AUTODESK

CIVIL IN NOVATION

INSIDE THE TRENDS OF CIVIL ENGINEERING

A2K Technologies

CIVIL INNOVATION

THE CHUNNEL, KANSAI AIRPORT, AND THE CARLSBAD DESALINATION PLANT. BENDABLE CONCRETE, KINETIC ROADS, AND MACHINE CONTROL GRADING. THESE ARE SOME OF THE MANY EXAMPLES OF INNOVATIVE CIVIL ENGINEERING PROJECTS, PRODUCTS, AND PROCESSES FROM THE LAST FEW DECADES. BUT DESPITE THESE ACHIEVEMENTS, CIVIL ENGINEERING STILL RANKS WELL BELOW OTHER ENGINEERING AND SCIENCE FIELDS WHEN IT COMES TO INNOVATION.

The following pages will layout an overview of pressures and trends that are influencing civil engineering innovation—sometimes motivating it, sometimes restricting it—and of how individual firms and the industry as a whole are working to increase innovation.

UNDER PRESSURE

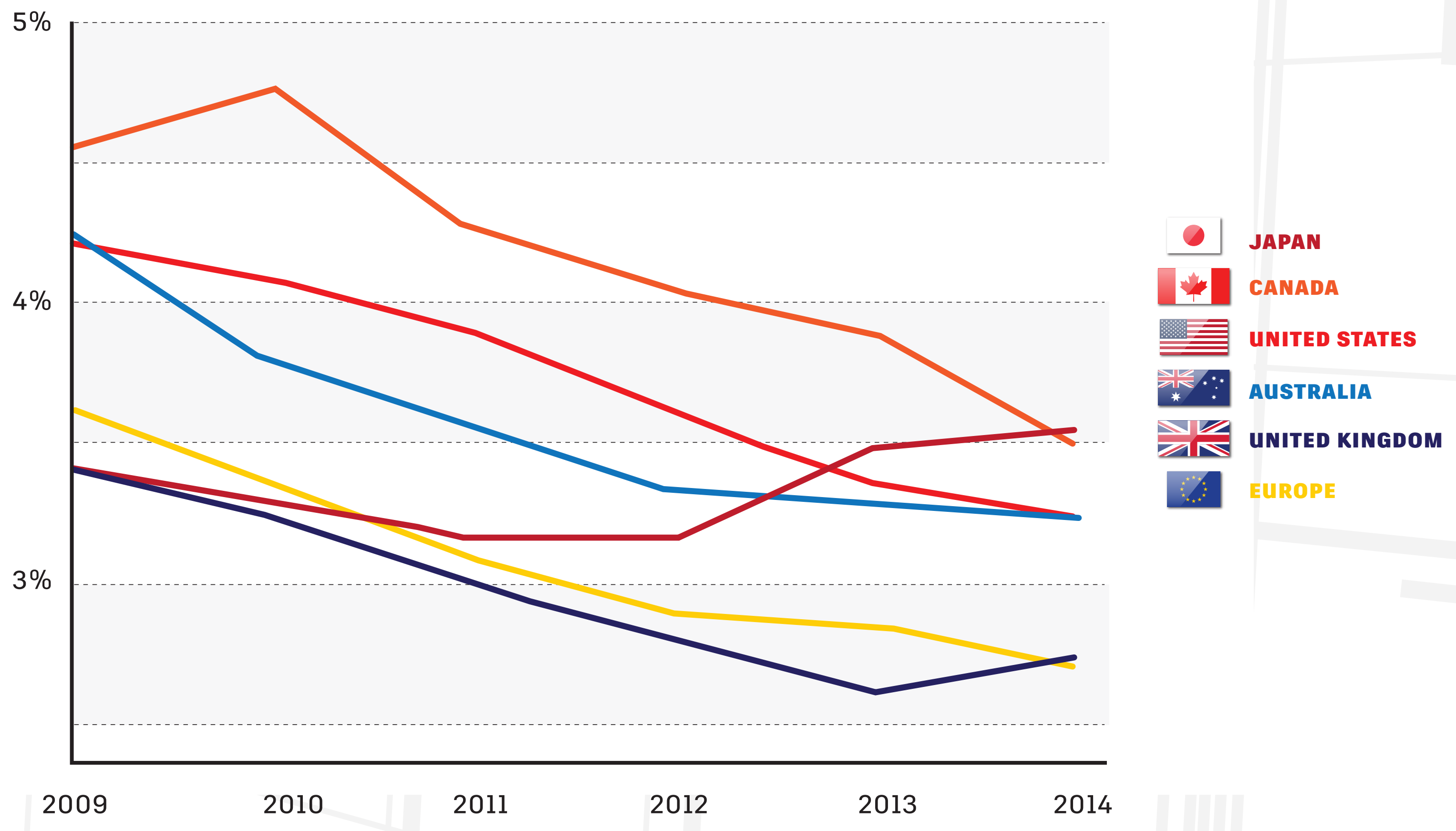
AROUND THE WORLD, CIVIL ENGINEERS ARE FACING INCREASING PRESSURES THAT AMPLIFY THE NEED FOR INNOVATION, SUCH AS:

- The lack of investment in the maintenance and improvement of existing infrastructure around the world is resulting in failing infrastructure, posing a risk to public health and safety, and inhibiting socioeconomic growth.
- Increased population and urbanization are fueling the need for reliable energy, fresh water, clean air, and safe waste disposal. At the same time, governments are struggling to fund and regulate these essential utilities.

In addition, people are trying to plan for and cope with climate change, but often face lack of government mandates and/or insufficient funding to do so.

- Low-bid procurements versus best lifecycle values have resulted in risk-averse business environments with small margins that suppress innovation.
- Increasing globalization of the market is changing the civil engineering competitive landscape, putting further pressure on margins and risk.

Public investment has been declining
General government gross fixed capital formation



NEW TRENDS

AGAINST THIS BACKDROP, NEW TRENDS ARE BEGINNING TO RESHAPE THE CONSTRUCTION INDUSTRY AND CIVIL ENGINEERING FIELD:

- When evaluating designs, owners are beginning to consider the full lifespan cost of a project instead of solely first cost (which has been the traditional approach). This shift from lowest cost to best value will help owners who retain their assets to better manage their portfolios over time.
- Sustainability and resiliency are becoming project requirements instead of just desirable characteristics, a fact that is impacting construction processes and the built assets themselves. Innovative projects have already proven that these are realizable goals and that develop ment does not have to compromise or deplete the environment or the budget.
- New ways of delivering projects such as design-build and public-private partnerships (PPPs) are competing with established delivery methods. These delivery partnerships increase the need for collaboration and transparency between project stakeholders, resulting in more holistic lifecycle planning and more innovative project outcomes.

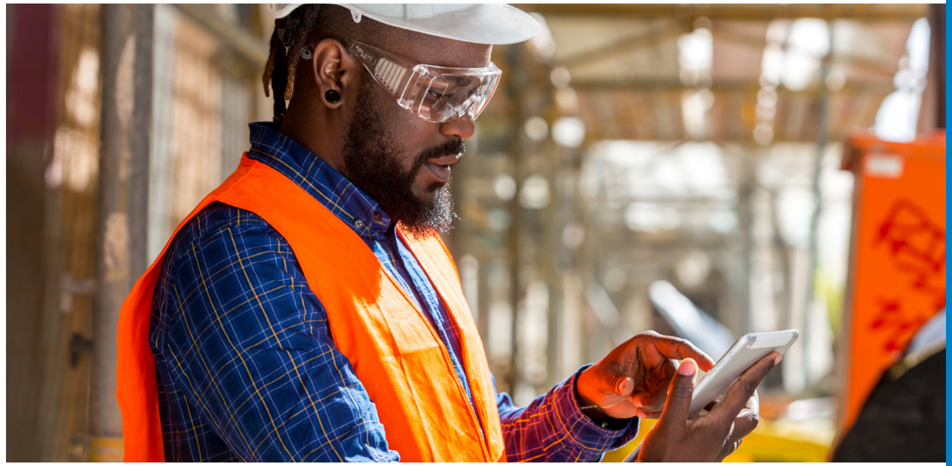
MORE TRENDS

- Transportation upheavals such as ride sharing and autonomous vehicles will dramatically change transportation infrastructure requirements. For example, broad adoption of autonomous vehicles will require intelligent roadways, and traffic may shift from mass transit back to cars. The accommodation of multiple modes of travel, from walking and biking to automobiles and mass transit, will change how integrated transportation systems are planned and designed, particularly in the growing number of urbanized areas.
- The use of unmanned aircraft vehicles (UAVs) or drones for delivery (of goods and maybe even people) will reduce the number of ground-based delivery vehicles and lessen demand on road networks, but it will also require new approaches for air traffic controland creating and managing pickup/drop-off staging areas.
- Manufacturing innovations such as 3D printing and advanced automation could redefine and shorten the supply chains for civil engineering projects, and may also shift production from the plant to the project site.
- Advanced materials and renewable or unconventional energy will alter the demand for traditional natural resources and change how projects are built, as will the development of high-performance materials created to improve air quality, water quality, flooding, hydrology, and global temperatures.

BARRIERS TO INNOVATION

W HY IS THE CIVIL ENGINEERING INDUSTRY LESS INNOVATIVE THAN OTHER ENGINEERING AND SCIENCE FIELDS? HISTORY, TRADITION, INVESTMENTS TRUCTURES, REGULATORY REQUIREMENTS, AND CHANGING DEMOGRAPHICS EACH PLAY A PART:

- Civil engineering is particularly risk-averse. This is partly due to the ingrained conservative nature of the industry. In addition, designing and constructing complex projects that can take years, if not decades, to complete carries huge risks—especially since the delivery of those projects is based on costs and timetables that have been determined years before project delivery.
- Historically, IT investment in the civil engineering industry has been very low compared to other industries. In fact, the construction industry overall currently invests only 1.2 percent of operating expenses on technology, compared to 33 percent for the manufacturing industry. As a result, the technology that many civil engineers rely on is out dated. And where innovation does exist, the lack of wide spread knowledge management and sharing suppresses its dissemination and replication.
- Innovation in other engineering and science fields usually involves digital prototypes. Even in the early 1990s, Boeing was already using 3D digital models to design the Boeing 777—models that then supported the entire lifecycle of the project, from design to manufacturing to field support. But as IT investment in the construction industry lagged, so did the tools to support it—tools that needed to be specialized for the very large structures and interconnected systems that characterize most civil engineering projects.
- Overly prescriptive civil engineering industry standards, regulations, and specifications are also inhibiting supply-chain innovation. Owners struggle to create a framework of performance-based objectives that can guide more informed, big-picture decision making. Too often, they are focused on getting the project right, instead of getting the right project. Moreover, their design and construction partners are not able to explore alternative methods of meeting both the project demands and its regulatory requirements.
- The baby boomer generation makes up a large part of the civil engineering industry workforce. But that generation is retiring without sufficient replacements, even as civil engineering industry needs are expanding. Science, technology, engineering, and math (STEM) programs for primary and secondary school children—girls in particular—are attempting to increase the pipeline of future scientists, engineers, and mathematicians. But in the short term, colleges and universities are struggling to graduate more well-trained people with these skills.



ENABLING INNOVATION

HOW CAN CIVIL ENGINEERING FIRMS INCREASE THEIR INNOVATION? THERE IS NO ONE-SIZE-FITS-ALL APPROACH. RATHER, THE ANSWER INVOLVES MANY DISCRETE CHANGES IN THE CLASSIC PEOPLE/PROCESS/TECHNOLOGY OPERATING STRATEGY.

People

Innovative project teams have leadership that promotes collaboration and communication, creating a workplace atmosphere that encourages brainstorming and fosters innovation. They also have a diverse workforce with a variety of experiences, resulting in a wide range of new ideas.

The management culture at innovative companies embraces new ideas and technology, rewarding experimentation and innovation. Innovative companies also provide ongoing training and development for their employees, helping to promote ongoing adoption of innovative techniques and technologies.

ENABLING INNOVATION

Process

Civil engineering should be looking at other industries and adopting practices that have stimulated innovation. For example, the manufacturing industry has used concurrent engineering practices combined with digital product prototypes to control product outcomes. Structured evaluation and risk-assessment processes, such as product development stage-gate approaches, have been used to guide a product from idea to completion. Knowledge management systems have been implemented to increase knowledge sharing.

Overcoming the risk-averse nature of the civil engineering field requires firms and projects to share risks and rewards, liabilities and benefits. It needs new contracts, new delivery systems, as well as owners who push for innovative designs and deliveries.

Some processes and delivery approaches already in use on civil engineering projects could be more widely adopted to drive further innovation. One example is the use of collaborative, life-cycle project planning and delivery approaches (versus the traditional design-bid-build model) such as design-build-operate, integrated project delivery (IPD), and public-private partnerships. Other examples include the use of sensors and the Internet of Things (IoT) to support data-driven construction and asset management. And the reliance on holistic urban and infrastructure planning to support big-picture decision making for smart cities.

On most projects, it's the owner or financier that drives innovation—because innovation follows the money.

TERRY NEIMEYER
CEO and Chairman of the Board
KCI Technologies

ENABLING INNOVATION

Technology

Finally, the civil engineering industry should fully embrace technology that supports the people and process changes needed to drive innovation. Full-scale digitalization—the development and deployment of digital technologies and processes such as Building Information Modeling (BIM)—could have a significant impact on project delivery and operations. Estimates show that it could lead to annual global cost savings of 10 to 25 percent in the engineering and construction phases, and 8 to 13 percent in the operations phase.[1]

- Cloud-based collaborative data sharing, even via mobile devices at project sites, enables easier, more open communication that can help civil engineers deliver projects more efficiently and help owners manage assets more effectively.
- The ability to communicate design intent and construction progress based on actionable data that can be automatically accessed helps boost job performance.
- Sophisticated modeling and visualization tools such as BIM software, generative design, augmented reality, and immersive virtual reality make it possible to produce software models of a physical thing or system that can be superimposed with calculated or measured data for visualization, construction QA/QC, and monitoring, and to support asset management decision making.
- Some automated construction techniques such as machine control and virtual surveying (using photogrammetry and laser scanning) are already staples at construction sites. They will soon be joined by other advances, such as robotic cranes and 3D printed building components.

[1] (2016), McKinsey Global Institute, Bridging Global Infrastructure Gaps, http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/bridging-global-infrastructure-gaps

CHECK IT OUT

IF YOU WANT A DEEPER DIVE INTO CIVIL ENGINEERING INNOVATION, HERE ARE SOME EXCELLENT RESOURCES:

- The U.K.'s Institute of Civil Engineering (ICE) published a report in 2015 on how civil engineers could drive innovation within their organizations. It even has an innovation checklist for different roles within a company—from CEOs to individual contributors.
- In 2007, the American Society of Civil Engineers (ASCE) published their vision of what the civil engineering profession would look like in 2025.

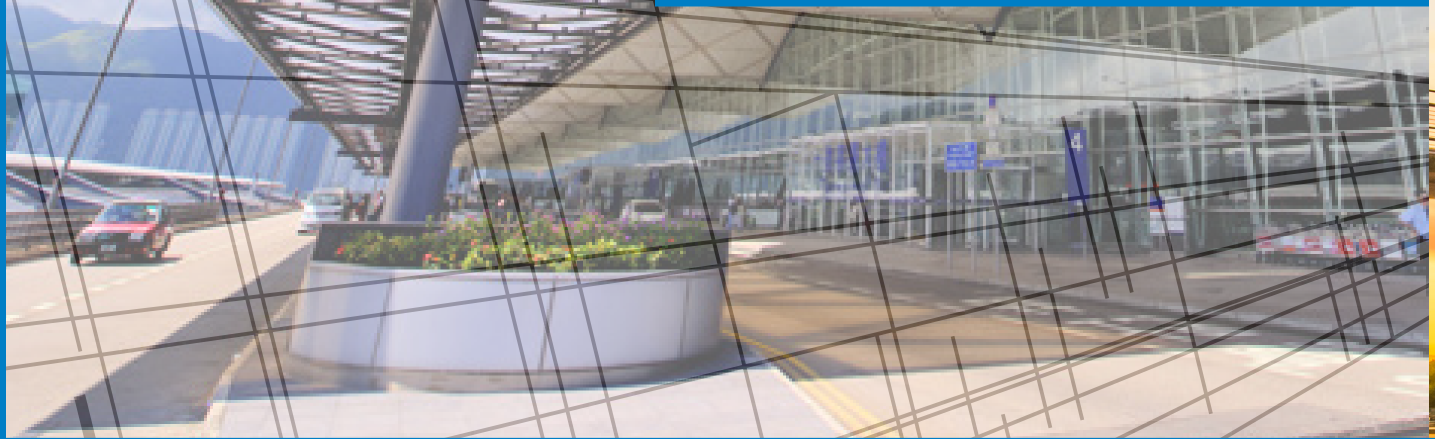
AND FROM AUTODESK SOURCES, HERE ARE SOME RELATED RESOURCES THAT DISCUSS PRESSURES FACING THE CIVIL ENGINEERING FIELD AND HOW INNOVATIVE TECHNOLOGY MAY TRANSFORM THE PROFESSION AND OUR WORLD.

- Civil Infrastructure Strategic Foresight
- 3 Tips on the Art of Everyday Innovation in Civil Engineering This article by Angus W. Stocking explores how engineers make innovation a regular, expected part of their work lives.
- A Tale of Two Cities: The Transformation of Transportation from Now to 2050 This provides a high-level look at some important technology that may drastically change transportation.
- Similarly, the Cities of 2050: Data and Technology Will Fuel the Megacities of the Future examines what cities will look like by the year 2050.

MSC North Concourse. Courtesy Corgan in Association with Gensler.

THE IN SIDE STORY

CIVIL ENGINEERING
CASE STUDIES



SAN DIEGO UNIFIED PORT DISTRICT

THE SAN DIEGO UNIFIED PORT DISTRICT recently completed a structural overhaul of its 135-acre National City Marine Terminal, as well as modifications to the B-Street Cruise Ship Terminal and the Tenth Avenue Marine Terminal. Western port cities like San Diego are already benefitting from the completion of the Panama Canal expansion and are updating their own ports to accommodate the larger ships that are now able to pass through the canal. San Diego is the primary port of entry for one out of every ten new foreign cars shipped to the United States. It also receives much of the country's banana crop from Dole, which annually ships about 50,000 refrigerated containers that are plugged in at the terminals upon arrival to prevent their contents from spoiling.

In preparation for the larger ships, the port has almost completed the design phase of a $24 million modernization plan for the Tenth Avenue Marine Terminal. The updated facility will include more space for refrig erated containers as well as large irregular break-bulk items, such as the massive windmill blades used for electric generation. Other planned renovations include rail improvements, improved conveyor systems, and new gantry cranes.

During the design process, the San Diego Unified Port District has been using digital 3D modeling and model-based simulations and animations to reflect changing tide elevations and water levels. This ability to virtually see into the future helps the designers ensure that the facilities will work the way they should before a single ship arrives in port.

RAMBØLL SWECO ANS

RAMBØLL SWECO ANS was hired by the Norwegian Railway Infrastructure Managers to help them plan 75 kilometers of double track between Sørli and Brummunddal. This InterCity project involved the creation of entirely new tracks, as well as the intersections of new and old tracks. The rail lines also had to navigate roadways, either by crossing main streets over the railway, or vice versa. And the surrounding terrain posed the biggest challenge. The railway corridors cross several valuable landscapes that have significant environmental and cultural restraints, including an important nature reserve. Another special concern was that the rail lines would be close to a lake, necessitating flood plain analysis.

Rambøll Sweco ANS used BIM to help them identify and develop project plans to meet these challenges in the very earliest stages of design. They used virtual models to simulate 200-year flood events and identify the impact on corridors and station areas. Simulations also helped to determine the optimal elevations of station platforms to limit, or even prevent, railway downtime during floods.

The team's project planning also had to consider the needs of residents, preserve elements that were of historical significance, and keep the project's environmental impact to a minimum. External communication with local agencies and community groups was a key factor to gain public and agency consent. This communication required a system that could aggregate huge amounts of disparate data and present it in a format that was easy to view and understand. Even with a tight schedule, BIM helped the team secure project acceptance and agreement from 120 different design and approval stakeholders in record time.

The paradigm shift requiring purely 3D model based project delivery instead of traditional 2D document based delivery provides the catalyst for this high speed rail BIM project. The use of a robust data rich model for multidisciplinary planning, engineering and approval processes not only exceeded the stringent owner requirements, it also exposed countless other benefits realized from leveraging information modeling methods. Image courtesy of Rambøll Sweco ANS.

STRATHCONA COUNTY

LOCATED NEAR EDMONTON IN ALBERTA, CANADA, STRATHCONA COUNTY poses a surveying challenge during the snowy months of the year. To mitigate the number of times it needs to visit a site, the County uses laser scanners and photogrammetry technology for its digital surveying. This allows County personnel to refer back to the highly accurate point clouds captured during initial surveys instead of making additional trips back to a site.

For example, the County is currently working on a major roadway upgrade for several intersections along a heavily used roadway. As there are many businesses along the route being upgraded, public engagement is a crucial component of the project. The County took a detailed scan of the area to use for its engineering design and to create visualizations of the upgrades in the context of the surrounding buildings and businesses. The scans were then imported into the digital model used for infrastructure planning.

By visualizing the proposed roadway upgrades in the context of local landmarks and real-life building facades, business owners can easily understand the proposed changes and determine the impact of the project on their property. Moreover, the County is able to visually demonstrate the impact of changes, such as adding a road where there is currently a drive-through for a business. The scans also allow for feature extraction (such as adjacent power poles), as well as virtual measurements and excavation calculations. County planners have access to data that captures exactly what is already there, without have to manually resurvey areas.

Business access is challenging for this project. A new service road will be built to maintain a high level of access to the local businesses. This access road will be built between two adjacent buildings, creating a challenging engineering scenario. To improve public engagement, color point clouds with images overlaid of the effected local businesses were imported into an InfraWorks360 model. Image courtesy of Strathcona County.

NORCONSULT

LOCATED ON THE RIVER GLOMMA IN NORWAY, THE VAMMA HYDROPOWER

PLANT is the country's largest river hydropower plant. Originally built in 1915, the plant is undergoing its latest upgrade, featuring a new turbine, generator, and the associated control systems and switchgear. Multidisciplinary consultancy firm Norconsult is using BIM to provide digital insight into the design.

Due to the age of the original plant, the firm is using photogrammetry technology to digitally capture the existing plant and its surroundings and to integrate that information in the 3D conceptual models of the upgrades, providing both photorealistic visualizations and extremely accurate details. This process is enabling Norconsult to improve their analysis and uncover potential problem areas that, if modeled in the traditional ways, would have been discovered only during the construction phase.

Since existing constructions and infrastructure had to be considered while building new ones in close proximity, the technology's ability to show consequences of geometric changes—in a fraction of the time taken by older methods—is crucial. Model-based design has also enabled ongoing project consistency and coordination—both of which help to reduce execution errors, as well as save time. The firm is using BIM to create a single digital source for any type of analysis, be it structural, mechanical, or solar. And all of the analyses can happen much earlier in the process than was previously possible.

Norconsult uses BIM to visualize geometric changes made to 3D model of the plant, improving analysis and uncovering issues well in advance of the construction phase. Image courtesy of Norconsult.

AIRPORT UPGRADES

LAX: THE LOS ANGELES INTERNATIONAL AIRPORT is the largest and busiest airport on the west coast of the U.S. An LAX modernization program launched in 2010 includes updating and expanding the airport's Tom Bradley International Terminal and the Midfield Satellite Concourse, as well as renovations and upgrades to several other terminals. Gensler, the design architect, used virtual reality and BIM to educate clients and project stakeholders—such as the airport authority and local government—about the project and immerse them into the 3D space. This enables people who aren't trained in architecture or design to understand the design challenges and the proposed solutions.

ISTANBUL NEW AIRPORT: By the project's completion in 2028, this will be the world's largest airport, with six runways for 3,500 takeoffs and landings per day and a capacity of 200 million passengers per year. BIM is playing a strategic role by facilitating integration of all disciplines and related stakeholders in a single virtual 3D modeling environment.

HONG KONG INTERNATIONAL AIRPORT: This airport is aiming to be the world's greenest with help from engineering firm AECOM. Sustainable features include maximizing natural light, energy reduction, solar panels on the roof, and even an offshore designated marine park. AECOM worked with the airport to establish a BIM strategy, standards, and specifications for design and construction stages, as well as supervising the BIM workflow and deliverables quality of the design contracts.

LAGUARDIA AIRPORT: The BIM process is helping designers, owners, and managers of this airport virtually see the building in 3D, while also helping to mitigate risk. Model-based construction helps the project team visually work and review constructability, make changes, and make decisions based on the existing schedule and project model.

Gensler architects used virtual reality and BIM (with Autodesk Revit) to educate clients—such as the airport authority and local government—about the project and immerse them into the 3D space. Image courtesy Corgan in Association with Gensler.