# An appraisal into the potential application of Big Data in Construction Industry

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**Abstract:** The volume of data generated by the construction industry has increased exponentially following an intense use of modern technologies. The data explosion thus lead towards the big data phenomenon which is envisioned to revolutionize the construction like never before. Like any other technologies, big data is a disruptive paradigm and inevitably will give impact to the construction industry. As the industry is refocusing towards an improved productivity, the appeal to embrace big data is certain given the value it offers. This certainly will benefit construction akin to the manufacturing and the retail industry alike. Nevertheless, a review of the literature suggested a limited coverage on the potential application of big data in construction as compared to other industries. This limits understanding of its potential, where the industry is seemingly unaware thus could not relate and extract its real value. Hence, this study aims to draw insights on the potential application of big data in the construction industry. The research objectives include: (1) to analyse the current extent of big data research in construction; (2) to map out the orientation of the current research on big data in construction; and (3) to validate the findings as the basis to identify the potential application of big data in construction. The qualitative method through a desk study approach has been carried out to attain the first two objectives. It involved a structured review process which covered articles from the online databases assisted by the Nvivo software. This resulted in the theoretical orientation which was conceptualized as: (1) project management; (2) energy management; and (3) decision making design framework. The theoretical orientation discovered from the review process will form the basis for the semi-structured interviews that are to be held with industry personnel who have experienced big data. This would gather substantial insights on the potential of big data from the industry perspective, thus validating the research findings. As big data is set to influence the industry, the research findings would be a catalyst for creating an awareness to support the development of big data for the construction industry.

**Keywords:** Big Data; Construction Industry; Disruptive Technology; Nvivo; Qualitative

## 1. INTRODUCTION

### *1.1 Background Information*

Big Data has been buzzing among many industries around the world on its potential in dissolving most of the industries' common issues and transform them into a smarter way of operating. The advent of big data era is initiated by the data explosion resulted from the presence of advanced technology in today's world. According to Waal-Montgomery (2015) prediction, the world's data volume will rise approximately 40% per year and fifty times by the year 2020 hence big data gain its traction. Basically, big data is often termed based on the 3Vs namely (i) Volume - amount of the data itself, (ii) Velocity – the speed where the data is generated and (iii) Variety – the diversity and complexity of data sources. The construction industry is known to deal with enormous amount of data that reflects the 3Vs and the utilization of these data could be the next frontier for construction industry development.

### *1.2 Issues and Research Aims*

Big Data is listed by Peiffer (2016) in her article as one out of three concepts that is significant to configure the direction of the construction industry which includes improving the industry's efficiency. Although construction industry is known as the biggest contributor towards the world's economy, it is still lagging in productivity and efficiency where according to Harenberg (2017) the efficiency of the industry today is much lower as compared to when it was 1993. The inefficiencies according to Santiago Castagnino, Christoph Rothballer, and Gerbert (2016) is resulted from the slow movement made by the industry in adopting new technologies. This is supported by the MGI's digitization index that put construction sector as the least digitized industry in the world. Santiago Castagnino et al. (2016) added the deliberate changes made by the industry is caused by the insufficient data-driven decision making.

Data is said to be the poster child in enhancing industry's productivity. This is because, according to Peiffer (2016), real-time data exchange could lead to a broadened insight into the industry's operational performance thus making way for a smarter working. However, albeit of the massive amount of data that is generated in the construction industry, the big data is usually siloed and not being fully utilized for a bigger picture. According to Burger (2017), the inefficiencies of data usage is due to the limited ability in dealing with unstructured data such as free text, images or sensors reading. This is where big data could be the saviour in improving the utilization of data.

Moreover, according to the Construction Industry Development Board Malaysia (CIDB), reliable and quality big data is being demanded aligned with the board's initiatives to meet the aspiration of the Construction Industry Transformation Programme. In conjunction with this, it is essential to identify the level of big data needs for the industry as according to (Portela, Lima, & Santos, 2016), the most typical error of organizations is to utilize big data without assessing whether their needs could satisfy their capabilities. This is supported by Addo-Tenkorang and Helo (2016), where they mentioned that there is limited understanding on the value and performance of big data and this causes the discouragement of progress made for the adoption of big data in construction industry compared to other industries.

Data and construction industry are inseparable as the industry are dealing with huge amount of heterogeneous data and this follows as data related to construction industry has been predicted by M. Bilal et al. (2016) to rise exponentially with the advancement of technologies and Internet of Things. According to Addo-Tenkorang and Helo (2016), new opportunities in excerpting the value can be developed from the huge amount of data obtained. Albeit the importance, a study that focuses on the potential application of big data particularly, in the construction industry has not been comprehensively undertaken (M. Bilal et al., 2016). This limits understanding of its potential, where the industry is seemingly unaware thus could not relate and extract its real value.

Hence, this study aims to draw insights on the potential application of big data in the construction industry. The research objectives include: (1) to analyse the current extent of big data research in construction; (2) to map out the orientation of the current research on big data in construction; and (3) to validate the findings as the basis to identify the potential application of big data in construction. As big data is set to influence the industry, the research findings would be a catalyst for creating an awareness to support the development of big data for the construction industry. This would further lead the industry to gear up in developing their capabilities in harnessing the potential of big data as well as encouraging talent and infrastructure development to tackle the arising issues in the construction industry.

## 2. BIG DATA

### *2.1 An overview of Big Data*

Initially, the renowned 3Vs of big data concept were established by one of the Gartner analyst named Laney Doug in 2001 wherein Gartner's IT Glossary, big data is defined as a 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 (I. Gartner, 2014).

Correspondingly to the arrival of big data, today's data will be no longer viewed as stagnant whose worth is limited to the accomplishment of its gathering purposes (Viktor & Kenneth, 2013). In order to cross the boundary of data collecting purposes, the data need to be handled by means of advanced technologies and human skills as well as data entry base. However, according to Akbar (2017), the current amount of digital information we had has surpassed the ability of present tools to process it. This situation is described as "The Industrial Revolution of Data" by Joe Hellerstein, a computer scientist at the University of California in Berkeley and it has affected various sectors both public and private Cukier (2010). Hence, this has led to the introductory of the term big data by scientists and computer engineers.

Definition of big data might varies in different literature, but the domain of the concept is the 3Vs attributes. Volume is the most important characteristic that represents the extent of big data magnitude and simply epitomized as the size of the data itself (C. P. Chen & Zhang, 2014) that are generated by the advanced technologies, networks and human interactions especially on the nets (Hammer, Kostroch, & Quiros, 2017). In addition, velocity signifies that data is produced at a remarkably high speed which outstrips the conventional systems (Zikopoulos, Parasuraman, Deutsch, Giles, & Corrigan, 2012). The velocity is supplementary to the volume of data as greater data volume requires the data processing to be winged (Özköse, Arı, & Gencer, 2015). Admittedly, based on Gartner (2015)'s predictions that in 2016 there will be 6.4 billion connected devices in use and it will continue to rise up to 20.8 billion by 2020. Hence, the data velocity would continue to speed up due to the connected devices' ability for data streaming (Lee, 2017) Last but not least, variety naturally means diversity and complexity of data categories and sources (Zikopoulos et al., 2012). According to Özköse et al. (2015), the data may derive from various resources of both internally and externally. Similarly, O'Reilly (2014) emphasized in his book that these data come from an assortment of structures and it is often hard to obtain an impeccably, processing-ready data. Such data can be categorized into structured, semi-structured or unstructured data. This classification of data is derived from the existence of the social network, sensors, mobile devices, GPS and other technological appliances (Portela et al., 2016).

### *2.2 Current Big Data application in other sectors*

In recent times, big data has been discussed across various sectors and agreed to be as a game changer in most types of modern industries (Gaitho, 2017). Many organizations have taken steps to change their plan of action in utilizing the big data value effectively (Akbar, 2017). A survey made by Gartner in 2015 illustrates the companies' investment and planning to invest in big data has risen to 75% from 58% in the same survey conducted in 2012. The extensive scope of big data has provided a massive scale of potential and value that can be generated across different sectors such as business sector, manufacturing as well as the upstream industry.

Business sector is said to be the early bird in harnessing the potential of big data as according to Laney (2001), big data concept was aroused from the upsurge of e-commerce during the big data 1.0 era. During that time business firms leveraged the power of basic internet technologies to establish a web presence, building capacity to process large data conducive to their efficiency improvements (Provost & Fawcett, 2013). The potential is further extended in analysing the vast amount of data in excite the business sector such as business expansion decision, improve cost efficiency and revenue forecasting (Meneer, 2015).

Manufacturing is another leading sector that has to move towards big data exploration in enhancing their product quality and at the same time reducing operational costs (Oracle, 2015). External data especially social network and suppliers' data combining with data from sensors and machines has given rise to the existing information. In conjunction with this, big data can be utilized by analysing varieties to enhance the efficiency of manufacturing and the operational process by providing the bird's eye view of the processes which led to a better decision making. Apart from that, big data technologies also assist in improving the product quality and reducing the overall cost through production and quality data analysis along with customers' returning data, capacity consumption as well as machinery efficiency (Oracle, 2015).

Last but not least, the oil and gas industry has also benefited from the potential of big data where according to B. Mathew (2016), in the current situation, data collected in oil and gas industry particularly in the operational process is used mainly for detection and control purposes. big data's advanced analytics could assist in the decision making in the way where it is used for predictive maintenance and could affect the maintenance cost down to about 13% (Choudhry, Mohammad, Tan, & Ward, 2016). The benefits of digital monitoring and predictive maintenance could also be harnessed by detecting errors on equipment and performing maintenance before it is damaged. This could enhance the production and help in addressing the financial impacts as reported by analytics firm, Kimberlite where approximately $49 million annually were imposed due to an unplanned downtime (Choudhry et al., 2016).

### *2.3 Big Data and Construction Industry*

Construction is one of the major industry that is responsible towards a country development. The construction works to be carried out in a project is dynamic (Wood, 2016) and involve a high volume of data exchange from various stakeholders to be gathered and processed (Shrestha, 2013). Shrestha (2013) added that data is generated throughout the various phases of construction projects from planning phase to the completion. For instance, construction data includes daily work progress report, sensors and equipment data, photos and videos and others. Thus, data in the construction industry apparently obey the 3V's concept of big data as shown in Table 1.

| Characteristics | Contributors | Examples |
|---|---|---|
| Volume | Large volume of data from different sources | Design data, cost data, financial data, contractual data, Enterprise Resource Planning (ERP) system, etc |
| Variety | Diversity in the content format | DWG (drawing), DXF (drawing exchange format), DGN (design), RVT (revit), ifcXML, ifcOWL, DOC/XLS/PPT (Microsoft format), RM/MPG (videos), JPEG (images) |
| Velocity | Dynamic nature of data sources | Sensors, RFIDs, Building Management System (BMS) |

Table 1: Big Data context in Construction Industry
*Source : (Aouad, Kagioglou, Cooper, Hinks, & Sexton, 1999; M. Bilal et al., 2016)*

From Table 1, it shows that the advancement of construction process through the widespread utilization of these data shall be the next frontier of construction industry innovation and productivity. This is supported by Harenberg (2017) that mentioned real-time data processing is the future productivity booster.

## *2.4 Trends that triggered Big Data in Construction Industry*

The digitalized revolution has given a significant impact to the construction industry as the industry is dealing with the heterogeneous amount of data emerging from a various branch of knowledge throughout the life cycle of a building (M. Bilal et al., 2016).

### 2.4.1 Building Information Modelling (BIM)

BIM is anticipated in capturing multi-dimensional CAD data deliberately to support multidisciplinary coordinated among the stakeholders (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013). As BIM involves with an additional layer of information that is collected through the entire building lifecycle, it is considered to transform the construction industry across various perspectives (Azhar, 2011). However, according to Humphreys (2016), although BIM is incorporated with an abundance of data, they are not precisely big data. This is because, the huge files of BIM with the combination of numerous models, it is still promptly prepared to be processed by BIM applications. In addition, the arrival of built-in devices and sensors has increased the amount of data generated where eventually leads to the wellsprings of Big BIM Data (M. Bilal et al., 2016). Thus, this driven the construction industry to invade into the big data era.

### 2.4.2 Cloud Computing

Cloud computing is an internet computing trend where it is on request access to the merge of configurable resources equipped (Bughin, Chui, & Manyika, 2010). The main purpose is to provide access to the data storage and computation to multiple users without having an individual license. The acceleration of big data cloud computing and cloud data stores has contributed to the evolution of big data (Qubole, 2017). As cloud computing is supporting the coordination of errands in the BIM-based application, it has been broadly applied in the construction industry and big data performance in this revolution is astounding (M. Bilal et al., 2016). In addition, cloud computing and big data are said to be an ideal combo that contributes to the cost efficiency and extensible infrastructure in supporting Big Data and Business Analytics (Ferkoun, 2014).

### 2.4.3 Internet of Things (IoT)

As being discussed previously in the big data evolution, Internet of Things (IoT) has been the main pillar that triggers the era of big data 3.0. Basically, IoT is a system of Internet-connected devices that gather and transfer data through installed sensors (Meola, 2016). IoT application is frequently conveyed a substantial number of sensors devices for data accumulation. As the industry presents boundless big data utilization cases for IoT, big data is inalienably the subject of intrigue (M. Bilal et al., 2016). Among the prominent areas of IoT applications includes logistics, transport, asset recording, intelligent homes and buildings, energy and agriculture. M. Bilal et al. (2016) claimed that IoT and big data are interdependent trends where a huge amount of data is created then stored and analysed in real-time in construction particular area applications. Additionally, Pal (2015) suggested that during the selection of big data processing technology, one must remember the huge flood of information that needs to be conveyed by IoT. Organizations should conform to technologies in order to deal with IoT data.

### 2.4.4 Smart Buildings

Smart Building technology is another transformation to grasp the assimilation of contemporary technologies with existing building systems to attract the attention of trade between maximization of comfort and energy reduction (Khan & Hornbæk, 2011). Generally, these systems will produce an enormous volume of data and the greater part of this information often stay undiscovered and disposed of. In relation to that, according to M. Bilal et al. (2016), this data needs to be interpreted to truly recognize smart buildings hence the significance of Big Data Analytics. The information and communication technology (ICT)-based integration and development systems, particularly Internet of Things is an important catalyst for various applications, both industry and the general population in realizing the smart buildings (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014). In sense to that, Moreno et al. (2016) scrutinize that big data and IoT are an impeccable combination in enhancing energy efficiency for Smart Buildings.

### 2.4.5 Augmented Reality (AR)

Augmented Reality is a technology that coordinate virtual object images into real-world images. These images can be taken from the camera or, using a live view, the audience can add directly to the world (Reiners, Stricker, Klinker, & Müller, 1998). According to Jiao, Zhang, Li, Wang, and Yang (2013) AR comes from 'Virtual Reality' (VR) and provides a half-depth environment that highlights the exact alignment between actual scenes and virtual world images in real time. It is also broadly recognized as an assuring technology to improve human viewpoint. Additionally, the means to enhance prevailing big data visualization techniques is correlated with AR and VR where it is relevant for human limited perception capabilities (Olshannikova, Ometov, Koucheryavy, & Olsson, 2015). Consequently, AR and BD are certainly unavoidable where the complexity related with big data in construction is tremendous and must be overcome by advanced visualization methods, specifically AR and VR (M. Bilal et al., 2016).

### 2.4.6 Social Networking Services

Social media is one of the exciting trends that could assist the construction industry in enhancing the communication between project teams where communication is the major problems in the industry (Jiao, Wang, et al., 2013). One of the main challenges in the enormous heterogeneous data of social network is to inherit the value and ways of analysing it (H. Chen, Chiang, & Storey, 2012). Therefore, to properly analyse data from social media, analytical techniques, and traditional analytical methods or known as data analysis need to be modified and incorporating them into the new enormous data for enormous information processing (Bello-Orgaz, Jung, & Camacho, 2016). In relation to this, big data can be utilized in developing appealing domain applications through the high volume, velocity, and variety of social network data to improve stakeholders' productivity.

## *2.5 Current Big Data research in Construction Industry*

Big Data has begun to set foot in the construction industry in competing with other sectors that have long benefited from the big data potential. In the construction industry, big data can be exploited for the same aim of how other sectors are utilizing big data as discussed in section 2.2. This includes enhancing efficiency, decision making, and sensors monitoring and supported by M. Bilal et al. (2016) that outlook the applicability of big data in the construction industry is magnified by the emerging trends mentioned in the previous section. Thus, the surge of these data and trends could be utilized in projecting the construction industry to the next level.

The current big data research or application excerpted from various literature is summarized in Table 2 with the important concepts identified from the review process are reflected in bold font.

| No | Big Data research area from the literature review | Authors |
|---|---|---|
| 1 | BD with Visual Analytics used for (**building performance)** comparison that leads to renovation and construction with low (**energy**) consumption. | (Ioannidis et al., 2015) |
| 2 | LEED uses actual data to verify the (**building performance**) | (Davis, 2015) |
| 3 | Improve **(project management)** by using technologies or sensors for (**performance**) monitoring and tracking | (Wood, 2016), (Bleby, 2015), (Yang, Park, Vela, & Golparvar-Fard, 2015) |
| 4 | Cost efficiency (**design**) through a real-time, data-focused predictive model. | (Sadhu, 2016) |
| 5 | BD assist in (**project management)** to ensure the project is delivered on (**time**) and on (**budget**) | (Sadhu, 2016), (Rijmenam, 2015), (Faure, 2016), (Augur, 2016), (Akbar, 2017) |
| 6 | Real-time data sharing to improve (**communication)** between stakeholders | (Rijmenam, 2015), (Augur, 2016) |
| 7 | (**Resource management**) through data from sensors-equipped machinery | (Rijmenam, 2015), (Augur, 2016), (Azzeddine Oudjehane & Moeini, 2017), Akhavian and Behzadan (2015) |
| 8 | Deriving information from stakeholders to improve the (**planning**) process and (**project management**) | (Caron, 2015) |
| 9 | Integration of information technologies with data handling in facilitating (**decision-making**) for (**project management**) | (Martínez-Rojas, Marín, & Vila, 2015) |
| 10 | BD generate (**prediction**) system for construction businesses bankruptcy | (Hafiz et al., 2015) |
| 11 | Drones use for construction progress monitoring for (**project management**) | (Azzeddine Oudjehane & Moeini, 2017), Knight (2015) |
| 12 | Geospatial/geo-location data for (**resources optimization**) and (**resource management**) | (Akbar, 2017) |
| 13 | Data simulation tool in reducing project (**risk**). | (Akbar, 2017) |
| 14 | BD for construction (**cost management**) through tender price assessment system. | (Y. Zhang, Luo, & He, 2015) |
| 15 | Visual BD to improve (**communication**) among project stakeholders. | (Han & Golparvar-Fard, 2017) |
| 16 | Assess (**Construction waste management**) performance using BD | (Lu, Chen, Ho, & Wang, 2016), (Lu, Chen, Peng, & Shen, 2015) |
| 17 | Developing (**waste**) simulation tool using BD for (**Construction waste management**) | (Muhammad Bilal et al., 2016) |
| 18 | Social network analysis and (**energy**) usage analyses as sources in establishing an integrated green building (**design**) model | Redmond, El-Diraby, and Papagelis (2015) |
| 19 | BD algorithms to accurately reduce the design space and enabled generative (**design**) tool | (M. Bilal et al., 2016) |
| 20 | BD and VR for better building (**design**) decision | (Bernstein, 2017), (Barista, 2014) |
| 21 | BD helps in generating a predictive model for (**energy)** consumption | (Moreno et al., 2016) |
| 22 | BD algorithm for (**building performance**) in terms of (**energy)** consumption | (P. A. Mathew et al., 2015) |
| 23 | Implementing prototype software called Project Dasher for (**energy**) data visualization and real-time monitoring. | (Khan & Hornbæk, 2011) |
| 24 | BD analysis used to understand energy consumption behavior thus help to improve (**energy efficiency**) in building | (Koseleva & Ropaite, 2017), (Janda et al., 2015) |
| 25 | Real-time (**energy**) consumption data monitoring and control to improve energy efficiency | (Wei & Li, 2011) |
| 26 | BD-based platform to visualize workers' unsafe (**safety**) act in real-time | (SY Guo, Ding, Luo, & Jiang, 2016), (Shengyu Guo, Luo, & Yong, 2015) |

| | | |
|---|---|---|
| 27 | Use wearable to track worker proximity to rolling (**safety**) exclusionary zones | (Wood, 2016) |
| 28 | Use drones to check on site (**safety**) | (Oudjehane & Moeini, 2017) |
| 29 | Real-time location tracking and data visualization technologies improve (**safety**) understanding. | (Teizer, Cheng, & Fang, 2013) |
| 30 | Application of BD-driven BIM system in improving construction (**safety**) | (S. Zhang, Teizer, Lee, Eastman, & Venugopal, 2013) |
| 31 | Integrating BIM data with external data such as Linked Open Data (LOD) for better (**project management**) and reduce project (**risk**) | (Curry et al., 2013) |

Table 2: Big Data research from various literature
*Source: As shown*

## 3. RESEARCH METHODS

The qualitative research design is adopted for this study and in according to Bryman (2008), qualitative research is a research strategy that typically emphasizes on the words rather than the computation of data collected and analyzed. Hence, it is suitable to be applied for this study as the research objectives is to analyse the current extent of big data research in the construction industry as well as its orientation and potential application. These objectives are better to be achieved through a more analytical explanation. According to Creswell (2005), qualitative data collection and results will give a better analytical explanation by going into depth of the general picture of the research.

Desk study method is used for data collection in attaining the first and second objectives. According to Travis (2016) desk study is relying more on the researcher to review the previous research findings in order to obtain an expansive comprehension of the study area. This method is chosen to be adopted as it is the fastest and inexpensive methods in enhancing the understanding the realm of the research where a thorough review on the previous research findings, articles or dissertations is made to obtain an expansive comprehension of the study area which is big data in the construction industry.

In an expansion of the desk study findings, an interview with the construction industry personnel who have experienced big data is conducted to gain wider views on the big data orientation as well as its potential application. This is where desk study is relevant as it gives the researcher a sip of the research topic before conducting the interview and thus assists in structuring the interview questions. According to Rubin and Rubin (2011), the qualitative interview is a discussion where the researcher aides a conversational accomplice in a broadened exchange. The semi-structured interview allows the interviewer to expand the questions to the extent of the information that interviewee is willing to share. Therefore, it is chosen to be adopted in achieving the third research objective which is to identify the potential of big data in the construction industry. The method to be used to analyze the findings from the semi-structured interview is the interview content analysis method where it is the most common method used to analyze communication content such as the interview transcript.

## 4. PRELIMINARY FINDINGS AND DISCUSSION

Detail analytical study is conducted in analysing the literature findings by following the steps in SALSA framework (an acronym for Search, Appraisal, Synthesis, and Analysis), an approach introduced by Booth, Sutton, and Papaioannou (2016). The results are then further analysed using Nvivo software in mapping out the outcome of the analysis made. The process undergone in literature review is further explained in following sections.

### *4.1 Searching*

The aim of this study is to review comprehensively the relevant topic related to the potential application if big data in the construction industry. The method adopted in achieving this aim is through desk study where the relevant literature is searched on the Internet as well as library database. UTM Library Online Database where it contains academic journals from Emerald, Science Direct, IEEE Xplore Digital Library, and Springerlink. The main keywords used in searching the literature were <<big data>> and <<construction industry>>. Additionally, snowballing technique is adopted in selecting the relatable articles or journals especially those recommended by the reviewed articles. Based on the search results, there are numbers of big data articles and journals were displayed from both construction industry as well as another irrelevant research field. However, the results are filtered where only the content that portrays the presence of big data in the construction industry is of interest.

### *4.2 Mapping Ideas and Analysis*

Mapping ideas involve the literature content from the search results being organized into categories where it will further be sorted to establish connections (Hart, 1998). The literature findings are then being analysed by highlighting the ideas where according to Hart (1998), the aim is to dynamically reduce the huge amount of information extracted from the analytical study and emphasized on the main point of the argument. For this study, a table is developed as in Table 2 to organize the data extracted from the literature where it contains predefined area related to the application of big data in the construction industry that connects the literature. Table 2 shows that the analysis made by pinpointing the common area across the different literature that reflect the current extent of the big data research area.

### *4.3 Synthesis and Mapping Outcome*

The analysis findings were then being synthesized through aggregative synthesis in grouping the information into relatable themes or area. This is done by using the Nvivo software to map the outcome which in this underpinning research is the direction of the big data research. The frequently mentioned area is mapped out through the automating coding with word frequency. In the 'Word Frequency Query' command, it counts the frequency of a particular word or phrase or a set of alternative words immediately from the analysis. In relation to the research underpinning this study, 'Word Frequency Query' in Nvivo is used to produce a specified area of big data that has been acknowledged the most. From this, the predilection of big data in the construction industry is obtained hence attaining the second objective.

The model developed from the Nvivo software can be seen in Figure 1 where the major area of big data research is more towards 'management' especially 'project' management and 'energy' management. In this context, big data in 'project management' involves (i) real-time data generated by IoT devices such as drones, sensors or smartphones in tracking or 'monitoring' construction work progress and performance, (ii) linked-data in the cloud provide broad understanding on complex project which leads to better 'cost' and 'time' management a (iii) data wise enhancing 'decision-making' process especially in

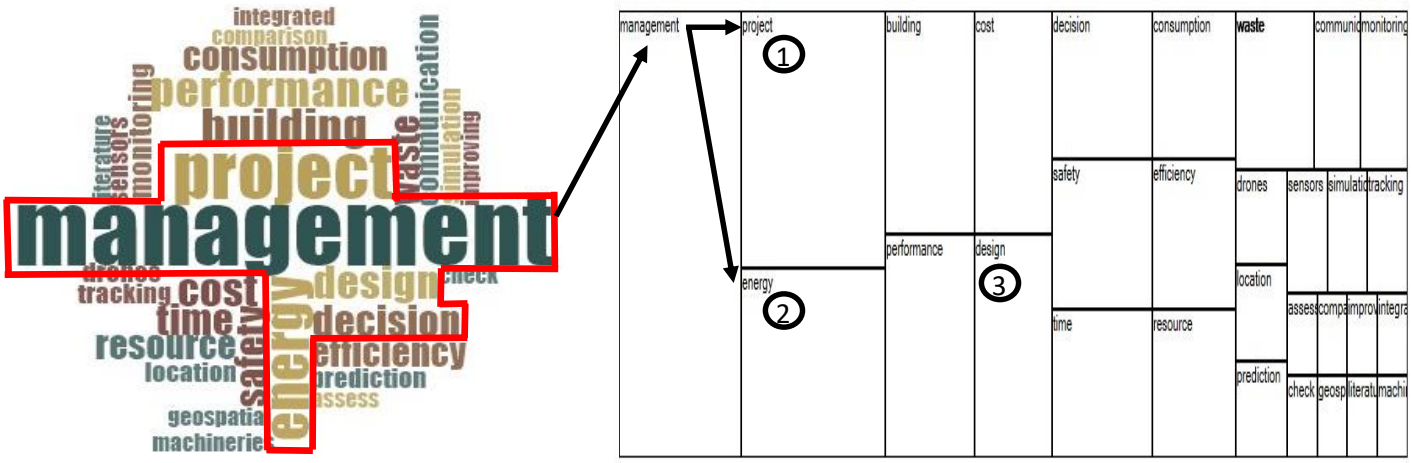


Figure 1 : Generated model representing the frequency of big data research area

predicting the project orientation that leads to lower project risk and better management. On the other hand, 'energy management' encompasses integration of Iot or BIM with big data analytics in understanding the building energy consumption to intensify energy efficiency and add to 'building performance'. Energy analyses further assist in decision making 'design' framework where the results could be the determinant in generating integrated models for building design. Also, big data provide an aerial view of all aspects of the built environment that facilitates a better decision-making design framework. Another research area on big data in construction industry includes 'safety', 'resource' management and 'waste' management.

Based on the previous paragraph, it indicates that the theoretical orientation which was conceptualized by using Nvivo software is (1) project management; (2) energy management; and (3) decision making design framework. Table 3 summarizes the interpretative context of the top three most frequent big data research area in relation to the findings presented in Table 1. The resulted findings are able to address the objective of the study in predicting the big data orientation. This could act as the basic structure in the next process which is interviewing to gain extensive findings.

| Category of BD research area | Area keyword | Detail of research area |
|---|---|---|
| Construction Project Management | monitoring | Progress/performance monitoring through IoT devices |
| | time, cost | Better time and cost management |
| | Decision-making | Making decision using predictive data that leads to lower project risk and better management |
| Energy management | Consumption, building performance | Enhancing energy efficiency and building performance through an understanding of building energy consumption |
| Decision-making design framework | Decision-making | BD for better decision-making design framework |

Table 3: Frequent big data research area and details

## 5. EXPECTED OUTCOME

The expected outcome will give extensive findings on the direction of big data in the construction industry through in-depth semi-structured interviews with industry personnel who have experienced big data. The potential application of big data from the personnel's point of view will also be highlighted thus shed some light on the area where big data could be best applied in the construction industry. As big data is set to influence the industry, the research findings would be a catalyst for creating an awareness to support the development of big data for the construction industry. Accordingly, the industry could harness the potential of big data by initiating the resources towards its direction and be infrastructure ready to develop big data into the industry. This will further contribute to the acceleration of the construction industry development.

## 6. CONCLUSIONS AND RECOMMENDATION

In conclusion, the direction and potential application of big data in construction industry need to be well defined. This follows as the construction industry is a data-dependent industry hence data must be managed efficiently with the right tool to ensure the success of a project. From the preliminary findings, the orientation of big data research falls to construction project management. Such findings could help the industry to sail towards the right direction in providing resources in enhancing the project management process. It is undoubtedly that by having a better understanding of the big data impacts to the construction industry could lead to an optimal utilization of the resource. The next level of the research would be able to determine the extensive views on the potential application and its direction.

A collaborative working environment should be exercised between the personnel in the construction industry with big data experts as it is essential in attaining a broadened insight of how and to what extent construction industry could be profited from the adoption of big data. Since this study concentrates only on the potential application of big data, it is recommended that another research conducted regarding the challenges of big data adoption in the construction industry as well as the industry readiness in leveraging big data.

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## REFERENCES


Addo-Tenkorang, R., & Helo, P. T. (2016). Big data applications in operations/supply-chain management: A literature review. *Computers & Industrial Engineering, 101*, 528-543.

Akbar, S. (2017). Is Big Data The Most Trending Thing In Construction Now. Retrieved from https://geniebelt.com/blog/big-data-in-construction

Akhavian, R., & Behzadan, A. H. (2015). Construction equipment activity recognition for simulation input modeling using mobile sensors and machine learning classifiers. *ADVANCED ENGINEERING INFORMATICS, 29*(4), 867-877.

Aouad, G., Kagioglou, M., Cooper, R., Hinks, J., & Sexton, M. (1999). Technology management of IT in construction: a driver or an enabler? *Logistics Information Management, 12*(1/2), 130-137.

Augur, H. (2016). Big Data is Transforming Commercial Construction. Retrieved from http://dataconomy.com/2016/07/big-data-is-transforming-commercial-construction/

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering, 11*(3), 241-252.

Azzeddine Oudjehane, & Moeini, S. (2017). Big Data in Construction Projects Risk and Opportunity Management.

Barista, D. (2014). The Big Data revolution: How data-driven design is transforming project planning. *Building Design+Construction*.

Bello-Orgaz, G., Jung, J. J., & Camacho, D. (2016). Social big data: Recent achievements and new challenges. *Information Fusion, 28*, 45-59.

Bernstein, P. (2017). How Big Data and VR in Architecture Will Greatly Improve Design. Retrieved from https://www.autodesk.com/redshift/big-data-vr-in-architecture/

Bilal, M., Oyedele, L. O., Akinade, O. O., Ajayi, S. O., Alaka, H. A., Owolabi, H. A., . . . Bello, S. A. (2016). Big data architecture for construction waste analytics (CWA): A conceptual framework. *Journal of Building Engineering, 6*, 144-156.

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. doi:10.1016/j.aei.2016.07.001

Bleby, M. (2015). Big Data boosts construction. Retrieved from http://www.afr.com/real-estate/commercial/big-data-boosts-constrcution-20150109-12l8xx

Booth, A., Sutton, A., & Papaioannou, D. (2016). *Systematic approaches to a successful literature review*: Sage.

Bryman, A. (2008). Mixed methods research: combining quantitative and qualitative research. *Social research methods, 3*, 608-626.

Bughin, J., Chui, M., & Manyika, J. (2010). Clouds, big data, and smart assets: Ten tech-enabled business trends to watch. *McKinsey Quarterly, 56*(1), 75-86.

Burger, R. (2017). How the Construction Industry is Using Big Data. Retrieved from https://www.thebalance.com/how-the-construction-industry-is-using-big-data-845322

Caron, F. (2015). Data management in project planning and control. *International Journal of Data Science, 1*(1), 42-57.

Chen, C. P., & Zhang, C.-Y. (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. *Information Sciences, 275*, 314-347.

Chen, H., Chiang, R. H., & Storey, V. C. (2012). Business intelligence and analytics: From big data to big impact. *MIS quarterly, 36*(4).

Choudhry, H., Mohammad, A., Tan, K. T., & Ward, R. (2016). The next frontier for digital technologies in oil and gas. Retrieved from https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-next-frontier-for-digital-technologies-in-oil-and-gas

Creswell, J. (2005). Planning, conducting, and evaluating quantitative and qualitative research: Educational research. In: Prentice Hall: Upper Saddle River, NJ Creswell, JW (2007). Research method: Qualitative, quantitative and mixed methods approaches (2nd ed.). Thousand Oaks, CA: Sage.

Cukier, K. (2010). *Data, data everywhere: A special report on managing information*: Economist Newspaper.

Curry, E., O'Donnell, J., Corry, E., Hasan, S., Keane, M., & O'Riain, S. (2013). Linking building data in the cloud: Integrating cross-domain building data using linked data. *ADVANCED ENGINEERING INFORMATICS, 27*(2), 206-219.

Davis, D. (2015). How Big Data is Transforming Architecture.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction, 36*, 145-151.

Faure, A. (2016). Big data is revolutionizing business: the construction industry in general and building sites in particular. Retrieved from https://blog.serenacapital.com/big-data-is-revolutionizing-business-the-construction-industry-in-general-and-building-sites-in-de7a53a20516

Ferkoun, M. (2014). Cloud Computing and Big Data: An ideal combination. Retrieved from https://www.ibm.com/blogs/cloud-computing/2014/02/cloud-computing-and-big-data-an-ideal-combination/

Gaitho, M. (2017). How Applications of Big Data Drive Industries. Retrieved from https://www.simplilearn.com/big-data-applications-in-industries-article

Gartner. (2015). 6.4 billion connected "Things" will be in use in 2016, up 30 percent from 2015. *Gart. Inc*.

Gartner, I. (2014). Glossary.(2013). *Big Data*.

Guo, S., Ding, L., Luo, H., & Jiang, X. (2016). A Big-Data-based platform of workers' behavior: Observations from the field. *Accident Analysis & Prevention, 93*, 299-309.

Guo, S., Luo, H., & Yong, L. (2015). A big data-based workers behavior observation in China metro construction. *Procedia Engineering, 123*, 190-197.

Hafiz, A., Lukumon, O., Muhammad, B., Olugbenga, A., Hakeem, O., & Saheed, A. (2015). *Bankruptcy prediction of construction businesses: towards a big data analytics approach.* Paper presented at the Big Data Computing Service and Applications (BigDataService), 2015 IEEE First International Conference on.

Hammer, C., Kostroch, D. C., & Quiros, G. (2017). *Big Data; Potential, Challenges and Statistical Implications*. Retrieved from

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

Harenberg, M. (2017). 5 ways to boost construction productivity. Retrieved from https://www.planradar.com/construction-productivity/

Hart, C. (1998). *Doing a literature review: Releasing the social science research imagination*: Sage.

Humphreys, R. (2016). How Big Data Complements Information Management. Retrieved from https://sourceable.net/how-big-data-complements-information-management/

Ioannidis, D., Fotiadou, A., Krinidis, S., Stavropoulos, G., Tzovaras, D., & Likothanassis, S. (2015). *Big Data and Visual Analytics for Building Performance Comparison.* Paper presented at the IFIP International Conference on Artificial Intelligence Applications and Innovations.

Janda, K. B., Patrick, J., Granell, R., Bright, S., Wallom, D., & Layberry, R. (2015). *A WICKED approach to retail sector energy management.* Paper presented at the Proceedings of ECEEE Summer Study.

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.

Jiao, Y., Zhang, S., Li, Y., Wang, Y., & Yang, B. (2013). Towards cloud augmented reality for construction application by BIM and SNS integration. *Automation in Construction, 33*, 37-47.

Khan, A., & Hornbæk, K. (2011). *Big data from the built environment.* Paper presented at the Proceedings of the 2nd international workshop on Research in the large.

Knight, W. (2015). New boss on construction sites is a drone. In: MIT Technology review.

Koseleva, N., & Ropaite, G. (2017). Big Data in Building Energy Efficiency: Understanding of Big Data and Main Challenges. *Procedia Engineering, 172*, 544-549.

Laney, D. (2001). 3D data management: Controlling data volume, velocity and variety. *META Group Research Note, 6*, 70.

Lee, I. (2017). Big data: Dimensions, evolution, impacts, and challenges. *Business Horizons, 60*(3), 293-303.

Lu, W., Chen, X., Ho, D. C., & 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.

Lu, W., Chen, X., Peng, Y., & Shen, L. (2015). Benchmarking construction waste management performance using big data. *Resources, Conservation and Recycling, 105*, 49-58.

Martínez-Rojas, M., Marín, N., & Vila, M. A. (2015). The role of information technologies to address data handling in construction project management. *Journal of Computing in Civil Engineering, 30*(4), 04015064.

Mathew, B. (2016). How Big Data is reducing costs and improving performance in the upstream industry. Retrieved from http://www.worldoil.com/news/2016/12/13/how-big-data-is-reducing-costs-and-improving-performance-in-the-upstream-industry

Mathew, P. A., Dunn, L. N., Sohn, M. D., Mercado, A., Custudio, C., & Walter, T. (2015). Big-data for building energy performance: Lessons from assembling a very large national database of building energy use. *Applied Energy, 140*, 85-93.

Meneer, D. (2015). How Big Data is Transforming Construction Businesses. Retrieved from https://www.constructionmonitor.com/blog/2015/06/26/how-big-data-is-transforming-construction-businesses/

Meola, A. (2016). What is the Internet of Things (IoT)? Retrieved from http://www.businessinsider.com/what-is-the-internet-of-things-definition-2016-8/?IR=T

Moreno, M. V., Dufour, L., Skarmeta, A. F., Jara, A. J., Genoud, D., Ladevie, B., & Bezian, J.-J. (2016). Big data: the key to energy efficiency in smart buildings. *Soft Computing, 20*(5), 1749-1762.

O'Reilly. (2014). *Big data now: 2014 Edition*: O'Reilly Media, Incorporated.

Olshannikova, E., Ometov, A., Koucheryavy, Y., & Olsson, T. (2015). Visualizing Big Data with augmented and virtual reality: challenges and research agenda. *Journal of Big Data, 2*(1), 22.

Oracle. (2015). Improving Manufacturing Performance with Big Data: Architect's Guide and Reference Architecture Introduction. Retrieved from http://www.oracle.com/us/technologies/big-data/big-data-manufacturing-2511058.pdf

Oudjehane, A., & Moeini, S. (2017). Big data in construction projects: Risk and opportunity management.

Özköse, H., Arı, E. S., & Gencer, C. (2015). Yesterday, today and tomorrow of big data. *Procedia-Social and Behavioral Sciences, 195*, 1042-1050.

Pal, K. (2015). The Impact of the Internet of Things on Big Data. Retrieved from http://data-informed.com/the-impact-of-internet-of-things-on-big-data/

Peiffer, E. (2016). 3 concepts that will shape the future of construction. Retrieved from https://www.constructiondive.com/news/3-concepts-that-will-shape-the-future-of-construction/417049/

Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Sensing as a service model for smart cities supported by internet of things. *Transactions on Emerging Telecommunications Technologies, 25*(1), 81-93.

Portela, F., Lima, L., & Santos, M. F. (2016). Why Big Data? Towards a Project Assessment Framework. *Procedia Computer Science, 98*, 604-609.

Provost, F., & Fawcett, T. (2013). Data science and its relationship to big data and data-driven decision making. *Big Data, 1*(1), 51-59.

Qubole. (2017). Big Data Cloud Database & Computing. Retrieved from https://www.qubole.com/resources/big-data-cloud-database-and-computing/

Redmond, A., El-Diraby, T., & Papagelis, M. (2015). Employing an Exploratory Research Stage to Evaluate Green Building Technologies for Sustainable Systems. *Submitted to international journal; under review*.

Reiners, D., Stricker, D., Klinker, G., & Müller, S. (1998). Augmented reality for construction tasks: Doorlock assembly. *Proc. IEEE and ACM IWAR, 98*(1), 31-46.

Rijmenam, M. v. (2015). Big Data Can Help Construction Companies Deliver Projects On Time. Retrieved from https://datafloq.com/read/big-data-construction-companies-deliver-projects-t/143

Rubin, H. J., & Rubin, I. S. (2011). *Qualitative interviewing: The art of hearing data*: Sage.

Sadhu, R. (2016). Big Data For Construction: How It Can Help You Deliver Your Project On Time. Retrieved from https://www.planacademy.com/big-data-construction/

Santiago Castagnino, Christoph Rothballer, & Gerbert, P. (2016). What's the future of the construction industry? Retrieved from https://www.weforum.org/agenda/2016/04/building-in-the-fourth-industrial-revolution/

Shrestha, J. (2013). Big Data, Predictive Analytics, and Data Visualization in The Construction Engineering. *CCEE Graduate Student Research Showcase and Poster Competition*.

Teizer, J., Cheng, T., & Fang, Y. (2013). Location tracking and data visualization technology to advance construction ironworkers' education and training in safety and productivity. *Automation in Construction, 35*, 53-68.

Travis, D. (2016). Desk research: the what, why and how. *Dostupno na http://www. userfocus. co. uk/articles/desk-research-the-what-why-and-how. html, pristupljeno, 10*, 2017.

Viktor, M.-S., & Kenneth, C. (2013). Big data: A revolution that will transform how we live, work, and think. *Houghton Mifflin Harcourt*.

Waal-Montgomery, M. d. (2015). World's data volume to grow 40% per year & 50 times by 2020: Aureus. *Retrieved Syyskuu, 28*, 2016.

Wei, C., & Li, Y. (2011). *Design of energy consumption monitoring and energy-saving management system of intelligent building based on the Internet of things.* Paper presented at the Electronics, Communications and Control (ICECC), 2011 International Conference on.

Wood, C. (2016). Betting on big data: How construction firms are leveraging digitized job sites. Retrieved from https://www.constructiondive.com/news/betting-on-big-data-how-construction-firms-are-leveraging-digitized-job-si/431047/

Yang, J., Park, M.-W., Vela, P. A., & Golparvar-Fard, M. (2015). Construction performance monitoring via still images, time-lapse photos, and video streams: Now, tomorrow, and the future. *ADVANCED ENGINEERING INFORMATICS, 29*(2), 211-224.

Zhang, S., Teizer, J., Lee, J.-K., Eastman, C. M., & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. *Automation in Construction, 29*, 183-195.

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.

Zikopoulos, P., Parasuraman, K., Deutsch, T., Giles, J., & Corrigan, D. (2012). *Harness the power of big data The IBM big data platform*: McGraw Hill Professional.