How Artificial Intelligence is Transforming the Construction Industry: Past, Present and

<u>Future</u>

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Abstract

The construction industry is facing many challenges such as labor shortages, delays, and inefficient communications. Utilizing Artificial Intelligence (AI) through data analysis, predictive analytics, and machine learning helps address some of these challenges. This paper covers AI's evolution and its current applications in areas of construction such as scheduling, estimating, contract administration, and site safety, showcasing benefits and highlighting some of the challenges. The author also examines potential AI applications over the next five years based on the current trends to improve construction and ultimately reshape the industry practices through technology's application like autonomous drones, digital twins, and AI-enhanced robotics.

Introduction

The construction industry plays a vital role in shaping the built environment. From residential housing and commercial buildings to large-scale infrastructure projects such as bridges, roads, and dams, construction is an integral part of our daily lives. However, despite its critical importance, the construction industry is currently facing several significant challenges. Labor shortages, worsened by aging workforces' safety issues as construction continues to be one of the most hazardous industries, fluctuating material costs due to supply chain disruptions, inefficient project management practices, and poor communication continually leading to delays and increased costs (Muhammad, A. F., et. al, 2024, Constance, O. N., et. al, 2024). While technologies have been developed that could resolve many of these problems, the construction industry has historically been slow to adopt new technology and practices, often lagging behind other sectors (Aletha Marie, Blayse, et. al, 2004). This slow adoption of new technologies makes it more difficult for the industry to keep up with its increasing challenges and growing demands as construction projects become ever more complex.

Artificial Intelligence (AI) and its Origin

To address these challenges, advanced technologies have been developed, one of the most promising being artificial intelligence (AI). In recent years, AI has had profound impacts across many industries such as healthcare, agriculture, finance, education, transportation, and manufacturing, as it provides smarter, more efficient ways to solve problems. Contrary to popular belief, AI was developed decades ago and has gone through great change to evolve into the incredible tool it is today. In the 1950s, researchers Alan Turing and John McCarthy experimented with the idea of machines being able to replicate human intelligence and make decisions. In its simplest form, AI is the ability of machines to perform tasks that typically

require human intelligence. AI works by analyzing large amounts of data to learn patterns and make decisions just like a human would (Rashid, A.B. & Kausik. A. K., 2024).

How AI is Currently Being Implemented in Construction

The construction industry generates vast amounts of data every day, from cost estimates and project schedules to site conditions, safety reports, and material usage. However, much of this data often is underutilized because it is difficult for humans to process and analyze huge amounts of information effectively and in a timely fashion (Buchner, S., 2024). AI can analyze all this data and give intelligent, human-like insights that project teams can use to increase efficiency and address challenges. In construction, AI has been used for project scheduling, cost estimating, site safety, automating contract review, and to address labor shortages (Nwankwo, C. O., et. al, 2024).

Project Scheduling

In construction, project schedules are a critical control tool that helps project teams manage time and cost in addition to clearly communicating a timeline with stakeholders. Professionals base schedules on past projects and data, which makes construction scheduling the perfect task for AI to accomplish. Currently, AI is being implemented to optimize project schedules from the initial planning phase and throughout the project's lifecycle. By providing accurate and relevant data to AI software, it is capable of generating schedules that account for many challenges just like a human would, as AI can account for many factors such as historical weather patterns, current lead time on materials, labor shortage information and so on.

AI is being implemented to automatically update the schedule by comparing the baseline against the actual. For example, Gilbane Building Company is currently using a robot through Didge / Nextera. The Didge robot autonomously navigates buildings, traveling up and down stairs to

capture 360-degree photos once per day. The photos are then analyzed to update the percentage of work completed in the schedule, which results in weekly tracking updates. This helps the project team by automatically updating the schedule with no human intervention. Collecting this data and analyzing it through AI software has helped Gilbane understand how to develop project schedules in the future (Gilbane Building Company, 2023).

Cost Estimating

Another area where AI has been implemented is construction cost estimating. Cost estimating often relies on analyzing historical data, something AI excels at (Zainab, H., A., et. al, 2022). Shawmut Design and Construction is currently using an AI software called Trimble Precision IQ for conceptual design cost estimating. Precision IQ works by analyzing cost data from previous projects to create conceptual budgets for future projects. The Trimble AI software considers many factors when making an estimate, such as inflationary indexes to adjust for the time and location of the project (Trimble, 2024). General contractors can quickly produce accurate conceptual cost estimates, helping them win bids.

In addition, AI is being used for quantity takeoffs because it is capable of reading drawings and processing Revit models to pull quantity information from them; this is referred to as 5D BIM (Zainab, H., A., et. al, 2022). Software's such as Autodesk Assemble analyze 3D Revit models and can instantly pull accurate quantity information from them, saving countless hours (Assemble Systems, 2024). Additionally, when changes in design are made, the model can be updated, and an instant cost estimate update can be provided to the owner, which is critical.

Site Safety and Hazard Identification

AI is transforming construction site safety by upgrading traditional security systems with realtime data analysis to proactively detect and report safety issues. Leading construction companies

are implementing this technology to enhance safety and efficiency on their job sites. One company, EarthCam, offers advanced AI monitoring technology that is already seamlessly integrated with project management platforms like Procore and CMiC. These AI-powered systems are trained on thousands of images using computer vision and machine learning technology, enabling them to interpret and analyze what they see on-site. This allows the AI software to examine site footage in real-time, detecting safety hazards as they occur, such as workers working too close to heavy equipment, or identifying potential fall hazards. Additionally, the technology monitors compliance with personal protective equipment (PPE), automatically generating safety reports in Procore when it detects workers not wearing their proper PPE (EarthCam, 2024).

Contract Review

Contract review is another area where AI is being used in the industry. Given the large volume of contracts involved in construction, each document must be thoroughly reviewed to ensure compliance with company policies and owner requirements. This labor-intensive task can now be streamlined with AI software, which quickly analyzes lengthy contracts and highlights specific language that may be of concern to the team.

For example, Bond and Commodore Builders use an AI-powered software called Document Crunch to simplify the contract evaluation process. Document Crunch assists project managers by analyzing new contracts and identifying terms and clauses that deviate from the company standards and policies. This AI software has been trained on historical contract data, which allows it to flag problematic language based on issues in past agreements, and at the same time, it allows stakeholders to reference their contracts more easily when disputes arise (Document Crunch, 2024).

Project Management

Another AI technology being used in the industry is Procore's "Co-Pilot" AI feature, designed to improve information retrieval. Many companies utilize Procore to manage project documents such as drawings, specifications, submittals, RFIs, and daily reports. By centralizing all project information in one platform, Procore's AI Co-Pilot can analyze and retrieve specific details within those documents in a matter of seconds which significantly reduces the time and effort involved in manually searching through project documents (Procore Technologies, 2024). For example, if a team member needs to determine the exact location of a piece of HVAC equipment on-site, Co-Pilot can sift through all the project data to provide an answer that shows exactly where it got its information from to verify its findings.

Addressing Labor Shortage

AI-driven robotics in construction are changing the industry by taking on tasks previously performed by human labor, particularly in areas of intense physical demand. Advanced AI robotics can now perform activities like bricklaying, plastering, and even large-scale 3D printing of buildings (Muhammad, A. F., et. al, 2024). For example, an Australian company called FBR has created a robotic CMU block laying machine that assembles structures from 3D CAD models. The FBR truck has a large material handler that autonomously places CMU block and grout efficiently and completely by itself. Major US home builder Pulte Group has signed a Master Trade Contractor Agreement with FBR as this AI technology is helping address the labor shortage in construction (FBR, 2024).

Potential Challenges to AI Application in Construction

While there are many benefits of using AI in construction, it is important to consider the challenges that it also presents in construction, particularly in areas such as job displacement, data security, legal implications, resistance to change, and environmental issues.

Replacing Humans

AI is currently augmenting human workforces, but the technology has the potential to replace skilled labor, creating a problem known as machine substitution. For example, the FBR robotic CMU block-laying machine can perform the work of a full crew of masons all by itself with minimal human interaction (FBR, 2024). This is great considering the current labor shortage in the skilled trades, but it raises concerns about job displacement and may even discourage people from going into these trades. Labor Unions across the country will be opposed to such implementation as it will be taking away their members' jobs (Xinyao, M., et. Al, 2022).

Data Security

AI software relies heavily on data which often contains confidential information such as contracts, plans, specifications, costs, schedules, and correspondence (Rashid, A.B. & Kausik. A. K., 2024). In the event a data breach occurs, all the sensitive and confidential information could be exposed online, leading to costly lawsuits and reputational damage to the company. For example, Bouygues Construction had a ransomware attack in 2020 where 200GB of its data was stolen, forcing the company to shut down key operational systems. This data breach hurt the company by causing project delays and imposing significant financial burdens and risks, highlighting the serious effects of data breaches (Jennifer, A, B., and Parziale, D. J., 2021).

Legal Concerns

AI in construction also presents various legal concerns, including liability for decision-making errors and data privacy issues. For instance, AI systems are not always accurate and can make errors also known as "hallucinations," which raises the question about who is liable if a project is delayed or compromised due to an AI-generated recommendation (Constance, O., N., et. al, 2024). AI mistakes can often fall into a gray area between the software provider and the user. Additionally, AI-powered surveillance tools like EarthCam raise privacy concerns, capturing and processing images of sites and workers for safety monitoring and progress tracking. These systems store photo data to train AI models, posing risks around data ownership and employee consent (Vishnu, S., P., and Matus, K., J., 2020).

Humans Resisting to Changes

As mentioned earlier, the construction industry has traditionally been slow to adopt new technologies and practices, often lagging behind other sectors (Aletha, M., B., et. al, 2004). Construction tends to rely on familiar methods because they are more predictable and oppose newer approaches. While change, especially in technology, is meant to make processes more efficient, it is often challenging to implement and get it right the first time (Rashid, A.B. & Kausik. A. K., 2024).

Energy Usage / Environmental

The final concern regarding AI is its environmental impact. Although AI is software-based, it has a substantial environmental footprint due to the extensive energy and computing power required to process massive datasets. For example, AI-powered analysis can use up to ten times the electricity of a typical Google search, creating questions about the long-term sustainability of these technologies (Goldman Sachs Research, 2024). As society transitions toward greener

practices and electric power becomes more in demand, AI's energy needs could strain resources even further.

How AI Will Change the Industry In The Next 5 Years

Although AI presents challenges, the author believes its potential for the construction industry is vast and transformative. In the coming years, AI will be implemented more widely throughout the industry in a primarily supportive role to humans. Tools like Procore's Co-Pilot are likely to be adopted on a broader scale allowing for quicker information retrieval and better decision-making. AI will become an essential tool and work alongside humans for a more efficient and safer construction industry.

Additionally, AI robotics will play a crucial role in filling gaps caused by the current labor shortages. However, the complexity required for robots to adapt to unique job sites presents challenges. Significant advancements are expected in the next five years, but broader implementation may take longer. The author expects AI-powered autonomous drones to become common within the next five years. With advanced technology already available, these drones can easily navigate buildings, capturing photos and videos for AI analysis to generate project insights. Unlike ground-based robots, drones are highly maneuverable and unobtrusive, making them ideal for tracking project progress, ensuring safety and site security. AI-powered drones will become a permanent staple in the industry in years to come.

Furthermore, AI's integration with digital twin technology will revolutionize how we manage and operate complex building systems. Digital twins are online models that replicate a physical building to monitor energy usage. AI will analyze patterns in lighting, heating, and other building needs to optimize energy usage. As digital twins become more common, AI will make

buildings smarter and more efficient, improving long term sustainability of our built environment.

Conclusion

While AI does have its challenges, it will reshape construction practices and will be an essential tool in the way we conduct business. Those who embrace AI will gain a competitive edge as this technology continues to develop and transform the industry. We are at the beginning of a new era in technology, where AI will drive our industry forward, making us more efficient and changing the way we design, build, and manage our built environment.

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