BENEFITS OF BIG DATA APPLICATION EXPERIENCED IN THE CONSTRUCTION INDUSTRY: A CASE OF AN AUSTRALIAN CONSTRUCTION COMPANY

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The fourth industrial revolution (Industry 4.0) has contributed to technology uptake in the global economy. It is suggested to make industries effective and efficient. The technologies in the revolution include internet of things, augmented and virtual reality, cloud computing, smart sensors, artificial intelligence, automation, robotics and big data. These have given rise to high rate of generating massive amount of varied data, which are analysed for process improvement: Simply termed as big data. Current studies on big data in the construction industry have recommended some benefits based on inference from other industries. However, the actual benefits is silent in the discourse amongst construction management practitioners and researchers. Using a phenomenological research method through a single case study, this study answers the question, what are the benefits of big data to the construction industry? The selected case is a tier one construction firm and known to be technology-led company in the Australian construction industry. Construction personnel in different portfolios, years of experience and at various level of hierarchy were interviewed through semi-structured interview to share their experiences on big data as far as their respective practices were concerned. Data were analysed through first level coding and self-reflections by researchers. The preliminary findings reveal the benefits of big data in management of claims, project monitoring and control, and procurement on projects. By implication, the findings provide real experiences of big data in the construction process. This study contributes to the discourse on the promises of big data as an element of the fourth industrial revolution and the future of the construction industry.

Keywords: big data, Australia, Industry 4.0, qualitative

INTRODUCTION

The fourth industry (Industry 4.0) is technology driven, which is aimed at improving and transforming business operations across all sectors of the economy (Department of Industry, 2019). The technologies include internet of things, augmented and virtual reality, cloud computing, smart sensors, artificial intelligence, automation, robotics and big data. These have contributed to the high rate of generating massive amount of varied data, which are analysed for process improvement: Simply termed as big data.

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Adoption of technologies, like big data in the construction industry continue to suffer a major setback (Low *et al.,* 2019), though Cheng *et al.,* (2020) indicated that failing to "ride the wave" of Industry 4.0 will affect the survival of businesses. Current studies on big data in the construction industry have recommended some benefits (Bilal *et al.,* 2016) and big data capabilities (Atuahene *et al.,* 2018) based on inference from other industries. However, the actual benefits of big data are silent in the discourse amongst construction management practitioners and researchers. This empirical study explores the benefits of big data in the construction industry.

LITERATURE REVIEW

Big Data

A perfect definition of big data has become a major challenge due to different interpretations. However, the concept of big data has two main components at the metalevel: The characteristics of data, and the technology (to store and process the data). There is a consensus on the technology component but dissenting views on the characteristics of data that defines big data. The definition of Davenport (2014) is adapted for this study because it provides a holistic description of big data and widely cited as well, thus:

> the collection and interpretation of massive data sets made possible by vast computing power that monitors a variety of digital streams - such as sensors, marketplace interactions and social information exchanges - and analyse them using 'smart' algorithms.

Component of big data

The two main components can further be decomposed into the three stages of data management life-cycle. The three stages of the data management life-cycle include big data sources, big data storage and processing, and big data analytics.

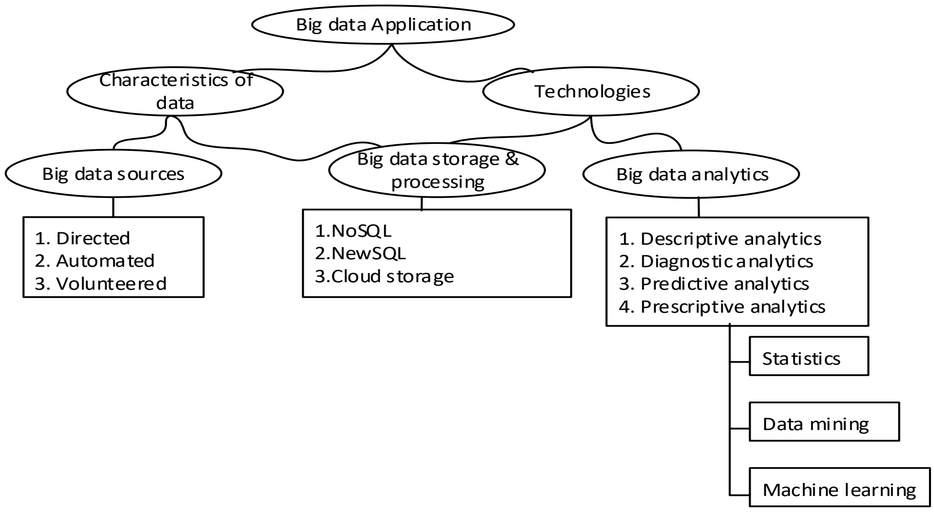

Figure 1: Deconstructed big data concept (Kitchin, 2014; Bilal et al., 2016; Strohbach et al., 2016)

Big data sources: The characteristics of big data relate to the sources of data and storage as shown in Figure 1. Kitchin (2013) classified the sources of big data into directed, automated and volunteered. The directed sources are from "digital forms of surveillance" like the drones and Time Lapse Cameras etc., which are used on construction project (Han and Golparvar-Fard, 2017). The automated data are generated from digital devices, machines, sensors and actuators embedded into objects like phones, smart wearables, RFIDs. The volunteered data are those available on social media platforms and crowdsourced data, as used in construction studies (Kanjanabootra *et al.,* 2019). Whilst the traditionalists (Russom, 2011; Davenport, 2014; Bilal *et al.,* 2016; Han and Golparvar-Fard, 2017) - a term for some researchers in the context of this study - consider the characteristics of data to be 3Vs, thus large amount (volume) of heterogeneous (variety) datasets, generated at a faster speed (velocity), the progressives (Demchenko *et al.,* 2013; Wamba *et al.,* 2015) - used in the context of this study - accept the traditionalists view of 3Vs but believe the relevance of valuable information (value), and the authenticity and trustworthiness of data (veracity) should be included. The characteristics of data depends on data capturing technologies, the frequency and rate of use, and the security of the data.

Big data storage and processing: This includes data storage either through the cloud server or traditional storage device, and management of data using Hadoop Map/Reduce and Spark. Different formats of captured data require appropriate storage and management technologies. Many forms of state-of-the-art technologies are available for storing and managing data depending on the types (Strohbach *et al.,* 2016): NoSQL (Not only Structured Query Language) is a distributed database designed to handle a wide variety of data and perform well at the same processing time, should there be an increase in workload (scalability), other than the relational database management system (RDBMS). NewSQL is a modern form of RDBMS which combines the benefit of NoSQL's scalability and the traditional RDBMS's strong consistency. Cloud storage has become relevant in modern times due to amount of data created, replicated and used daily.

Big data analytics: The analytics process and analyse the data by providing insight that guide management in making decisions, which depends on the level of analytics. The levels of big data analytics include descriptive, diagnostic, predictive and prescriptive analytics. These levels provide insight from data on what is happening, why it happened, what is likely to happen and what should be done respectively. These analytics are achieved by performing machine learning, Natural Language Processing (NLP), Business Intelligence or Cloud Computing. Construction practitioners are not trained as data scientist to perform those analytics, however, construction practitioners can be trained to developed expertise in the big data concepts (life cycle), which are integral to the performance of their duties, like data capture and application of the data.

Benefits of big data experienced in other industries

Russom (2011) revealed the benefits of implementing big data in organizations through a survey. Though the study did not include construction practitioners, but some benefits identified from those industries would be beneficial to the construction industry. These include accurate business insights, automated decisions for real-time processes, fraud detection, leverage and return on investment for big data, risk quantification, planning and forecasting and identifying root causes of cost. Table 1 summarizes benefits of big data applications identified from other industries as well. The benefits are classified into strategic and operational, which are aligned and inspired by the classification of Raguseo (2018) and Wang *et al.,* (2018). These two main benefits can be seen from the project and organizational level in the context of construction, though there is an over-lapping relationship between them. In the organization level, the operational benefits from the project(s) level accumulate to enable top management to design plans and make informed decisions (strategic benefits) on achieving its goal and mission. These decisions are intended to make the organization competitive amongst the other industry players. And the competitiveness of a construction organization is a measure of the number of contracts won and the number of completed projects within a time period. Construction organizations like those in other industries are in business to maximize profit and minimize cost. At the project level, the decisions (strategic benefits) made by top management are put into practice. At this level achieving the project objectives of time, cost, quality and safety become the focus. Every bottlenecks are addressed to contribute to the overall efficiency of the project.

Table 1 Benefits of big data experienced in different industries

Benefits	Description	Industry	Authors
Strategic benefits	Competitive advantage on cost and services; provide comprehensive view of service delivery for innovation	Health	Wang *et al.*, (2018); Lin *et al.*, (2018)
	Provide better products or services; aligning IT with a business strategy; enabling a quicker response to change; improve customer relations; create a competitive advantage; establish useful links with other organizations	Health/ Retail/ Services	Raguseo (2018)
	Enables decision making based on customer behaviours	Tourism	Miah *et al.*, (2017)
Operational benefits	Improvement in workflow efficiency; monitor quality; improve costs and outcomes; explore new insights in improving productivity; reduce time of patient travel; immediate access to relevant data to analyse; predictive and diagnostic capability leading to improved decisions	Health	Wang *et al.*, (2018); Lin *et al.*, (2018); El-Shafeiy *et al.*, (2018)
	Predicting fault in shop floor scheduling; reduce operating costs; enhance employee productivity; savings on supply chain management; increase return on financial assets	Manufacturing/ Retail/Services	Raguseo (2018); Ji and Wang (2017)
	Diagnosing potential faults in reciprocating compressors	Petroleum	Qi *et al.*, (2018)
	Detecting credit card frauds	Banking	Melo-Acosta *et al.*, (2017)

RESEARCH METHODOLOGY

The main concepts of the study are based on big data and construction process. The big data concept was gathered from big data literature, which is still evolving. Though big data research is positioned in the data-driven science (Kitchin, 2014), especially when large amount of data is being analysed but the current study considers the managerial aspect of big data. Phenomenology is employed in the study of learning within and outside the field of education, like exploring the experiences of people (Bowden, 2000; Mapp, 2008). Using a phenomenological research method, this study explored the benefits of big data experienced in the construction process, which is part of a broader ongoing PhD research.

The empirical research concerns a single case that voluntarily consented to participate in the study and known to be technology-driven in the Australian construction sector. The case has the capacity to be a unit of analysis on its own (Eisenhardt and Graebner, 2007), and in order to avoid biases and understanding of the concept (Papadonikolaki and Wamelink, 2017), data were collected from seven (7) employees at different hierarchical levels in the organization.

Review of articles in the domain area contributed to the formation of the research questions, which were validated, and reliability established on three stages. The first stage went through a review by an expert in Internet of Things to check the content and construct, which went through one iteration. The second stage was a review conducted by two construction management faculty members in our university. The third stage was done after receiving ethics approval for the study, where four construction professionals - a Construction Project Manager, a Civil Engineer, and two faculty members who worked as Mechanical Engineer and a Quantity Surveyor - were piloted for the study. The piloting exercise help in restructuring the questions to make it easier and simpler for construction professionals to understand without altering the aim of the study.

The questions were about the technologies used, data management and application of the data in their substantive roles as far as a project is concerned. Some of the questions include: What technologies, smart devices, apps and software do you use in your role? Where are the data from these technologies stored? How does the data from the technologies help you in performing your role and responsibilities? The semi-structured interview was administered by the first author through face-to-face, Skype and telephone. The data for this study is based on preliminary analysis of the application of big data in the construction process through the structural coding approach. Structural coding is appropriate for studies with multiple participants, exploratory study and semi-structured interview (Saldaña, 2016), like the case of this study.

RESULTS

Case description

The case is a tier one construction firm, operational in almost every state in Australia and involved in the construction of buildings in every sector of the Australian economy: Residential, defence, health, industrial etc. Table 2 describes the details of the respondents for the study.

Table 2: Description of interviewees for the study

Position	Abbreviation	Hierarchical level	Years of experience
Head of Unit	HU	Senior	12years
Project Administrator	PA	Middle	11years
Contract Administrator	CA1	Middle	15years
Contract Administrator	CA2	Middle	11years
Project Engineer	PE	Middle	10years
Site Engineer	SE1	Junior	4years
Site Engineer	SE2	Junior	2years

The HU is in charge of the operations within the geographical unit. HU ensures that all projects within the unit's jurisdiction are delivered to the expectation of the client and the firm, as well as ensuring that people, resources and equipment are properly allocated to all projects. The PA, CA1 and CA2 perform contract administration roles for the unit on projects assigned to them. Relationship management, procurement of subcontractors and suppliers, vetting and approval of subcontractors claims form part of the administrators' roles. The PE is in-charge of design management on projects. The SEs are primarily responsible for all forms of data capture on site and its associated technologies, contractor - subcontractor relationship, as well as safety and quality checks. The captured data by the SEs are managed and processed on the firm's platform, which becomes the go-to fact check spot for CAs, HU and senior level staff in the firm's regional, state and national headquarters. The interviews revealed a closely-knit relationship amongst the professionals in solving the puzzle of data management in the construction process.

Case analysis

Three main benefits of applying big data in the roles of these construction professionals are discussed here: Management of claims, project monitoring and control, and procurement.

Management of claims

Management of claims emerged from the interview data. A demand for payment or compensation within a contractual framework is called claim (Project Management Institute, 2017). Contractors and subcontractors receive their payments after claiming for work done. Conflict is an inevitable issue associated with working with different stakeholders especially on construction projects. Whittling-down conflicts in the issuance of subcontractor's claim require material of evidential value, to respond to the claims, the CA1 stated:

> I use time lapse camera and drone footage data to assess or respond to subcontractors payment claim in the first step. So if a subcontractor say 90% of the work done and the footage also say 40% has been done, there is no thing argument about it when it is a visuals (CA1)

Concerning its relation to big data, the data are generated from directed and automated streams of big data sources on construction projects. Though the construction professionals are not experts in technical component of big data but are aware of the data management processes in the project setup. Availability of the time lapse camera data on site can reduce the time for physical inspection on site because validation of claims can be done remotely by any member of the contract administration team without necessarily being on site. As admitted by CA1 "I just watch the footage to make sure when I walked around the site what I think I have seen is what I have seen". The reliance on these data might not override the presence of the contract administrator on site as indicated by CA: "I do walk around the site and compare percentages completed and what we can claim…we get to see what's happening, we get a demo file…" But the data could override the presence of the contract administrator on site, when the site engineers are directed to capture some portion of the work done onsite. The drone(s) and the time lapse cameras could then be adjusted to focus on the completed work, which is claimed by the main contractor or subcontractors.

Project monitoring and control

The construction process is benefiting from big data through project monitoring and control. The purpose of having project monitoring and control mechanisms is to achieve efficiency, as admitted by the HU in relations to the benefits of generating data on construction project "…try and identify issues before they become issues. I think the primarily drive is efficiencies and main is efficiency". Buttressing the point of efficiency, the HU acknowledged that "…we capture data around defects and non-conformance… and again is the case of analysing the data and deciding whether or not if there is any deficiencies, so any red flags in terms of what the data is telling us". Defects affect the progress of the project, thus the ability to identify defects at the earlier stages of the project help to reduce the cost of rework at later stages of the project, as well as having a behind-schedule project. The PE admitted that "we go generally around the day to take photos of all reinforcement in the day…and sometimes it comes like we have a few incidence where a bit of the post tension is burst and we go back to the photos and see what was installed in the slab and pick up on if there is a bar missing that is why it got burst". These mechanisms enable the contractor to have an eagle-eye on the project and rectify every defect within the process, thus, delivering and handing-over a quality project becomes the hallmark of the contractor. SE1/2 use the smart devices assigned to them like the IPads to capture defects and safety incidence and assign them to the responsible subcontractor(s) and the responsible team member from the contractor's side to rectify and/or address them immediately. This was admitted by SE2: "On site we use BIM360 fields and we synch all that onto out server for our BIM360 field and populate data onto our intranet system, where management, CAs and others that can see the data, tell us whatever they need... It just gives them an easy and quick way to any issues or how well or poor we are doing on a project. The contractor also achieves efficiency on the project by comparing the data on subcontractor attendance and the duration worked as against the budgeted labour performance. The sign-in and sign-out data are recorded through the "Whos On Location" app, which is synchronised with the contractor's intranet system by providing statistics on daily attendance and hours worked. These statistics enable staff both on-site and off-site who have access to the intranet system to have a near to real-time updates on the progress of the project. This was accounted by SE1: "…the intranet system is an overview and graph on certain stuff, let's say how many subcontractors were on site as compared to how many were predicted on site at this point in time and things like that". The statistics offer the main contractor the opportunity to query subcontractors absenting themselves from sites. Attendance are recorded to check for absenteeism on-site and a mechanism for ensuring that every individual have evacuated from site should there be an accident on site, as well as juxtaposing the actual cost of labour as against the budgeted cost of labour. Reassignment of resources becomes the strategy, if the earned value analysis suggests the project is underperforming, in-terms of working behind schedule or spending over budget.

Procurement

Procurement is a function of bidding for the right project based on organizational resources and selecting the right subcontractors. Those are the two main application of big data identified in the context of procurement in the study. Data from old projects offer an insight and guidance to CAs and HU in selecting and awarding contracts to subcontractors. In real life, no individual will be happy to forge and work with "messy subcontractors" upon knowing their capabilities and attitude towards work. This was admitted that "… the next time we want to select a subcontractor we have worked with before, it pulls up to say that subcontractor has done 10 - 15 jobs with us before, these are the values and the time they did it so that we are able to figure what the subcontractor can handle" (CA1). No builder is in the position to associate itself with abysmal and poor output of work, because their ability to survive depend on what they have been able to achieve from previous projects. And a tier one company would not risk its reputation by awarding a demanding job to an under-performing subcontractor. Accumulation of data serve as organizational memory in situations where some staff might have left the organization. The availability of such data provides an insight in inviting the capable subcontractors in tendering for a project and selecting the best.

In addition to subcontractor's procurement is the contractor's aim to bid for new projects. An organization that refuses to learn from its previous project performance will fail to grow and not survive in a dynamic and turbulent industry. Stored data on earlier projects do influence bidding for new projects, as admitted by the HU "We pull all our data to understand what job will cost us and going forward and how long it will take us… a good example is on waste, we will capture data on the amount of waste that we produce on a particular project maybe it is an aged care project, and we can use that data to make an assessment of what the cost is going to be in the next aged care job we gonna do and that's probably the benefit …". Under-pricing for a project affects the contractor's ability to win or lose a tender due to the selection criteria of tender, making it imperative to rely on the massive amount of available data. Tendering for projects is very competitive and the contracting firm's ability to gain valuable insights from existing data strengthens its competitive advantage edge over others.

In summary, big data contributes to achieving efficiency in the construction process through management of claims, project monitoring and control, and procurement. In the broader sense of the classification in Table 1, management of claims, and project monitoring and control are operational benefits, whilst procurement is strategic benefits. Meanwhile, these big data benefits can be deconstructed further based from the above discussion:

1. Management of claims:
   a. Reduces conflict amongst project stakeholders.
   b. Reduces time spent on contract administrators' inspection on site.
2. Project monitoring and control:
   a. Enables "near to real time" communications and updates between site and head office.
   b. Contributes to quick response to issues on site.
   c. Contributes to the identification of defects and its causes.
   d. Contributes to achieving project objectives: Time, cost, quality and safety
3. Procurement:
   a. Contributes in the selection and award of contract to responsible and capable subcontractors.
   b. Contributes to submitting competitive bid for projects.

CONCLUSION

Big data application in the construction industry is inevitable in the current dispensation of the fourth industry. Sophisticated technologies will continue to evolve and the construction industry should strategize and ride on the wave of big data since the industry's rate of technology adoption is slow. This empirical study identified three benefits of big data in the construction process thus, claim management, project monitoring and control, and procurement. By implication, the findings provide real life experiences of big data in the construction process. This study contribute to the discourse on the promises of big data as an element of the fourth industrial revolution and the future of the construction industry.

From the forgoing, there is the need for practitioners to rethink and employ best practices and develop data management competencies as far as the industry is concerned. Aside the benefits identified from the study, it would be highly recommended to conduct further research on the barriers and capabilities of big data application in the construction industry. Such research will provide a comprehensive view and understanding of big data to both construction management practitioners and researchers.

REFERENCES

Atuahene, B T, Kanjanabootra, S and Gajendran, T (2018) Towards an Integrated Framework of Big Data Capabilities in the Construction Industry: A Systematic Literature Review. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 547–556.

Bilal, M, Oyedele, L O, Qadir, J, Munir, K, Ajayi, S O, Akinade, O O, Pasha, M (2016) Big Data in the construction industry: A review of present status, opportunities and future trends, *Advanced Engineering Informatics*, **30**(3), 500-521.

Bowden, J A (2000) The nature of Phenomenographic research, *In*: J A Bowden and E Walsh (Eds.) *Phenomenograph*y, Melbourne: RMIT Publishing.

Cheng, C T, Bab-Hadiashar, A, Lai, C Y, Chan, J, Peszynski, K, Vldoni, M, Sun, X (2020) *Demystifying Industry 4.0 - Helping SMEs Lay Tracks for Australia's Digitalisation Express Train*, Melbourne: RMIT Publishing.

Davenport, T H (2014) How strategists use big data to support internal business decisions, discovery and production, *Strategy and Leadership*, **42**(4), 45-50.

Demchenko, Y, Grosso, P, de Laat, C and Membrey, P (2013) Addressing big data issues, in scientific data infrastructure, *In*: *2013 International Conference on Collaboration Technologies and Systems (CTS)*, 20-24 May, San Diego, CA, USA

Department of Industry (2019) *Industry 4.0*, Australian Government, Department of Industry, Science, Energy and Resources.

Eisenhardt, K M and Graebner, M E (2007) Theory building from cases: Opportunities and challenges, *Academy of Management Journal*, **50**(1), 25-32.

El-Shafeiy, E A, El-Desouky, A I and Elghamrawy, S M (2018) Prediction of liver diseases based on machine learning technique for big data, *In*: *3rd International Conference on Advanced Machine Learning Technologies and Applications (AMLTA*), Springer Verlag, 362-374.

Han, K K and Golparvar-Fard, M (2017) Potential of big visual data and building information modelling for construction performance analytics: An exploratory study, *Automation in Construction*, **73**, 184-198.

Ji, W and Wang, L (2017) Big data analytics-based fault prediction for shop floor scheduling, *Journal of Manufacturing Systems*, **43**, 187-194.

Kanjanabootra, S, Peszynski, K and Atuahene, B T (2019) On-going social commentary and the new project manager: Sentiment in large infrastructure projects, *In*: *17th Annual Engineering Project Organization Conference*, Vail, CO, USA.

Kitchin, R (2013) Big Data and human geography: Opportunities, challenges and risks, *Dialogues in Human Geography*, **3**(3), 262 - 267.

Kitchin, R (2014) Big Data, new epistemologies and paradigm shifts, Big Data and Society, **1**(1).

Lin, M, Gong, P, Yang, T, Ye, J, Albin, R L and Dodge, H H (2018) Big Data analytical approaches to the NACC dataset: Aiding preclinical trial enrichment, *Alzheimer Disease and Associated Disorders*, **32**(1), 18-27.

Low, S P, Gao, S and Ng, E W L (2019) Future-ready project and facility management graduates in Singapore for industry 4.0: Transforming mindsets and competencies, *Engineering, Construction and Architectural Management* [Ahead of Print], https://doi.org/10.1108/ECAM-08-2018-0322

Mapp, T (2008) Understanding phenomenology: The lived experience, *British Journal of Midwifery*, **16**(5), 308-311.

Melo-Acosta, G E, Duitama-Munoz, F and Arias-Londono, J D (2017) Fraud detection in big data using supervised and semi-supervised learning techniques, *In*: *2017 IEEE Colombian Conference on Communications and Computing (COLCOM 2017)*.

Miah, S J, Vu, H Q, Gammack, J and McGrath, M (2017) A Big Data Analytics Method for Tourist Behaviour Analysis Information and Management, **54**(6), 771-785.

Papadonikolaki, E and Wamelink, H (2017) Inter- and intra-organizational conditions for supply chain integration with BIM, *Building Research and Information*, **45**(6), 649-664.

Project Management Institute (2017) *A Guide to Project Management Body of Knowledge: PMBOK Guide,* Newtown Square, PN, USA: Project Management Institute.

Qi, G, Zhu, Z, Erqinhu, K, Chen, Y, Chai, Y and Sun, J (2018) Fault-diagnosis for reciprocating compressors using big data and machine learning, *Simulation Modelling Practice and Theory*, **80**, 104-127.

Raguseo, E (2018) Big data technologies: An empirical investigation on their adoption, benefits and risks for companies, *International Journal of Information Management*, **38**(1), 187-195.

Russom, R (2011) Big Data Analytics, TDWI Research, Available from https://vivomente.com/wp-content/uploads/2016/04/big-data-analytics-white-paper.pdf [Accessed 29th July 2020].

Saldaña, J (2016) *The Coding Manual for Qualitative Researchers Third Edition*, London SAGE.

Strohbach, M, Daubert, J, Ravkin, H and Lischka, M (2016) Big Data storage, *In*: J M Cavanillas, E Curry and W Wahlster (Eds.) *New Horizons for a Data-Driven Economy: A Roadmap for Usage and Exploitation of Big Data in Europe*, Cham: Springer International Publishing, 119-141.

Wamba, S F, Akter, S, Edwards, A, Chopin, G and Gnanzou, D (2015) How 'big data' can make big impact: Findings from a systematic review and a longitudinal case study, *International Journal of Production Economics*, 165, 234-246.

Wang, Y, Kung, L, Wang, W Y C and Cegielski, C G (2018) An integrated big data analytics-enabled transformation model: Application to health care, *Information and Management*, **55**(1), 64-79.