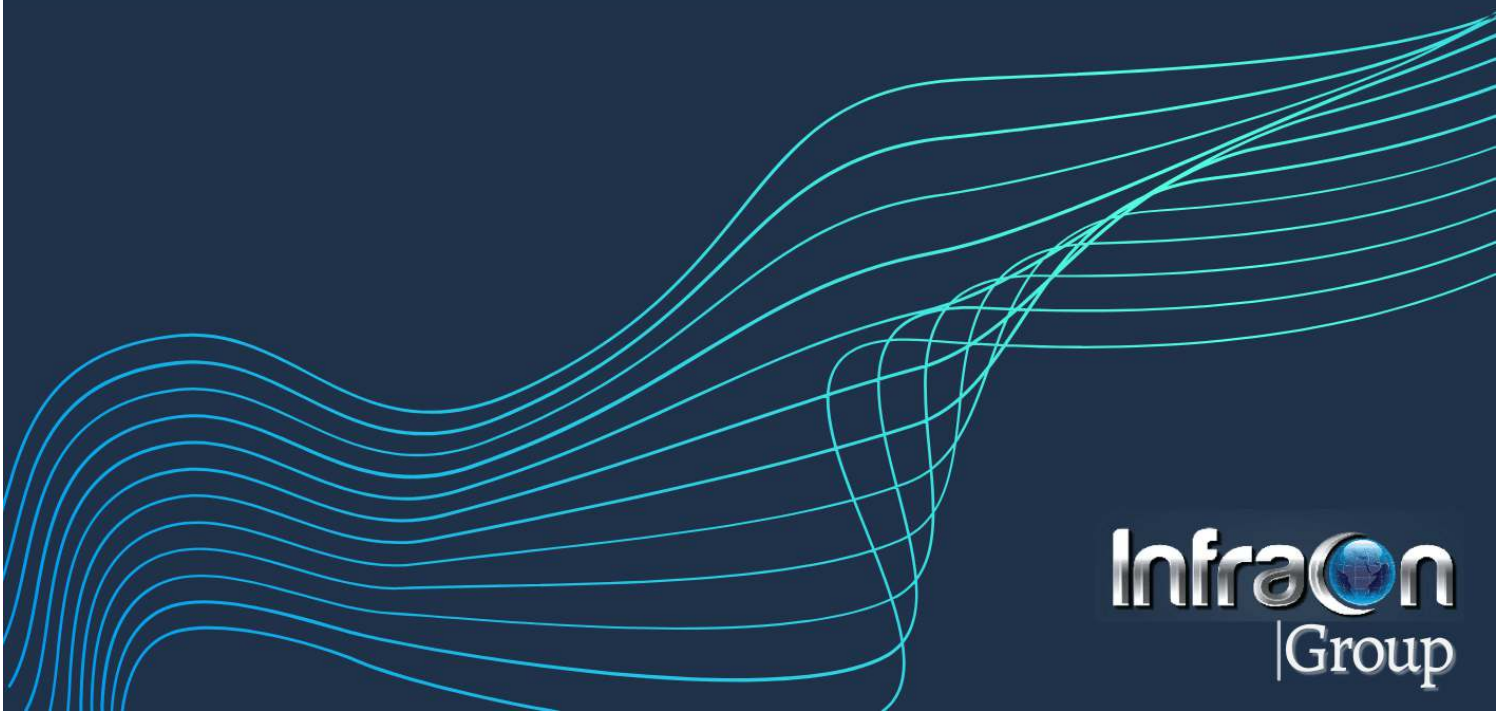
White Paper

MACHINE LEARNING – AN APPLICATION TO QUANTITY SURVEYING



InfraCon Group

The Use of Machine Learning in Quantity Surveying

Introduction

In the face of the Fourth Industrial Revolution (Industry 4.0) and the data and digital economies, machine learning will soon become an important tool that will evolve the manner in which the role of quantity surveying is fulfilled. For this reason, it is important to understand how machine learning can be applied to quantity surveying to fully grasp the depth of the evolution required in order to be effective. The Quantity Surveying discipline is a discipline that has data-rich activities at the core of its competencies and function with the wide adoption of digital services likely to cause significant changes and disruptions (Eriksson, Cheng, Pitman *et al*., 2017). Industry 4.0 will disrupt the logic base of the discipline as Artificial Intelligence (AI) and other Industry 4.0 technologies and systems are introduced. Current technologies like Building Information Modelling (BIM) and 3D-printing have already started to infiltrate the built environment and the quantity surveying discipline will need to evolve its role, responsibility or skill-set in order to remain relevant in the face of a changing industry (Eriksson *et al*., 2017). Aibinu & Venkatesh (2014) found that BIM, for example, has the potential to enhance the services provided by Quantity Surveyors. However, there are numerous barriers to adoption.

Background

One of the technological developments that have the potential to directly and significantly impact the quantity surveying discipline, in terms of digital adoption, is machine learning. This potential is expressed in the study by Hegde and Rokseth (2020) that looked at the application of machine learning in engineering risk assessment. The summary of this article posits that real-time predictive solutions provided by machine learning will fuel the adoption of machine learning. Accurately predicting all aspects of cost-related elements in terms of estimates (including Bills of Quantities), variations, contingencies etc. is possible when using machine learning. This predictive capability is expected to significantly disrupt the profession as current technical competencies are likely to be replaced or augmented by some form of AI such as machine learning (Eriksson *et al*., 2017).

Machine learning is a form of AI that is characterised by utilising computerised mathematical algorithms that learn from data of various types. The algorithms create a probabilistic model that makes assumptions and predictions when provided with data sets that have a similar basis to that on which the model was built (Noponen, 2019). This means that when it comes to quantity surveying, there are technical competencies that can be decoded into computerised mathematical algorithms in order to create probabilistic models that make assumptions and predictions. These models can then be applied by quantity surveyors in order to increase accuracy and predictability. The aim of this study is to demonstrate the application of machine learning to quantity surveying.

Quantity Surveying Competencies

The Royal Institute of Chartered Surveyors (RICS) describes a quantity surveyor as a highly trained expert offering advice on costs in various sectors for all stages of a building project (RICS, 2018). Quantity surveyors have various technical competencies that are applied in the execution of their duties. As per RICS (2018), these core competencies are:

- Commercial management (of construction works)
- Contract practice
- Construction technology and environmental services
- Design economics and cost planning
- Procurement and tendering
- Project finance (control and reporting)
- Quantification and costing (of construction works)

In a study by Chamikara, Perera, and Rodrigo (2020), it was found that construction technology and environmental services ranked highest in terms of the significance of quantity surveying competencies in techniques for sustainable projects. Similarly, Shayan, Kim, Ma *et al*. (2019) found that the most critical challenge for quantity surveyors is adopting new technologies and the level of knowledge regarding sustainable construction. In their findings, Shayan *et al*. (2019) advise that the quantity surveying discipline develop competencies to include sustainability advisory and BIM for cost management. Both findings indicate strongly that the construction industry is changing rapidly and quantity surveying competencies in technology and sustainability need to develop equally as quick in order to continue to deliver value to the industry. The findings underpin the importance of studies regarding the practical application of machine learning to the quantity surveying discipline.

Industry 4.0 and the Construction Industry

As the world adapts to changes brought on by Industry 4.0, it is important to consider how the construction industry will be impacted. Industry 4.0 deals with creating more digitised systems and network integration via smart systems. Erboz (2017) frames Industry 4.0 as being underpinned and defined by big data, autonomous robots, simulation, horizontal and vertical integration, Internet of Things (IOT), the cloud, additive manufacturing, augmented reality, and cyber security. Understanding Industry 4.0, and the opportunities and challenges that it brings, is critical to understanding the way in which it will impact the construction sector and subsequently the quantity surveying discipline. According to Schwab (2017), the fourth industrial revolution is characterised by the use of various new technologies that bring together the physical, digital and biological worlds. This confluence of technologies is expected to impact all disciplines, economies and industries Schwab (2017). Industry 4.0 is characterised by technology and innovation evolving the way in which engineering and construction are done. This evolution brings the expectation of improvements in both quality and productivity within the construction sector (Maskuriy, Selamat,

Ali, *et al*., 2019). Construction projects that incorporate Industry 4.0 innovations and technologies can use them to increase productivity levels, safety, and quality, as well as use them to execute project management processes more effectively. Of the various technologies available, the most mature tools currently being used by the industry include three-dimensional (3D) scanning and printing, BIM, drones and augmented reality (Maskuriy *et al*., 2019). The increased use of these technologies will have an increasing impact on the way in which quantity surveying competencies are applied (Eriksson etal, 2017).

Industry 4.0 comes with many opportunities and challenges for the construction sector (Alaloul, Liew, Zawawi, *et al*.). The study by Alaloul *et al*. (2020) categorises the opportunities into political, economic, social, technological, environmental, legal and security opportunities. Technological opportunity refers to the creation of enhanced systems that would ensure little to no errors that result in an increase in quality assurance. Reliable decisions could be made to achieve more effective results through the processing of available information.

The opportunity discussed in this study is the technological opportunity that can be exploited by quantity surveyors. The findings of Maskuriy *et al*. (2019) and Alaloul *et al*. (2020) both indicate that there is not a complete understanding of what Industry 4.0 entails with regards to the construction sector. The studies found that not only is the uptake and adoption of new technologies slow, but most research studies are theoretical and simply semphasise the potential impact that a collaboration of technologies and processes will have on the construction industry. Comprehensive studies on the integration and collaboration of construction processes and activities using available Industry 4.0 tools and technologies has increasing importance.

Digital-age tools and systems in construction

In 2017 the construction industry posed as one of the largest economic sectors in the world and the creation of different tools and systems had emerged, thus giving it a competitive edge and ultimately strengthening the construction industry as a whole (Ahmed, 2018). It has to be noted however that amongst all the other industries such as banking, manufacturing and the retail industry, the construction industry is lagging behind and is yet to fully explore the new tools and systems that come with the new era of Industry 4.0 (Osunsanmi *et al*., 2018). There are various tools and systems sutilised within the construction industry such as BIM, augmented reality, virtual reality, 3D printing, drones, CAD systems and robotic total stations (Hossain and Nadeem, 2019). These new tools and systems are capable of solving numerous challenges faced in the industry. However, their level of implementation in different parts of the world varies. There are various examples of the use of these technologies in the construction industry. In Dubai, there are offices that were constructed using the 3D printing system and a house in Milan was constructed using the same system (Craveiroa *et al*., 2019). 4D BIM was used in the United Kingdom to improve project delivery and time predictability (Gledson and Greenwood, 2016). In South Africa, a test project was conducted on the use of drone technology combined with BIM integration to improve infrastructure delivery (Musonda and Pillay, 2019). Amongst all the new and revolutionary innovations entering the construction

market, BIM is one of the oldest tools and systems that existed and it has undergone several improvements after being owned by the Autodesk company (Bhatti *et al*., 2018).

BIM is a process of collective creation and use of information about the structure, forming a reliable basis for all decisions throughout the life cycle of the object. (Zolotova *et al*.,2015)

BIM is also defined as "a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward" (NIBS, p.1, 2015).

It poses as a ground-breaking technological advancement for the entire Architecture, Engineering and Construction (AEC) disciplines as it is a tool that can be used for drawing, modeling, simulation, management and control (Ahmed, 2018). Similarly, to BIM, Augmented and Virtual Reality technology are other technological tools that are transforming the construction industry and making it easier for the different stakeholders of a project to be at the finishing line of a project through a 'virtual' exploration of the end product of a development. Virtual Reality (VR) is defined as;

A computer-generated simulation of three-dimensional (3D) environment, in which the user is able to both view and manipulate the contents of that environment whereas Augmented Reality (AR) creates an environment where computer generated information is superimposed onto the user's view of a real-world scene. (Behzadi, 2016)

Artificial Intelligence used by Quantity Surveyors

The roles and duties of the professionals within the construction industry are continuously evolving and this has been amplified by the different softwares and technological inventions that are entering the construction market. A lot of decisions made in any project are largely influenced by costs and therefore Cost Managers (Juszczyk, 2017), also known as Quantity Surveyors are one of the core project stakeholders that play a pivotal role in cost estimation predictions. The application of AI in different areas of a construction project has proven to serve as an enhancement to the overall success of the project and the areas that AI addresses include costs, productivity, risk analysis and safety, duration, dispute and unit rate (Kulkarni *et al*., 2017). AI will have a profound impact on the construction industry but considering the various opportunities that come with it, those who understand the changes that AI brings will be in a better position to exploit those opportunities to their optimum level (Hoar *et al*., 2017). This segment will be focussing specifically on the AI used by Quantity Surveyors and how the discipline is exploiting the opportunities to their advantage.

According to Hoar *et al*., (2017) AI is a branch of computer science that deals with the study of computer software and its capabilities in making intelligent decisions, reasoning and problem solving. AI enables machines 'to learn from experience, adjust to new inputs and perform human-like tasks. Examples are computers learning to play

chess using AI or self-driving cars (Prieto, 2019). AI tools should be viewed as a set of activities rather than occupations (Chui *et al*., 2015). Cost estimating for a construction project is a prediction of the entire cost for a construction project and this ultimately assists the client of the project to budget and plan for the construction of the project. The cost predictions done by the Quantity Surveyor have to be accurate and reliable. There are five different intelligent construction project cost estimation methods, namely:

1. Machine-Learning (ML)
2. Knowledge-Based Systems (KBS)
3. Evolutionary systems (ES)
4. Agent-based systems (ABS)
5. Hybrid systems (HS)

(Al-Zwainy and Hadal, 2016)

Machine learning is a construction system that is capable of learning from data and is able to work with incomplete data, deal with different levels of uncertainty and use acquired experiences from the past similar cases to determine new cases. One of the most common machine learning techniques is the Artificial Neural Network (ANN) which imitates the human brain in computer systems and this approach strives to solve problems in a similar way to the human brain (Bhosale and Konnur, 2019). The ANN model is also used in the prediction of site overhead costs and a study was conducted by Leśniak and Juszczyk (2018) where 143 cases of completed construction projects were used. 'The modelling involved a number of artificial neural networks of the multilayer perceptron's type, each with varying structures, activation functions and training algorithms. The neural network selected to be the core of the developed model allows the prediction of the costs' index and aids in the estimation of the site overhead costs in the early stages of a construction project with satisfactory precision' (Leśniak and Juszczyk, 2018).

Machine learning and the construction industry

The impact of Industry 4.0 on technical competencies, skills and occupational mobility is the nexus between its impact on the construction industry and technical competencies of the quantity surveyor. As the tools and technologies available to the construction industry increase in use, there will be increasing pressure on the quantity surveying discipline to keep up with the productivity that can be achieved. Being an iterative, process-driven discipline, quantity surveying is in the position to utilise AI effectively in order to make task execution simpler, more efficient, and more accurate. Machine learning, an AI-based technique, is one of the tools that can be used in order to achieve higher productivity.

Machine learning is when a computer has the ability to learn and make predictive decisions without being specifically programmed for the task processed (Samuel, 1959). "Machine learning is a type of AI that involves using computerised mathematical algorithms that can learn from data and can depart from strictly following rule-based, pre-programmed logic. ML algorithms build a probabilistic model and then use it to make assumptions and predictions about similar sets of data" Noponen (2019).

Machine learning algorithms are built from large data sets, and then subsequently applied to logical processes. The algorithms can then be deployed to make predictions about the results that would be achieved from engaging any particular set of data. Quantity surveyors work with large amounts of cost and contract data that can be potentially modelled using machine learning in order to build predictive algorithms and models that facilitate increased productivity. Eriksson *et al*. (2017) identify that there is a 63% potential for job losses in the surveying discipline if the discipline does not keep up with the skills required for machine learning application. Eriksson *et al*. (2017), Ahmed (2018), Maskuriy *et al*. (2019) and Alaloul *et al*. (2020) all indicate that there is slow adoption of digital tools and that there is a significant need for true understanding of the application of machine learning in the quantity surveying discipline.

Machine learning in the construction sector has already begun to take-off in some areas. A study conducted by Hegde and Rokseth (2020) looked at the application of machine learning in engineering risk assessment. The study assessed the adoption of machine learning methods for risk assessments such as risk identification, risk analysis, and risk evaluation. The assessment was done by looking at the number of journal articles looking at machine learning in real-time and using historical data. It was found that 70% of the articles used historical data, and 20% used real-time data in order to build the machine learning model. The study posits that as the industrial need and expectation for real-time assessments increases, so will the adoption of machine learning techniques and methods. Akhavian and Behzadan (2015) used machine learning to investigate the use of built-in smartphone sensors as ubiquitous multi-modal data collection and transmission points to collect data on the movement of construction equipment. The aim of the research was to create a simulation model to make equipment usage more efficient. The research was successfully conducted with the key observations being the impact that classification performance has on model results.

Hegde and Rokseth (2020) and Akhavian and Behzadan (2015) findings indicate that machine learning can be applied effectively to data-rich activities, functions or processes within the construction industry. Aibinu and Venkatesh (2014) noted the following barriers to the adoption of BIM by quantity surveyors in Australia;

- Internal Barriers
    - Lack of information on business process changes and how to change those processes;
    - Technology change and ability of firms to adapt to the change from a cultural perspective and financial perspective
    - Transformation and adaptation issues;
- External Barriers
    - Cost of implementation;
    - Lack of awareness of the benefits from cost benefit analysis perspective;
    - Lack of demand by clients;
    - Lack of trust in the integrity of BIM;

- Lack of standard for description of BIM objects and a coding systems;
- Contract/legal issues and uncertainties;
- Skills shortage;

Internal barriers are barriers that a quantity surveyor (firm or individual) can overcome using an implemented process or procedure, whereas an eternal barrier is a barrier that is not within the control of the quantity surveyor. Considering BIM as one of the more mature and widely known advanced digital tools available to quantity surveyors gives a snapshot of the general barriers to adoption of digital tools. Using the barriers to adoption of BIM as a basis, it can be inferred that the external barriers will decrease over time as different technologies mature meaning quantity surveyors will need to decrease the internal barriers at the same pace at which the external barriers are decreased. The research done by Akhavian and Behzadan (2015) gives insight to the classifications required to create machine learning models that have the potential to work within the quantity surveying discipline in order to overcome the internal and external barriers found by Aibinu and Venkatesh (2014).

About Infracon

Infracon is a **100% black owned level 1 BBBEE** entity with **black female ownership** and has offices in Woodmead, Johannesburg. Infracon is determined to deliver services that exceed your expectations through our unique skills on how to optimise processes and overcome project challenges.

In 2016 Infracon partnered with ARES Corporation through its ARES PRISM software which provides Project Management solutions, including but not limited to Estimating, Scheduling, Procurement Value Chain Management, Contract Management and Administration, Engineering Management, Earned Value Management, Cost Management, Accurate Forecasting, Policy and Procedure Development, Project Execution Plan (PEP) Tracking and Scope Management. Infracon consistently provides high-value added products and services that allow projects to be achieved on time and within budget.

Authors

Yaw Yeboah (Infracon Group)
Faith Dowelani (University of Pretoria)
Oratile Mose (Independent)