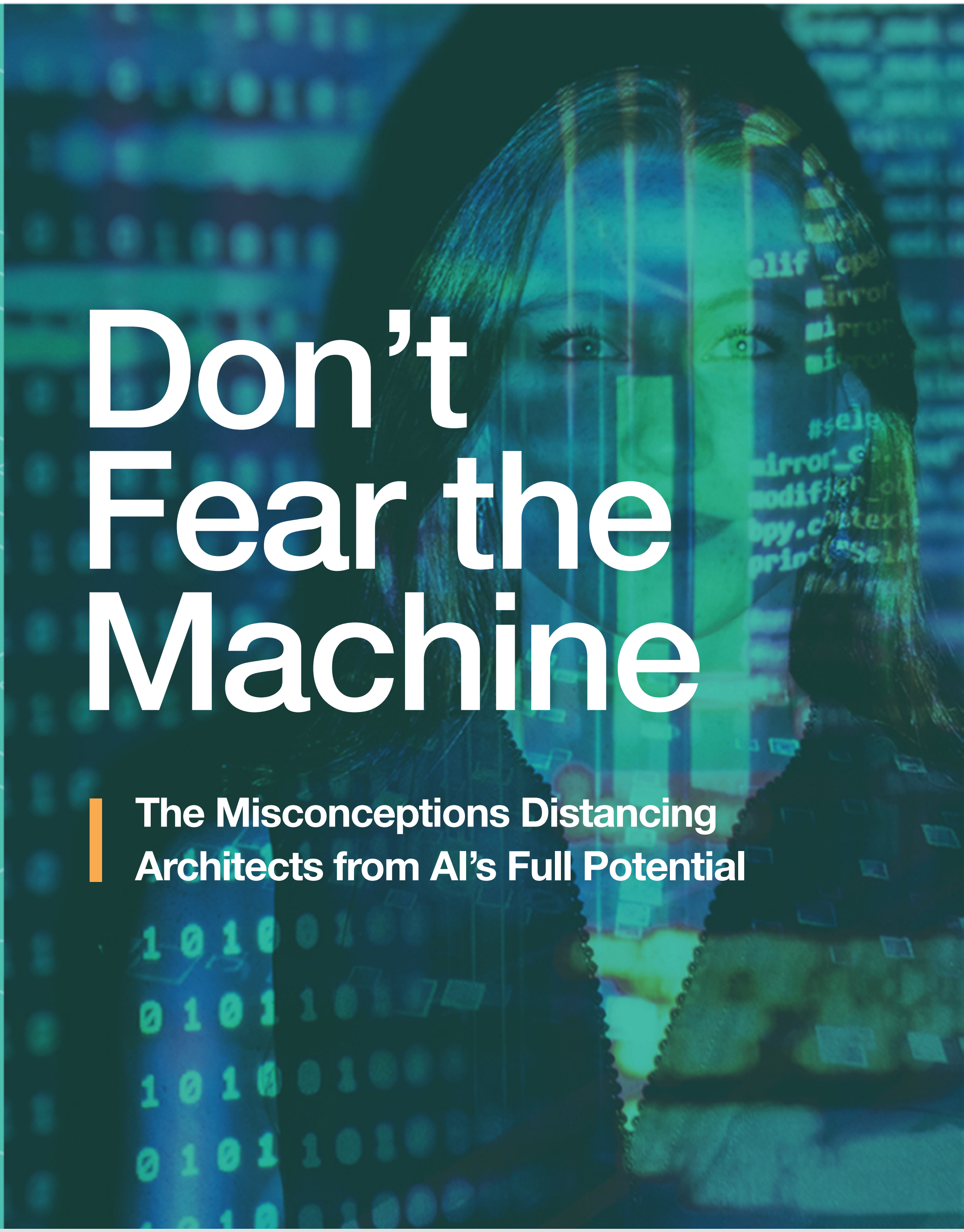

Don’t Fear the Machine

The Misconceptions Distancing Architects from AI’s Full Potential

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Table of Contents

Introduction

Artificial intelligence (AI) is a term being used far more frequently in the consumer press and across a wide range of industries, but it's not a term that's always well defined, particularly in the architecture, engineering and construction (AEC) industry. Given its history in science fiction, this lack of definition around what AI means today has led to confusion and misconceptions that are holding back professionals across the AEC industry from utilizing AI technology to its full potential. In many cases, this confusion is costing the AEC industry a powerful tool in solving some of its biggest challenges.

Here at Schnackel Engineers, we find that many of our clients do not fully understand the different categories of AI and the potential they hold to boost efficiency in design, construction and future operations. With a stronger understanding of AI as a software tool to solve problems (not to replicate the brain, let alone the human mind), architects can begin to see AI solutions as a key differentiator in their competition for new projects.

AI-driven software can solve problems that would have previously been considered the exclusive purview of human intelligence, or even impossible to solve. In fact, AI-driven software is being used to do just this in a number of industries, and is beginning to make inroads into the AEC industry.

In this guide, we will arm you with a stronger understanding of what AI is, and what it is not, as well as use cases that can create a path forward for design firms. With a greater understanding of these leading-edge tools and how to leverage them, we believe architects and designers will be able to better address some of the industry's, and the world's, most pressing challenges.

CHAPTER 1

Misconceptions around AI and Machine Learning

Long the stuff of science fiction, the mention of artificial intelligence (AI) in the AEC industry can elicit a wide range of reactions. On the one hand, there is excitement about how AI tools can push the envelope of what's possible across all areas of life. On the other extreme, there are concerns around security and privacy (and, of course, robots wanting to harm humans or take over the world). These ethical concerns have their place in the development of any advanced technology. However, they are somewhat the result of misconceptions about exactly what AI is and what it's capable of accomplishing.

As with any computer program, AI is a tool that can be used to drive accuracy, productivity and efficiency to a level that people simply can't achieve on their own. While that may seem daunting, it's important that professionals in the AEC industry in particular understand that this higher level of efficiency can actually support them in reprioritizing the design work that they love most.

By understanding three of the most common misconceptions about AI in AEC, design professionals can address their concerns and better benefit from a greater collaboration with machines.

Misconception 1: AI Tools Will Program Me Out of My Job

As long as machines have been around, workers have been concerned about losing work to them. The AEC industry has not been immune to those concerns. As New York-based Chilean designer Sebastian Errazuriz commented in an Instagram post on AI in AEC, "It's important that architects are warned as soon as possible, that 90% of their jobs are at risk. If you haven't really realized that, you should be taking measures right now, as soon as possible."

This is a somewhat shortsighted approach that doesn't account for how AI solutions can help architecture professionals apply AI solutions to solving their biggest pain points and provide unprecedented levels of service and added value for clients.

To better understand the real impact of AI in AEC, it may help to look at a current trend in the manufacturing industry. While it's true that manufacturing jobs have been impacted by automation, a more accurate comparison for the creative, problem-solving AEC professionals would be today's push toward "Industry 4.0." This fourth industrial revolution, as it is called, is geared toward achieving higher levels of productivity and efficiency by maximizing the strengths of both machines and humans through collaboration between the two. By leveraging AI-powered tools, humans can turn to performing more valuable work.

Colin Parris, the vice president of Software Research at GE, put it this way in an interview with TechCrunch: "The only way to fight [job losses], is to train the talent that we have. Because in the future, we have to embrace robotics. It allows us to reduce cost. If I reduce cost, I have more money that I can use for innovation. The more money I have, the more new products I can create. The more products I create, the more workforce I can hire."

Change is always daunting, but AI tools can help push the AEC industry to better addressing some of its biggest challenges, including climate change—and that's a change worth exploring.

Misconception 2: AI Will Make My Job More Difficult

Again, change is difficult, and adopting new tools and software solutions does require retraining and a change in processes. Many architects may recall facing this same concern as CADD and building information modeling (BIM) solutions first became prevalent.

AI may seem to present a steeper learning curve, but it's not one that is impossible to overcome. As with any advanced new tool, AI has the potential to change the nature of the job as it exists today. It isn't responsible for putting people out of work, but it may drive a need for reskilling of the workforce. In truth, however, that's one reason that architects should consider adopting these tools early on. As with BIM, early adopters will have time to gain an edge in using these more advanced tools.

The Diffusions of Innovation theory developed by E.M. Rogers explains how an idea gains momentum and diffuses through an industry over time. Early adopters of an idea, those who are among the quickest to adopt an innovation, tend to have the highest degree of opinion leadership. These early adopters also recognize, Rogers found, how their rapid adoption can help them maintain a central communication position within their industry. Early adopters can control the conversation surrounding AI benefits.

Will AI in the AEC industry make these jobs harder? That depends on how the AI user wants to redefine how they personally provide value. AI allows its users to perform at a higher value add level than was previously possible.

Misconception 3: AI May Make Decisions That I Don't Like

AI-driven tools are able to evaluate near limitless design possibilities, but they can't force you to act upon one. Ultimately, the architect or engineer is in control of the design process and the output from the machine. It's up to the professional to provide the appropriate constraints that will drive the eventual outcome. If you trust your input, you can trust the computer's output. And if you don't like the outcome? Simply revisit your inputs and try again.

As architect Duo Dickinson wrote about BIM back in 2016, "Beyond the fear of underemployment, or simply not having the newly required skills to be hired, there is a professional undercurrent that BIM's impact on the creativity and value of the built product has been hurt by the latest round of technological tools." There remains a fear that these software-driven processes can eliminate design creativity and, ultimately, push designers in directions with which they may not feel comfortable.

In truth, AI holds great potential in AEC processes for returning creativity back into the design process. Because computational tools can help automate some of the most routine and monotonous portions of design, they free designers up to focus on more creativity-driven solutions. AI-powered design tools can ultimately support architects in getting closer to their vision and better supporting their aesthetic decisions.

These misconceptions are only part of what has been holding AEC professionals back from using AI-driven technology to its full potential. With a deeper understanding of how AI and machine learning actually works, architects may find there are no longer any barriers preventing an investment in this powerful technological tool.

CHAPTER 2

Understanding AI and its Evolution

While it may seem that AI solutions have taken the world by storm, the truth is that this technology has been around for decades—since the 1950s, in fact. Despite that fact, many professionals have only a fuzzy understanding at best of the growth of AI and the technology's real capabilities. It is out of this incomplete understanding of the growth of AI that the misconceptions outlined in Chapter 1 have emerged.

The definition of AI moves with the current state of technology and the acceptance of that technology into the mainstream.

Below we'll dive into an explanation of how AI has evolved and our current understanding of the promise it offers. By understanding these terms, architects can gain a stronger grasp of how AI-related programming can help their practice.

The Definition of AI

One reason for the confusion behind AI comes from the fact that, since the term's introduction in the late 1950s, our understanding of AI has continuously evolved. Its capabilities have progressed with improvements in computing power that enable the development of more, and more robust, applications. As a specific AI technology becomes more widely adopted, its position within the realm of AI science becomes diminished until it is no longer considered an "advanced" technology or part of the field of AI. Take, for example, optical character recognition and automatic speech recognition technology. Not long ago, reading and interpreting written text was considered the exclusive purview of the human mind. The same goes for a computer listening to speech and interpreting instructions. Today, however, these applications are so commonplace they are no longer considered an AI technology. The definition of AI moves with the current state of technology and the acceptance of that technology into the mainstream.

The computer science definition of AI, according to Gartner, is an application of "advanced analysis and logic-based techniques, including machine learning, to interpret events, support and automate decisions, and take action." As mentioned previously, the goal of this analysis is not to replicate the human mind, but to apply advanced computer science techniques to solve problems that would have previously required human intervention, or been considered impossible to solve.

The growth of AI today is due largely to major advances in computing power combined with reductions in the cost of applying this technology. Dramatic improvements in the computational speed of graphics processing units (GPUs) have fueled much of today's rapid advances in AI. The result is the widespread availability of computers with the processing power necessary to make the complex and voluminous calculations that drive AI technologies.

Understanding Machine Learning

Machine learning is a subset of the AI field in computer science, and is perhaps even more misunderstood than AI. Despite the misnomer, machines do not "learn." They are only capable of storing, retrieving and computing datasets.

Machine learning is a term that encompasses predictive analytics and data mining. These systems attempt to extract value by identifying patterns and/or correlations within large data sets (visual or otherwise) that would be impractical to identify using conventional database or computational techniques. Once a pattern or correlation has been identified, human-written algorithms instruct the computer how to react to those conditions and act accordingly.

In practice, this can be as simple as feeding a computer program a large number of images of apples until the point that the computer can identify apples on its own from a large data set of images of other objects that may or may not include apples. Unless instructed by the human software developer, the computer doesn't know what an apple is or what use it may have. It simply knows what patterns within an image represent a high probability that an object is an "apple." The human programs the computer what to do with the result this is an "apple."

While this is a simplistic example of machine learning, it is representative of more complex applications, including facial recognition software and autonomous vehicles. Unless the software developer tells the machine what to do when it recognizes a pattern, it will continue to do what it has been instructed to do in the past, right or wrong, with respect to the desired outcome. It will not change and do something different on its own to see what would happen if it did, and therefore "learn" from its experience.

The Promise of Neural Networks

Neural networks show useful promise in the growth of AI and machine learning. However, this term is also often misunderstood. That’s because an artificial neural network is simply a computing system programmed within a powerful computer in an organizational structure inspired by the function of the biological networks of the human brain.

While artificial neural networks are loosely based on the processing “technology” of the human brain, they are not attempting to replicate the 86 billion neurons with more than 1,000 input connections to each human neuron. Nor do they issue a single pulsed output based on the summation of their inputs, as occurs in a biological neural network like your brain.

The “neurons” that make up the artificial neural network are mathematical functions residing on a computer. These neurons receive one or more inputs and sum them together to produce an output. There can be multiple inputs with varying “weights.” The summing function (algorithm) is typically not a linear function, but can take on many different forms specific to the type of processing desired. These individual computational modules are connected with one another through software to process logic sequences on multiple paths to a solution.

The largest artificial neural network created to date has about 16 million “neuron” computational modules. Built on one of the largest supercomputers in the world, the computational power of this artificial neural network has been compared to the complexity of a frog’s brain. The largest neural networks presently capable of being operated on a powerful desktop computer would constitute only about 100,000 artificial “neurons” and it would take weeks for even a simple function to be “trained” on it.

Neural networks have a long way to go before they will be able to handle even the most basic of AI tasks. Even then, those tasks must be established by human software developers, not by the computer itself. In fact, human software developers play a critical role in creating the parameters that guide each of these functions.

While there are certain tasks that are likely to be more effectively done by machines in the future, offloading these types of calculations will help people to better perform more value-added tasks. Some of this is already taking place today, as we’ll describe in the next chapter.

CHAPTER 3

How AI is Reimagining Industries Today

Despite the misconceptions around AI, there are ample examples of AI's capabilities in supporting critical industries. AI is already being used today to improve productivity, accuracy, and reduce conflicts across a wide range of sectors. Exploring these applications of AI is a valuable form of exploration that can help AEC design teams find inspiration in the ways that other industries have tackled similar challenges.

Understanding the application of AI in other industries can help architects better imagine how AI adoption could change the traditional architectural design process.

AI in Medical Applications

The medical industry has embraced the application of AI, as it has dramatic capabilities to strengthen decision-making that holds life-or-death consequences. AI solutions have a proven ability to support physicians with diagnosing diseases, helping provide earlier detection of diseases and improving workflows so that physicians can better prioritize care for the most acute conditions.

For example, Seoul National University Hospital and College of Medicine developed an AI algorithm called DLAD (Deep Learning based Automatic Detection) to analyze chest radiographs and detect abnormal cell growth, such as potential cancers. The algorithm's performance was compared to multiple physician's detection abilities on the same images and outperformed 17 of 18 doctors.

Google AI Healthcare has also created a powerful AI algorithm. In an early use case, LYNA (Lymph Node Assistant) was used to analyze tissue samples and identify metastatic breast cancer tumors from lymph node biopsies. The algorithm could identify in the biopsy samples suspicious regions that were undistinguishable to the human eye. On two datasets, LYNA was shown to accurately classify a sample as cancerous or noncancerous 99% of the time. When given to doctors to use in conjunction with their typical analysis of stained tissue samples, LYNA halved the average slide review time.

These examples of AI in action are a clear demonstration of the value of AI holds in reducing errors that humans might otherwise overlook, as well as improving process efficiency.

Application of AI in Business

AI is widely used in a vast array of business applications to streamline operations, boost efficiency and improve customer service. For example, AI-supported chatbots have become ubiquitous for streamlining communication and improving customer service. AI is also helping to develop and execute marketing strategies. Its analysis provides the power behind advertising campaigns that target ads to consumers based on patterns identified through online browsing.

These tools have promise in the AEC industries as well, where they can help streamline communication among partners, and identify market trends or client interests that match architects' target projects.

> **AI is in action in a broader variety of applications than many people may realize.**

AI is also being used in finance, where it has compelling safety and security benefits. Financial institutions use AI-driven tools to detect illicit activity early on, preventing application and credit fraud. Algorithms are also being used to look for connections between applications for credit cards and loan applications, thereby monitoring newly opened accounts to prevent financial damage before it occurs. AI is also a powerful tool in sifting through vast amounts of worldwide transactional data to identify and vet out money laundering schemes and the illicit flow of funds between financial institutions and countries.

AI in Robotics Applications

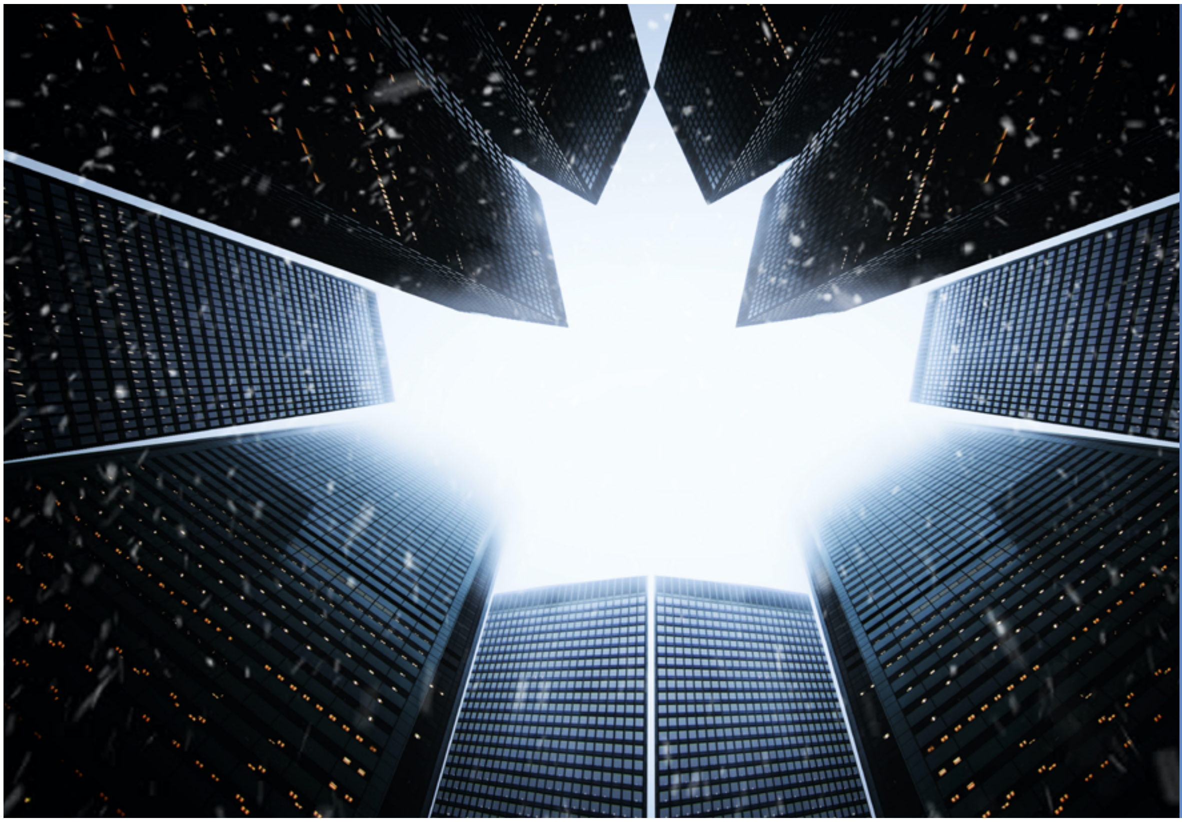
As one example, the autonomous vehicles being tested today are nothing more than highly skilled robots. These AI-based tools operate a vehicle based on data inputs from multiple sensors and billions of computations to determine what actions should be taken based on the algorithms embedded in them by a human software developer. The vehicle's control unit is basing its "decisions" on gathered data and the algorithms that humans have provided to it in order to react to ever changing driving conditions. However, the vehicle is not "learning" how to drive based on experience, as a human would. It is simply repeating what it has been instructed to do and will continue to do so until instructed otherwise by the human software developer.

AI solutions are also well known for providing automation solutions in manufacturing and product distribution to prevent worker injury from repetitive or dangerous tasks. Robots are taking on tasks such as welding, parts assembly, raw material handling, and product packaging. Autonomous robots are also improving the speed and accuracy of routine operations in warehousing. Amazon has more than 200,000 robots deployed across its warehouse network to support package retrieval, allowing workers who once had to walk up to ten miles each day to retrieve goods to instead stand in place and sort robot-delivered materials.

Promise for Future Applications

AI is in action in a broader variety of applications than many people may realize. The results it is driving across other industries demonstrates just some of the promise AI holds for helping AEC professionals address their unique challenges, as we'll see in Chapter 4.

It is important to recognize that AI is still relatively new technology, and there is no set path on how to best apply these tools in support of human operators. As adoption of AI-driven solutions increases across a broader range of industries, professionals will be able to better tailor solutions that meet their needs and better harness the creativity of the human mind using the calculation capacity of AI technologies.



CHAPTER 4

Applying AI to Architecture’s Leading Challenges

The architectural industry is being pushed to solve new challenges in a rapidly transforming world. AI’s application in architecture may provide designers with the support they need to meet these challenges. AI technology solutions can add greater value to the architect’s service to clients and the environments in which their projects will operate.

Below we outline for examples of how AI-driven technology solutions can address AEC industry challenges.

Cost and Schedule Overruns

Schedule overruns, and the additional costs they drive, remain a major problem for the vast majority of construction projects. Data from global consultant KPMG indicates that, from 2012 through 2015, only 25% of projects came within 10% of their original deadlines and only 31% of all projects came within 10% of their budget.

Through more precise calculations and, in many cases, clash detection capabilities, the use of AI-supported software in architecture can help reduce the risk of rework in the field. As a result, architects find there is less chance of cost and schedule overruns in the long term.

AI-driven design in architecture can also lead to more efficient solutions by identifying opportunities to use less material, therefore reducing overall costs. For example, MEP systems carry a considerable share of overall project costs. AI-powered MEP design tools can help reduce those costs significantly. By working through all potential layouts, AI solutions can determine the shortest, most direct solution—using the least amount of costly pipe, wiring or ductwork—that also best meets a project’s specific design requirements. This cost optimization capability is unique to AI-powered design tools.

Construction Waste

The Environmental Protection Agency estimates that construction and demolition activities generated roughly 600 million tons of debris in 2018. This waste is felt in the energy-intensive production of excess building materials and in landfills throughout the nation. And it's a problem that's getting worse. If not addressed, Transparency Market Research projects that the volume of construction waste generated worldwide each year will reach 2.2 billion tons by the year 2025.

AI can help. At the onset of design, more precise and efficient AI-driven design solutions can reduce the risk of error and resulting rework. As a result, architects can bring less material onto the jobsite and reduce the percentage of waste generated.

AI is also being deployed at end-of-life solutions. HISER (Holistic Innovative Solutions for an Efficient Recycling) is a project driven by companies and research centers across the European Union to optimize construction waste recycling. By applying AI technology, the team is looking to automate certain steps of material recovery for more efficient reuse and recycling of waste materials.

Labor Shortages

In addition to reducing material waste, AI may be able to help people move more efficiently on construction sites. Given that this industry has long faced a skilled labor shortage, this is a solution that could help organizations more efficiently deploy skilled and unskilled labor as well.

Construction companies can harness AI to better plan for labor distribution across multiple jobsites and meet a range of complex scheduling priorities. These AI-driven tools can be used to continually evaluate job progress and identify patterns in worker location that enable human managers to tell at a glance which jobsites have enough workers to complete the project on schedule, and which might be better served with additional labor.

Climate Change

While the challenges noted above are industry-specific pain points, the architectural industry has also been given ever-increasing responsibility for helping solve some of the biggest challenges of our time. Due to the fact that buildings are among the largest contributors to the carbon emissions driving climate change, architects worldwide have made strong commitments to lowering the carbon footprint of current and future building stock.

Studies have found that energy efficiency measures alone can produce nearly half of the greenhouse gas emissions reductions needed to achieve 2050 climate change goals. However, better design is the single most effective strategy for reducing a building's carbon footprint. AI tools will prove invaluable in driving more environmentally friendly design decisions.

To build upon the example noted above, more direct MEP layouts use less material, which means less embodied and operational carbon over the life of the building. Architecture 2030 reports that embodied carbon will be responsible for nearly half of the total new construction emissions between now and 2050, unless more efficient design solutions can reduce a building’s embodied carbon footprint.

What’s more, more direct wiring, piping and ductwork layouts radiate less energy, requiring less air-conditioning to offset the heat generated. These optimized systems also result in lower electrical voltage drops. Through improvements in MEP distribution system design, buildings can reduce the energy consumption of these systems by as much as 20% to 30%.

AI can help architects move forward in identifying new opportunities for reducing carbon emissions. As Climate Change AI notes, the next step toward making buildings more energy-efficient will require a greater understanding of the growing levels of data produced by meters and home energy monitors. Machine learning can be applied to better evaluate the effectiveness of combined energy efficiency measures, better automate the usage of energy-intensive systems, and in the development of better low-carbon urban planning.

CHAPTER 5

How AI Can Shape the Future of Architecture

As mentioned in Chapter 3, the greatest inspiration for industry improvement often comes from watching other industries work through transformation. The use cases in Chapter 4 suggest ways architects could adopt AI solutions to address their unique challenges. Opportunities exist in many areas of the AEC industry, ranging from automated design tools to clash resolution systems, and extending on to the construction site in terms of automated labor, inspections and quality control.

These opportunities aren't just theory. A few leading AEC firms are already exploring AI's potential for shaping the future of architecture.

AEC-specific AI Solutions

While it is a fairly basic application of AI technology, some project scheduling programs can be considered AI applications. When the user provides input and sets up the appropriate parameters, the computer creates a myriad of alternative schedule opportunities from which project partners can select the schedule that is either faster, cheaper, or otherwise meets project goals. However, this is just the tip of the iceberg in terms of reaping the full benefits of AI solutions.

Other AI applications have been developed which are designed to automate decision-making with respect to workflow, space planning and even optimization of residential unit mixes in order to maximum the return potential of buildings still in the preliminary design stages. These applications employ sophisticated algorithms intended to study alternative solutions that would be impossible for a human to complete in any reasonable period of time. The computer assists the architect or planner in making better decisions through the use of computational power that did not exist a few short years ago.

Another possibility lies in optimized routing, a very complex subject in computer science. The idea is to use computer optimization tools to identify the best possible route for materials, a route that accounts for all relevant factors, including cost, energy consumption, environmental impacts, installation obstructions, other systems, and so on.

This type of problem is not solvable by a human mind in any reasonable period of time, as the number of variables is astronomical, even on a small building. Using AI technology, however, computers can be taught how to find the most likely solutions and test those solutions to determine which one is most adept at meeting all design goals. For example, through advanced optimization routines, AI for MEP software can identify an optimal route, which meets all constraints, within a very reasonable period of time. This type of technology will likely see even greater use in the future of architecture.

AI Construction Solutions

Robotics are finding unique niches across a wide range of construction subsets. These AI-supported robotic solutions are being deployed to handle some of the most repetitive and dangerous construction jobs, hinting at what's possible in the future of architecture. Canvas has built an AI-driven robot Wired magazine says is capable of drywalling with nearly as much artistry as a human worker. The startup Built Robotics has created autonomous construction machinery, including diggers and dozers. The intelligent control system behind the HadrianX bricklaying machine from Australia-based Fastbrick Robotics calculates the necessary materials and movements for bricklaying. This solution is able to build the walls of a house in one day.

As noted by the 2020 Construction Hiring and Business Outlook report from the Associated General Contractors of America, 81% of U.S. construction businesses are having a hard time finding qualified skilled labor to fill open positions, a problem that this report has tracked since 2009. Rather than putting workers out of jobs, as has long been feared, these applications are helping solve some of the labor shortages long plaguing the construction industry.

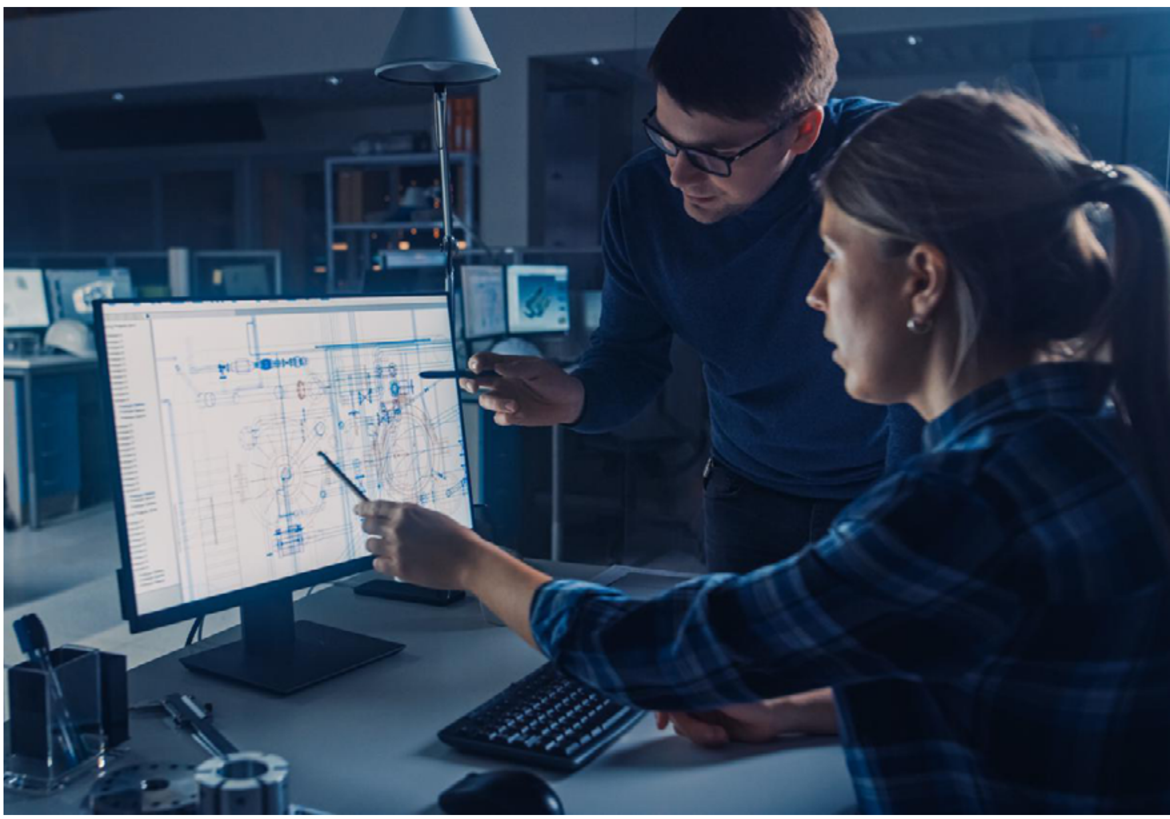
AI Fabrication Solutions

AI solutions are also blurring the boundaries between design and construction for even greater efficiency. DFAB House is the first inhabitable house constructed by robotic solutions. A project the National Centre of Competence in Research (NCCR) Digital Fabrication, which aims to revolutionize architecture through the combination of digital technologies and physical building processes, it demonstrates the efficiency of AI design solutions.

Benjamin Dillenburger, architect and Assistant Professor for Digital Building Technologies at the Institute of Technology in Architecture at ETH Zurich, explains that AI technology helped identify a design that could use the least amount of material possible without losing critical strength. The result was less waste and greater design efficiency. Upon designing the optimal solution, AI-driven tools could then order a robot to move those materials into place, with a construction precision of mere millimeters.

Driving AI Adoption

AI remains a relative novelty in the AEC industry. It is making some inroads in construction where it is able to remove workers from dangerous jobs or replace repetitive tasks. In design, it is already finding optimized solutions for MEP systems. These areas where AI is demonstrating improved accuracy and efficiency present an inkling of what is possible with the support of AI's computational power. Early investment in data-driven technologies and partnerships with industry leaders in AI can help move design and construction possibilities forward faster.



Conclusion

AI technology is still evolving. However, as it becomes more widely used in the AEC industry, early adopters will have a stronger say in the next evolution of this technology. Education about the technology will be a key for combatting the misconceptions surrounding AI that are preventing architecture professionals from better utilizing AI tools. AI is not something to fear. A better understanding of the technology will help architects determine how to best apply it to their own challenges.

Perhaps the best place to begin will be by watching how AI is transforming other industries, providing new levels of efficiency and productivity across manufacturing, business, finance, healthcare, and others. By considering these use cases in connection with the AEC industry's unique challenges, architectural firms can create their own path forward into AI-supported possibilities.

AI is beginning to see beneficial use cases in the AEC industry, but it still has a long way to go to become widespread. Even the smallest architectural firms can secure these benefits by working with a partner experienced in AI-driven design. By adopting AI solutions today, architectural firms can begin to gain a productivity and efficiency edge that can set their work apart and win more projects in the future.

History

When Schnackel Engineers first began working in CAD, there were none of the symbol libraries, layering systems and line type standards that are commonplace today. The firm had to develop its own symbol libraries and drafting standards to streamline design work. Later, as commercial CAD software packages advanced, our company moved to writing macros and scripts that could automate certain basic drafting functions. Since that time, technology has advanced rapidly.

In the early 2000s, AutoCAD released the structure of its CAD database and provided a programming interface to allow external programming languages to manipulate the CAD database. This opened the door to performing engineering calculations and other functions in any software programming language desired, allowing manipulation of the objects in the CAD database directly. Schnackel Engineers jumped on this opportunity and began the process of teaching the computer how to do the engineering and routing calculations for MEP systems. With this, the final D—Design—could be added to the CADD acronym.

Today, Schnackel Engineers' AI-powered computational MEP design software is able to test all viable design solutions in a quest to determine which solution best meets all of a project's specified requirements at the minimum cost and least environmental impact. This evolution in MEP design processes is where we see the industry headed.