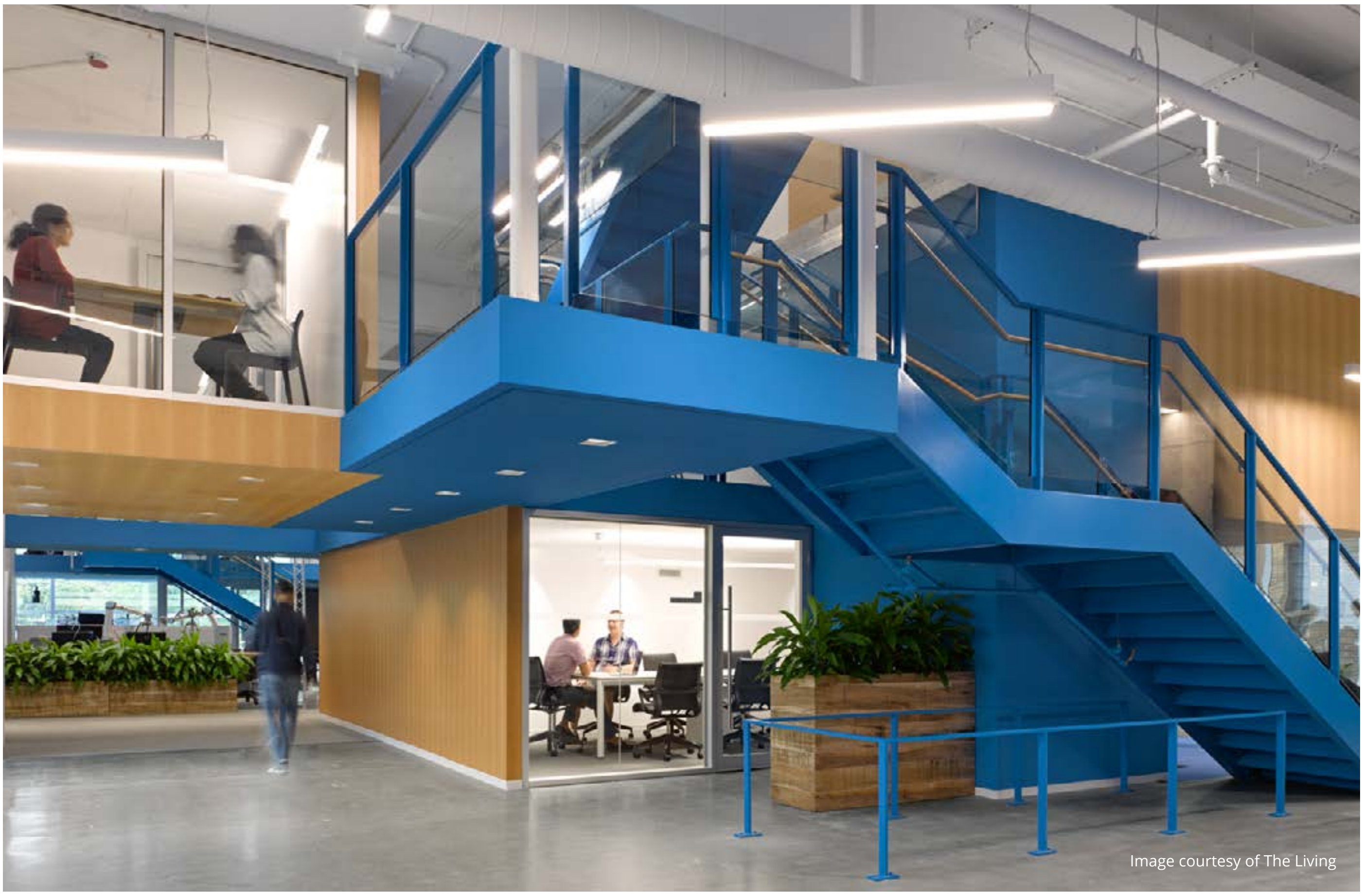
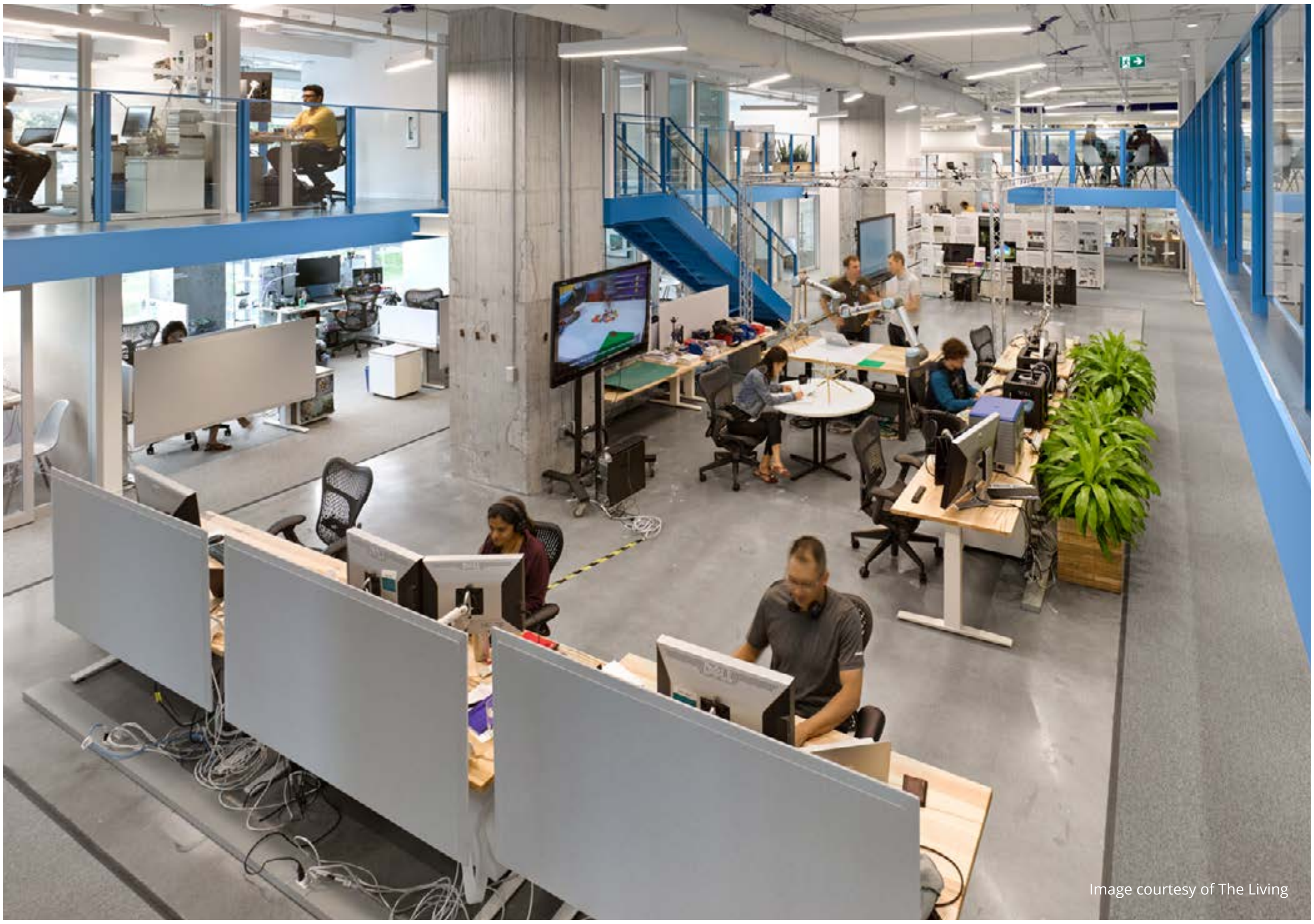


Image courtesy of The Living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KEY TAKEAWAYS

The concept of Connected BIM anticipates the computational future of the building industry. Cloud technology will enable more powerful tools to support a broader range of building activities across the design, procurement, construction, and asset operation lifecycle, with two very important effects.

First, much like data on today's internet that is easily accessed by indexical search engines, large collections of data created by a variety of tools will flow seamlessly in a project-centric environment, unfettered by interoperability or synchronization constraints.

Collaboration environments, with interactions from the team managed in harmony with the creation of data, will create the representation of the design intent, procurement approach, and construction strategy and a detailed record of its development.

As the capabilities of machine learning and expert systems increase, a second implication will become apparent: these project "data lakes" will become resources for understanding, anticipating, and monitoring the performance of both current and future projects, and anticipate a future where digital information is a critical resource to machine learning and artificial intelligence evaluation of construction projects across the delivery cycle.

Those designers and builders that take advantage of connected BIM data today will be those who will be best informed to improve design objectives and construction operations, and ultimately the quality of the built environment.

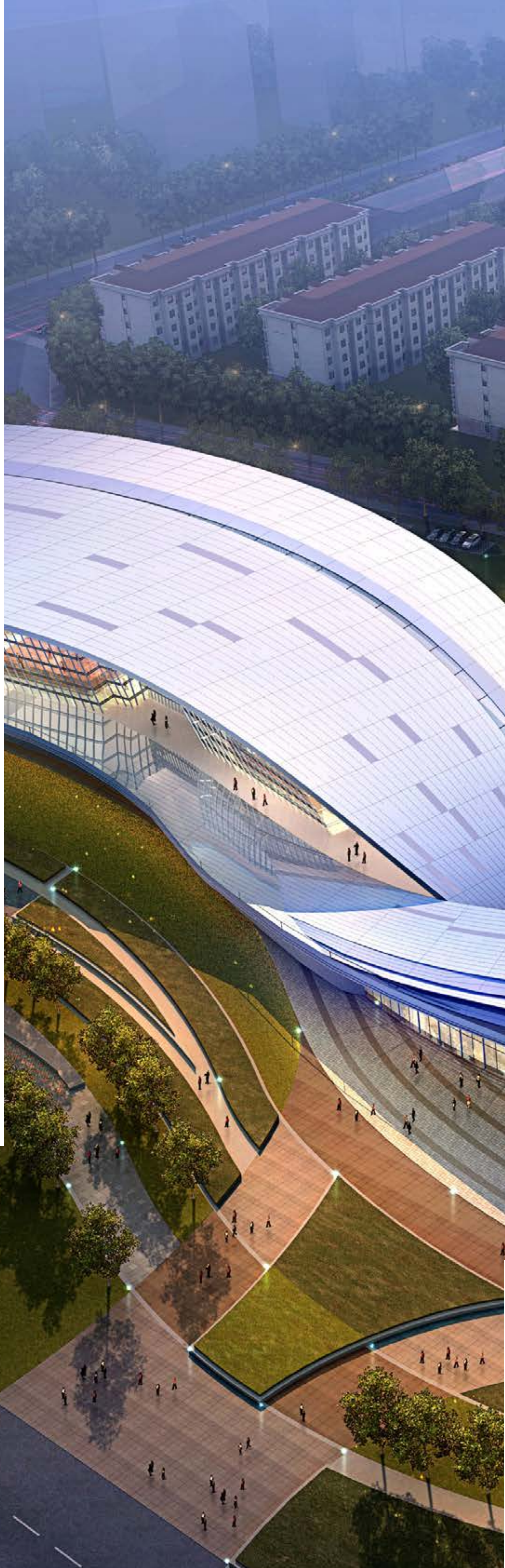

Image courtesy of BIM Design Center, TADI

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2 Leading the Future of Building: Connecting Design and Construction

3 Piper, C. (2016). Fentress and Hennebery Eddy Architects work as one team on PDX Airport

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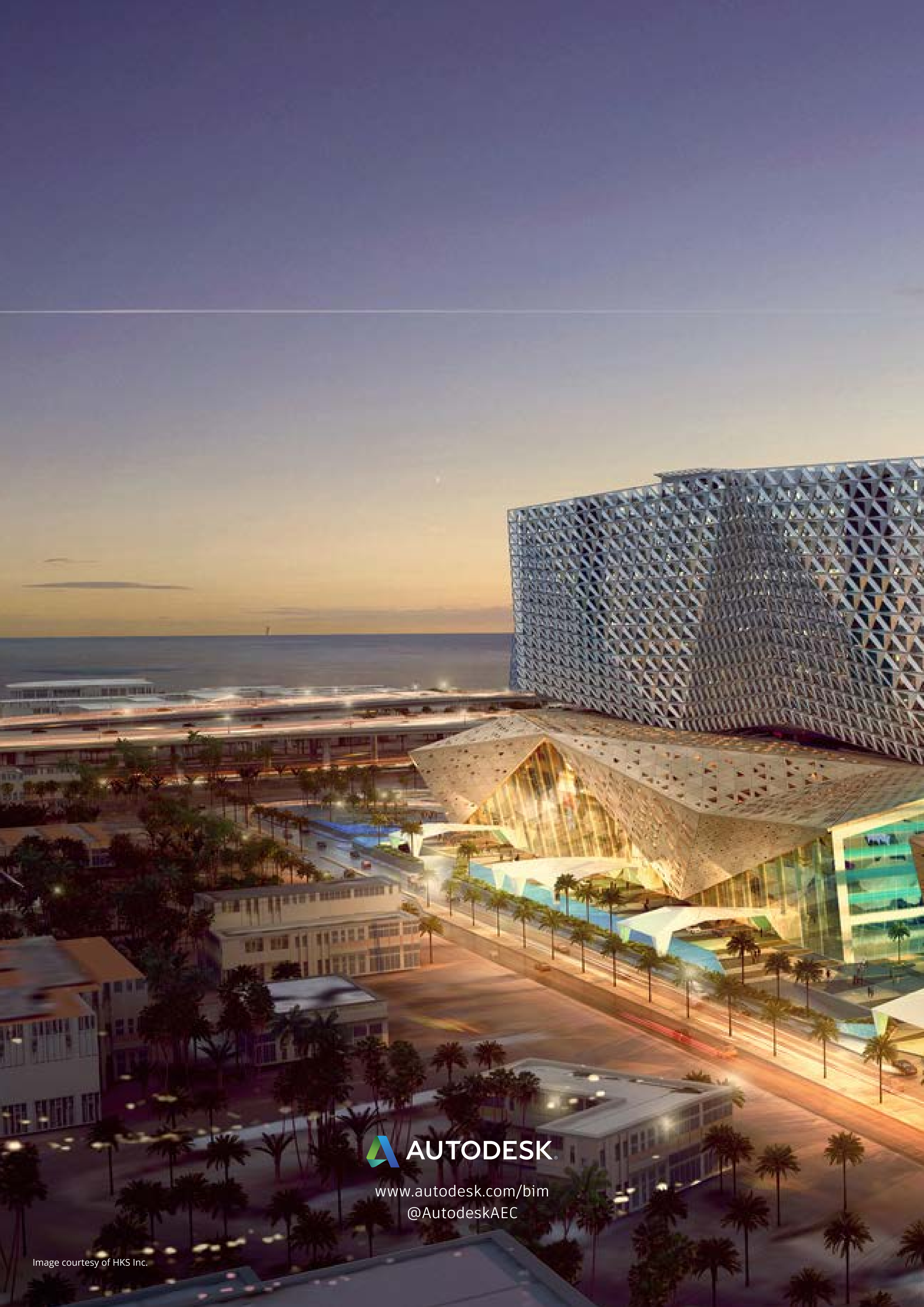
5 Nagy D., Lau, D., Locke, J., Stoddart, J., Villaggi, L., Wang, R., Zhao D., and Benjamin, D. (2016). Project Discover: An application of generative design for architectural space planning



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