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Demystifying Artificial Intelligence (AI) in Construction

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There have been four major revolutions in human society to date. The cognitive revolution was first and is best exemplified by the development of language. The agricultural revolution was second, bringing about the transition from hunter-gatherers to farmers and the advent of centralized government, empires and writing. The third was the industrial revolution, which gave rise to the development of urban manufacturing societies, European colonization and international trade. The fourth was the technological revolution, encompassing such innovations as the introduction of modern computers, global communications and the internet. We are rapidly entering a fifth major revolution with the increasing use of artificial intelligence to undertake tasks that were previously only performed by humans or which could only ever have been accomplished by AI.

To quote Graeme Wood: "The pace of change has never been this fast, yet it will never be this slow again." As developments and advancements in technology, and more specifically, in AI, come at a faster and faster pace, it is important for the construction industry to be aware of the current trends and the potential future uses of AI in order to benefit from them and manage the challenges that they may bring. This article provides an overview of AI's current and future role in the construction industry.

Artificial Intelligence: What It Is and *What It Is Not*

AI is a misunderstood and often misused term. For the purposes of this article, we must first clarify what it is, but, more importantly, *what it is not*. The first person to define AI was British computer pioneer Alan Turing in the 1950s. He stated that AI exists when a person who has asked wide-ranging questions to both another person and a computer is subsequently unable to distinguish which answers were from the person. This is the famous Turing test. For AI to pass the Turing test, human-like intelligence must have occurred. It is commonly accepted that AI will ultimately

reach this stage of sophistication, but it is not there yet.

In order to examine AI as it is currently employed in the construction industry, however, a different definition of AI is required. In this report, AI will therefore be understood as an entity that "perceives its environment and can use data from this perception to better accomplish its goals."

There have been many recent technological developments which, while very useful, are not strictly AI. For example, basic Building Information Modelling ("BIM"), 3-D and 4-D[1] design, simple manufacturing process robots,[2] Monte Carlo risk simulations and big-data are not AI in and of themselves. However, all of these can be inputs, outputs, or make up part of an AI system.

As an example, a remotely controlled drone that surveys earthworks construction progress and transmits the data in real time back to the project office is not technically AI. However, if it is linked to a computer that analyzes this data (and other data such as current weather conditions, the design, haul route restrictions and the hours worked by each machine and driver) and then provides optimised operating instructions directly to the driver and/or the earthmoving equipment, such a system would be AI by the definition used in this report.

Out of twelve industries assessed by McKinsey & Company in 2018, the construction industry is the slowest at significantly adopting AI.[3] The assumed reason for this is the extreme competitiveness of the construction market, which works against long-term technology investments that impact short-term margins.[4] What is clear is that companies who can achieve better efficiency and predictability in the quality and delivery of their work through the use of AI are likely to have an increased competitive advantage.

As the world's second-largest industry "that is projected to reach $10 trillion by 2020, according to market reports based on data released by the Construction Intelligence Center,"[5] the construction industry is arguably ripe for AI-led disruption. Indeed, there is too much money at stake in construction for AI-led savings not to be pursued.

Main Technical Areas of AI Research

Machine Learning

Machine learning tries to execute a task with ever-increasing efficiency by using past data to predict and improve future performance. IBM's Deep Blue computer famously beat chess grand master Gary Kasparov in 1997. However, every second, Deep Blue was merely analyzing all of the millions of possible moves from previous grand masters that its programmers had already fed it. Hence, it was not really AI. In December 2017, Google proved that it was possible for AI to learn from rules and develop an expertise equal to or greater than that possessed by a human expert. Google's AlphaZero algorithm was given the core rules of chess, but with *no historical information from real games*. In four hours, it taught itself how to play by the given rules and then it conclusively beat the world's most advanced chess program. Imagine how AI might contribute to improving construction if we were to find an effective way to give it the "rules"[6] of the industry!

The construction industry generates a lot of data. The practice of systematically "mining" this data[7] for machine learning to improve the predictability of construction project outcomes will accelerate in the next few years. Machine learning has been the single biggest leap forward in AI in the last decade.

Natural Language Processing

Natural language processing aims to enable machines to understand, respond intelligibly and take appropriate actions in response to the written and/or spoken word. Chatbots are increasingly used to perform customer service functions such as answering questions from consumers. Siri, Google Home and Alexa are all versions of chatbots. Although they are not currently seen on construction sites, one can nevertheless imagine that very soon, we will see construction-related versions of these chatbots in every project manager's office. Such a unit could be asked about, and give instantaneous and accurate updates on, key project performance metrics such as safety, productivity, status of procured items, changes and schedule slippage. All that would be needed for this imagined unit to be able to make sense of the changes on a project and determine the optimal solutions to them is for it to be granted access to real-time project information and to have machine learning capabilities. Natural language processing is likely to be a big part of future AI-driven project administration and management.

Robotics

Robots are mechanical devices that can undertake physical tasks: these being tasks previously done by a person, or tasks that could never have been performed by a person. Robots are not AI unless they can make sense of changes in their operating environment and respond accordingly.[8] Currently, robots are rarely found on construction sites[9] because of the difficulties involved in making them efficient in a work environment that is constantly changing and is thus very different from, for example, a production line in a factory. However, once robots are advanced enough to deal with the ever-changing conditions on a construction project, their use will rapidly accelerate because they will then be able to relocate themselves as needed on the project

site, work in very poor weather conditions, never cut corners, work longer hours and have higher productivity.

Optical Recognition

Optical recognition refers to an AI's capability to recognize, understand and communicate what it is looking at in picture and/or video format. There is currently AI technology that can discern different types of construction equipment, not unlike other such technology that can identify individual people using facial recognition.[10] Such AI has the ability to automatically record who is doing what, where, when, and with what equipment. It is likely that AI solutions for such monitoring will soon be both more accurate and more cost-efficient than using people. Optical recognition could then be used to measure progress of work on most large projects. This will likely take longer to do accurately for certain trades, such as mechanical and electrical.[11]

One quickly developing AI-based system uses rovers and drones to capture progress on a construction site in full 3-D. It then compares its surveys in real time with the design (digital model), budget and schedule. This system can also detect errors in ongoing construction by recognizing differences between its visual data and the digital model data of the project.

We can already see the main technical areas of AI research, or the potential for these developments, emerging in the different phases of construction.

AI in the Pre-Construction Phase

Design

Design is a creative human process. Additionally, it is also based upon a design team's members' previous experiences. AI provides an opportunity for design teams to utilize an infinitely larger data set than the sum of their collective personal experiences. For example, a team of five designers may collectively have experience from fifty different projects, whereas AI could "mine" the experience from tens of thousands of projects.[12] More importantly, machine learning allows AI to learn from this data set and make predictions without human intervention.[13] This will eventually make design more efficient as we will learn better from previous mistakes. This will in turn make the cost of project execution[14] more predictable.[15] This increased predictability would allow companies utilizing this capability to lower their risk allowances based not only on their combined experience, but also on thousands of man-years of experience from similar projects, thus allowing them to win more work.

The American Institute of Architects (AIA) has expressed interesting views about AI in design, noting that "[a]rchitects should see artificial intelligence as an opportunity—a tool to augment practice, replacing mundane tasks—not as a threat to their jobs" and that "[a]rchitecture firms should seek to acquire data from owners, other firms, contractors, and software companies—and share theirs in return. This would create an industry-wide information loop that may redefine practice methods and drive profits."[16] Furthermore, there is software available that allows industrial designers to define engineering problems and then provides computer-generated design solutions to these problems.[17] The next development of this technology is likely to be for civil and building engineering.

Cost Estimating

Accurate cost estimating is extremely difficult. It requires, among other things, the assessment of labour, equipment and material costs, as well as the assessment of risk contingency. Critically, all of these assessments must be made by considering the *unique* project environment. The conditions that make every project different might include: working hour restrictions, access restrictions, safety requirements, local availability of labour/equipment/materials, local permit requirements and laws, predicted weather and owner's style of contract administration. There is no question that, in a reproducible environment, AI could be used to calculate quantities, costs and risks based upon standard formulas and methodologies. However, adjusting all of this for a unique project environment is an extremely complex cognitive function driven by both experience and creativity.[18] Relying solely on AI for business-critical cost estimates is unlikely to occur in the foreseeable future, except in situations where project environment factors are negligible.[19]

Scheduling

As with cost estimating, scheduling must also address project environment factors, but generally to a lesser degree of rigour and uncertainty. Scheduling of course, can also use float as a "solution" to uncertainty.

Most construction projects in Canada are scheduled using either Microsoft Project or Oracle's Primavera P6. Schedules are project-critical for both the contractor and the owner as they are used to aid in estimating project cost and defining cash flow requirements. They also typically define the project financing and contingency required. The quality of these schedules is directly linked to the quality of the input data received. Usually, the input data comes from a single person, or, at the most, from a very small group of people. This input data is based upon, and limited by, what this person or group has experienced in their career, perhaps 15 to 20 projects for a senior scheduler. However, AI can facilitate the production of better quality schedules, as machine

learning enables it to access and select input data from thousands of similar projects. The key to this technology is finding a way to efficiently give AI access to the knowledge from many previous projects. In other words, it needs "big data".

One innovative scheduling tool[20] is designed to accept data *directly* from both BIM models and from people, which it then analyzes in order to find the optimum scheduling solution for a given project, including accurate resource optimization. This product is being actively tested in the UK, Asia, the Middle East and the United States, but has not yet been tested in Canada. This tool can produce multiple schedule options based upon different input variations such as crew size, access locations, working hours and construction methodology. The makers of this product promote that it significantly reduces the man hours required to produce credible schedules and believe that the investment required (0.1% of project value) can generate substantive bottom-line savings[21] (6–10% of construction cost). Similarly, Oracle is currently looking at opportunities for deploying AI with Primavera, the construction industry's most common scheduling platform.

AI-driven project scheduling is likely to become widespread over the next 10 years. Experienced schedulers will still be required, but their skill set will need to encompass the data needs of the incoming AI scheduling tools.

AI in the Construction Phase

Safety

There is a huge opportunity for AI to improve safety on projects because most human health metrics can be easily measured, for example heart rate, breathing rate, core body temperature and the wearing of personal protective equipment ("PPE"). Until now, compliance with site safety rules, such as PPE and housekeeping requirements, has typically been monitored by supervisors and safety officers. However, their attention can be limited to what they can see and by their ever-shifting job priorities. Conversely, AI can rapidly and continuously analyze site safety for instances of non-compliance with rules and/or signs of worker health distress. It could then take appropriate measures, ranging from issuing alarms and warnings to preventing equipment from being used until the safety issue is rectified. Some products currently in use[22] are able to predict, with 80% accuracy, one in every five safety violations.[23]

In this respect, AI works by being fed thousands of images of unsafe situations on a construction site, as determined by health and safety inspectors. It then uses machine learning to teach itself what to look for and when to send alarm notifications.

Health and safety data can be collected from smart wearable clothing, sensors in the workplace environment or in construction equipment, as well as by the use of smart video. This technology is already in use by some contractors. Smart video is particularly interesting, as with advanced facial recognition, an AI system could even determine whether or not the worker who has just picked up a piece of equipment actually has the training and/or license to use it.

Progress Monitoring

The typical approach to progress monitoring and documentation includes preparing field reports that present numerous photographs which are filed by date and discipline. Finding when a specific event occurred requires reading through each report until the event is found. A more sophisticated approach includes manually tagging the images when they are stored for easier retrieval, but this process is time consuming and prone to omission. AI can automatically tag images and narrated videos using object and speech recognition. Combined with autonomous robots fitted with laser scanning, current developments allow AI to measure construction progress and inspect quality, allowing for timely identification of construction errors and up-to-date project completion forecasts.[24]

Physical Construction Activities

AI is currently not used extensively for performing physical construction activities. However, this is likely to change as companies widen their product development into autonomous robots focused on manual tasks.

Some companies are testing 3-D-printing technology that can interpret design information and then optimally place concrete with voids for later rebar installation and subsequent post-tensioning. They also test self-directed drilling robots that could replace humans for the installation of utility fixings on concrete ceilings (with an estimated 250% productivity improvement), and self-directed rebar robots which can interpret design information, bend rebar and then assemble rebar cages.

Self-driving mining trucks are already in use around the world, including in Canada. Further developments in this area might be, among other things, autonomous vehicles, drilling rigs, mobile and tower cranes, forklifts, concrete trucks and pumps.

While this is a realistic possibility, the replacement of trades and labourers through the large-scale use of robots on a construction site may still be a long way off, as functioning autonomously in the ever-changing conditions on construction sites is still a major technical challenge.

Administration and Management

This area is particularly ripe for rapid

disruption by AI in the next decade. Below the middle management level, most decisions made on a construction project are relatively predictable and can be made in accordance with fairly uncomplicated rules and processes. Ordering materials, sending out invoices and payments, performing coordination checks between drawings and specifications, calculating earned value and monthly progress reporting are prime examples of tasks which can be made more efficient using AI.

AI in the Post-Construction Phase

Digital Twins

The data we create and store about a physical asset over its entire life cycle is known as a "digital twin" and can be a rich data source for AI. This area of AI research promises significant benefits to the long-term owners of infrastructure.

The digital twin of an asset can allow us to monitor and improve the asset's performance. Such digital twins need to be predictive and adaptive, meaning that they should be able to reflect changes that occur in the physical environment and then respond to them. Potential benefits include the harmonization of operations to deliver optimal user outcomes, fault/repair identification and automated remediation, and reduced operating cost and risk.

Collecting and managing the necessary data is a big challenge. While most industries analyze little of the data they collect, there is a potential for major savings and operational improvements by doing so. For context, Google has stated that it has realized savings of 40% on its data centres by applying AI to analyze the operational metrics of these facilities.

Claims and Disputes

Claims and disputes are primarily concerned with proving cause and effect for delay and disruption on site in order to justify extra time and/or money and showing that entitlement exists for such claims. Proving cause and effect usually requires the examination and analysis of very large amounts of data, including requests for information, change directives, change orders, notifications, meeting minutes, schedules, re-issued drawings, stop-work notices and non-conformance reports. In the future, such records are likely to be stored more intelligently and comprehensively, and, hence, to be available for analysis by AI in real time during a project. While the need for seasoned claims experts and lawyers is unlikely to ever disappear, it is easy to imagine that experts in the prosecution and defence of claims will begin using AI as a tool sometime in the near future.

The use of AI in law started in the 1980s and has been accelerating ever since. There are many related professional associations around the world, such as the International Association for Artificial Intelligence and Law (IAAIL) and the Association for the Advancement of Artificial Intelligence (AAAI).[25] Both large law firms and private software development companies have been involved in the development of usable AI products.

AI in law is mainly used for e-disclosure, contract analysis,[26] case prediction and document content automation. A lawyer will only be exposed to at most a few thousand cases during his or her professional training and early career. AI allows a legal team to work more efficiently by quickly finding the most relevant cases among hundreds of thousands. This would provide a focused reference source that is beyond the individual case knowledge of the legal team.[27] AI tools can increasingly be used by lawyers to automate and improve their own research,[28] assessments and document processes.[29]

For business owners, the most interesting development of AI in construction law will likely be a holistic enhancement of the business owner-lawyer interface that is bound to improve both the cost and quality of lawyers' services. Such improvements might include faster contract reviews, mostly automated contract preparation (for larger companies), automated management of contract notices and quicker decision-making on cost-recovery strategy based upon better predictions for the likely outcomes of different options available to an owner.[30]

While the use of AI in the construction industry could open up many possibilities for innovation, there remain limitations and challenges which must be considered.

AI's Current Limitations

Data Collection and Quality

First and foremost, AI requires a lot of quality data as input. The maxim of "garbage in, garbage out" applies to AI in the same way it applies to any other system that makes decisions based upon what information is fed into it. Data collection and processing capacity is still a restriction for very large and/or complex AI systems.[31]

Societal Acceptance and Privacy Concerns

Societal acceptance of AI varies widely. Everybody likes to use AI-powered applications such as Facebook, Google Search, Siri and Google Translate. However, many people are also nervous about the loss of control over their personal data. This concern is unlikely to disappear anytime soon.

Human Impact

The biggest constraint on AI will be allowing it to make decisions which impact human lives. Implicitly, we know that such decisions should be based, wholly or partly,

on value judgements. Until recently, AI researchers believed that the most difficult AI challenges were those concerning deliberate complex and logical tasks, such as playing chess. We now know that the most difficult AI challenges are those that rely on emotional intelligence and that involve making value judgements. At the present time, AI cannot reliably do this, but one day, it may be able to do so.[32] The question will then be of knowing whether we will ever be prepared to let it… [33]

Intellectual Property Sharing Protocols

Privacy is a crucial aspect of governance. AI in construction, by implication, must use vast amounts of data and different data will have different privacy requirements. As technology develops, it will be possible for multiple projects to have (similar) designs driven by the same data set—so the need for intellectual property ("IP") sharing protocols is likely to increase. Future projects, and thus future companies, will probably have a bigger need for "data experts" in order to manage *both* the technical nature of the data and also privacy and IP issues.

The collection and sharing of big data for AI on construction projects is not without its challenges. These include issues around common recording platforms, national and provincial data regulations, intellectual property and perceived loss of unique competitive knowledge. That said, some of the larger international companies[34] have already made significant investments into finding ways to use AI and big data to improve their business performance.

Is Canada a Leader or a Follower in AI?

Funding in AI research is led by the United States and China, which is not surprising when we consider that these are the world's two largest economies. However, Canada is also a major international leader in AI research. The federal government invests in AI via Innovation, Science and Economic Development Canada. That ministry funds such programs as the Innovation Supercluster Initiative, through which major companies and academia work together to develop AI supply chains for projects.[35]

Although companies in the Canadian construction industry are not currently large investors in AI compared to their peers in banking, medicine, finance, etc.,[36] they might be in the future, as Canada is one of the places in the world where it is easiest to invest and partner with others in AI. More importantly, the potential AI-led savings are too huge to ignore any longer.

Do You Need an AI Strategy for Your Company?

Ultimately, important business decisions are made by predicting what events might occur based on data that is available for assessment and then applying judgment based upon experience. AI is rapidly improving the prediction of what events may occur and, in an increasing number of instances, it can do so faster and more reliably than humans. However, the application of "seasoned judgement" will remain critical for the foreseeable future.

Clients, designers and contractors will become increasingly dependent on AI, whether we like it or not. Although the construction industry is generally a late adopter of new technology, AI will soon be here in force. Companies involved in construction should ask themselves whether they should take their first tentative steps in developing an AI strategy. Fundamentally, the questions to ask are: (i) do I need to use currently available AI to remain competitive and viable? (ii) should I be an early adopter of new incoming AI to gain a competitive advantage? and (iii) how will the increased use of AI change the people skills needed for my business and how my business functions? There are no universal right or wrong answers to these questions. Each unique business will have different answers.

Larger owners, designers and contractors use substantial amounts of data in the planning and execution of their work. They are all candidates for making use of AI, particularly if they can find a way to collect more and better quality data that would improve their operations. Logically, smaller organizations will eventually make use of AI as well to improve performance based on data. However, the "lag" time for the significant use of AI between the larger and smaller organizations in construction is currently unknowable.[37]

Looking to the Future

Advances in more research-focused non-construction industries are likely to have their developments adopted by the construction industry at some stage. According to McKinsey,[38] this might include the application of transportation planning AI to improve construction planning optimization, the application of drug trial AI to better predict construction risks, the application of retail supply chain AI to improve construction logistics, the application of robotics AI (those that learn from simulation) to create more versatile construction robotics and the adoption of medical imaging AI to better detect construction quality issues.

The biggest challenges in implementing AI for most business leaders will ultimately be political and ethical rather than technical. AI will impact real people and cause significant changes to jobs. Some jobs will be eliminated and new jobs, required for the development and management of the AI replacements, will be created. The acceptance of both job losses and the reality of AI ultimately making important decisions that affect people[39] remain to be

seen on a large scale in any part of the construction industry.

In the course of time, there is likely to be a challenge in training future senior industry leaders, as by definition, many of the simpler professional jobs that they initially train on early in their career might eventually be replaced by AI. Hence, the future career path of industry leaders might be very different from what it is today. Data is increasingly becoming the most important currency and the people and companies best able to assimilate, examine and learn (using AI) from the data will likely prosper the most. There will therefore be an increasing demand for these skills.

For those who are sceptical about how fast the future might change, here are a few sobering thoughts. Twenty-three years ago, we did not use email. Eleven years ago, we did not use smartphones. Eight years ago, in 2011, we did not have iCloud. In less than twenty years, entire industries have been disrupted and transformed, including the music, film, personal computing, photography, retail, telephone and banking industries.

To date, the construction industry has arguably only been moderately impacted by technological advancements, such as the use of iPads on site, remote and laser surveying, basic BIM, 3-D-computer-aided design, virtual reality walk-throughs, smartphones, etc. The big AI-driven changes in the construction industry are yet to arrive, but they are no less imminent.[40] This trend is indeed already noticeable on the job market, as exemplified by a recent summer 2018 job advertisement from a top-five Canadian contractor describing the sought after individual as "Data Scientist: Artificial Intelligence and machine learning Specialist" for their new head office AI group.

As Bob Dylan famously wrote, "the times they are a changing."

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1 3-D design with an added cost or time component.

2 Such as those found on a typical car production line.

3 Jose Luis BLANCO, Steffen FUCHS, Matthew PARSONS, and Maria Joao RIBEIRINHO, "Artificial Intelligence: Construction Technology's Next Frontier" (April 2018), www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/artificial-intelligence-construction-technologys-next-frontier. Accessed Jan. 22, 2019.

4 With the exception of a very small number of large international companies.

5 Andrew RINK, "Artificial Intelligence Advances to Improve Construction," *Engineering News-Record* (September 2018), www.enr.com/articles/42686-artificial-intelligence-advances-to-improve-construction. Accessed Jan. 22, 2019.

6 Such construction industry "rules" are hugely complex due to the infinite range of project environments which can occur.

7 Machine learning is only limited by the amount of quality data available. Hence, in theory it can be applied to planning, design, estimating, scheduling procurement and project management.

8 This area is progressing rapidly from the simple "single-task-orientated" robots used on car production lines.

9 With the exception of mechanized brick-laying and steel-fixing machines and self-driving autonomous mining trucks, of which there are some examples in Canada.

10 Western government anti-terrorism agencies are currently the leaders in this technology.

11 Much of the completed work is often hidden from direct view in comparison with civil and structural engineering, etc.

12 But only once an efficient way is found to assimilate project experiences on a very large scale. A possible way of achieving this might be through replication of the Allen Institute's Project Alexandria. This is based on using crowdsourcing methods to help AI realize "common sense lessons" and thus know what cause-effect relationships to derive from the experiences that it is analyzing.

13 As with the AlphaZero algorithm previously discussed.

14 Cost of execution includes all the extra project costs typically generated by missing design, erroneous design, uncoordinated design, unbuildable design and non-code-compliant design.

15 Better cost predictability will likely eventually lead to lower insurance and bonding costs for projects that use AI.

16 Kathleen M. O'DONNELL, "Embracing Artificial Intelligence in Architecture," *The American Institute of Architecture* (AIA) (March 2, 2018), www.aia.org/articles/178511-embracing-artificial-intelligence-in-archit. Accessed Jan. 22, 2019.

17 This came about through Autodesk's Project Dream Catcher. The software is called "generative design" and is an add-on to Autodesk's Fusion suite.

18 What events or combination of events may occur on the project is part of the estimating process as the estimator must try to ensure that the money available can accommodate them. For example, risk events may be modelled using a Monte Carlo simulation, but currently, human thinking still has to develop the inputs for such modelling.

19 Such as simple projects within factory settings, as opposed to new greenfield or brownfield building and civil engineering construction.

20 Artificial Intelligence in Construction Engineering (ALICE). It should be noted that ALICE does not use critical-path methodology.

21 The authors have not seen any first-hand evidence to corroborate this. Also, the extent to which ALICE uses "real AI" as compared to Monte-Carlo-type probability simulations is unclear to the authors.

22 Skanska Construction is an early adopter of AI site monitoring systems such as Smartvid.io.

23 Smartvid.io overview presentation provided to Revay.

24 One such system is Doxel AI.

25 The 17th joint IAAIL and AAAI conference will be held in Montreal, Canada on June 17-21, 2019

26 Such as Dentons' Nextlaw Labs Brexit project.

27 Theoretically, a legal team could check every existing case that might be relevant, but this is usually not practical.

28 There is increasing evidence that AI technologies can be quicker and more accurate than junior lawyers and paralegals.

29 For example, predictive coding enables users to sample data on a large project to determine what is relevant (i.e. AI enables searching for concepts rather than just for keywords).

30 AI would have a near-limitless access to historical trials which it could assess to increase the quality of lawyers' mediation and/or trial outcome predictions.

31 For example, to utilize machine learning on their big data, most companies would need to go to a specialist external provider such as IBM's Watson Machine Learning (which is a rentable resource specifically designed and marketed for this purpose).

32 When this day arrives, we shall finally have AI which can pass the Turing test.

33 This is currently a hot topic in the arena of driverless cars. If a driverless car ever has to make a choice when there is a technical fault and it has to take action that will result in injury to pedestrians and/or its passengers, how does it make such a choice?

34 These include Jacobs' Connected Enterprise and Autodesks' BIM360 software.

35 SNC, one of Canada's largest contractors, is part of the Innovation Supercluster Initiative.

36 Like SNC, Pomerleau is one of the exceptions. They have appointed a Chief Digital Officer and have stated that they are actively pursuing the collection of big data for use in AI (such as data collection by drones, BIM, mobile devices and sensors on helmets/bracelets/watches).

37 However, small subcontractors' entry into AI will likely be caused by the forced data requirements for AI that they receive from their larger clients.

38 Jose Luis BLANCO, Steffen FUCHS, Matthew PARSONS, and Maria Joao RIBEIRINHO, "Artificial Intelligence: Construction Technology's Next Frontier" (April 2018), https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/artificial-intelligence-construction-technologys-next-frontier. Accessed Jan. 22, 2019.

39 This is a very sensitive topic in the rapidly growing use of AI in medical diagnostics.

40 The larger Canadian contractors all appear to be taking tentative steps into seeing how AI might help improve their businesses. Examples include SNC's Supercluster Initiative and PCL's Smart Building Partnership (with Microsoft) and Smart Construction Technology Challenge.

* Any views expressed in this article are those of the author and may not necessarily reflect the views of the company.

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