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# THE ROLE AND VALUE OF INTEGRATING AI, DRONES AND ASSOCIATE TECHNOLOGIES IN CONSTRUCTION PROJECTS

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**Abstract:** The rationale to integrate and apply drone technology may differ pending on the industry sector, As a tool that improves communication, safety, and marketing, the use of drones in construction provides many advantages including increased productivity. For decades, the construction industry has had the lowest productivity rate worldwide. Conservative and traditional managerial processes in the construction industry have impeded the adoption of innovative technologies such as unmanned systems, AI and big data. In the past year alone, the construction sector has become the leading sector using drone technology. From site survey, safety induction, maintenance inspection, progress reporting, quality control, site logistics, virtual walkthrough marketing as well as legal dispute resolutions, Unmanned Systems have disrupted construction practices and processes. Hence, in 2018, a leading cloud software platform for drone operations measure a +239% year to year growth in construction applications. Unmanned Systems have also driven the application of associated technologies such as Infra-red thermography and laser technology. As a result of these adoptions and applications, the potential for Artificial Intelligence in construction sector has not only became an important focus of AI and robotic specialist, but also investors and forward-thinking managers in construction industry. From both economical, technical and managerial perspectives it is essential to understand how will the disruptive AI and Unmanned technology impact the future of construction industry and its work forces? This presentation will focus on the implications and value to the integration of unmanned systems and AI in the construction industry with some key learning objectives such as:

- Reviewing the trends for drone technology applications in construction
- Recognizing the pitfalls and benefits inherent to adopting disruptive innovation such as Artificial Intelligence (AI) within the construction sector
- Recognizing some of the operational risks and challenges unique to construction projects

## 1 INTRODUCTION

The Construction sector is slowly embracing abc adopting AI – Artificial Intelligence often enabled disruptive technologies because the added value and benefits to construction projects are tremendous.

The construction sector is worth over 10 Trillion$ annually making it one the largest driver for the GDP up to over 13% of the global GDP worldwide and in Canada construction investments in value is expected to exceed US$ 267 billion by 2022 accounting for over 7% of the annual GDP in Canada. However, and despite continuous investment and value rate increases over the past decade, the construction sector is recognized to lack in productivity. Whether it is the perspective of the owner or that of the contractor, a large percentage of construction projects underperform and are completed behind schedule, with cost overruns or both (KPMG Global construction survey 2015). In fact, overtime and over budget is a common theme with global reports indicating that 75% of construction projects fail to be completed within 10% of the original estimated deadline, also, only 31% of global construction projects come within 10% of estimated budget.

According to the 2016 World Economic Forum report (Schwarz 2015), the unimpressive productivity achieved in the construction industry is mainly caused by:

- Lack of innovation and delayed adaptation
- Insufficient knowledge transfer from project to project
- Weak project monitoring
- Fiscally conservative company culture resistant to uncertainty

Alongside the above-mentioned causes, factors affecting productivity of construction projects were identified in some instances to relate to elements during the pre-construction phase to include as the most critical factors influencing site productivity. the adequacy of the selected site and project managers, design errors, constructability of the design, project planning, communication or its lack of, leadership style and procurement and project delivery method. (Naoum 2016).

In an effort to bridge the gap of productivity in the construction sector, most recent trends indicate a slow change with the early adoption of technological innovation by engineering abc construction firms. One of the biggest challenge and hurdle to technology adoption lays in the fragmented structure of the construction sector. Indeed, the construction industry regroups several stakeholders that can be involved under one project. It is seldom that only one organization is involved throughout the entire life cycle of a project. In Canada 95% of construction companies (contractors) employ less than 10 people with a specialized job activity be it engineered design or specialty trade (IRC Report on Construction in Canada 2008). Therefore, there will always be a lag in technological adoption unless there is a consensus or standardized type of technology applicable across the spectrum of expertise and stakeholders, i.e architects, engineers, contractors and owners. Building Information Modeling or BIM 3D modeling is one good example of disruptive technology that is reshaping the AEC sector. Because BIM can be considered the depository of data related to a construction project, it is in a sense the starting point for Artificial Intelligence and data analytics. The Construction industry is “data rich”. For instance, let us consider any infrastructure and construction project that surround us: they all have required a long array of information before being executed. Throughout the life cycle of a typical construction project (road, house, school, underground utility, …), there may be a phenomenal volume of information and data, from design drawings to contracts and project specs, even prior to the start of construction. However, up until recently, most of the data related to a construction project has been unstructured data, I.e.written/drawn on paper on multiple format of files including electronic files. Big data can help transform the construction sector by using the AI technology to extract precise information and insights to enhance the safety and productivity (Barbosa et al 2017)..

The top 10 trends for the construction industry in 2019 are advanced material or technology driven (Initiafy.2019). These include: pre-fabrication and modular construction; autonomous construction; big data and analytics; BIM and 3D photogrammetry; cloud based and real-time visualization and collaboration.

The integration of UAS Unmanned Aerial Systems or drones for project progress monitoring has already been explored and effectively tested (Oudjehane et al 2017), This paper will focus primarily on the principles used to integrate a process based on drones, 3D photogrammetry, Aerial Infra red thermography and AI within the framework of construction site monitoring or quality control post construction.

## 2 AI in Construction

Adoption of AI is expected to be modest and limited to very few applications of the construction industry where digital data is widely adopted. However, it is expected that the market for A.I. in construction will see the highest investments by construction companies in North America, driven in part by the shortage of skilled force and invest in robotics-based solutions. The potentials for AI is immense and worth several Trillion $ in terms of value added earnings across the entire economy. The chart below indicates the top 10 economy sector by potential value impact that AI can induce (source McKinsey Global Institute Analysis). It is to be noted that the Construction sector does not make the top 10 economical sectors.

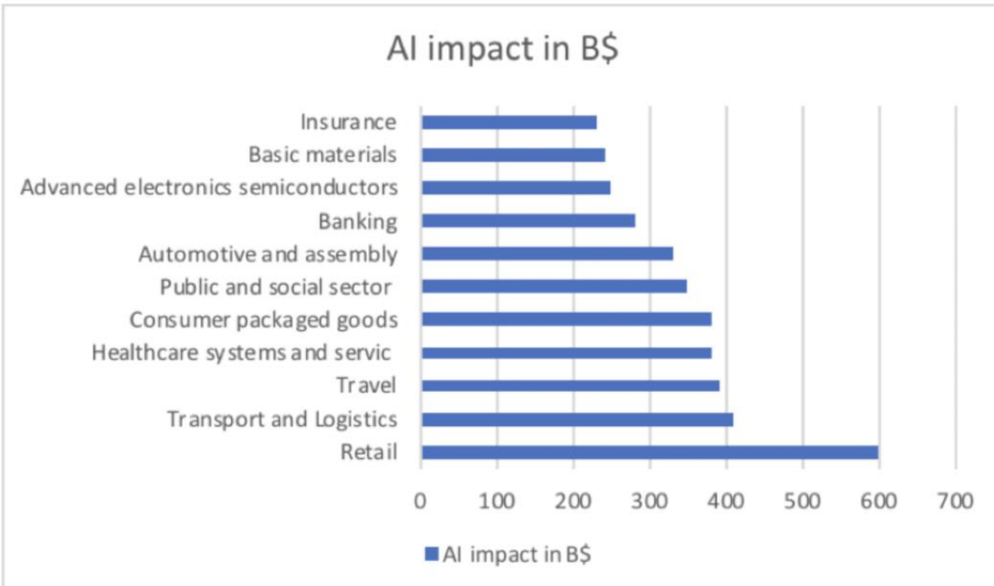


Figure 1. Top 10 Value impact in Billion $ by economy sectors

According to a McKinsey report of 2018 and as highlighted in the table below, some of the key priorities and drivers of value investments for construction firms were identified by a study of case uses of technology investments by engineering, design and construction (EDC) firms. These priorities were categorized in accordance to construction project phases as well.

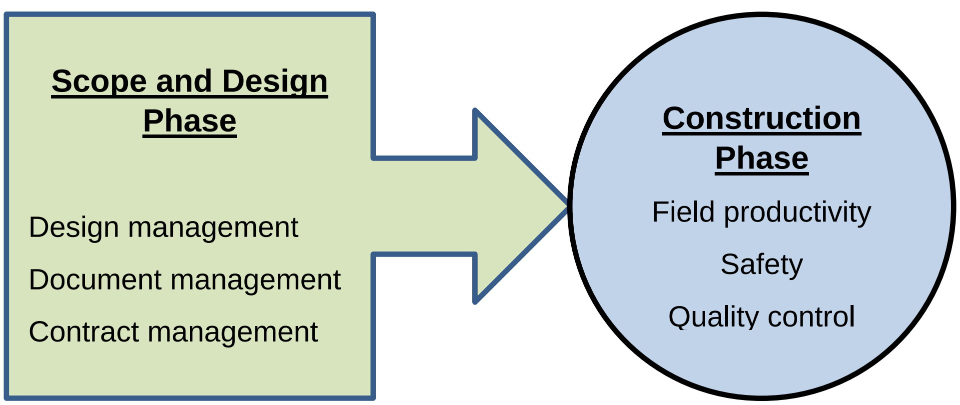


Figure 1. Priority case uses of technology in construction projects

Artificial Intelligence is certainly a buzz word across various industry and business sectors. Because AI is rapidly evolving through constant advancement of technologies and practices, the science and R&D in support how AI have yet to clearly define and identify a low risk path to adopting AI. Furthermore, the levels of investments and reliance on high technology elements are quite different pending on the industry sector. It is hence quite challenging to outline a unique model suitable across sectors. This challenge alone limits the early implementation and integration of AI unless the value of AI outweighs the risks associated with it. The potential of AI in construction sector has not only became an important focus of the AI and robotic specialist, but also investors and forward-thinking managers in construction industry. From both economical, technical and managerial perspective it is essential to understand how will the disruptive AI and Unmanned technology impact the future of construction industry and its work forces?

AI is primarily concerned with getting computers to do tasks that would normally require human intelligence. For construction, AI can compare millions of potential options within a project - something that would take humans years - monitor video footage or photographs and learn to recognize risks within both data and real-life situations. A.I. and machine learning in construction nevertheless require a vital pipeline of data and information that disruptive technologies like UAS, 3D photogrammetry and Aerial Infra-Red thermography may enable.

## 3 The Value of technology in construction

The lagging global construction productivity equates to a yearly USD 1.6 billion and the value to stay ahead of the competition construction firms need to build a technology-enabled business strategy. Experts predict that within 10 years, full-scale digitization could save up to $500 billion in operations costs alone. Hence, companies may use real-time visibility technologies to:

- Save millions in operational efficiency
- Catch potential construction issues and avoid costly rework
- Improve stakeholder communication throughout the entire construction life cycle
- Maximize productivity at job-sites

As illustrated in Table 1, the key benefits of transforming the construction sector using advanced technology reside in 3-three general areas where the impacts of technology is significant and in alignment with industry priorities

### 3.1 Productivity

Construction productivity has long been the focus of several research given the stagnation of productivity levels measured globally and fir consecutive years. In order to evaluate the direct impacts of implementing A.I., it is however critical to understand the various factors that tend to affect construction projects. In addition, it is important to also note the scarcity of data with absolute measurement of productivity improvement. In a NIST - National Institute of Standards and Technology – special publication (NIST 2009), several metrics were defined in an effort to measure construction productivity. Three major factors are generally recognized: skilled labor shortage or availability; technology adoption; and offsite manufacturing and modularization.

AI is often negatively associated with the introduction of robots deemed to replace the traditional labourer. When AI or automation is implemented, the displacement effect for the replacement of labor tends to also reduce the demand on labour and wages in routine less productive tasks. Automation ultimately increases rates of productivity which often translates into higher demand for labour in non-automated tasks (Acemoglu. D. et al 2018), thus the displacement effect. The impact of investment in labor training has been found by the CI – Construction Industry Institute to positively impact profit and productivity with ROIs ranging from 130% and 300% (Huang. A, et al. 2009), thereby demonstrating that whilst accrued investment in machinery and AI is necessary to increase productivity, it is accompanied by investment in higher skilled labour. Another facet to increased productivity can be indirectly related to increased performance from the reduction of work related accidents and increased safety on job-suites.

## 3.2 Safety

Safety ranks high amongst the drivers and reasons construction firms invest in in technology to improve the safety practices on job sites. From virtual reality in safety training, to wearables and sensors on construction site all theses measures aim to minimize the risks for accidents, injuries and fatalities on the jib site. According to the Centre for Disease Control and prevention (CDC) construction worker are 16% more likely to have some kind of muscular disorder than in any other industry sector.

From a project management viewpoint and a financial value rationale to implement AI and advanced technology it is necessary to evaluate the typical direct and indirect costs inherent to any construction project. This concept underlines that improved safety operations can have a significant financial impact and long-term cost saving benefits. In addition, improved safety can indirectly impact the performance of workers and thus overall productivity on the job site. The value of cost savings by integrating technology tools to improve safety was measure by looking at the incident claims reported to the WCB - Workers Compensation Board in Alberta. Hence and according to Alberta OHS 2017 statistics the numbers are: 301 fatalities from 2013-2017 within the Construction related sector; over $1 billion per year in total Dollar value of WCB claims. It is to be noted that the construction sector in Alberta accounts for the highest number of fatalities across the economic sectors.

## 3.3 Quality control

The value impact analysis of implementing advanced technology in construction was undertaken for the specifics of utilizing Unmanned Aerial Systems with 3D photogrammetry and Aerial Infra-Red thermography. The financial impact of UAS on construction management activities for quality control has revealed that this technology can be implemented with a high degree of accuracy.

Hence for example: Land survey activities can enjoy an average 80% reduction in unit costs per hectare; UAS based quality control inspection systems represent a minimum 65% reduction in overall costs by comparison to traditional methods. The most undeniable value however beyond real-time access to information for decision making, Unmanned Aerial Systems provide enhanced freedom of access without any additional risks. The financial impact of 3D modeling and safety management applications were difficult to quantify on the basics of construction activities. The near real-time and remote access to information for decision making were often noted to be the key added value criteria for adopting the integration of Unmanned Systems with various modeling tools.

# 4 Integration of AI and disruptive technologies

The integration of AI in construction projects has to be adaptive and flexible to be successful particularly given the complexity and multitude of stakeholder's relationships and intricacies in large projects. The scope of principles herein developed establishes a framework that is valid primarily during the construction phase.

This framework encompasses the integration of 3 technologies for data pipeline and data analytics to ultimately enable machine learning for decision making in operational excellence with quality control and safety management. The 3 technologies that were experimented and tested so far are: Unmanned Aerial Systems UAS or drones, 3D photogrammetry and Aerial Infra red thermography.

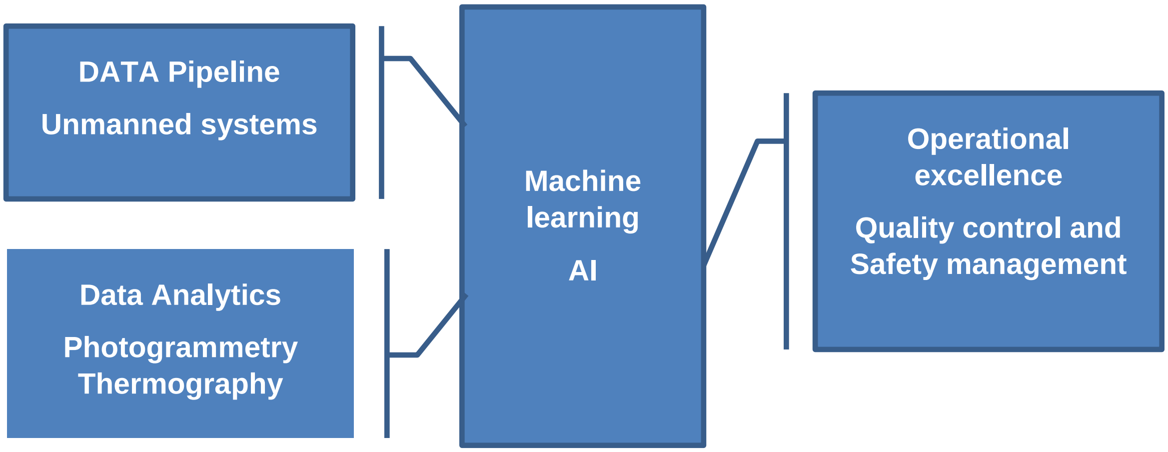


Figure 2. A framework for integrating 3 technologies with AI in construction

Machine learning on the other hand can be achieved through respectively supervised and unsupervised learning to achieve construction operational excellence. In this case, Machine learning is used like a smart assistant that can scrutinize the large volume of data. It then alerts project managers about the critical things that need their attention, with grounds to make informed decisions.

The framework defined above was tested on SAIT campus to oversee a retrofit construction project as illustrated below. The integration of a drone (DJI M210) with multiple sensors including an Infra-Red sensor. He As the framework is intended to cover all stages of the construction phase, the multiple sensor capability has enabled us to achieve: progress monitoring and quality control at the same time.

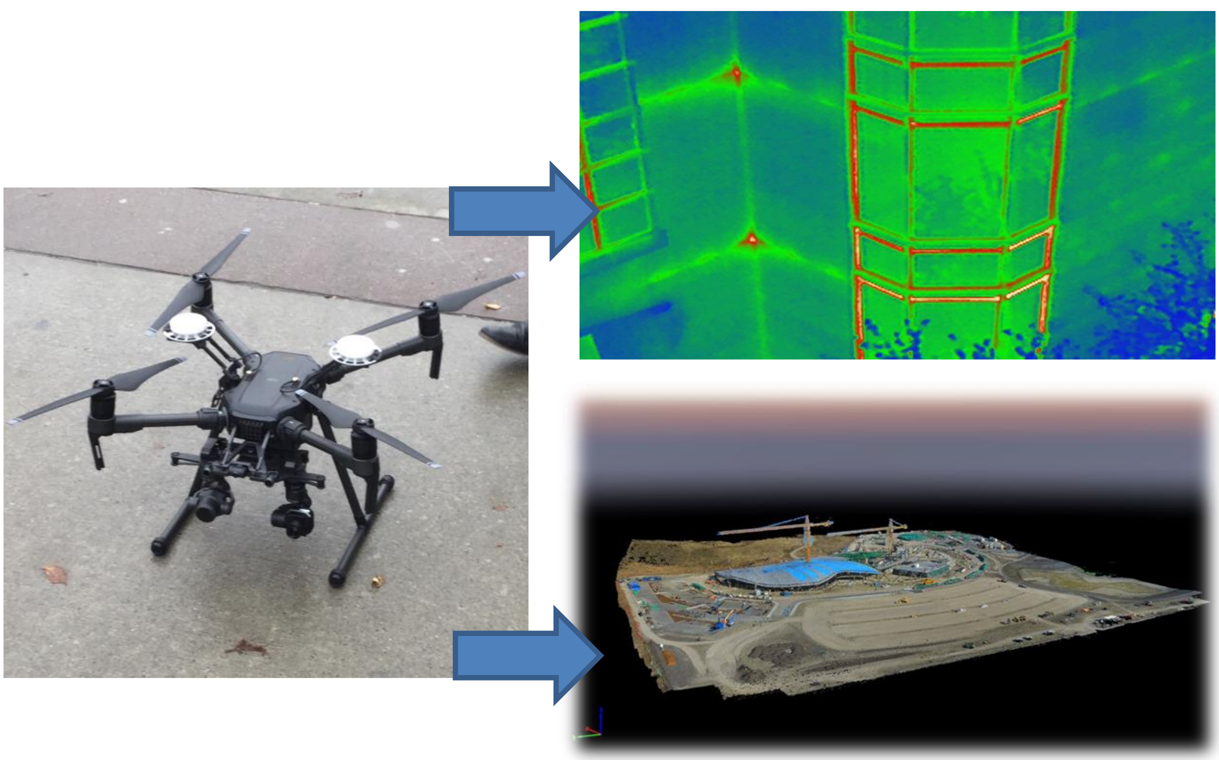

Figure 3 Data pipeline using a DJI M210 UAV (left) with Infra-red sensor to generate an Infra-Red building envelope scan (top right) and a 3D cloud models (bottom right)

The images above illustrate the power and wealth of information that can be extracted from the operation of unmanned aerial systems or drones They remain the central and key node for the integration of AI in construction projects whilst the full automation of machine learning in construction project management remains limited in and scarce. Within the framework of integrating AI with the use of unmanned aerial systems equipped with various sensor technologies, the developed process consisted of:

- UAS operations to:
    - capture images of a building undergoing building envelope retrofit
    - Capture of Infra-Red thermography images of the building envelope
- Generation of a 3D model of the existing building using 3D photogrammetry
- Generation of 2D and 3D thermal model of the existing building
- Develop algorithms to identify thresh-holds and create gap notifications

The last step of the process in the full integration has yet to be validated in our current research investigations. It results primarily from the initial goals and objectives of our research investigation aimed at testing and validating the use of drones with multiple sensors for excellence in construction project management through progress monitoring and quality control.  The drone was hence used to capture data on an ongoing retrofit construction project at SAIT as shown below throughout construction and in commissioning. The fact that this is an old and existing building with old and limited design data adds another layer of benefits to the integration framework in support of re-generating new data for the operation and maintenance of the new project.

Figure 4. Building envelope retrofit of the John Ware building on SAIT campus

## 5 Operational risks and challenges

AI in construction relies on a data pipeline where drones and Unmanned Aerial Systems are key. Unmanned Aerial Systems have disrupting the construction sector and hence enabled the capture of access to critical data and information during the construction phase.

Despite the advanced technology and the operation of UAS is not without risks in addition to regulations and necessary compliance. Laws and regulations keep changing in Canada and most recently Transport Canada has issued new stringent rules that may dampen the exponential growth in drone operation service providers. Nevertheless, the risks for operating will have to continuously manage from the perspective of the construction project manager.

Like with any new and innovative technologies, full integration of Unmanned Aerial Systems as part of all construction project will have to overcome several challenges such as:

- operational best practices and standards;
- legal issues;
- privacy and data protection;
- Injuries and property damage.

The key challenge that construction firms will have to address is to whether UAS Operations should be sub-contracted or integrated within the firms' business processes. Currently, drone integration has been driven by software and intelligence service providers such as Autodesk, Oracle, IBM, Microsoft and few others. Some other early adopters of the drone innovation from the construction sector such as PCL Construction have developed their own drone business division to oversee and monitor large construction projects using Unmanned Aerial Systems.

The legal and liability implications will hence be pendant on the project delivery system which without a body of case law and established principles to provide legal clarity, drones give rise to new legal issues and uncertainties.

Regardless of the business or project delivery process to be adopted by construction firms, in order to effectively integrate the key data pipeline to AI during construction, best practices and minimum standards for using unmanned aerial systems need to be developed and adopted. These standards could also be part of a risk management plan for technology adoption. One such example that was most recently investigated includes radio-frequency and other electro-magnetic interferences on construction sites when operating drones. Dealing with wireless technology is an additional consideration to the integration of AI with drones and associate technologies. The fact that most communication devices on site nowadays are wireless, it is to be expected that the standards for construction applications, particularly in urban areas, include the best practices of measuring interferences. Our next publication will include a sample based on our site tests and simulations.

In conclusion, as highlighted in this paper, the integration of AI with drones and associate technology in construction is not straightforward and simply the developed of automation through algorithms capable of generating information that supports project decision making. This may also be symptomatic of the careful and slow adoption of technology in construction: requirement for risk management plans due to the multitude of stakeholders and uniqueness of every single project is not necessarily a big driver of innovation adoption.

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