



HOW DIGITAL TRANSFORMATION IS DRIVING THE DESIGN AND BUILD INDUSTRY FORWARD



4
A Green BIM Process Shapes Construction of an Iconic Sports Venue in China



8
Infrastructure Innovators Use VR Games to Streamline Scandinavian Tunnel Design



14
How an Architecture Firm Is Integrating Smart-Building Technology From Block One



18
Dubai's Museum of the Future Is Shaping Up as the World's Most Complex Building

HOW DIGITAL TRANSFORMATION IS DRIVING THE DESIGN AND BUILD INDUSTRY FORWARD

Introduction

Digital transformation isn't a single piece of technology or a change that happens overnight. The architecture, engineering, and construction (AEC) industry has been undergoing a sea change for years; in fact, the industry has already experienced three waves of digital transformation, each building on the previous one.

The first wave, the movement to CAD, was driven by the widespread use of personal computers. The second wave, the movement to BIM (Building Information Modeling), was catalyzed by the global economic downturn of 2008 and the increase in BIM mandates from governments and private owners. The most recent wave, cloud collaboration, has been dramatically accelerated by the COVID-19 pandemic.

Around the globe, AEC firms are shifting to a digital-first mindset. By using BIM-based software in concert with technologies such as Internet of Things (IoT), extended reality (XR), predictive analytics, and simulation, they're seeing benefits including reduced risk, business growth, and improved sustainability. In the following pages, learn how the convergence of BIM and multidisciplinary technologies is at the heart of successful AEC projects worldwide. Read about how a state-of-the-art sports arena in China and a groundbreaking museum in Dubai have benefited from BIM and XR. See how BIM and virtual reality (VR) are being used to test a Norwegian rail tunnel's sign and signaling system. And learn how a Toronto architecture firm is integrating smart devices into buildings and developing a digital twin to manage the captured data.

These projects are not only examples of digital transformation; they're also past winners or nominees of the Autodesk [AEC Excellence Awards](#), a global competition that honors those who push the limits of technology—and the projects that are testaments to their ingenuity. The innovators behind these projects are embracing the possibilities of digital transformation to deliver better outcomes for their businesses, the industry, and the built world.

They're also on the cusp of the next wave of change. When the pandemic hit, businesses moved thousands of projects—and trillions of data points—into the cloud for remote collaboration. This data will fuel the next wave of digital transformation, one that's powered by artificial intelligence (AI) and machine learning and driven by owners and innovators. This fourth wave will leverage data and insights to connect processes, automate workflows, and provide a better understanding of the built environment. The projects and firms featured in this e-book are ready for this next wave. No matter where you are on your digital transformation journey, I hope you find them inspiring.

NICOLAS MANGON

*Vice President of AEC Industry Strategy
Autodesk*

In Chengdu, China, an innovative arena—built to host international sports, from soccer to basketball—was completed on time and on budget thanks to a well-coordinated, eco-friendly BIM process.

A GREEN BIM PROCESS SHAPES CONSTRUCTION OF AN ICONIC SPORTS VENUE IN CHINA

BY BETTY WANG

In recent years, huge sporting events such as the Olympics and the FIFA World Cup have ignited a fitness boom across China, driving the country's overall sports development. High-profile venues are springing up around the country in picturesque city landscapes. One highlight is the Phoenix Mountain Sports Park in Sichuan's provincial capital, Chengdu, the "Land of Abundance." The Chengdu municipal government's mission is to speed the city's urban development and make the city a renowned host for international events.

Phoenix Mountain Sports Park, which opened in March 2021, will be the core venue for the 2021 Chengdu 31st Summer Universiade (FISU World University Games) and the primary venue for the 2023 AFC Asian Cup.



The stadium at Phoenix Mountain Sports Park features a futuristic, high-tech membrane structure and sunflower-shape cable-dome roof. Courtesy of China Construction Eighth Engineering Division Corp. Ltd.

China Construction Eighth Engineering Division Corp. Ltd. (CCEED) is leading construction for the venue, with a strong commitment to green-building techniques. Despite many technical challenges, the team is using BIM to facilitate close collaboration during the building process.

The Phoenix park won first place in the Construction–Large Project category of the

2020 AEC Excellence Awards, from a field of more than 260 entries from 35 countries. Due to the project’s innovative building techniques, 21 patents have already been granted, with 17 more pending. The project has had 36 papers published about it and has garnered three provincial-level construction-method awards from Sichuan Province.

Scaling New Heights Through Engineering

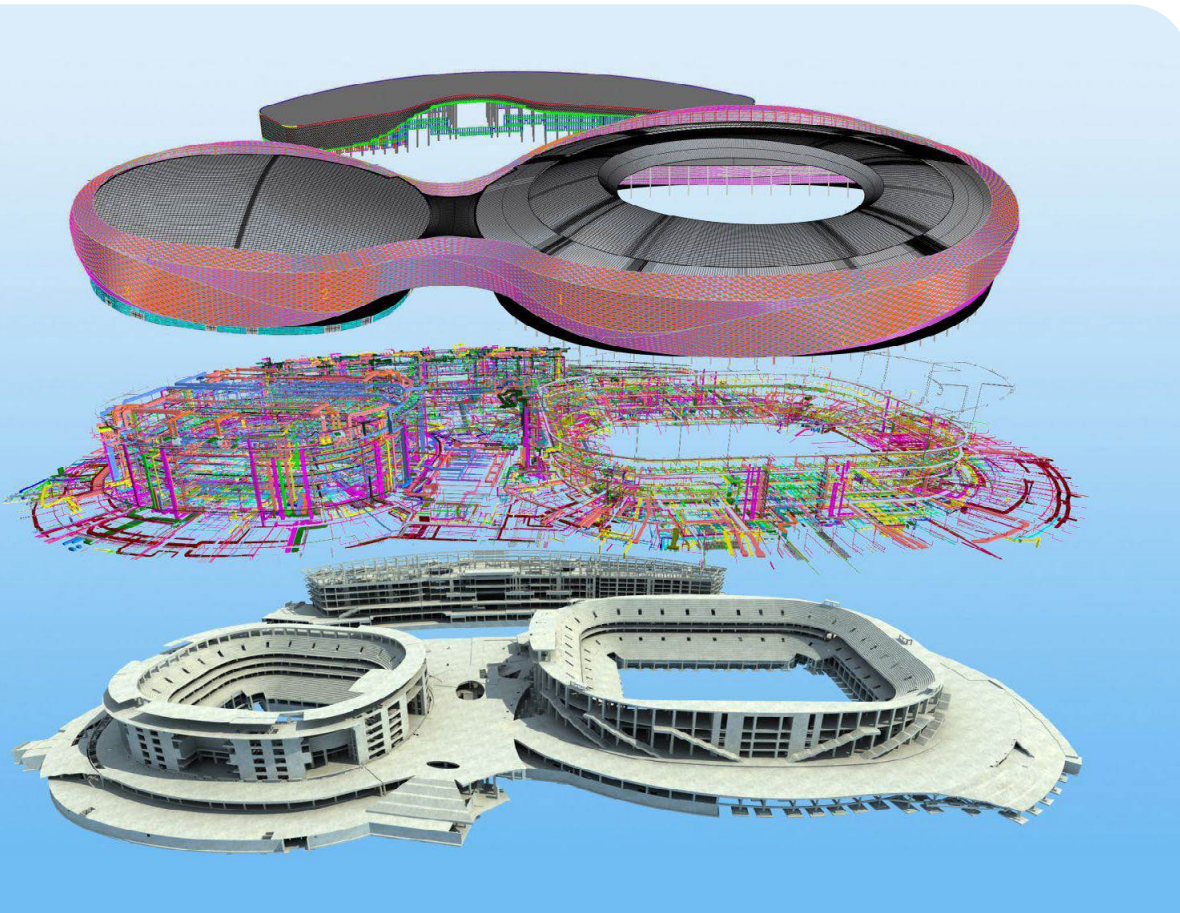
With a total floor area of approximately 456,000 square meters, Phoenix Mountain Sports Park comprises a 60,000-seat, FIFA-standard stadium for professional soccer; an 18,000-seat, NBA-standard arena; green landscaping; and a supporting commercial complex. The site will host top international sporting events and domestic leagues—and provide an exemplary model for modern sports arenas in urban park settings.

The professional soccer stadium has a futuristic, high-tech membrane structure; its massive, sunflower-shape cable-dome roof is a global first. The single-layer ETFE (ethylene tetrafluoroethylene, a fluorine-based plastic) membrane structure is also the largest of its kind, reaching 25,000 square meters when fully unfolded.

These designs presented enormous challenges to the construction team. According to Qin Zhang, BIM director at CCEED Southwest China Branch, building the membrane structure’s dome roof was a highly technical process, a first for the team. There were no precedents for the steel-grid structure and massive, open cable dome, within or outside China. Without relevant construction experience to draw on from completed stadium projects, the construction was fraught with difficulties and unpredictability.

The CCEED team researched dozens of technologies to address these challenges. Using BIM, 3D scanning, and smart construction technology helped ensure lean and safe practices when building

A model of the building structure, MEP (mechanical, electrical, and plumbing), and curtain wall. Courtesy of China Construction Eighth Engineering Division Corp. Ltd.



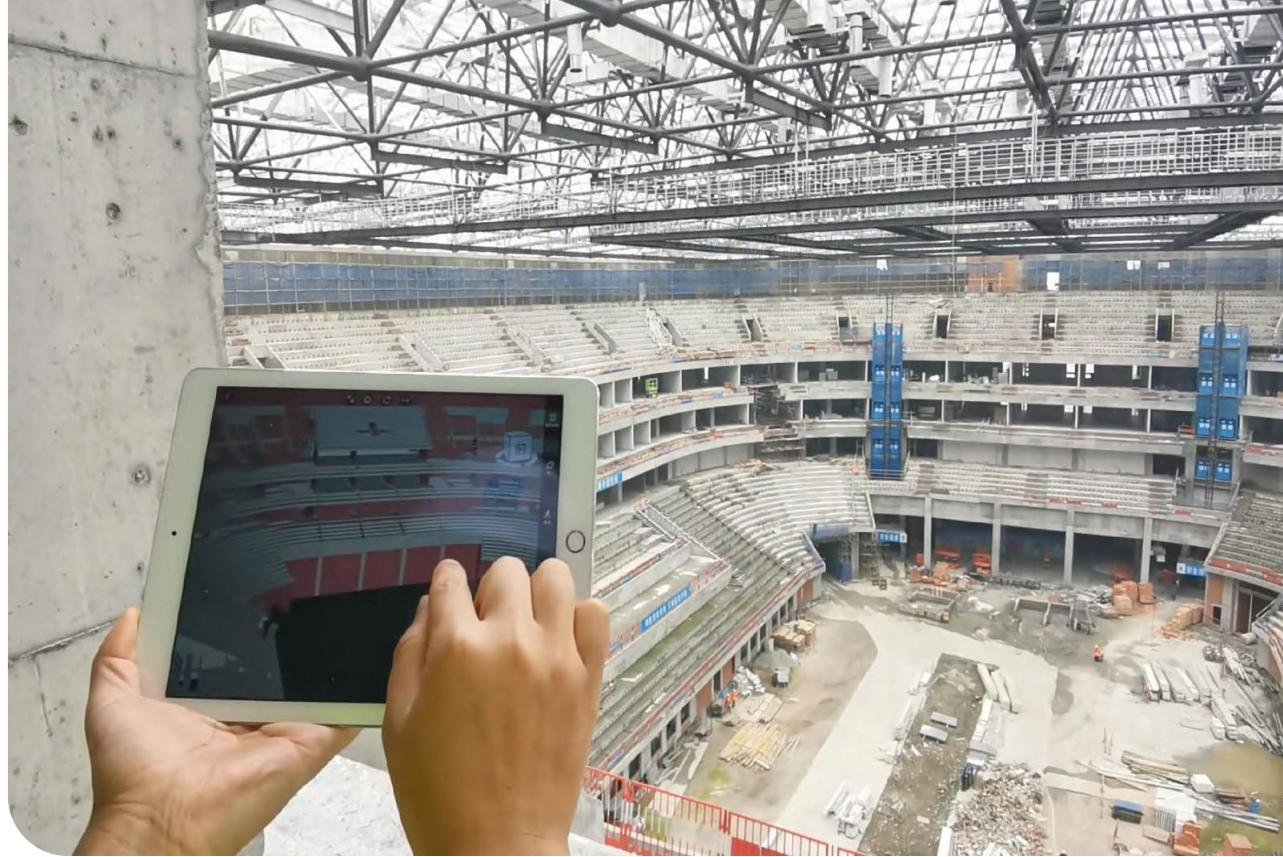
the membrane structure. Planning was optimized via strict monitoring to improve construction quality and shorten lead times.

BIM Process Used Across Design, Fabrication, Construction

The project's engineering, procurement, and construction (EPC) contract presented many challenges to the design, fabrication, and construction teams, including close collaboration requirements, short schedules, and tight budgets. Despite these challenges, the BIM process was used successfully throughout the project lifecycle to facilitate efficient collaboration between teams.

The construction contractor's design-management team intervened early in the design process, using BIM and green-analysis software to help designers improve quality and practices. This process played a crucial role in reducing time and costs for the project. The team used BIM to previsualize, simulate, and analyze the fabrication process digitally before starting physical fabrication. Every stakeholder viewed models and relevant information throughout the project.

The design team used Autodesk **Revit** and Autodesk **Navisworks** to coordinate and integrate multidisciplinary designs, connect design and construction, optimize architectural renderings and construction methods, and resolve construction technology and management issues. The lead time was shortened by 132 days, cutting building costs by more than \$15 million.



Accessing models via tablet at the construction site. Courtesy of China Construction Eighth Engineering Division Corp. Ltd.

Advanced Technologies Help Construction Stay Lean

In addition to implementing BIM throughout the lifecycle, the Phoenix project used advanced building technologies—such as VR, augmented reality, visualization, 720-degree panoramas, sensors, drones, GPS positioning, and GIS—to improve lean practices in the construction process. “A lot of cutting-edge technology has been incorporated in the Phoenix Mountain Sports Park project from the beginning, from design to the construction phase,” Zhang says.

The team used Autodesk Dynamo to automatically generate templates matching the curved spectator stands, which saved time on manual measurement and calculation. Real-time drone monitoring powered by AI helped ensure safety and controllability in the construction processes. And with 180-degree holographic projections and real-time sensor-data collection, various stakeholders could interact and cooperate on critical solutions, maximize efficiency, and reduce safety risks.

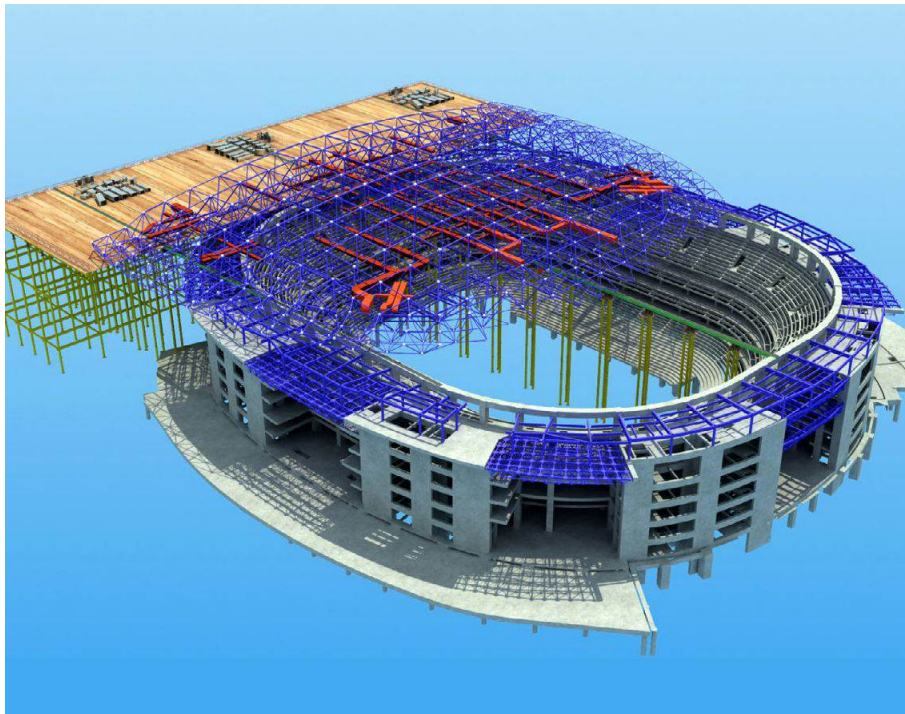
Building Green for Better User Experience

The Chengdu Phoenix Mountain Sports Park project presents a sustainable green building model for future venues. Interactions between the buildings and the surrounding environment were fully considered throughout the construction process, with the goal of ensuring the best possible user experience under natural conditions throughout the year.

The construction team used green-building-analysis software to optimize natural ventilation, daylighting, building acoustics, and line-of-sight effects. The team analyzed the temperature, air distribution, and thermal comfort in winter and summer, then continuously optimized the design based on the simulation results.

Zhang says that BIM was key to this massive undertaking: “It’s the goal-driven use of BIM that makes it so effective. The connectivity of BIM throughout the project lifecycle provides unlimited benefits and brings about a new industry ecosystem. BIM’s use has been extended to digital twins. BIM-centric virtual construction—using IoT sensors, simulation technologies, and AI—will deliver enormous quality improvements to the physical construction process and benefit the stakeholders.”

When similar buildings are constructed in the future, Zhang believes that this project’s success—and the experience drawn from it—will help drive the industry to use BIM throughout the project lifecycle, promising economic and social benefits to owners and contractors. 🏗️



Left: Intelligent models are used to guide assembly on-site. Right: An image of the construction happening on-site. Courtesy of China Construction Eighth Engineering Division Corp. Ltd.

Virtual environments help Norconsult speed up approvals and prevent costly delays on its railway-tunnel project.

INFRASTRUCTURE INNOVATORS USE VR GAMES TO STREAMLINE SCANDINAVIAN TUNNEL DESIGN

BY LAURA NEWTON

On infrastructure projects, everything is big: budget, schedule, scope, and—most of all—risk. When it designed a new rail tunnel near Bergen, Norway, the architecture, engineering, and design consultancy Norconsult made a large risk smaller by applying advanced technology to a critical yet cumbersome design requirement: the railway signaling system.

To prevent costly construction delays due to inadequate signs and signals, Norconsult used 3D modeling and VR gamification in infrastructure design to help foresee potential design problems. The interactive game environment that the firm created has set a new standard for streamlining design evaluation, validation, optimization, and approval.



A new double-track railway in Norway will be able to transport more people and cargo between the cities of Arna and Bergen. Courtesy of Norconsult AS/Bane NOR/Baezeni.



A rendering of Bergen Station, the terminus of the Bergen Line. Courtesy of Norconsult AS/Bane NOR/Baezeni.

A Large Organization Cultivates the Spirit of a Start-Up

With roots dating back to 1929, Norconsult is the largest multidisciplinary technical consultancy in Norway. It applies its expertise to the design and construction of airports, public event arenas, oil fields, highways, hospitals, dams, bridges, railways, and tunnels, to name but a few of the 20,000 projects in its extensive portfolio.

Based in Sandvika, near Oslo, Norconsult has nearly 3,300 employees across 88 global offices. Although its large size is an asset, it also can be a disadvantage: The bigger an organization, the slower it moves. To channel the ethos of a much smaller, nimbler firm, Norconsult established an internal team called the Bleeding Edge.

“We are 30 to 40 of the most innovative employees who push the development of

technology to make our work practices more efficient and offer our clients a better product,” says Bleeding Edge member Thomas Angeltveit, a civil engineer and BIM coordinator who evangelizes the use of 3D modeling and technology within Norconsult’s thriving transportation practice. “We’re trying to be the best consultant we can be by always using the newest technology.”

Unclogging a Vital Economic Artery

Known as the Bergensbanen, or Bergen Line, the Norwegian railway between Oslo and Bergen meanders 500 kilometers (approximately 310 miles) through breathtaking Nordic terrain. But it isn't just one of Europe's most scenic rail lines; because it connects Norway's two largest cities, it's also economically vital. It's critical that trains traverse it quickly, easily, and safely.

The route's final leg, between Arna and Bergen, passes through the Ulriken Tunnel, a 7.8-kilometer (4.8-mile) tunnel beneath Mount Ulriken. Built in 1964, it's the most-trafficked single-track tunnel in Northern Europe—and it has been a major bottleneck for years. “The capacity of the existing tunnel isn't sufficient to drive enough trains” to meet passenger- and freight-transportation needs, Angeltveit says. In 2010, Norconsult began working with Norway's state-owned rail authority, Bane NOR, on a project to double capacity by building a second Ulriken Tunnel parallel to the first.

Scheduled for completion in 2024, the project presents significant challenges for builders, who must bore a new tunnel through Mount Ulriken while also upgrading the existing tunnel and associated rail stations—all without disrupting current railway traffic.

Railway Safety Is the Priority

To create a new Ulriken Tunnel without disturbing the old one or disrupting rail service, Bane NOR would need to use an 1,800-ton tunnel-boring machine (TBM) that would take 18 months to excavate the hard rock on which Mount Ulriken rests. It's the first time a TBM would be used to bore a railway tunnel in Norway, where conventional blasting is the norm.

A large infrastructure project like this one doesn't just face technical challenges; there are also administrative hurdles. “On rail projects, the hardest thing to get approved is the [sign and] signaling system,” Angeltveit says. “That's because it's the heart of the rail. It operates everything. If a train driver can't see a signal—and drives too far or doesn't stop—it will shut down the whole rail system.”

Gaming the System

To tackle the Ulriken Tunnel project's complex design and construction challenges, Norconsult's use of BIM helped the company coordinate across disciplines more efficiently. “BIM is a key success factor in our projects, since we're developing new technologies so fast now,” Angeltveit says. BIM models for the tunnel project and station upgrades were created using Autodesk [AutoCAD](#), Autodesk [Civil 3D](#), and Revit, together with Navisworks to collaborate with construction teams.



The tunnel-boring machine breaks through Ulriken Mountain in Bergen on Aug. 29, 2017. Courtesy of Warren Eversley/Bane NOR/Norconsult AS.

GAMING THE SYSTEM

An immersive VR game lets train operators “drive” through the new Ulriken Tunnel in a simulated cockpit created using 3D laser scans of an actual train.



Train operators drive the route, using meter marks in the track bed to judge their distance from the nearest signal, and flag problems with signals as they're playing.



The testers advised moving some signals inside the tunnel for greater visibility, saving considerable cost by making the changes before construction.



The virtual environment also shows fixtures and equipment in the tunnel to run emergency simulations and support training for operations and maintenance.



A Drone mode provides a bird's-eye view of the upgraded Arna Station at the entrance to the Ulriken Tunnel. Images courtesy of Norconsult AS/Bane NOR/Baezeni.

Addressing the administrative challenges around the signaling system required a different approach. What makes the necessary approvals so difficult to obtain is the fact that signals typically are installed years before train operators can test them. Errors are therefore common. Angeltveit wondered: If train operators could test signals earlier, would approvals be easier to obtain?

To find out, he conceived the idea of marrying the BIM models with VR to create a game environment that would allow train operators to “drive” on the future tracks

before they were built. “We had models for all the disciplines—the same models we handed off to the contractors—and put them into a game engine,” Angeltveit explains. The team animated the 3D models with Autodesk **3ds Max** and augmented them with laser scans of real-world data, such as the layout of the train cockpit, using Autodesk **ReCap**.

Immersed in Potential

Within the game experience, train operators drove on the virtual train tracks under

the supervision of civil engineers, who used their performance to evaluate the placement of signs and signals. The virtual environment “feels as if you are there,” Angeltveit says, “and that’s a huge benefit when you’re trying to get approval for something that’s not yet built.” Through an iterative design process, the engineers refined and optimized the signaling system. “Working with train drivers gave us a better understanding of their thought process,” he adds. “We were able to benefit from their experience driving a real train.”

Bane NOR has also gotten additional benefit from the game as a visual aid for emergency responders. By playing the game in “drone mode”—navigating the project from the

“The virtual environment feels as if you are there, and that’s a huge benefit when you’re trying to get approval for something that’s not yet built.”

**—Thomas Angeltveit,
BIM coordinator, Norconsult**

perspective of an unmanned aerial vehicle—personnel can familiarize themselves with evacuation routes or simulate emergency scenarios. Similar immersive environments could help project teams foresee operational and maintenance needs, helping them design buildings and infrastructure that are optimized for end users. “There are lots of opportunities here to explore,” Angeltveit says.

The Arna Station upgrade under construction, with a train coming from the existing tunnel and the new tunnel to the left. Courtesy of Ingvild Eikeland/Bane NOR/Norconsult AS.



A Better, Safer Tunnel

Construction of the tunnel progresses toward the 2024 completion date, reaching a milestone when the TBM finished boring through Mount Ulriken in August 2017. When the new double-track railway is complete, more trains will be able to transport more people and cargo between Arna and Bergen, at faster speeds, and at more frequent intervals.

In the meantime, the marriage of BIM, VR, and gaming has already borne fruit for Norconsult, whose efforts won third place in the infrastructure category in Autodesk's 2017 AEC Excellence Awards competition. According to Angeltveit, the VR game experience has delivered benefits that include a streamlined regulatory-review process that cut years off the standard approval time; stronger stakeholder buy-in, as the game helped even nontechnical users visualize project plans; and, ultimately, reduced costs, because mistakes could be mitigated before construction rather than corrected afterward.

Perhaps the most powerful benefit of all is the tunnel itself, which, thanks to the game, will operate at peak performance long after construction crews are gone. "In the end, we can help to deliver a better, safer tunnel and stations than ever before," Angeltveit says.

Signaling Change for the Future of Infrastructure Design

Based on its initial success with the Ulriken Tunnel, Norconsult has made VR gamification a standard operating procedure on all of its rail projects to support signaling design and approval. The company is also exploring other use cases. On an urban light-rail project, for example, Norconsult is using a VR game experience to get feedback from tram drivers to optimize the design of traffic lanes for bikes and emergency vehicles. Clients, meanwhile, are using the immersive environments in presentations to senior management and community stakeholders, whose critical support and buy-in are being earned more easily and enthusiastically with the help of VR visualizations.


Long term, it's easy to see how VR gamification could help usher in a new era of proactive instead of reactive design. "For us, it's been a game changer," Angeltveit concludes. "Delivering an interactive virtual-reality experience with our BIM models truly disrupts the status quo in a traditionally conservative industry." 📌

For construction in Japan, adopting
CIM (Construction Information
Modeling/Management) has been an
uphill battle—until now.

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Redshift
by AUTODESK



Courtesy of Obayashi Corporation.

Smart-building technology is often an afterthought—but what if it's integrated from the beginning? One Toronto architecture firm is tackling this question with innovative prefab R&D.

HOW AN ARCHITECTURE FIRM IS INTEGRATING SMART-BUILDING TECHNOLOGY FROM BLOCK ONE

BY ZACH MORTICE

As smart-building technology filters down to the consumer level, it generally comes in the form of technology that's grafted into buildings piecemeal: a thermostat that adjusts temperatures based on which rooms are being used, or a washing machine that lets you start and stop cycles while you're away.

But one architecture firm is looking for ways to better integrate innovative technology systems into modular-building processes from the start—and to smarten existing structures.

Based in Toronto, [WZMH Architects](#) is a well-established firm that's developing a smart modular-panel system called the Intelligent Structural Panel (ISP).



WZMH's Intelligent Structural Panel integrates electrical, IT, security, audio-visual, HVAC, and other systems. Courtesy of WZMH.

This work has earned WZMH the 2018 UPPlift True Disruptor Award from the France Canada Chamber of Commerce, and earned WZMH R&D head Hiram Boujaoude a nomination for Innovator of the Year in Autodesk's 2019 AEC Excellence Awards.

The ISP system, currently in the prototype phase, is designed to integrate smart-building devices and network them with flexible hardware and a consumer-facing app. These panels are just two inches thick and have standard dimensions of 10-by-30 feet or 10-by-45 feet. Each panel is made of two steel plates and a perimeter, within which lies an intelligent highway. The panels, which were designed in Revit, work as structural members. As a resident at the Autodesk Technology Centre in Toronto, WZMH has been working on constructing room-scaled functional prototypes.

"If you're going to do a floor panel off an assembly line," says WZMH partner and principal Zenon Radewych, who spearheaded the firm's smart-building research, "let's see what else we can put in the floor panel."

The smart devices that are compatible with the panel system include sensors (for motion, occupancy, temperature, and lighting) and mechanical and electrical devices (HVAC, window-shade rollers, cameras, and light fixtures)—with many combinations possible. The ISP is a cloud-based system that lets users program and monitor their smart devices through an app, using real-time analytics on both a local and cloud level.

A Common Intelligent Highway

Once sensors and devices are plugged into the system via a standard Ethernet connection that also supplies power, the individual elements are designed to react as a unified network. "That's where you can create a true intelligent building: by having the different connected devices talk to each other because they're going through this common intelligent highway," Radewych says. A light sensor could trigger a window-shade roller to lower, for example. Train stations could use

the ISP to tell passengers on a platform which approaching train cars are full. In a hospital, these systems could offer deeper levels of automated patient monitoring.

An effective shift to modular construction promises higher material efficiency, and ISPs offer similar gains. "This started with technology and prefab, but we're seeing lots of benefits on the sustainability side," Radewych says. "Not only do you get the benefits of the smarts, you get the benefits of less material used."



An ISP system panel prototype. Courtesy of WZMH.



Building a prototype in the lab. Courtesy of WZMH.

Early studies indicate that a smart-panel system could reduce total building materials by 10%. By relying on power-over-Ethernet systems, ISPs can eliminate standard junction boxes and electrical conduits. “When you build a prefab component and include other materials and systems inside of it, you actually reduce the amount of materials you need compared to conventional work,” Radewych says. The ISP will also be able to

harness waste energy generated by its smart components and dissipate it gradually as part of HVAC heating systems.

While the panel system is intended for new construction, WZMH envisions using small black boxes (each measuring just a few inches) for retrofits and renovations that could be completed in only a few months. For example, standard light fixtures could

be plugged into the ISP systems and interact with the network. These units act as both power converters (devices can be powered through Ethernet cables) and networked switches that can tie each device’s essential functionality to the wider network. (WZMH is collaborating with Quasar Consulting Group, Stephenson Engineering, and C3PoE on the ISP and with Argentum Electronics for the black boxes.)

“Overnight, you basically have a smart building,” Radewych says. “Yes, we are building a lot of brand-new buildings every single day, but it doesn’t mean we’re tearing down the old buildings. They’re still going to be around for 50, 60, 70 years or longer. The market potential is to convert existing buildings to make them smart. The black box is totally aligned with that idea.”

Actionable Data on Building Usage

Whether they’re installed into new buildings or retrofitted into existing ones, the black boxes can supply building owners and tenants with actionable data on how the building is used. “Even if you plug in dumb devices, you can actually measure the amount of energy that is being used floor by floor and have spot renovations after that,” Boujaoude says.

“Whatever you can pull from a device, the ISP will pull,” Radewych says. “The really wonderful thing about this is that if you retrofit an older building, you suddenly have data on your day-to-day operations.” To manage this data, WZMH is using Autodesk [Forge](#) to create a digital twin of the panels and their devices.

The hope is that building owners and tenants can gather this data for machine-learning routines or other AI applications to make buildings maximally efficient. (The WZMH team is also using machine learning to teach computers about humans' thermal-comfort thresholds.)

This data can be mined for ways to trim energy expenditures, dynamically shutting off systems, rooms, and floors that aren't being used.

While the panel system is intended for new construction, WZMH envisions using small black boxes for retrofits and renovations that could be completed in only a few months.

The data could also be used to increase operational and maintenance efficiency. Occupancy and motion sensors could detect areas of the building that get the most traffic, which could be used to refine maintenance procedures and schedules accordingly. If it's a building type or program that will be repeated in a similar context, this data can be used to select more durable materials for the heavily trafficked areas.

In addition to significant material-efficiency savings, perhaps the greatest value of an off-the-shelf panel system that enables smart-building technology is that it can plug into a continual feedback loop for the steady refinement of the built environment. 📌



This black box will allow off-the-shelf, low-voltage devices to be powered by Ethernet and talk to other devices. Courtesy of WZMH.

With its floating form, windows in Arabic calligraphy, and space-age finish, the Museum of the Future pushes the limits of design, engineering, and construction.

DUBAI'S MUSEUM OF THE FUTURE IS SHAPING UP AS THE WORLD'S MOST COMPLEX BUILDING

BY KIM O'CONNELL

Dubai is rightly famous for its modern glass-and-steel skyscrapers, such as the unparalleled [Burj Khalifa](#). Yet no matter how sleek and tall you make it, a skyscraper is still a traditional building form, with its familiar repetitions and verticality. Dubai's new [Museum of the Future](#), however, takes a groundbreaking approach to architecture and what it means to be a museum.

While there are certainly taller and more expansive buildings, this incredible feat of design, engineering, and construction will rank as one of the most complicated projects ever built. "A building with this complexity has never been done, not with this shape of the facade and the superstructure," says Derek Bourke, BIM manager for construction firm BAM International.



Dubai's Museum of the Future is a radical departure from the traditional skyscraper form. Courtesy of Killa Design.

Designed by **Killa Design**, the **torus**-shaped building looks almost like an eye keeping watch over this growing city, the largest in the United Arab Emirates (UAE). The boundary-pushing project won first place in the Building Design category of the 2017 AEC Excellence Awards. Construction is complete but an opening date for the museum has not been set.

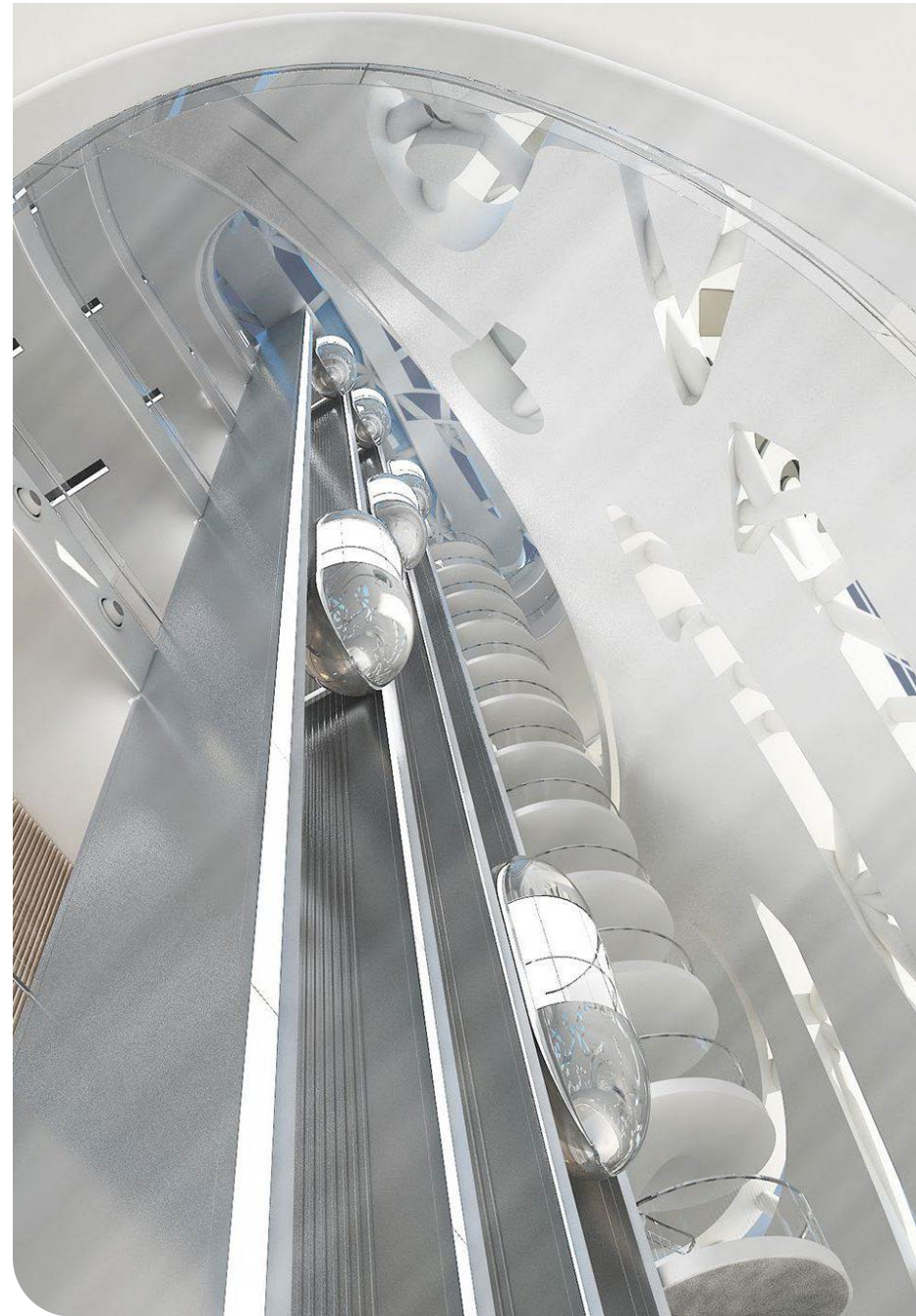
An Incubator for Innovation and Invention

Art and metaphor were driving concepts in the museum design: The idea for the museum stemmed from His Highness Sheikh Mohammed bin Rashid Al Maktoum, vice president and prime minister of the UAE and ruler of Dubai, and it is intended to be an incubator for innovation and invention. (Its motto: “See the future, create the future.”) It’s not a typical museum, as in a repository of artifacts, but an active place to be filled with innovation facilities and design studios, a repository for ideas not yet conceived. It was important that the design be emblematic of the mission: a dazzling combination of art, engineering, and construction.

“The form started to originate through the design of a building that, first of all, looked futuristic; however, I came to understand that the client appreciated the sense of feng shui,” says principal Shaun Killa, who conceived the building’s revolutionary form. In feng shui, a round shape represents both the fertile fields of earth and the limitless imagination of the sky above—therefore, the past, present, and future. While the building will evolve with exhibits of the future of education, health care, smart cities, transportation, government services, and more for the next five or perhaps 10 years, the void in the center of the building represents the unknown, according to Killa. “People who seek what we don’t know are the inventors and discoverers for the future.”

Art and poetry are manifest in the design of Dubai’s Museum of the Future, with Arabic calligraphy inscribed onto the exterior that features quotes from the prime minister about the future. But these “inscriptions” are in fact highly engineered windows, a dynamic blend of art and function.

But design metaphors only take such a project so far. To ensure constructability and attain LEED Platinum status, Killa worked closely with **BuroHappold** for engineering services and **BAM International** for construction, employing 4D sequencing in BIM and reality capture for visualization.



The void in the center of the building, visible from the inside as well as the outside, represents the unknown. Courtesy of Killa Design.

While there are certainly taller and more expansive buildings, this incredible feat of design, engineering, and construction will rank as one of the most complicated projects ever built.

“From the design models from BuroHappold, we were able to verify weights and constraints, using the models to produce data and the 4D sequencing, which also went in as part of the tender, to prove buildability,” says Bourke. “We continued that on to construction, using the models, updating them daily, filling the models with data that we would end up handing over as an output model.”

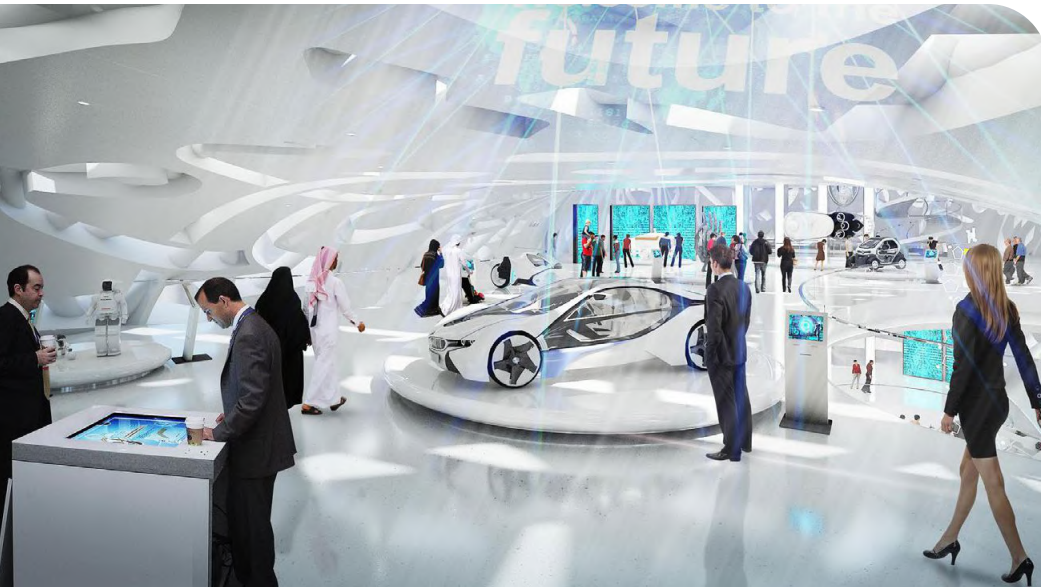
Once the team went into concept design, the entire process—all the way through to construction drawings and beyond—was designed and documented in Revit. By designing with 3D models, the team could work through many potential conflicts in the structure, facade, and MEP systems.

“We made the decision that we were going to run 100 percent with Revit throughout the entire process,” Killa says. “There was no space for any 2D drawings that sat outside that realm. The model was becoming incredibly large so we actually colocated all of the team within our office just to speed up the process of communication. When you’re designing a building that is three-dimensional in every respect, and essentially the only things that are horizontal are the floors, there are so many decisions that need to be made where you need to be next to each other.”

In the past, such a futuristic design would have hit roadblocks as soon as it was put before the engineers or contractors. Now, the team could use software to create immersive visualizations, allowing collaborators to “walk through” the whole museum and check each element. Every potential clash could be detected on the

The museum’s futuristic facade features windows engineered into calligraphy forms. Courtesy of Killa Design.





Left: Exhibits will showcase futuristic technologies in various industries. Right: The museum's facade is a perfectly smooth, joint-free assembly of 890 unique stainless steel-and-fiberglass-fused panels. Courtesy of Killa Design.

deeply complex facade, in which the 3D calligraphy windows had to align correctly with the building's unusual form, because overlaying a 2D calligraphy word onto a model would distort the word once it was applied to a 3D surface.

Stunning—and Sustainable

“During any highly complex building, the architect and engineers have to work hand in hand,” Killa says. “There is no other way that you could produce such a building.” This collaborative process also allowed the team to achieve LEED Platinum through more than 50 sustainable-design decisions, including the use of recycled-content products, photovoltaics for energy, and internal-air recovery systems.

The museum's remarkable facade is a perfectly smooth, joint-free assembly of 890 unique stainless steel-and-fiberglass-fused panels fabricated using methods borrowed from the aviation industry. And it's not just an eye-catching shape; it's doing all the real work that any standard building envelope is expected to do.

“Buildings with such complex surfaces are normally rain screens,” Killa says. “There's usually a building behind the surface that is made of a waterproofing system. And the external facade, which might be more complex, would be a rain screen. This simplifies matters because it's a bit more forgiving when creating these very three-dimensional forms. In this building, however, the envelope is doing the waterproofing, the airtightness, the structure, the lighting.”

The museum's interior presented its own challenges. In particular, a freestanding, double-helix staircase required some deep manipulation of Revit to make a model that was understandable, Killa says. The idea for the stairway came from DNA.

Tommaso Calistri, an architect with Killa Design, adds that the double helix also serves a practical function: Because staircases land at different places, the configuration allows differentiation between people who have paid the entry fee and those who haven't, such as people who just want to pop in to experience the architecture. “It's definitely an emotional building, because you will pass through and experience the building,” he says. “You will not just pass next to it without turning your head. That's what I think architecture should do: make your head turn.”

Despite its futuristic shape, the Museum of the Future fits into a long history of architects pushing the limits of engineering, Killa says. Yet modern technologies and materials are allowing a rebirth in the fundamental approach to designing the spaces people inhabit. “We have the ability to make extremely complex shapes that were not possible to even design perhaps 20, 30, years ago,” Killa says. “Through BIM and other software we have today, we can actually create a new sense of architecture.” 🇲🇦

The freestanding, double-helix staircase was inspired by DNA. Courtesy of Killa Design.



With an imposing two-tower design, the Atrio complex in Bogotá, Colombia, will transform the city’s skyline, create public space, and modernize the work processes of the teams building it.

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