

Research Report: Technology and Innovation in Today's AEC Community



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INTRODUCTION

In this year's AEC technology survey, we measured the acceptance of technology by structural engineers, architects, civil engineering professionals, designers and people working in the construction and building trades.

The majority of participants were at the managerial level or had some degree of leadership within their organizations. This included managers, team leaders and owners or proprietors of individual firms. In addition, there were a number of individual contributors who were technology users, and they provided us with some useful insights and feedback.



The organizations we spoke to varied greatly; however, most had more than 50 employees. In order to gauge a better and more diverse assessment, we felt that it was important to get input from smaller firms that had between six and 20 employees, as well as even smaller ones with just a few employees. All of these firms were located worldwide, with most in North America, and a smaller number in Europe and Asia. We asked participants about their use of new and emerging technologies as well as archaic and legacy technologies within the AEC industry. We asked specifically about their usage of the following:

- 3D modeling
- BIM
- Cloud data storage
- Aerial laser scanning
- Ground laser scanning
- Photogrammetry
- Point cloud technology
- Rendering technology
- Scanning technology (scanning legacy paper drawings into a raster or vector format)
- Triangular irregular network (TIN) surfaces

Many of these technologies are advanced and are used by peripheral professionals to the AEC community, such as mapping specialists, 3D printing and additive manufacturing designers and others. Because 3D modeling was the overwhelming majority of technology usage, much of our report is dedicated to building information modeling (BIM). We have exhaustively researched BIM and extracted commentary and perspectives from many different users at all levels. Thus, this report provides the deepest coverage of BIM as it's not only commonly used, but is also central to the business of building and construction and is related to many of the other technologies that we examine.

The survey explored data storage. We found that almost everybody was using some degree of storage technology or cloud-based data storage real estate to house their files and ensure that such data is not only backed up but is secure due to the merits of modern-day cloud data storage technology.

Our study found that fewer and fewer of the participants were using some of the more sophisticated technologies previously mentioned—primarily because such technologies are more specialized and are not necessary or part of their daily design and modeling efforts. For example, for more complex laser scanning—both aerial and ground-based—many respondents indicated that they have plans to use the technology in the future but aren't using it currently. In addition, not as many were using photogrammetry or point cloud scanning.

Many respondents were using rendering and also maintain that ability to scan paper drawings to CAD. However, much of the AEC community works in digital technology and maintains that data and its associated renderings and drawings in a digital format. Thus, it is not always necessary to have that scanning capability. However, there are plenty of situations where archaic and legacy paper drawings still exist and where it could be beneficial to an architect in a redesign. As a result, the technology is still being utilized. We found that the triangular irregular network surface technology is being used by very few in our dataset of participants and found only a limited interest in this technology by those we queried. This is probably because it's being used by specialists outside of the AEC community. When such technology would be valuable and beneficial, it's more likely that the specialists—or firms that have this specialty within their service offerings—will be brought in.

In summary, we found overall that the survey results directed us to focus most on BIM as the principle means of 3D modeling. This in no way intimates that other innovative technology, such as imaging and scanning platforms and software, are not emerging as disruptive technologies for the planning, design and construction of structures and sites. It only means that the firms we spoke to seem to be most focused on the comprehensive capabilities of building information modeling. Such technology is not only very useful, commonly used and flexible in the end-to-end design process, but is also now commonly used by a majority of firms in the AEC community.

TECHNOLOGY OVERVIEW OF EMERGING TECHNOLOGIES

This section provides an overview of the technologies we explored. It also includes roundtable comments from some of our survey participants.

Because 3D modeling and BIM are congruent and related, we dedicated the latter portion of this research report to this topic with an in-depth discussion of the applications and future of this technology. But first, we'll explore each of the technologies mentioned in our research.



DATA STORAGE SYSTEMS

In the AEC community, many of the files are dense and graphically intense, and consume megabytes of information. Thus, it's more practical to store them remotely in the cloud in many instances.

In addition, doing so allows adequate backup and averts much of the risk of a disaster where recovery would be problematic. If the files are stored in the cloud, then the data and the intellectual property of the firm is preserved. This is true of many industries and not just the AEC community; however, it's important to point out that there are other factors that come into play when this discussion focuses on architecture, engineering and other civil engineering pursuits.

One of these factors is the speed by which technology and the files need to interact. For this reason, data storage is sometimes approached by using a hybrid cloud. A hybrid cloud actually has a server that works in the cloud and partially works outside of the cloud. This allows better speed and resolves much of the concerns over file storage.

Another concern related to data storage is that of security. Cybersecurity is a true threat, and intellectual property is always vulnerable to adversaries. Thus, when data is turned over to a third-party data storage provider, the owner loses control of the security in this way—but in a good way. Data

storage providers will dedicate resources and undertake cybersecurity measures that are not available to the typical AEC firm. Therefore, security is sometimes heightened by storing file data outside of the AEC premises.

That said, many of the participants in our survey noted that they use a combination of site licenses either in the cloud or on their own premises, or they buy technology outright. So, there's a mixed bag of how technology is installed, but for the most part when it comes to data and files suffice it to say that the cloud is an advantageous means of data storage for today's architect or engineer.

AN AEC ROUNDTABLE DISCUSSION



(Image courtesy of LinkedIn.)

Dillon A. Mitchell, PE, Kowabunga Studios, Twain Harte, Calif.

Mitchell: *"I currently use cloud storage—both for files as well as for project collaboration. This allows people in multiple locations to access the same file and see any changes that are associated with it in real time. Giving everyone on the project access to what they need to see when they need to see it, rather than having a delay in uploading, sending and downloading. This will be standard and the way that more firms operate to save themselves the infrastructure costs and to increase security and uptime."*



(Image courtesy of Silicon Valley Business Journal.)

James McGibney, senior director, cybersecurity and compliance, Rosendin, San Jose, Calif.

McGibney: *"We have deployed cloud storage within numerous facets of our production environment. It definitely has both advantages and disadvantages. From an advantage perspective, eliminating the need for on-site storage is a major plus and the ROI for deploying cloud storage is easily achievable within a 12-month budget cycle, if deployed correctly. One major*

disadvantage is data creep. The movement of data is harder to track and the potential for sensitive data and/or intellectual property to be housed and not properly accounted for is a growing concern for any company who has deployed cloud storage. We intend to keep using cloud storage and have a strong emphasis with respect to ensuring that our cloud data is secure. Our rationale is quite simple: the ROI makes logical business sense and the instant scalability, from a storage perspective, makes the decision an easy one. Cloud storage isn't going anywhere and will continue to grow. One needs to look no further than Dropbox's IPO to see the future of cloud storage. Just over a year ago, Dropbox went public. Since that IPO, they've posted double-digit growth, robust cash flow, and even a major acquisition. Their revenues rose 26 percent over a year at \$1.4 billion, and they have 12.7 million paying users (source: TMF.) Companies are continuing to migrate to the cloud for a myriad of reasons, including but not limited to: savings on storage, stronger and more robust security features and scalability."



(Image courtesy
of LinkedIn.)

James Both, MBA, P.E. CEO of OneHour SmartHome.com.

Both: *"When dealing with BIM files, having a good cloud storage option is essential for storing and sharing massive BIM files. As we continue to add more data into BIM models, the size of the models continues to grow and can quickly fill up the drive space on your average computer. Good file storage also allows for easy sharing of the files and allows remote workers to make change[s] to the model even when they're not on site. Good cloud storage is a must-have for any project using BIM."*

Christopher McGrath, P.E., structural engineer, Baltimore, Md.

McGrath: *"Convenient, but there are security issues. I use it personally, but am not allowed to use at my current job."*



AERIAL LASER SCANNING

This technology is one that commonly utilizes drone technology and LIDAR, which stands for light detection and ranging. The technology extracts data from high resolution images and senses data using light that is in the form of a pulsed laser. This laser pulsation is able to measure varying distances and ranges to the Earth's surface. In essence, it's a surveying method that employs light to very accurately measure distances and then extrapolate all of the data that is gathered in order to recreate a 3D rendering of an object such as a building or other type of structure.

It's sometimes referred to as 3D laser scanning—though the term can have many different connotations depending on its context—and it employs both scanning in the 3D sense as well as laser scanning.

The great advantage of aerial laser scanning with the use of drone technology is that drones are able to travel where humans can't. Drones are also able to capture hard-to-survey areas and structures, as well as cast a much wider array of domain that can be better used to extract data and ultimately turn that data into a 3D model.

COMMENTS FROM OUR AEC ROUNDTABLE

Mitchell: *"I have not used this technology on a project but have seen it used at the beginning of the project to assess site conditions as well as progress in site preparation. This will continue to grow and be a standard portion of any site project moving forward—especially as costs come down and the technology is more prevalent."*

Both: *"Aerial laser scanning is primarily used in large civil engineering projects where contractors are trying to determine accurate volumes of materials that must be moved and potential conflicts that might be encountered. It can also be used to benchmark progress payments as an accurate way to calculate how much of a large earth moving project has been completed."*

McGrath: *"Have used in a limited way."*

**Example of
ground laser
scanning
technology.**

(Image courtesy
of Faro.)



GROUND LASER SCANNING

LIDAR may be employed with other methods of laser scanning from a terrestrial perspective, or on the ground. Scanning of this type is a very fast way to gather dimensional data such as height and distance and then use this data as it relates to buildings, structures and other infrastructure, which is the area of focus for designers and engineers.

Terrestrial-based laser scanning as well as aerial-based laser scanning is something that's more central to geographic information systems (GIS), and is not commonly used by today's AEC firms—particularly those that are smaller in size and without a surveying department or functional area.

The technology, however, is extensively used by surveying firms as well as large-scale AEC firms that have invested in such a technology and also have staffed their workforce to include GIS technicians and surveyors.

In this context, the technology is separate and unique but quite useful and continues to develop to work synergistically with BIM as well as other technologies at the core of the AEC technology portfolio.

In the future, we will likely see more aerial laser scanning technology as well as terrestrial or ground laser scanning technology being used, being developed with more sophistication and integrating well with technology to ultimately create a most useful combination of software and data that not only expedites the entire design process, but also greatly improves it with accurate and finite data.

COMMENTS FROM OUR AEC ROUNDTABLE

Mitchell: *"I've used laser scanning to generate a point cloud for projects, especially in locations that are not easily accessible such as clean rooms and sterile areas. This allows for people in the office to get the information they need without visiting the site, saving time and having a defined understanding of the current conditions of the project rather than an*

incomplete set of pictures or documentation from a single site visit. This will continue to grow and be a standard portion of any remodel project moving forward, especially as costs come down and the technology is more prevalent."

Both: *"Laser scanning is a great way to map existing buildings and sites. With laser scanning, you can make a 3D model of an existing building or structure and import the information into a BIM model for renovation projects. Laser scanning is a valuable tool that saves architects, engineers and contractors from spending hundreds of hours taking measurements and making construction drawings of existing buildings."*

**Example of
photogrammetry.**

(Image courtesy of
Autodesk.)



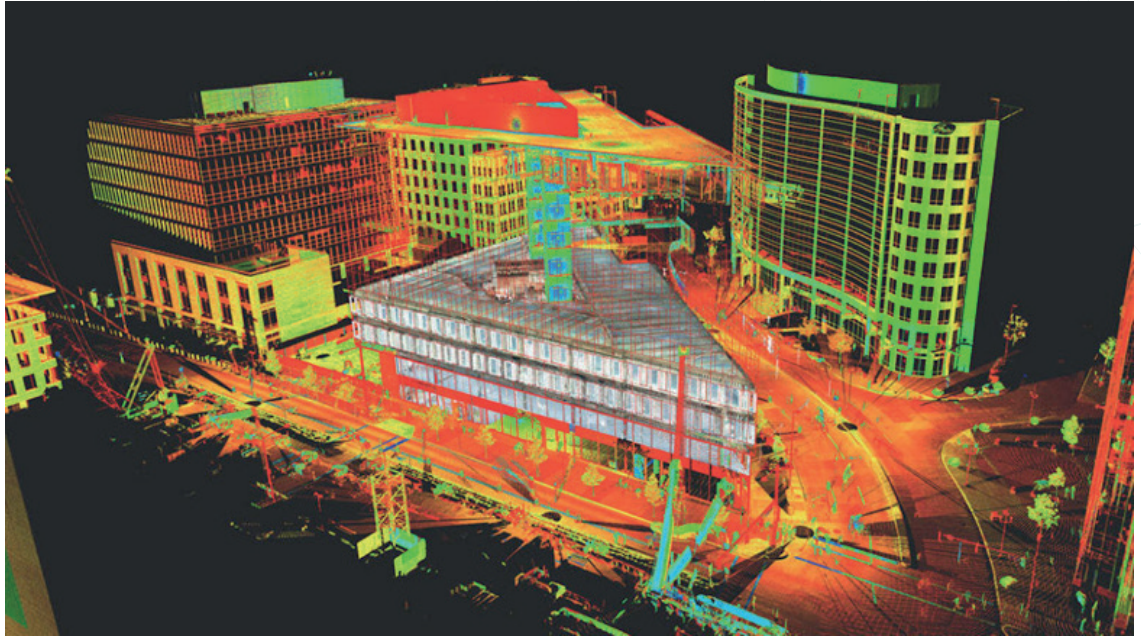
PHOTOGRAMMETRY

This technology, simply stated, is the extraction of 3D from 2D data. It's a collection of photography that is at closer distances than aerial photography, which has been the traditional form of photogrammetry.

The data that's extracted using photography, when combined with modern computational methods, is the most useful application that is not only emerging and becoming more and more valuable, but as it integrates with other forms of technology in the AEC community, it will also prove itself to be something that's very useful in generating 2D and 3D images and designs.

COMMENTS FROM OUR AEC ROUNDTABLE

Mitchell: "Do not use currently as it's not a completely needed as a design engineer. See this becoming more prevalent as the quality and clarity increases."



**Example of
point cloud
technology.**

(Image courtesy
of WeWork.)

POINT CLOUD TECHNOLOGY

Point cloud technology is a means of gathering a set of data points in space. Point cloud technology is most common in 3D laser scanning, whereby data is extracted from a large number of points on an external surface from the objects around them and the scanning process creates a point cloud arrangement that can be transported and utilized as data is fed into different software and technology. Such software and technology may include 3D CAD models that could be used for physical objects such as parts or products, but it can also be used for other areas such as rendering customized applications and different designs that an architect or engineer may encounter.

Again, 3D modeling technology is very central to the technology portfolio of today's architect or engineer and their firm. Thus, point cloud technology is expected to become increasingly popular within the community, and 3D laser scanners are also becoming more popular and commonly used not just by architects and engineers but by many other communities as well as laypersons. Learning about and understanding this technology is not a steep learning curve and the equipment is becoming less and less expensive.

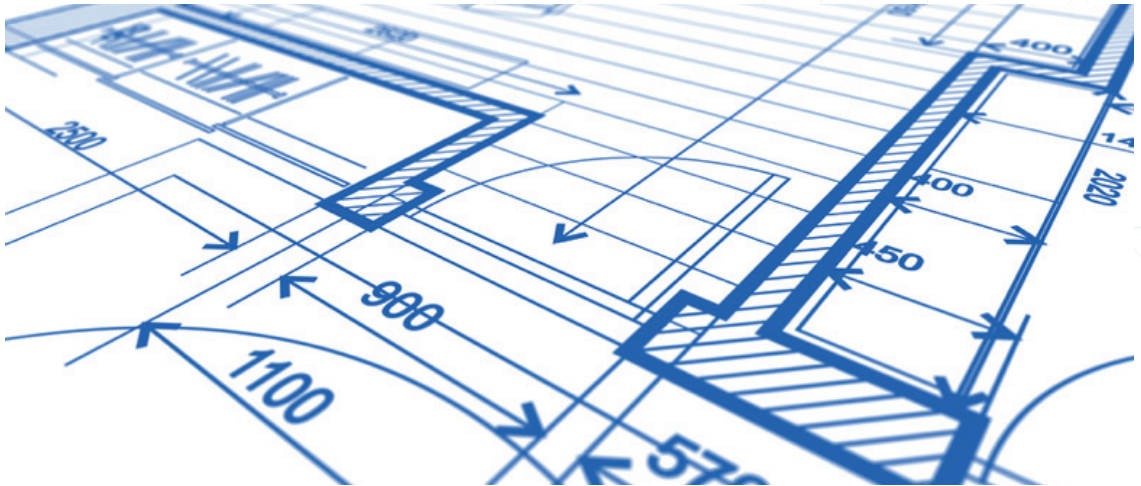
As this unfolds, we can expect to see more point cloud technology being used in varying degrees within the AEC community and we can also expect that it will be affordable and easier to embrace. In addition, the AEC community will be able to collaborate better with other disciplines when such technology exists and when more parties are using the same essential type of scanning technology.

COMMENTS FROM OUR AEC ROUNDTABLE

Mitchell: *"I use [this technology] and [it] should be standard for any firm that needs to represent to clients what they are going to build. From construction managers to architects to mechanical engineers building a central plant, it's necessary to be able to show all elements in 3D and present that to a client as well as other stakeholders for the project."*

Both: *"New laser scanning equipment has the capability to not only create a 3D model that can be imported into BIM model but the laser scanners also take pictures of the surroundings, which can be used to create realistic renderings of existing structures laid over top of the 3D laser scanned model. This is great for historical renovations or documentation to maintain the historical look of a building."*

McGrath: *"Nice but not really helpful in my position (structural). Does help with complex features on buildings."*



LASER PAPER-SCANNING TECHNOLOGY

Yes, there still are paper drawings and documents, which are used by AEC workers every day. This is particularly true for the drawing and engineering databases of legacy buildings or other structures. It's often necessary for professionals within a civil engineering firm or an architecture firm, or a similar entity, to scan paper documents so that they can be made into a vector drawing and become intelligent and rich with data. This is particularly true as they are more commonly commissioned to convert and refurbish existing structures. In addition, a drawing may just be converted to a raster image for informational or reference purposes.

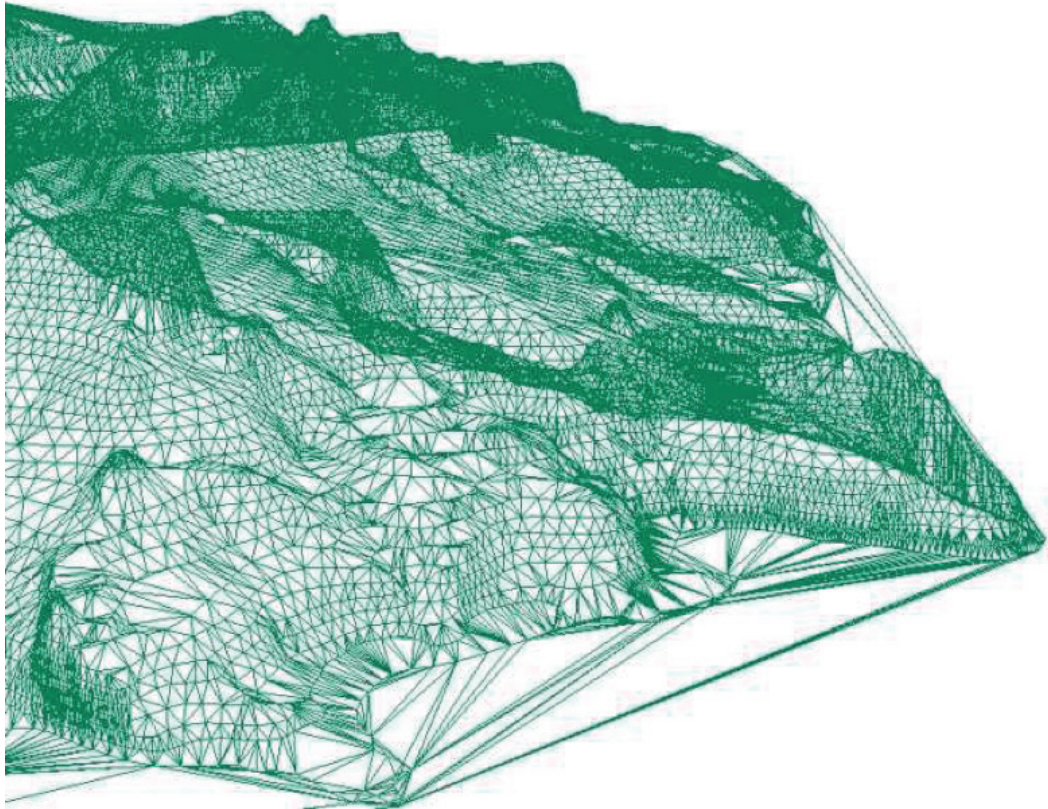
This technology, though, is something that was more common in the past, when there was a pivotal time when CAD migrated from paper to digital. That time has long since passed, and scanning technology is now used as a situational rather than a more routine practice. That said, most of our survey participants indicated that they had the technology and do occasionally use it as required.

COMMENTS FROM OUR AEC ROUNDTABLE:

Mitchell: *"This is crucial, especially for older buildings and keeping the documentation accessible for everyone who has or will be working on the project. This becomes crucial for places like hospital and office buildings when doing remodels. This will continue to grow until all has been transferred to digital, since all new deliverables are digital."*

Both: *"Digital scanning is a valuable tool for historical renovations to capture existing blueprints and turn them into digital documents. However, depending on the age of the documents, it may require a draftsman to overlay a new digital model of the drawing for it to be used with new BIM models or construction documents. For historical information, we have found that the most valuable tool is using laser scanners to scan an existing space [that] can easily be imported into a new BIM model."*

McGrath: *"Love it."*



**Example of
TIN surface
technology.**

(Image courtesy
of Pinterest.)

TRIANGULAR IRREGULAR NETWORKS (TIN) SURFACE TECHNOLOGY

This type of technology is another that is central to the GIS community and has been for quite some time. It's a digital means of rendering surfaces of a physical form. TINs are vector-based data with a geographical component, and in a sophisticated way, are developed by triangulating a series of data points. The data points are then connected with edges and form triangles. As a result, triangulation is then possible, and surfaces are developed. Geometric shapes result from that development.

This technology is rather sophisticated and, based on our survey, was not something that's commonly found within the first level of technology for most AEC firms. It's more commonly seen with surveyors and GIS users, as that is their more central focus. That said, the technology continues to be developed and is emerging as a valuable tool that may synergistically work together with other tools such as BIM or other 3D modeling software. We can expect to see more interactions between TIN surfaces and BIM in the future; however, it always depends on the project and its level of complexity.

Other technologies—for example, laser scanning and data storage—have a longer history. While that technology was once innovative, it's been used for some time; however, they continue to improve and be of great benefit to designers and engineers.

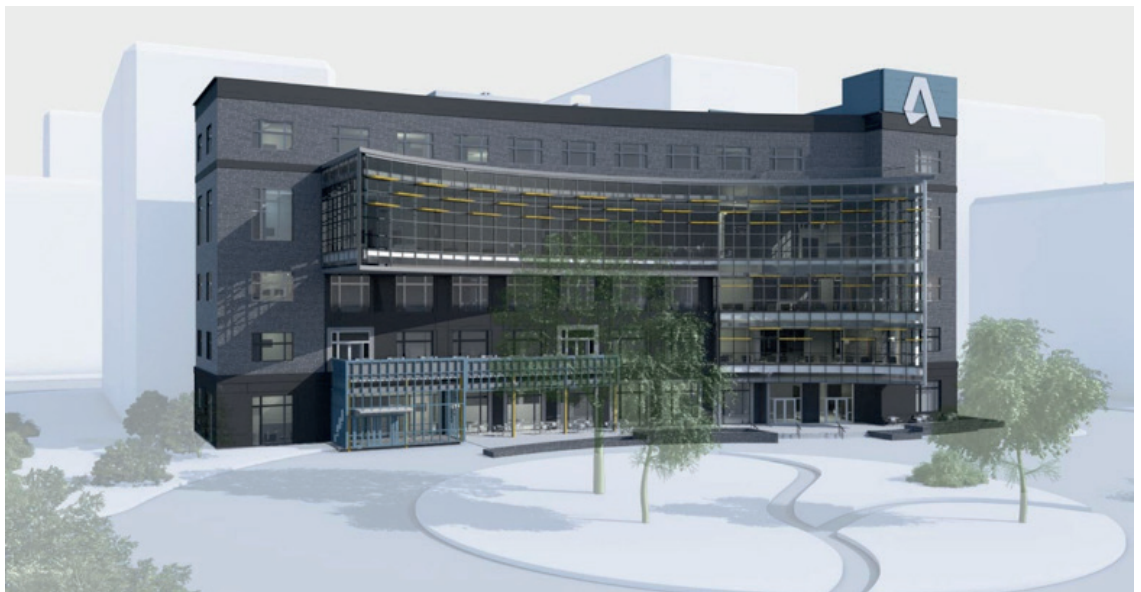
Much of the technology that we've looked at is outside of the normal purview of today's architect, engineer or civil engineering professional in

the routine design of building structures and other site plants. In the AEC community at large, however, such technology is usually specialized and focused on those professionals who use the technology every day and are more ardent about its application. In addition, they are better trained and more adept at its use and its limitations. Some of the more sophisticated imaging technologies require a more specialized skill and level of focus that aren't always privy or akin to a more ordinary architect, engineer or other professional found at smaller and medium-sized design firms.

However, technology is booming. If we were to look back in time, we would see dramatic differences in the way tools were used to conceive, design and plan civil engineering projects. The tools and technologies that are now available to many different professionals who all have a role to play in complex project development and planning are very instrumental and useful, and are expected to provide a very prosperous future for the accuracy and capability of the AEC community to design and build very robust structures.

AEC FIRMS EMBRACE BIM

Just as all industries embrace digital transformation to improve their processes, the architecture, engineering and construction communities—and all parties associated with their work—are avidly embracing building information modeling (BIM) as a valuable tool. When it comes to technology that serves this community, BIM is the new normal. It has evolved and matured, providing a most useful digital tool for project execution. For such reasons, this technology deserves a dedicated discussion; we have therefore dedicated the largest part of this report to it.



Example of BIM model. (Image courtesy of Autodesk.)

BIM is a process supported with many technological intricacies that involve generating and managing a digital representation of both the physical and functional characteristics of structures. BIM files can be extracted, exchanged or networked with others catalyzing collaborative project management for the end-to-end design and build of assets and infrastructure.

It is used by many in the project team structure—from individuals, businesses and owners to government agencies, electrical contractors and anyone who plans, designs, constructs and even operates and manages any minute facet of a physical infrastructure. Such infrastructure spans the gamut of different applications. For example, utility industries that incorporate water, waste processing, electricity and gas all have complex infrastructures under design and construction at some phase of their life cycle, making them good candidates for BIM. Roadways and railways as well as bridges, ports, tunnels and all transportation infrastructure also lend themselves well for utilizing BIM technology in building all of the structures within those sectors.

The data used in BIM is a rich digital depiction that accurately accounts for, and catalogs, the physical as well as functional characteristics related to the design and construction of such infrastructure. The underlying objective of BIM technology is to enhance the design process with explicit information that fulfills design intent. It aids the creators and innovators who plan and design great projects to be better understood and evaluated—automatically, and in real time.

BIM technology adds value by offering new features and benefits that empower the extended design and construction team—every day. Such teams collaborate better through the design process. BIM alleviates tasks that would otherwise be overwhelming and cumbersome, and further allows these teams to concentrate on the most important parts of a project. Now they can smartly insert their creativity and problem-solving abilities to bring about positive results for the project.

The computational power that BIM provides enables very detailed and extensive processing of volumes of data that would otherwise be prohibitive because of their cumbersome and laborious requirements. Thanks to BIM, this process can be automated and worked quite well, delivering a very successful outcome of the project.

All parties involved in design, as well as the extended construction process, will benefit from BIM, as will the underlying property and project owners. Information modeling is now strategically integrated into the total life cycle of the project and will have a long-standing and sustainable effect on the project's durability.

The technology has been in existence for a while and is accelerating at a great pace; however, with the advent of digitization and various improvements in the processing of data volumes from multiple sources, BIM is now very ripe to produce some of the greatest benefits in the history of architecture and engineering work. There has perhaps never been a better time in history for BIM to show its true colors by allowing complex projects to be built with improved quality—better than ever seemed possible—and at costs and schedules that are unprecedented—because of the underlying power that lies within BIM's true value.

SMART MODELING FOR TODAY'S DEMANDING DESIGN ENVIRONMENT



(Image courtesy of LinkedIn.)

Mia Dibe, architect and BIM analyst at Enstoa, Beirut, Lebanon.

Today's designs are complex and BIM is a very important part of taking on the challenge of such complexities. "The value of BIM is based on a collaborative and automated approach of working," said Mia Dibe, a BIM analyst with Enstoa in Beirut, Lebanon.

"Instead of drafting manually and drawing line by line (CAD), BIM products switched to the logic of objects, elements, families—all contain a set of parameters with data and information relevant to each. At a design level, BIM improves the design quality, reducing errors, waste and risk. At a management level, it facilitates the workflow for construction managers and project managers who are able to directly access schedules from the data, keep track of all assets and increase the communication within teams."



Fred Meeske, corporate director of BIM at Rosendin.

Fred Meeske is the corporate BIM director for Rosendin, a contracting firm in Phoenix, Ariz. He says that today, BIM provides instant access to critical and accurate information related to a building or design project. This differs from perhaps 15 or 20 years ago when such data was collected differently than it is today.

"It was in silos, separate file structures and geographical locations, with different formats that did not easily talk to each other. These included differing noncompatible file formats, various software applications and licensing structures, and process differences between firms or groups," he said. "BIM now enables more streamlined collaboration in real time between owners, designers, specialty contractors and other project participants. Every day, new tools or processes are developed to improve this technology further."

One of the notable benefits of BIM is the allowance it affords teams to better collaborate. Collaboration is instrumental and intrinsic in almost any design and construction project. The very intent of BIM is to enable better collaboration among parties who are distributed and maybe located anywhere around the world.



(Image courtesy
of LinkedIn.)

Melanie Stone, facilities solutions and data manager with FM:Systems in St. Louis.

"The biggest benefit, from the owner's side, is intelligence—that is, data behind the model—and improved collaboration," said Melanie Stone, a junior solutions consultant with FM:Systems in St. Louis, Mo. Stone attends to post-construction facilities management. She says that having data in the model allows data to be linked to many other systems that can be easily cataloged using an AutoCAD file for the space and graphical data. She then explains that pulling in equipment and materials through other spreadsheets and programs, or even manually, can be affected.

"So, maintenance and operations can get up and ready almost immediately," explained Stone. "BIM is most suitable for complex, high-change facilities. Health care is an obvious one, infrastructure like water treatment plants or specialized places like breweries. You can't just look at a glance to tell piping apart or that it's not safe due to infection risk, or it's got a very tight tolerance. I think the effort would be wasted on most office buildings."

Stone explains that in the implementation that she's worked on when they open a new building, it's usually not always worth the time to go back and model existing buildings when they're doing renovation, and that it can sometimes be overkill. She purports that BIM is better suited for new construction.

She also adds that incompatibility can sometimes throw a wrench into the works. Consultants have to be coordinated with different versions of a software program and revisions of the project models and data. They must be in sync with the owner as well as all the standards imposed on the project. With BIM, models and data can easily be published in a manner that is suitable to everyone and be set up with appropriate boundaries as required.

IMPROVING EFFICIENCY

Another attribute of BIM that project teams stand to benefit from is the added efficiency that it brings. Dillon Mitchell of Kowabunga Studios says that just looking at the sizes of AEC companies, a company with the same revenue just five years ago can now have the same revenue—which might even mean more projects due to reduced fees—with a fraction of the employees. Mitchell contends that the only way this is possible is with BIM. He says that pieces like schedules, sections and elevations are all linked together, making for more accurate information that can be put in multiple locations on documents and changed once, with a rippling effect throughout all the documents and reaching all of the parties who need to know about it.

Mitchell also says that BIM is very suitable for all building types. “I’ve used BIM from small 1,000-square-foot renovations to over 300,000-plus-square-foot new buildings,” he said. “It’s easier to share models across firms. It’s also easier to view templates and transfer data no matter the other firms you’re working with and their layer settings.” He says that the layering functions of BIM are done by the type of element and make this easy.



Matt Man, CEO and cofounder of indus.ai.

Matt Man is the CEO and cofounder of indus.ai with offices in Toronto and San Francisco. Man says that the inherent value of BIM lies in its ability to provide a common language for all stakeholders along the life cycle of a building, so they can work to the same specification and subsequently minimize errors and misinterpretation of any information.

(Image courtesy of LinkedIn.)

“It’s not unusual to encounter thousands of changes on the BIM model from the conceptual design to the final constructed building,” said Man. “Before BIM—say, five to ten years ago—architects, owners and general contractors were all using traditional pen and paper to communicate whatever it was that needed to be built. This leads to delays, misinterpretation and, of course, many unwelcome surprises.”

Man reminds us that BIM has been used extensively in the planning and designing of buildings for quite a few years now. He says that it’s the standard for modern construction and is the underlying catalyst for a new wave of construction technology that we’re all experiencing and benefiting from.

“It’s the common language foundation which enables new technologies to interoperate with each other and fit well into existing workflows and systems for easier adoption,” he added. “The challenge now is employing BIM for work-in-progress buildings and updating changes, so that everything can be visualized properly.”

The BIM model may not be defined to the level of detail necessary for constructability and maintenance. There are some good technologies available now to visualize BIM using augmented reality and virtual reality technologies. However, to update the BIM model as the building is being built is very time consuming, especially when the model becomes more complex with additional dimensions.

James Both of OneHourSmartHome.com, who specializes in smart home design, says that BIM is one of the most useful tools in the construction industry because it can help save time and money, and prevent conflicts during construction.

"The first iterations of BIM modeling were mainly used for modeling mechanical, electrical and plumbing routes in ceilings to prevent pipes and equipment from conflicting with steel beams and HVAC ductwork systems," he said.

Both adds that in the first iterations of BIM, contractors only modeled larger items using BIM because it was new to the industry and not everyone had bought into the idea that it would truly help the construction process.

"Prior to the use of BIM, we would sit at a table with our mechanical, electrical and plumbing contractors and go sheet by sheet without paper shop drawings to try and figure out where there might be conflicts with mechanical systems. It was an OK system but nowhere near perfect," Both said. "Even the first iterations of BIM modeling were far better than this paper process because it gave everyone a 3D model to view to better assess where conflicts might arise. This made it much easier to discuss a solution and update the model to distribute the new information to the tradesmen after a decision on a conflict was made."

Both emphasizes the progress BIM has made, which is the cornerstone of its prescient and continual value to designing spaces. He says that since the first iterations, BIM has evolved to an all-encompassing design, construction and scheduling tool. As architects, engineers and contractors all started to embrace 3D BIM modeling, it allowed us to bring all the parts of a building together in 3D models before a building was ever constructed. Additionally, he adds that using BIM has greatly reduced construction waste because contractors can rely on the accurate information provided in BIM models to prefabricate their components and work around other construction trades without the fear that their work might interfere with another subcontractor's work.

"Since most architects and engineers are now on board with the benefits of 3D modeling, the base building models received from architecture firms typically include detailed 3D BIM structural and connection information that allow even further details to be planned throughout the construction process."

ACCOMPLISHING COMPLEX PROJECTS

All said, BIM, with its smart use of data, is making a big difference in the completion of very sophisticated projects.

BIM and its capability to be used by knowledge workers in different locations, says Fred Meeske of Rosendin, has potential for any construction project delivered as a closed unit, meaning all-in-one locations, as well as those that have varying and remote co-locations.

"Each has pros and cons to measure for unique project situations and should not be dictated by any one group," said Meeske. "The most critical part for project success regardless of the team locations is to develop a solid plan with clearly defined goals for the project team and other stakeholders. Understanding the overall needs allows each specialty group to better provide for their teams as well as other team members to the extent that's reasonably possible."

While BIM can be tailored precisely to fit the needs of a project, it does not always have to be customized to meet every specific need. Melanie Stone adds that BIM should only be bought from a large long-lived provider with a big user base.



(Image courtesy of LinkedIn.)

Shane Goodman, manager of project services for AE Works in Pittsburgh, Pa.

Shane Goodman, LEED AP, is the manager of project services for AE Works, based Pittsburgh, Pa. Goodman says the more complex the design, the more suitable the use of BIM.

"The reason for this is that complexity comes in all different forms, as does the application of BIM," explained Goodman. "A health-care project is not only complex from a MEP systems standpoint, which would support the use of BIM for 3D MEP coordination, but also complex from an end-user [such as a nurse or doctor] input standpoint. Therefore, a health-care project may also warrant the use of BIM for virtual mock-ups of rooms for review with the end users. As another example, an office building project may be very simple from a MEP systems design standpoint but has a very complex building façade design that requires a heightened level of BIM detailing to understand connections and system overlap of the façade. Another example of a complex requirement for BIM would be pursuing a net-zero design, which requires an amplified use of BIM around the energy usage of the building. This specifically could warrant BIM daylighting and lighting analysis and energy modeling."

INTEGRATING BIM IN THE EXTENDED IT ENTERPRISE

Typically, the design and construction of complex projects require different technologies that work in concert with BIM. This coexistence can present challenges, though not insurmountable ones. It's important for users of BIM products to be mindful of such interoperability.

Meeske is emphatic that everybody should be mindful of BIM and the integration with other platforms used through the extended enterprise, around which the project is being built. He says that while software developers are working on integrating tools for the construction industry, emerging companies sometimes make it more challenging to know what and when, let alone how, to utilize them all. Many of these companies only provide a small fraction of the necessary tools needed to meet the project requirements. This can be problematic, he feels and, in turn, he says it can cause users to have multiple applications to sort through while ensuring accuracy and no loss in translation.

"While improvement is necessary for continuous improvement, it also can be detrimental in the short term," he added. "The reason is primarily due to a team being distracted from achieving timely and needed agendas because they are busy chasing shiny objects. New tools should be evaluated in pilot settings for users to scrutinize, both qualitatively and quantitatively, then refined for how and when to best utilize them." Meeske adds that this should not be a buy-and-try approach for a new project. He contends that there are many aspects and dynamics to a project team. He says that some tools may help. But he also says that they may provide little or no value to some and even negative values to others. In short, it's important to be careful about what other software will be integrated in with BIM and whether such software is necessary and valuable and truly relevant to the entire project needs overall.

Tom Armbruster is the BIM manager for the AEC Group in Wilkes-Barre, Pa. Armbruster says that there were very few structural portions of the BIM software about a decade ago and it was mostly architecture. But he says since that time, BIM has really evolved to include more sophisticated engineering and analysis programs as well as energy modeling and sky lighting studies that are all quite helpful for today's design and construction. He adds that all projects are suitable for BIM, but he said there are more benefits for any type with a facility team that can harness BIM data after its occupancy and the building construction is completed.

"Once we had the hardware to run the software, the training to use it was the main integration hurdle," he said. "Our BIM software is not backwards compatible. Therefore, all users in model must be on the same version. All our purchasing of software has been done through resellers or integrators

that could assist us with integration after the sale. Integration and training are key and should be customized to your staff. We understand that the cloud is a big push now. But as all of our disciplines are in house. We did not see an advantage to using the cloud nor did our ownership want to see files hosted out of our office.”

Dillon Mitchell says that you can source directly from some vendors or their distribution partners, but he says it’s important to have a single on-premise server that’s configured with their token system in a straightforward pay-per-usage system that’s more economical than having a license for every user in the company.

“Cloud-based solutions will also help with up-time and remote work throughout the company,” said Mitchell. “This can also come in handy for presentations in client meetings.”

But Mitchell says there are pieces such as your initial template, including symbols and abbreviations as well as schedules, that you’ll need to create when transitioning to BIM. He also says the different layers of the software will have to be configured in order to meet your specific needs. So, there is some startup time commitment or the requirements of somebody such as a consultant to help create templates for you so that you can seamlessly get up and running in the smoothest and quickest time frame. He also adds that there are a number of add-ins and other features that bolt onto BIM. This will allow the system to pull information from databases that aren’t necessarily available in AutoCAD and other 2D drawing programs. He notes that BIM has more reliable counts and costing data, though, and the possibilities are becoming better simply because of the options that BIM provides. Another important point that he makes is that BIM allows coordination with all trades during preconstruction and construction in order to resolve problems before they happen.

“As an owner, I can only transition my technology about every 15 years, and any technology I adopt has to be applicable to every trade,” Stone said. “I have to be able to edit the models and drawings as well as the prints that come to us after a new build or renovation. Things change every day, and we have to be able to update models. Also, my facility’s BIM implementations have been slow, simply because it took so long for qualified contractors to have the skills in house to properly utilize solutions and the infrastructure and policies to collaborate with other firms,” she said.

But overall, Stone has had many positive experiences in using BIM. For example, document turnover as well as easy connectivity to some of her own software solutions that are used for facility management are expedited now that BIM is being used. She says that you’re not going to forget to include sheets and you’re also not going to miss sections that are important because everything is contained together now, thanks to the utilization of BIM.

“The only really negative experience I’ve had—that wasn’t just the result of poor scoping or reduced budget outside of our control—was when I had a project manager who lied to me,” she recalled. “I worked for one of the

nation's top 10 hospitals and we were adding a new outpatient clinic. Only about 25 percent of our main campus was BIM by that time, and this would be the only whole building on campus that would be a multidisciplinary model."

In the case she describes, the design variants did not come to fruition as they had planned. Stone says that they paid for many models of the project but only received one—because of the project manager who did not enforce that requirement. Another project manager replaced the previous one and paid the invoices without checking against the time that was served to the contractors. In this case, it wasn't the technology that caused the problem—it was the responsible parties who were at the root of the problem.

Such issues do happen. But they're often outliers. Stone adds that she has had positive experiences in receiving models and linking them to other databases. The only issue she's had was purging the model of extraneous details that made room bounding lines appear when they shouldn't have. In addition, she says that importing equipment and other asset data is now a breeze—thanks to BIM.

She feels the future will only offer gains in the use of cloud services and other integrations with other systems and services, particularly when it comes to facilities management. This will enable data analysis as well as business intelligence and analytic software to be employed.

"Nothing is an island," she said. "It will eventually all work together, with [Human Resource Information Systems] HRIS and finance software as well. The ecosystems will get better at sharing and using data, and people will become more comfortable with the technology needed to do the initial data load."



Karen Panetta, professor at Tufts University.

Karen Panetta is an IEEE Fellow and Dean of Graduate Education at Tufts University. She says one of the most instrumental contributions of BIM has been the ability to bridge the gaps at the interface boundaries throughout the entire design and construction process.

"Traditionally, the boundaries of these interfaces were dependent on handing off drawings and documentation, requiring multiple revisions which had to be communicated to many stakeholders," explained Panetta. "Providing all stakeholders access to the most recent files may not seem to be such a big deal by today's standards, but just a few years ago this was done by emailing large files. The burden of managing those files fell to each entity receiving the files, which made any project susceptible to miscommunications that could impact its schedule and cost."

As Panetta explains, data nowadays can be managed in the cloud and partners can access those files from anywhere at any time, ensuring that all eyes are looking at the same information. While it may not seem to be a huge deal, it was a giant leap in helping to address this challenge.

(Image courtesy
of Tufts
University.)

Panetta points out that the handoff and communication of designs and data has always been a challenge for any interdisciplinary project in every industry, but the building industry may be the leader in terms of requiring the most varied stakeholders from different fields. Each field must adhere to its own regulations and laws, which vary and change constantly, making it a challenge to keep up with evolving technology and safety protocols.

“Integrating all these fields’ simulation models through computational modeling was too time consuming and expensive. However, today, thanks to advances in cloud computing and low-cost computing technologies, complex computational models from all stakeholders can be integrated early on. This has made a tremendous impact in creating efficiencies that have resulted in decreases in project time and ensuring robust design from start to finish. It also translates into more accurate budgeting and maintaining on-time schedules. This is a drastic change from traditional approaches, where each discipline would use its own discipline-specific tools and software. These tools did not always work synergistically across disciplines and certainly didn’t have the capacity to include the massive amounts of data for all the different stakeholders.”

EMBRACING TODAY'S BIM FOR TOMORROW'S DIVIDENDS

Getting BIM on board and in motion pays dividends. Such dividend yield is for today, but also tomorrow. BIM saves time. It streamlines your overall project efforts. If used properly, it will provide a return on investment in several ways.



(Image courtesy of LinkedIn.)

Abe Morris, BIM Manager at SSR in the greater Nashville Tenn., area.

Utilizing BIM to produce our construction document deliverables has enabled us to streamline certain processes and design calculations,” said Abe Morris. “While these have generated some efficiencies, we must consider that we are also spending more time modeling to provide higher-level spatial coordination than when producing 2D drawings. This level of coordination requires additional effort, particularly for MEP when dealing with continuous architectural and structural changes. We stand to recoup some of this effort by minimizing RFIs and encountering less constructability issues during construction.”

Morris says that BIM is here to stay and it's going to continue to improve as industry processes and technology evolves. He says that the Internet of Things (IoT) will continue to change how we interact with the world around us and that we are seeing the potential to connect BIM and IoT.

“The new normal is change. The younger generations are accustomed to this. They were born with devices in their hands. And as they continue to enter the workforce, adapting to technology-driven change will come naturally,” he said. “More and more owners are becoming technologically savvy and are looking for ways to benefit from BIM. As this evolves, I believe we need more standards around how BIM information is exchanged across software platforms and to project stakeholders. If everyone is following a standard process, the data can flow more seamlessly and be more useful.”



(Image courtesy of LinkedIn.)

Paul McGilly, digital design director for BuroHappold Engineers in New York.

Paul McGilly is the digital design director for BuroHappold Engineers and is based in New York. He says the future of BIM has arrived and is being embraced at various levels across our industry.

His firm has made the decision to fully employ BIM and now delivers all projects on a BIM platform. “I believe that how it can be improved is dependent on how your team implements BIM. What do you want from your BIM model? Simple 3D geometry, to be able to fully design your building and extract data for calculation or analysis or embed intelligent data that can be utilized by the owner’s facilities management teams. Improvement comes from feedback and development from the end user and what your end goal is.”

Dillon Mitchell says that BIM will have more solutions that are formed around it and that doing more of the routine work that architects and engineers used to do will allow them to focus on more critical problem-solving instead of paying attention to more mundane and less valued tasks than they used to.

"It will be easier to create construction drawings moving forward, which will allow for more training and not just rushing from project to project without time to really learn anything new," Mitchell said. "BIM gives the ability to do more iterations on projects and use data-driven design to make decisions for each project—getting better solutions without the time investment of the design team. BIM is already being used for roadways and infrastructure, although not to the extent it is used for buildings, primarily due to the compatibility of existing DOT maps," he said.

But Mitchell says that BIM is going to provide more automation in the future and allow AEC firms to move faster than before. He says it's going to be through software that the entire transition is going to be speeded up. He's also quick to add that not adopting BIM will ultimately reduce the opportunity for any enterprise or firm to win projects. This is because it's becoming more of a requirement for most building owners. He says that you might be able to ride on the coattails of AutoCAD to your retirement. But anyone working in the firm will be at a disadvantage moving forward. Fred Meeske says that BIM is evolving every day and will continue to grow well into the future.

"BIM is a process or set of principles that uses a model, along with associated project information, for others to use and benefit," said Meeske. "Someday, we will have applications that can easily share the data we wish to convey for other stakeholders in a more interoperable environment."

In Meeske's experience, most design build projects have a significant expectation from BIM in order to add value and improve the overall efficiency of the design as well as the coordination, procurement, and packaging of the entire project in order to build process.

"All this can be accomplished if there's adequate time to do so," said Meeske. "If the design schedule, coordination schedule, and construction schedule are appropriately sequenced and integrated, the project will thrive. This integration allows for each step in the process to be designed, evaluated, match value target design, project owner requirements and the analysis of other cost benefits to occur."

He adds that projects flourish with this because there's one team with one objective, and that includes the owners. This representation of true collaboration is the very basis for any BIM project to succeed. We're not just going to be fitting things into BIM, he posits, and we're also not going to provide the time needed to achieve the objectives. He seems to believe that BIM will stand on its own feet and that the merits of using the technology will become more self-evident as time goes by and the technology's values are better recognized.

CONCLUSION

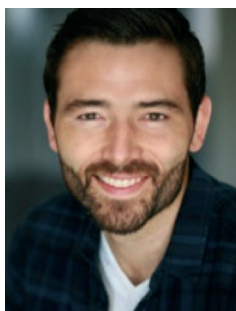
New technology is upending the AEC community. It enables things to be accomplished that were not previously possible or which took inordinate amounts of time. It makes things easier.

It allows design variants. It streamlines documentation. It speeds project time from concept to delivery. It is a catalyst for improved collaboration across distributed project teams. And it is a must-have to improve the quality of complex projects. It turns an overwhelming project into one that is manageable.

"Imagine if a camera could see all the different components there being built," said Matt Man. "An AI-based computer vision system recognizes what the component is, its start time for installation and its end time when it is installed. In addition, it can understand how many workers are involved to make these things happen. It's a type of important thing that can be fed directly into the BIM model with human involvement."

In summary, laser scanning, laser imaging, 3D modeling, photogrammetry and other technologies all have multiple benefits that extend throughout the very diverse and extended chain of stakeholders in the planning, design, building and construction and facilities maintenance processes that occur in producing and managing buildings today. Owners have higher demands and are attached to more complex architecture with more complex systems inherent within them. This only means that BIM is going to have heightened importance as time goes by and its utility is going to be even more valuable than ever before.

Yesterday's technology is displaced by many new technologies, with many new and important features. The road ahead is well-paved and prepares the AEC community for a time where BIM is central to the design and construction industry anywhere in the world for whatever needs to be built.



(Image courtesy of LinkedIn.)

Christopher Clifton, the owner and founder of Okkem Design in Austin, Tex.

Christopher Clifton is the owner and founder of Okkem Design, based in Austin, Tex. He believes the value of technology is endless.

"It depends on where you stop in the design process," he said. "If you're just designing a floor plan or somebody's space, then I think it allows you to create a better-quality design. In other words, spaces that are better accounted for because you're able to rotate and view them from

a perspective that usually comes from years and years and years of experience."

Looking to the future, Clifton says using AEC technology such as BIM is a must; it's simply hard to be competitive without it.

"In the next three to five years, if you are still a design firm or engineering firm that is drawing in the 2D environment," he said, "I think it's fair to say you would be considered an old-style firm. It would be equivalent, I think, of a firm nowadays creating drawings by hand."



This research has been sponsored by U.S. CAD.
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