The Turkish Online Journal of Design, Art and Communication - TOJDAC
ISSN: 2146-5193, September 2018 Special Edition, p.1470-1480

BIG DATA IN THE CONSTRUCTION INDUSTRY: POTENTIAL OPPORTUNITIES AND WAY FORWARD

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ABSTRACT
Coined as the 'gold rush' of the 21st century, big data is believed to make a headway and spark researcher's interest to promulgate big data research from the lens of the construction industry. Paired with an escalating trend of emerging technology usage, this welcomes the upcoming wave of digital information surge earlier than expected. Pivots on a universal form of technology, big data is believed to bring greater benefits albeit being an infancy in the construction industry. However, research on big data from the lens of construction industry is limited in contrast to the other industries resulting to rudimentary understanding. Thus, this research aimed to gain understanding big data form the construction industry perspective and suggest direction for future works. Through content analysis on literature review and semi-structured interview, this research explores and validates the potential opportunity of big data in the construction industry as well as deciphering the value of big data. The analysis reveals data driven design, waste management, decision support system and data management among four main potential opportunities of big data with significant transperancy, experimentation and data driven decision making value. Finally, this paper concludes that the construction industry can greatly benefit from big data, hence, paving a huge room for future big data research in the construction industry.

Keywords: *Big Data, Big Data Opportunities, Construction Industry, Construction Organizations*

1. Introduction

Investment in IT is the catalyst to productivity and business growth (Roztocki & Weistroffer, 2009; Shahiduzzaman & Alam, 2014). Dahlan (2007) suggests that IT poses a critical role for business to improve their operational effectiveness whilst enabling them to cope with the competitive pressures, especially, businesses in developing countries. Viewed as an enterprise, construction industry is taking a strategic move in IT investment. The emerging technology usage published by KPMG (2016) shown in Figure 1 indicates a substantial uptake of IT technologies. This shows that construction organizations have taken a leap from utilising IT as an administrative function towards IT capitalization to improve business productivity.

Evidently, this shows a substantiated move towards digitalization. This reflects a possibility of an upcoming wave of digital information surge, bringing greater benefits to the construction industry. Taking a cue from other industries, big data is believed to make a headway and to spark researcher's interest to promulgate big data from the lens of construction industry.

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
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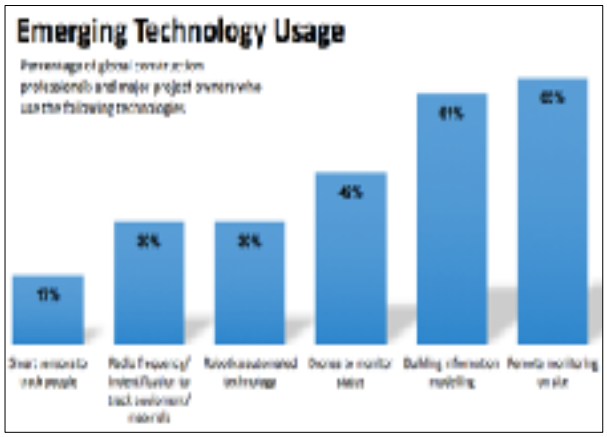

Fig. 1. Emerging Technology in Construction Industry Adapted from KPMG (2016, p. 3)

Despite, research of big data from the lens of construction industry is limited in contrast to other industries (Bilal et al., 2016), leading big data research in this industry are rather technical (Barista, 2014; Chen, Lu, & Liao, 2017; Olsson & Bull-Berg, 2015). This left a fuzzy understanding on the big data potential opportunities; creating a gap for big data implementation in construction industry. As the scope of the Malaysian construction industry is concerned, the Construction Industry Transformation Plan 2016-2020 is geared to double its productivity through the implementation of big data, hence, flag a significant research need in this area. Befitting, this paper attempts to build up current understanding of big data from the construction industry perspective with an aim to suggest some potential directions for future works to be expedited. This was achieved by accomplishing two objectives which are: (1) to identify the potential opportunities of big data in construction; (2) based on objective (1), to gain the industry insights to validate the potential opportunities of big data in construction. The final objective of this research is to determine the significant value of big data in construction industry.

Accordingly, the first part of this paper introduces the construction industry current state of art from digital growth perspective. The second part presents big data concept by looking into its definition and opportunities. This section moves to analysis and discussion on the potential opportunities of big data in the construction industry, addressed in the third section. Subsequently, this paper presents the industry insights on big data and explain the dimensions on how big data creates value to the construction industry prior to suggestions on the way forward for big data research in construction indsutry.

Fifteen papers were analysed using the content analysis method in the light of exploring the themes on big data potential opportunities. These papers are the result of a much-narrowed databases searched focusing on two keywords which are 'Big Data' and 'Construction Industry'. Emerald and Science Direct databases were searched from the year 2008 as research on big data started to gain attention. A total of 48 and 194 papers were obtained. The papers were filtered according to content similarity on organizational context or its relation to big data as technological component in construction.

Due to the scarcity of literature, cross-reference analysis was conducted to increase the number of articles while gaining deeper insights of research context addressed. According to Bryman (2004), content analysis is the most prevalent approach to spot underlying themes while Mayring (2000) believes this approach is a sophisticated form of qualitative analysis. The robustness of this research was addressed by analysing the transcribes of the semi-structured interviews transcripts gathered during the Statistic, Indices in Construction and Automation Conference (SICA) 2017. Transcribes were analysed using Nvivo software by coding themes emerged on big data potential in construction industry (Piaw, 2012). Themes guided by codes emerged were further analysed by making inferences based on respondent's agreement and opinion to form a clearer, structured and validation on researcher's understanding as well as findings on big data in the construction industry.

2. Big Data

2.1.Definitions and Concepts of Big Data

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The simplest form of big data definition reflects the situation of extreme large amount of data for the current technology capacity to store, manage and process efficiently (Kaisler et al., 2013; Manyika et al., 2011). However, big data is most commonly defined through its characteristics (Cunningham, 2014; Gandomi & Haider, 2015; Halaweh, 2015; Kaisler et al., 2013; Singh & Singh, 2012). Gartner (2012) defines big data through the 3V characteristics "high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation". As the knowledge evolve, 4th (IBM, 2013; Miele & Shockley, 2013) and 5th (Ohlhorst, 2013; Oracle, 2011) 'V' of 'veracity' and 'value' characteristics were introduced. Nonetheless, the commonly accepted definition on big data refers to the 3V big data characteristics (Berman, 2013; Chen et al., 2012; Kwon & Sim, 2013; McAfee & Brynjolfsson, 2012; Russom, 2011).

However, the recent research by Bilal et al., (2016), Bizer, Boncz, Brodie, & Erling (2011) and Ohlhorst (2013) suggests big data can alternatively be defined through its concept which encapsulates big data technology and data analytics governing the process of turning information into valuable insights. Big data technology pivots upon subset of big data platform, big data processing and big data storage. Nonetheless, Bhatt & Kankanhalli (2011) argues that data analytics is the most important concept of big data. Some examples of data analytics methods are statistical and algorithm based techniques such as regression, naïve bayes, decision trees, support vector machines, genetic algorithm, natural language processing, information retrieval, machine learning, artificial neural network, latent semantic analysis and crowdsourcing (Bilal et al., 2016; Chebbi, Boulila, & Farah, 2015; Chen & Zhang, 2014). Perhaps, analytics governs the criticality of big data where organizations incorporate 'insights' in decision making process, driving values and opportunities to organizations.

While there is an increase number of research across industries to enhance the understanding and defining big data, there is yet to be a universally agreed definition of big data (Hartmann, Zaki, Feldmann, & Neely, 2014; Wielki, 2013). Hence, big data definition is inconsistent and vague. This is suggested due to the incoherent development of technology and academic research where the rapid technology evolution and active industry adaptation on big data creates a convolution paradigm for academic researcher to precisely define big data.

2.2.Opportunities Through Big Data

Organizations are leveraging big data to lead their market. With big data, organizations gain insights and improve productivity, customer experience, reducing business cost and opportunity to new business (McAfee and Brynjolfsson, 2012). Big data offers 5% to 6% higher profitability to organizations (McAfee & Brynjolfsson, 2012). In a wider landscape, the Centre of Economics and Business Research (CEBR, 2012) published an anticipated £24 billion revenue to the UK economy through big data. This suggests a related impact of the four domain of big data activities; collection, combination, analytics and visualization paving the universal implementation across industries (Chen, Mao, & Liu, 2014).

Table 1 shows the application of big data across three main industries; medical, manufacturing and retail. It can be seen that big data has brought different opportunities to the industries tailoring to its needs. The opportunities of big data are focused on understanding the process and operations of the industries to create customer value while increasing the overall business return. However, the opportunities shall not be viewed in discrete. Instead, the opportunities of big data should be addressed from a chain impact point of view. Each improvement further lead to opportunities of improving efficiency, productivity and create new forms competitive advantage (Barton & Court, 2012; Gobble, 2013; Halaweh, 2015; Manyika et al., 2011; Ohlhorst, 2013). Nonetheless, big data pave towards proactive innovation; giving organizations more control on the industry's market. Proactive innovation enables them to capture market just the way they want it and enables organizations to compete with a new strategy in the market.

Table 1. Opportunities of Big Data in Multi-Industries

Industry	Opportunities	Authors
Medical	Real-time treatment analysis	Groves et al. (2013); Knowledgent (2014) and Murdoch & Detsky (2013)
	Ubiquitous healthcare	Groves et al, (2013) and IBM (2012)

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	Personalized healthcare	IBM (2012); Murdoch & Detsky (2013) and Savage (2012)
Manufacturing	Product, market and risk forecasting	Charted Global Management Accountant (2014); Columbus (2014) and Gutierrez (2017)
	Process and business performance integration	Oracle (2015); Kurtz & Shockley (2013) and General Electrics (2012)
	Performance efficiency	Oracle (2015); Yin & Kaynak (2015); Kurtz & Shockley (2013)
Retail	Understanding customer, optimize product offerings	Davenport & Patil (2012) and McAfee & Brynjolfsson (2012)
	Pricing strategy and advertising	Miele & Shockley (2013); CEBR (2012) and Chen & Zhang (2014)

3. Results and Discussion

The number of research on big data in the construction industry is limited, but, believed to have great impact in improving industry productivity and performance. According to Deutsch (2015a), the built environment domain is a data intensive industry. This indicates that the construction industry hosts huge volume and wide variety of data. Exhaustive analysis on fifteen papers through content analysis method reveals the potential opportunities of big data in the construction industry centres towards four different themes of data driven design, waste management, decision support system and data management as visualized in Figure 2.

From the perspective of construction industry, big data transformed the time intensive traditional design delivery towards data driven design (Barista, 2014). Data driven design are mostly practiced by developers and consultants in the United States. Data driven design was successfully adopted in John F. Kennedy Harvard School of Government and Kaiser Permanente small hospital United States (Deutsch, 2015b; Imbler, 2013). Big data enables designers to capture key performance metrics and conduct experiments on design prototypes based on client's needs. While big data innovates product offerings in retail industry, the construction industry applies big data in optimizing building models. Moreover, automization of construction planning process such as project durations and work schedule can be established and addressed during the conceptual stage through algorithm analysis of pooled internal and external data. Big data technology enables designers to understand and see though patterns on how end-user utilize building spaces. This give flexibility for designers to produce building design which tailors to user preference and usage pattern.

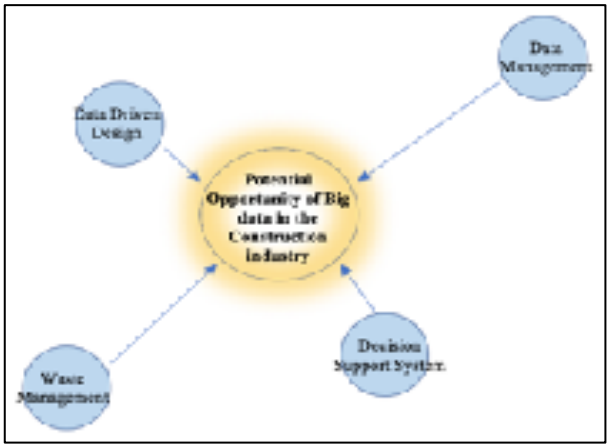

Fig. 2. Potential Opportunity of Big Data in Construction Industry

Secondly, big data host the opportunity to transform waste management process in the construction industry. Big data optimize the waste management process through integration of waste and construction data. This enables detection of construction material, supply chain and process as well as

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procurement system. Construction organizations can better manage construction waste during pre-construction period and further strategize waste reduction and elimination practices (Chen, Lu, & Liao, 2017; Lu, Chen, Ho, & Wang, 2016; Lu, Chen, Peng, & Shen, 2015). This shows that the construction industry is utilizing big data by transforming the way they do things (Fosso Wamba, Akter, Edwards, Chopin, & Gnanzou, 2015). This reflects that waste management process has been transformed and improves productivity, efficiency as well as performance of the construction industry.

The research of Zhang, Luo and He (2015) as well as Taylan, Kabli, Porcel and Herrera-Viedma (2017) shows the opportunity of big data to govern construction management by assisting construction decision makers such as contractors and quantity surveyors to make data driven decision on construction issues. The first research outlines a framework which guides construction organizations on tender price decision making by evaluating bidder's tender price using big data. The variability of data source in this research enables higher degree of tender price accuracy for construction organizations to evaluate the tenderers. On the other hand, the latter research conducted in Saudi Arabia indicates that big data supports decision making in which to identify key criteria for contractor selection. Large data from seven contractors and five construction project were analysed to identify key criteria for contractor selection. Although both research shows progress in integrating the application of data-driven decision making specifically in the construction management area, it is seen that the difference on how big data is perceived in both research shows that the construction industry has poor understanding of big data concept.

Despite data management is a prominent area in IT research, this is rather new to the construction industry. Most literature discussed on data storage, processing and cloud storage (Fathi, Abedi, Rambat, Rawai, & Zakiyudin, 2012; Jiao et al., 2013). While data management was limited towards facilitating BIM research, current data mining and management research look into big data concept which facilitates large volume and different source of data management for construction projects (Das, Cheng, & Kumar, 2014; Das & Kumar, 2013; Lin, Hu, Zhang, & Yu, 2016). Although big data is at its infacy, this implies that BIM is a stepping stone to push big data adaptation in the construction industry.

Industry insights were solicited through unstructured interview conducted during the Statistic, Indices in Construction and Automation Conference (SICA) 2017 among five industry representatives with the knowledge on big data. This conference was held on 16th November 2017 in Kuala Lumpur as an ongoing initiative of the Construction Industry Development Board (CIDB) Malaysia to prompt discussion between various industry parties such as contractors, developers and construction professionals with academic researchers in understanding the current scenario of big data and explore ways to push big data into this industry in the light of combating sore construction productivity scenario.

Based on the interviews conducted, all respondents agree with data driven design, waste management, decision support system and data management as the big data potential opportunities proposed in which, reflects that opportunities are closely related to process improvement rather than product and customers. However, one respondent highlights the opportunity of big data across construction stage and the building lifecycle. Although it is seem that the literature focuses on opportunities during the pre-construction stage which co-aligns big data as a proactive technology innovation (Chen et al., 2012), the respondent views that this simply do not represent the overall opportunity of big data. Instead, digital information (data) in the construction industry are capable in deriving insights not only to address construction issues across construction stage, but to govern the effectivity and management of building lifecycle. This view is further supported by the research of Olsson and Bull-Berg (2015) which present the application of big data in analysing internal performance to assist project manager in spotting signs for project deviation. Insights form big data assist construction managers to make operational, tactical and strategic decisions. Hence, transforming both construction process and product.

Other than that, two respondents suggest that the construction organizations must be able to see big data as a paradigm to improve productivity before leading to discussion on the potential opportunities. This further emphasised by the Minister of Works Malaysia where big data is the remedy towards the productivity issues and overcoming the disruptive technology impact (Yusof, 2017). However, the lack of data integration in the construction industry is concerning towards the development of big data knowledge in the construction industry as this is reflected by the 'silo' working practice.

The specific technical applicability for opportunities mentioned are general towards all construction organizations specifically for decision support system and data management. For example, decision support system improves quantity surveyor's ability to make prompt and strategic decisions on tender

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price while data management acts as a platform for construction organization such as contractors, engineers and developers to store data in digital format and improves current data management capability. On the other hand, respondent views data driven design is beneficial for architects and engineers to better articulate construction designs while waste management process is an advantage to contractors and industry regulators to best manage construction waste.

In relation to the second research question as well as the cruciality of understanding big data highlighted from the industry perspective, this research proposed the concerns shall be addressed by understanding how big data creates value to the construction industry. This believed to create a push for big data application and sparks academician's interest in big data. Figure 3 shows the values of big data in the construction industry.

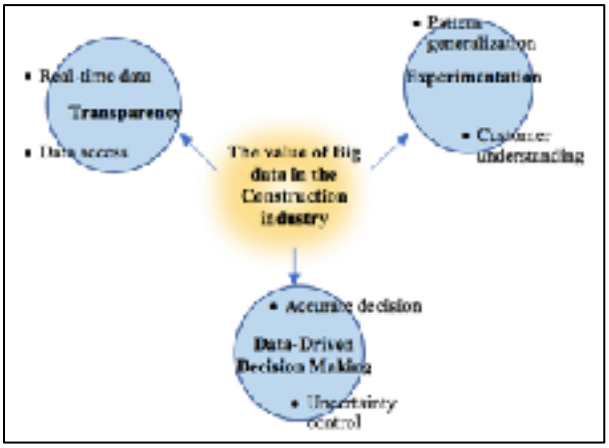

Fig. 3. Values of Big Data in Construction Industry

The values stemmed from the McKinsey Global Institute 2011 key report addressed five ways on how big data creates value for organizations (Manyika et al., 2011). It is seen that big data research in construction industry deliver values in terms of creating transparency, enabling experimentation to discover needs, expose variability and improve performance as well as replacing or supporting human decision making data-driven decision making. Two other aspects of value creation suggest by the report; segmenting population to customize actions and innovating new business models does not aligned with our data analysis. However, there is a potential that this shall be among the area of future research as its significance are yet to be discovered.

Our data shows that big data delivers value to construction organizations by creating transparency. The concept of big data on integration and collaboration enables construction organizations to have instant data access. For example, data from building performance analysis can be accessed even before design stage. This enables construction organizations to have clear overall picture and further reduce rework issues. On the other hand, real time access on building operation data enables construction organizations to monitor building usage efficiency and delivering the ability on instant remedy on problem occurrence on site (Olsson & Bull-Berg, 2015). This enables construction organizations to save cost and improve its efficiency. Many research viewed BIM as the latest cutting edge technology innovation in the construction industry. Research however fails to go beyond the norm and ask, what is after BIM? Yes, we now know that we hold abundance of data but what do we do about it?

From this, we see the presence of BIM as among the driving factors of big data emergence in the construction industry. Big data is the knowledge that is discussed along and perhaps, the extension on BIM developments. The concept of big data shall harness this industry advancement of data collection, storage and integration of BIM and further develop a coherence towards data analytics to derive actionable insight which delivers highest value. The essence of big data, together with BIM, breaks the monotony of construction organizations working in silo and move towards the idea of collaboration and integration while creating a transparent construction organization's feedback loop.

Secondly, our analysis reflects that big data creates value for construction organizations and stakeholders through experimentation, discovering needs and exposing variability. Big data delivers insights and solution through understanding the context and pattern generalization (Davenport, 2014). Big data enables construction organizations to understand how spaces in building are being utilized by end user as well as the relationship between user behaviour and how that can be leveraged into designing building that are tailored to the end user's needs as well as generating higher investment

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return though the relationship understanding. Construction organizations can deliver better design solution to clients while improving end user surplus in one.

For instance, the usage of Bluetooth movement tracking using phone devices to understand how end user move about and time spent in the Louvre Museum Paris (Yuji Yoshimura, Stanislav Sobolevsky, Carlo Ratii Fabien Girardin, Juan Pablo Carrascal, Josep Blat, 2014) as well as understanding customer purchasing pattern in stores (Olsson & Bull-Berg, 2015). This enables construction organizations to better design future project which incorporates the pattern of customer consumption, leaving clients with higher investment of return through higher rent value and significant customer experience improvement. Looking though this issue from the business point of view, cost savings and income generation increases when construction period is shortened (Goss & Veeramuthu, 2013; Ramon Casadesus-Masanell, 2010; Teece, 2010). This reflects towards shorter time for client bearing the responsibility on construction cost and enables them to move towards operational stage and start to generate return from their investment.

Finally, big data drives value by offering support and aid in human decision making process. For example, the contractor selection tool, tender price evaluation as well as automated generation of project planning through data driven design supports, enhanced and somewhat replace the human decision making process. However, this does not justify that human skills are no longer significant and technology poses better capability and supersedes human capability. This research believes that human skills are irreplaceable with technology. Instead, technology offers solutions to aid human incapability. Big data enables zettabytes data size to be analysed in few seconds which then, enables human to see through pattern in real time. With this, insights generated through the technology of big data enable humans to be equipped with informed decisions options. According to Osama Moselhi, Terek Hegazy (1991) analytics model such as ANN-based intelligent system offer better accurate decision making compared to conventional system based concepts. This provides construction organization with greater control on uncertainty. Therefore, this suggest that construction organizations shall move forward and embrace big data technology to improve decision making capability and drive the overall performance of construction industry.

Based on the potential opportunities agreed, this research believes that big data understanding in the Malaysian construction industry is modest yet, crucial to probe more discussion on big data from both the industry and academic realm. Hence, we postulate three possible directions for future research on big data which shall look into big data challengers and impediments which, exploring potential application of big data opportunities can be implemented within construction organizations. Lastly, research on the suitable data types for better decision making which tailors to construction organization's needs. Above all, these research found solid technical understanding for construction organizations to move forward with big data.

4. Conclusion

To build grasp understanding on big data from the construction industry perspective, this research considers the potential opportunities inter-relative data from both academic and industry perspective. Informed by the analysis, it is clear that the potential opportunities of big data are addressed in four different areas of; data driven design, waste management, decision support system and data management. From that, this research views that the understanding of big data in the Malaysian construction industry is modest. Hence, this research suggests that there are plenty of room for big data research from the construction industry perspective. The limited big data research shows both academics and industry expert shall work hand in hand to have an agreed direction, interest and solutions for the construction industry to advance towards realizing the big data dream

5. References

Barista, D. (2014). The Big Data revolution : How Data-Driven Design is Transforming Project Planning. Retrieved July 3, 2017, from https://www.bdcnetwork.com/big-data-revolution-how-data-driven-design-transforming-project-planning

Barton, D., & Court, D. (2012). Making Advanced Analytics Work For You. Harvard Business Review, (October). Retrieved from http://www.buyukverienstitusu.com/s/1870/i/Making%7B_%7DAdvanced%7B_%7DAnalytics%7B_%7DWork%7B_%7DFor%7B_%7DYou.pdf

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
Research Article - This article was checked by Turnitin

Berman, J. J. (2013). Principles of Big Data. Massachusetts, United States: Morgan Kaufmann.

Bhatt, C. A., & Kankanhalli, M. S. (2011). Multimedia Data Mining: State of the Art and Challenges. Multimedia Tools and Applications, 51(1), 35–76. https://doi.org/10.1007/s11042-010-0645-5

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. https://doi.org/10.1016/j.aei.2016.07.001

Bizer, C., Boncz, P., Brodie, M. L., & Erling, O. (2011). The meaningful Use of Big Data: Four Perspectives – Four Challenges. SIGMOD Record, 40(4), 56–60.

Bryman, A. (2004). Social Research Methods (2nd ed.). New York: Oxford University Press.

CEBR. (2012). Data equity Unlocking the Value of Big Data. Centre for Economics and Business Research. https://doi.org/10.1108/MIP-05-2012-0055

Charted Global Management Accountant. (2014). Big Data: Readying Business for the Big Data Revolution. World Congress of Accountants. https://doi.org/10.1109/TKDE.2013.109

Chebbi, I., Boulila, W., & Farah, I. R. (2015). Big Data: Concepts, Challenges and Applications Imen. In 7th International Conference of Computational Collective Intelligence (pp. 638–647). Madrid, Spain: Springer International Publishing Switzerland. https://doi.org/10.1007/978-3-319-67077-5

Chen, C. L. P., & Zhang, C.-Y. (2014). Data-Intensive Applications, Challenges, Techniques and Technologies: A Survey on Big Data. Information Sciences, 314–347. https://doi.org/10.1016/j.ins.2014.01.015

Chen, H., Chiang, R. H., & Storey, V. C. (2012). Business Intelligence and Analytics: From Big Data to Big Impact. MIS Quarterly, 36(4), 1165–1188. https://doi.org/10.1145/2463676.2463712

Chen, M., Mao, S., & Liu, Y. (2014). Big data: A survey. Mobile Networks and Applications, 19(2), 171–209. https://doi.org/10.1007/s11036-013-0489-0

Chen, X., Lu, W., & Liao, S. (2017). A Framework of Developing a Big Data Platform for Construction Waste Management: A Hong Kong Study. Proceedings of the 20th International Symposium on Advancement of Construction Management and Real Estate, 1069–1076. https://doi.org/10.1007/978-981-10-0855-9_94.

Columbus, L. (2014). Ten Ways Big Data is Revolutionizing Manufacturing.

Cunningham, S. (2014). Big Data and Technology Readiness Levels. IEEE Engineering Management Review, 42(1), 8–9. https://doi.org/10.1109/EMR.2014.2300254

Dahlman, C. (2007). Technology, globalization and international competitiveness: Challenges for developing Countries", Industrial development for the 21st century, Department of economic and social affairs of United Nations.

Das, M., Cheng, J. C. P., & Kumar, S. S. (2014). BIMCloud: A Distributed Cloud-based Social BIM Framework for Project Collaboration. In International Conference on Computing in Civil and Building Engineering (pp. 455–462). Orlando. https://doi.org/10.1061/9780784413616.053

Das, T. K., & Kumar, P. M. (2013). BIG Data Analytics: A Framework for Unstructured Data Analysis. International Journal of Engineering Science & Technology, 5(1), 153–156. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=88917864&site=eds-live%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=09755462&AN=88917864&h=oI5GF+qdtLnyxEKvYFe0YPeNMLsOnOKP7sN58dAdrk2J/2I

Davenport, T. H., & Patil, D. J. (2012). Data Scientist: The Sexiest Job of the 21st Century. Harvard Business Review, (October).

Davenport, T. (2014). How Strategists use "Big Sata" to Support Internal Business Decisions, Discovery and Production. Strategy & Leadership, 42(4), 45–50. https://doi.org/10.1108/SL-05-2014-0034

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
Research Article - This article was checked by Turnitin

Deutsch, R. (2015a). Data-Driven Design and Construction: 25 Strategies for Capturing, Analyzing, and Applying Big Data. New Jersey: John Wiley & Sons.

Deutsch, R. (2015b). Leveraging data Across the Building Lifecycle. Procedia Engineering, 118, 260–267. https://doi.org/10.1016/j.proeng.2015.08.425

Fathi, M., Abedi, M., Rambat, S., Rawai, S., & Zakiyudin, M. (2012). Context-Aware Cloud Computing for Construction Collaboration. Journal of Cloud Computing, 1–11. https://doi.org/10.5171/2012.644927

Fosso Wamba, S., Akter, S., Edwards, A., Chopin, G., & 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. https://doi.org/10.1016/j.ijpe.2014.12.031

Gandomi, A., & Haider, M. (2015). Beyond the Hype: Big data Concepts, Methods, and Analytics. International Journal of Information Management, 35(2), 137–144. https://doi.org/10.1016/j.ijinfomgt.2014.10.007

Gartner. (2012). Big Data. Retrieved June 12, 2017, from https://www.gartner.com/it-glossary/big-data

General Electrics. (2012). The Rise of Industrial Big Data. GE Intelligent Platforms.

Gobble, M. M. (2013). Big Data: The Next Big Thing in Innovation. Research-Technology Management, 56(1), 64–67. https://doi.org/10.5437/08956308X5601005

Goss, R. G., & Veeramuthu, K. (2013). Heading Towards Big Data. In 24th Annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC) (pp. 220–225). New York: IEEE.

Groves, P., Kayyali, B., Knott, D., & Van Kuiken, S. (2013). The "big data" revolution in healthcare: accelerating value and innovation. McKinsey Global Institute. https://doi.org/10.1145/2537052.2537073

Gutierrez, D. D. (2017). Big Data for Manufacturing. insideBIGDATA.

Halaweh, M. (2015). Conceptual Model for Successful Implementation of Big Data in Organizations. Journal of International Technology and Information Management, 24(2), 21–29.

Hartmann, P. M., Zaki, M., Feldmann, N., & Neely, A. (2014). Big Data for Big Business? A Taxonomy of Data-driven BusinessModels used by Start-up Firms. Cambridge Service Alliance Whitepaper. https://doi.org/10.1016/j.im.2014.08.008

IBM. (2012). IBM big data platform for healthcare.

IBM. (2013). Big Data Analytics. Retrieved November 13, 2017, from https://www.ibm.com/analytics/us/en/big-data/

Imbler, S. (2013). Interactive Survey Results to Shape Future Campus Development.

Jiao, Y., Wang, Y., Zhang, S., Li, Y., Yang, B., & Yuan, L. (2013). A Cloud Approach to Unified Lifecycle Data Management in Architecture, Engineering, Construction and Facilities Management: Integrating BIMs and SNS. Advanced Engineering Informatics, 27(2), 173–188. https://doi.org/10.1016/j.aei.2012.11.006

Kaisler, S., Armour, F., Espinosa, J. A., & Money, W. (2013). Big Data: Issues and Challenges Moving Forward. In 46th Hawaii International Conference on System Sciences (pp. 995–1004). https://doi.org/10.1109/HICSS.2013.645

Knowledgent. (2014). Big Data and Healthcare Payers. Retrieved from https://knowledgent.com/wp-content/uploads/2014/07/Big-Data-and-Healthcare-Payers-Whitepaper.pdf

KPMG. (2016). Building a Technology Advantage. Harnessing the Potential of Technology to Improve the Performance of Major Projects. Global Construction Survey 2016. Retrieved from https://assets.kpmg.com/content/dam/kpmg/tr/pdf/2016/11/tr-global-construction-survey-2016.pdf

Kurtz, F., & Shockley, R. (2013). Analytics : The real-world use of big data in manufacturing.

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
Research Article - This article was checked by Turnitin

Kwon, O., & Sim, J. M. (2013). Effects of Data Set Features on the Performances of Classification Algorithms. Expert Systems with Applications, 40(5), 1847–1857. https://doi.org/10.1016/j.eswa.2012.09.017

Lin, J. R., Hu, Z. Z., Zhang, J. P., & Yu, F. Q. (2016). A Natural-Language-Based Approach to Intelligent Data Retrieval and Representation for Cloud BIM. Computer-Aided Civil and Infrastructure Engineering, 31(1), 18–33. https://doi.org/10.1111/mice.12151

Lu, W., Chen, X., Ho, D. C. W., & Wang, H. (2016). Analysis of the Construction Waste Management Performance in Hong Kong: The Public and Private Sectors Compared using Big Data. Journal of Cleaner Production, 112, 521–531. https://doi.org/10.1016/j.jclepro.2015.06.106

Lu, W., Chen, X., Peng, Y., & Shen, L. (2015). Benchmarking Cconstruction Waste Management Performance using Big Data. Resources, Conservation and Recycling, 105, 49–58. https://doi.org/10.1016/j.resconrec.2015.10.013

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C., & Byers, A. H. (2011). Big Data: The Next Frontier for Innovation, Competition, and Productivity.

Mayring, P. (2000). Qualitative Content Analysis. Forum: Qualitative Social Research, 1(2). Retrieved from http://www.qualitative-research.net/fqs-texte/2-00/2-00mayring-e.htm

McAfee, A., & Brynjolfsson, E. (2012). Big Data: The Management Revolution. Harvard Buiness Review, 90(10), 61–68. https://doi.org/10.1007/s12599-013-0249-5

Miele, S., & Shockley, R. (2013). Analytics : The Real-World Use of Big Data. Retrieved from http://www.informationweek.com/pdf_whitepapers/approved/1372892704_analytics_the_real_world_use_of_big_data.pdf

Murdoch, T. B. T. B., & Detsky, A. S. A. S. (2013). The inevitable application of big data to health care. Jama, 309(13), 1351–1352. https://doi.org/10.1001/jama.2013.393

Ohlhorst, F. J. (2013). Big Data Analytics: Turning Big Data into Big Money. New Jersey: John Wiley & Sons.

Olsson, N. O. E., & Bull-Berg, H. (2015). Use of Big Data in Project Evaluations. International Journal of Managing Projects in Business, 8(3), 491–512. https://doi.org/10.1108/IJMPB-09-2014-0063

Oracle. (2011). Oracle: Big data for the enterprise. Oracle White Paper. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Oracle+:+Big+Data+for+the+Enterprise#0

Oracle. (2015). Improving Retail Performance with Big Data Architect 's Guide and Reference Architecture Introduction.

Osama Moselhi, Terek Hegazy, P. F. (1991). Neural Networks as Tools in Construction. Journal of Construction Engineering and Management, 117(4), 606–625. https://doi.org/doi.org/10.1061/(ASCE)0733-9364(1991)117:4(606)

Piaw, C. Y., Mastering Research Statistics, Malaysia: McGraw-Hill Education, 2012.

Ramon Casadesus-Masanell, J. E. R. (2010). From Strategy to Business Models and onto Tactics. Long Range Planning, 43(2–3), 195–215. https://doi.org/doi.org/10.1016/j.lrp.2010.01.004

Roztocki, N., & Weistroffer, H. R. (2009). Event Studies in Information Systems Research: An Updated Review. In Proceedings of the Fifteenth Americas Conference on Information Systems (pp. 1–11). San Francisco, California.

Russom, P. (2011). Big Data Analytics.

Savage, N. (2012). Digging for drug facts. Communications of the ACM, 55(10), 11. https://doi.org/10.1145/2347736.2347741

Shahiduzzaman, M., & Alam, K. (2014). Information Technology and its Changing Roles to Economic Growth and Productivity in Australia. Telecommunications Policy, 38(2), 125–135. https://doi.org/10.1016/j.telpol.2013.07.003

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
Research Article - This article was checked by Turnitin

Singh, S., & Singh, N. (2012). Big Data Analytics. In 2012 International Conference on Communication, Information & Computing Technology (ICCICT) (pp. 1–4). Mumbai, India: IEEE. https://doi.org/10.1109/ICCICT.2012.6398180

Taylan, O., Kabli, M. R., Porcel, C., & Herrera-Viedma, E. (2017). Contractor Selection for Construction Projects Using Consensus Tools and Big Data. International Journal of Fuzzy Systems. https://doi.org/10.1007/s40815-017-0312-3

Teece, D. J. (2010). Business Models, Business Strategy and Innovation. Long Range Planning, 43(2–3), 172–194. https://doi.org/doi.org/10.1016/j.lrp.2009.07.003

Wielki, J. (2013). Implementation of the Big Data concept in organizations – Possibilities, impediments and challenges. In Proceedings of the Federated Conference on Computer Science and Information Systems (pp. 985–989). https://doi.org/10.1109/IC3.2013.6612229

Yin, S., & Kaynak, O. (2015). Big Data for Modern Industry: Challenges and Trends. Proceedings of the IEEE, 103(2), 143–146. https://doi.org/10.1109/JPROC.2015.2388958

Yuji Yoshimura, Stanislav Sobolevsky, Carlo Ratii Fabien Girardin, Juan Pablo Carrascal, Josep Blat, R. S. (2014). An Analysis of Visitors' Behavior in the Louvre Museum: A Study Using Bluetooth Data. Environment and Planning B: Urban Analytics and City Science, 41(6), 1113–1131. https://doi.org/doi.org/10.1068/b130047p

Yusof, F. (2017). Malaysia's Commitment to Increase Productivity in Construction Industry: The Big Data Approach.

Zhang, Y., Luo, H., & He, Y. (2015). A System for Tender Price Evaluation of Construction Project Based on Big Data. Procedia Engineering, 123, 606–614. https://doi.org/10.1016/j.proeng.2015.10.114

Submit Date: 10.07.2018, Acceptance Date: 22.08.2018, DOI NO: 10.7456/1080SSE/197
Research Article - This article was checked by Turnitin