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ARTICLE (PEER REVIEWED)

Unravelling the Factors Influencing Construction Organisations' Intention to Adopt Big Data Analytics in South Africa

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Abstract

The construction industry has been producing massive data that can be transformed for improved decision-making and better construction project delivery. However, the industry has been adjudged as a slow adopter of digital technologies such as big data analytics (BDA) to improve its service delivery. The implication of this slow adoption is the lack of innovativeness and unsustainable project delivery that has characterised the industry in most countries, particularly in developing ones like South Africa. Therefore, this study assessed the intention to adopt BDA by construction organisations using the unified theory of technology adoption and use of technology (UTAUT) model. A post-positivism philosophical stance was employed, which informed the use of quantitative research

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with a questionnaire designed to solicit information from construction organisations in South Africa. Data analysis was done using Cronbach alpha to test for reliability and Fuzzy Synthetic Evaluation to evaluate the impact of the different constructs of the UTAUT on the adoption of BDA by construction organisations in South Africa. The study found that variables relating to facilitating conditions, performance expectancy, and social influence will significantly impact an organisation's intention to adopt BDA. However, issues surrounding effort expectancy, resistance to use, and perceived risk cannot be overlooked as they also have high impact levels. The study provides an excellent theoretical and practical contribution to the existing discourse on construction digitalisation.

Keywords

Big Data Analytics; Construction Organisation; Digitalisation; Digital Technology

Introduction

The development of the construction industry has been described as a process that is well planned and managed to improve the industry's capacity and effectiveness to ensure that the high demand for construction products is met and to maintain the industry's contribution to socio-economic development (Ofori, 2000). This development cut across diverse phases, including technological advancement. The Fourth Industry Revolution (4IR) promises significant industry development through the optimization of technologies and innovations (Oke, et al., 2018; Pärn, Edwards and Sing, 2018). Studies showcasing the importance of adopting these digital technologies in the discharge of construction services and the industry's development has continued to emerge in recent times (Hager, Golonka, and Putanowicz, 2016; Sakin and Kiroglu, 2017; Aghimien, et al., 2018; Delgado, et al., 2019). One such technology that has gained significant attention among researchers and practitioners is Big Data Analytics (BDA). According to Bilal, et al. (2016), advancement in technology has created a world where a significant amount of data abounds. Organisations can now collect, store, and analyse the large amount of data (Big Data) gathered daily. Che, Safran, and Peng (2013) noted that there is an ever-increasing stream of Big Data being generated due to the increase in the use of various digital devices. The magnitude of the generated data has led to the emergence of BDA and data mining to get patterns and make informed decisions. In the construction industry, the advent of Building Information Modelling (BIM) and sensors has brought about significant data improvement (Bilal, et al., 2016). Effectively collecting and accurately analysing data from different sources can improve predictions of future events and better construction industry productivity (Ahiaga-Dagbui and Smith, 2013; Jin, et al., 2015). Furthermore, decision-making is increasingly becoming data-driven (Cabrera-Sánchez and Villarejo-Ramos, 2019). Therefore, construction organisations must make good use of valuable information that exists in the rapidly changing data environment.

The construction industry worldwide has been described as a slow adopter of technology (Pärn and Edwards, 2019). The case is worse for the industry in developing countries, constrained by several issues such as lack of technical knowledge, lack of adequate funds, skill shortage and lack of appropriate government support, among others (Windapo and Cattell, 2010; Elkhalifa, 2016; Haupt and Harinarain, 2016; Aghimien, Aigbavboa, and Thwala, 2019). The result of these constraints and poor technology adoption is the constant poor performance of cost, time and client dissatisfaction along with issues of poor health and safety, poor labour productivity and unsustainable project delivery that has characterised these industries in recent times (Laryea and Mensha, 2010; Ali and Wen, 2011; Chiocha, Smallwood, and Emuze, 2011; Aghimien and Awodele, 2017; Okoye, Okolie, and Ngwu, 2017; Othman, Shafiq, and Nuruddin, 2017). Hampson, Kraatz, and Sanchez (2014) noted that the industry in most of these countries consists of many small and medium-sized construction companies with limited capabilities for investments in the new technology. Addo-Tenkorang and Helo (2016) further stated that for some of these organisations, the limited understanding of the potential impact of BDA value in their service delivery has hampered their adoption of this technological advancement.

Based on this understanding, it becomes necessary to assess the factors influencing construction organisations' behavioural intention to adopt BDA with a view to promoting technology adoption and construction industry development. While several studies have emerged on Big Data adoption, challenges, benefits and diffusion with other digital technologies within the construction industry (Bilal, et al., 2016; Koseleva and Ropaite, 2017; Moynihan, et al., 2017; Lu, et al., 2018), not much as surfaced on the factors that might influence construction organisations intention to adopt this beneficial technology. Several adoption models have been introduced over time to assess technology adoption within organisations, with one of the most common being the technology adoption model (TAM) (Arbaugh, 2010; Charness and Boot, 2016). However, Cabrera-Sánchez and Villarejo-Ramos (2019) suggested that the unified theory of acceptance and use of technology (UTAUT) is more appropriate for a better view of technology adoption. Khatun, Palas, and Ray (2017) mentioned that the UTAUT model is the most sensitive and latest approach that explains the variance of technology acceptance and intention to use such technology. This model has been favoured in different studies that have assessed organisations' intention to adopt diverse technologies (Howard, Restrepo, and Chang, 2017; Cabrera-Sánchez and Villarejo-Ramos, 2019).

This study assessed the factors influencing construction organisations behavioural intention to adopt BDA in South Africa. The study's major objective is to unearth the key variables that will influence construction organisations' behaviour to adopt BDA in the construction industry. The study's findings provide some practical insight into the factors that should be considered by top management within construction organisations in the formulation of policies surrounding BDA usage. Furthermore, the study provides an excellent theoretical platform for future research within the area of BDA adoption.

Theoretical Background

In contemporary society, where data is generated at an exponential rate due to diverse available digital technologies (Che, Safran, and Peng, 2013; Cabrera-Sánchez and Villarejo-Ramos, 2019), organisations stand a chance to gain a better competitive edge over their competitors by transforming data into useful information. Furthermore, with the clamour for more digitalised organisations (Schwab, 2017), without the effective electronic collection and analysis of digital data, organisations' digital transformation journey will be practically impossible (Berger, 2016; Zhong, et al., 2016). The analysis of Big Data, therefore, becomes essential for organisations (construction inclusive) seeking better competitive advantage, digital transformation and overall organisation development.

By definition, Big Data refers to "information asset characterised by high volume, velocity and variety that require specific technology and analytical methods for its transformation into value" (De Mauro, Greco, and Grimaldi, 2016, p.127). Chahal and Gulia (2016) and Manyika, et al. (2011) also described it as a dataset that cannot be documented, secured, managed, analysed, and processed by every regular device. Thus, to draw value out of Big Data, BDA becomes essential. BDA has been described as using technology to gather and process a large stream of data in real-time and using the information derived from the analysis to become market leaders (McAfee and Brynjolfsson, 2012; Rüßmann, et al., 2015; Cabrera-Sánchez and Villarejo-Ramos, 2019). Simply put, BDA processes the complex and massive dataset known as Big Data (Nizam and Hassan, 2017). With the array of digital devices available to construction organisations, continuous output of data from diverse projects can be analysed to make informed decisions to improve project delivery and ensure organisations' survival and growth (Daniel, 2014). Bagheri, et al. (2015) also noted that analysis of previously recorded data could be used to determine the issues in the previous process and help forecast the future challenges that might arise and strategies towards mitigating these issues. Freitas and Magrini (2017) observed that business activities could be analysed with BDA in the construction industry to determine the optimal phasing of construction activities. Furthermore, data generated from the thousands of sensors installed in buildings and/or moving drones, bridges and any other construction project makes it possible to monitor each one at any level of performance.

The adoption of BDA in the construction industry, just like every other technology, has been overly slow, and this has negatively impacted the industry's development (Osunsanmi, Aigbavboa, Oke, 2018; Pärn and Edwards, 2019). To ascertain the factors influencing construction organisations' readiness to adopt BDA, UTAUT was adopted. The UTAUT is a TAM developed to achieve a unified view of users' acceptance of new technology and the probability of such technology's success (Venkatesh, et al., 2003). While several acceptance models have emanated, UTAUT has been widely embraced in recent studies that have explored technology adoption (Verma and Sinha, 2018; Ayaz and Yanartas, 2020). Significant studies have adopted this theory in unearthing the intention to use diverse technologies in various fields of studies (Isaias, et al., 2017; Asastani, Kusumawardhana, and Warnars, 2018; Cabrera-Sánchez and Villarejo-Ramos, 2019; Michels, Bonke, and Mußhoff, 2019; Ayaz and Yanartas, 2020). While these studies exist, only the study of Cabrera-Sánchez and Villarejo-Ramos (2019) assessed organisations adoption and intention to use BDA using UTAUT within an organisation's marketing context. The original designed UTAUT, as proposed by Venkatesh, et al. (2003), consists of four major constructs viz – performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC). It is believed that if organisations adopt these four main dimensions, they are most likely to develop a positive attitude towards using new technology (Donmez-Turan, 2019).

The dimension of PE assesses the behaviour to use technology by evaluating how an individual believes that the new technology will improve their task performance. Past studies have considered this dimension as crucial to the acceptance of new technologies (Afonso, et al., 2012; Chauhan and Jaiswal, 2016; Cabrera-Sánchez and Villarejo-Ramos, 2019). Therefore, understanding the perspective of construction organisations on BDA, making their service delivery easier and improving their performance is important in unearthing the factors influencing their intention to adopt this technology. EE deals with ease of learning and using the new technology (Venkatesh, et al., 2003). It has been noted that the extent to which an organisation will be willing to adopt new technology will be dependent on the ease of using such technology (Chauhan and Jaiswal, 2016). The proper implementation of BDA within construction organisations may require the need for a new set of skills. For an industry that has been characterised by skill shortage (Windapo and Cattell, 2010), the need for new skills to handle BDA might be a stumbling block to its acceptance and organisations' intention to use it. Understanding construction organisations' perception regarding this ease of use and learning of BDA becomes a crucial part of determining their intention to use the technology. Afonso, et al. (2012) also submitted that SI plays a vital role in technology acceptance, because the extent to which an individual or organisation thinks that they should use a particular technology can influence the actual adoption of such technology (Venkatesh, et al., 2003). This becomes essential for construction organisations as they do not operate in silos. Their perception of the expectation of their competitors and complementors might significantly influence their adoption of BDA. In a professional environment (like construction), the view of managers and stakeholders is germane. For organisations to be seen as relevant, they might be forced to adopt technologies that these sets of individuals believe is relevant (Chauhan and Jaiswal, 2016). Venkatesh, et al. (2003) described FC as the extent to which the technical infrastructure available is perceived to be adequate in supporting the use of the new technology. This particular dimension has been identified as directly influencing the intention to use and the usage behaviour of technologies (Ayaz and Yanartas, 2020). Based on this dimension's importance, this study assessed the extent to which facilitating conditions such as availability of technology, availability of required expertise, availability of trained staff to handle BDA, and compatibility of BDA with other organisational resources can influence construction organisations' intention to adopt BDA (Cabrera-Sánchez and Villarejo-Ramos, 2019).

While some studies have adopted the four components of the UTAUT holistically (Michels, Bonke, and Mußhoff, 2019; Ayaz and Yanartas, 2020), others have introduced new constructs to further assess diverse acceptance issues. Cabrera-Sánchez and Villarejo-Ramos (2019) introduced the dimension of resistance to use (RU) and perceived risks (PR) to use as key areas to consider in assessing the factors affecting BDA adoption. It was noted that the aspect of resistance to use involves negative reactions to the implementation of BDA. Several studies have affirmed that resistance from the workforce and unions is a crucial factor affecting the adoption of digital technologies such as BDA within the construction industry (Alaghbandrad, et al., 2011; Vaduva-Sahhanoglu, Calbureanu-Popescu, and Smid, 2016; Oke, et al., 2018; Ikuabe, et al., 2020). Similarly, the introduction of innovative processes and technologies such as BDA that threaten processes that work or have been working for years is often perceived as a risky act (Hwang, Trupp, and Liu, 2003; Vass and Gustavsson, 2017). Therefore, the perception of the risk involved in adopting BDA might be a significant yardstick to measure construction organisations' intention to use the technology (Cabrera-Sánchez and Villarejo-Ramos, 2019). Based on the above, this study draws from Cabrera-Sánchez and Villarejo-Ramos (2019) submission in assessing the factors influencing construction organisations' intention to use BDA using six constructs of PE, EE, SI, FC, RU, and PR.

Methodology

A post-positivism philosophical perspective with a deductive approach was adopted for this study. Using a questionnaire survey, quantitative data were gathered from construction organisations. This approach was selected due to its ability to cover a wide range of participants within a short time frame and also be able to provide quantifiability and objectiveness in research (Tan, 2011). These organisations are registered with the Construction Industry Development Board (CIDB) in Gauteng province, South Africa. The premise for conducting the study in this province is that the province houses many construction organisations, with a lot of construction work being carried out daily (CIDB, 2019). The CIDB construction monitor reported a significant number (4070) of construction organisations registered within the province (CIDB, 2019). These 4070 construction organisations formed the target population for this study. These organisations are involved in contracting, general sub-contracting, and specialised sub-contracting. Using Cochran's sample size equation, this total target sample was reduced to 352 at a 95% confidence level and a ±5% margin of error with a 0.5 estimated proportion of the population. Construction professionals were selected to represent each organisation using convenience sampling.

The questionnaire used was designed in two sections as seen in Appendix 1. The first section was on the respondents' background information, and information gathered was used to determine the respondents' suitability for the study. The second section focused on the six different dimensions of the UTAUT with the questions designed to understand the factors influencing these organisations intention to adopt BDA as proposed in Cabrera-Sánchez and Villarejo-Ramos (2019). A description of BDA was given in this section to ensure a general understanding of the concept among the respondents. This section adopted a 5-point Likert scale, with 5 being very high influence and 1 being a very low influence. The questionnaire was electronically distributed among the targeted organisations. A valid response of 110 was retrieved and deemed fit for data analyses. This represents a response rate of 31.3 per cent, which was considered adequate following Moser and Kalton (1999) submissions that a response rate of below 20-30 per cent might be considered as biased and of little significance.

The analysis of the data gathered on the respondent's background information was done using percentage and frequency. The reliability of the questionnaire was also tested using Cronbach's alpha (α) test. Moser and Kalton (1999) noted that this test is suitable for measuring a questionnaire's reliability. The test gives an α-value of between 0 and 1, and the higher value, the more reliable the questionnaire. For this study, α-values of between 0.834 and 0.903 (see Table 1) were derived, and this shows that the instrument used is reliable. The difference in the view from the different types of organisations (contracting, general sub-contracting, and specialised sub-contracting) was also assessed using Kruskal-Wallis H-Test (*K-W*). The *K-W* test is a non-parametric test used in ascertaining the significant difference in the view of three or more groups (Pallant, 2005), as in this present study. The *K-W* test revealed that out of the 28 variables measured under the six categories, only two had a p-value < 0.05. This implies that there is a convergent view among the respondents from the different organisations with respect to 26 variables, but a significant disparity exists in the way they view 'BDA is easy to understand' (EE1) and 'resistance to change in using BDA for decision making' (RU2).

To determine the factors with greater impact on construction organisations intention to adopt BDA, Fuzzy Synthetic Evaluation (FSE), an application fuzzy set theory (Zhao, Hwang, and Gao, 2016), was adopted. This approach's choice was premised on the ability of fuzzy set theory to solve issues surrounding ambiguity, subjectivity, and poor precision in the judgment of problems (Pedrycz, Ekel, and Parreiras, 2011; Zhao, Hwang, and Low, 2013). Fuzzy set theory can precisely and objectively explain and quantify information that is not correctly defined, adopting linguistic variables and terms to create distinctive imprecision in the human cognitive process (Wuni, et al., 2020). Studies have shown that with the fuzzy set theory, mathematical operators can be applied to the fuzzy domain, and the linguistic facet of available data can be quantified. Furthermore, through fuzzy set theory, preferences for individual or group decision-making can be achieved (Zimmermann, 2001; Xia, Chan, and Yeung, 2011; Ma and Kremer, 2015). FSE within the fuzzy set theory has been described as an approach that helps assess multiple criteria decision-making (Xu, et al., 2010). The adoption of FSE for this study was premised on the need to determine the synthetic evaluation of the factors influencing construction organisations intention to adopt BDA in a fuzzy decision environment with multiple criteria (Mu, et al., 2014). Moreover, this analysis approach has been adopted in different built environment research to solve complex issues (Ameyaw and Chan, 2015; Aghimien, et al., 2020; Wuni, et al., 2020).

Results

BACKGROUND INFORMATION

The respondents' background information revealed 60% of the respondents were from contracting organisations, while general and specialist sub-contractors accounted for 20.9% and 19.1% respectively. This is expected as contracting organisations form the bulk of organisations registered with the CIDB from whence the target population for this study was drawn (CIDB, 2020). The representatives of these various construction organisations comprised architects (11.8%), construction managers and construction project managers (34.6%), engineers (33.6%), and quantity surveyors (20%). The majority of these respondents (48.2%) have a bachelor's degree, while 31.8% have a diploma. The remaining 20% possesses a master's degree. In terms of years of experience, 42.7% have up to five years of working experience, while the remaining 57.3% have above five years. On average, the respondents for this study have 7.2 years of working experience in the South African construction industry. With adequate clarification given on the concept of BDA, the level of usage revealed that 58% have never used it in their organisations, while 24.5% stated that it is rarely used. Also, while 11% noted that it is sometimes used in their organisations, only 6.4% submitted that it is used always. These results revealed that this study's information was gathered from respondents with adequate academic background and a significant amount of experience in the industry to give reasonable answers to the study's questions. It further suggested that while BDA might be a beneficial tool, most organisations in the study area are yet to embrace its adoption.

FACTORS INFLUENCING CONSTRUCTION ORGANISATIONS INTENTION TO ADOPT BDA

While the level of adoption is low as seen in the background information, understanding the factors that might improve this level of usage was important. Thus, Table 1 shows the factors assessed in the questionnaire survey. The respondents were asked to rate the sub-variables under each factor based on their level of influence. Based on the data gathered, analyses were done.

Table 1. Factors influencing construction organisations intention to adopt BDA

Code	Factors
	Performance Expectancy
PE1	BDA is useful to carry out the tasks of our organisations
PE2	BDA offers faster delivery of tasks in our organisations
PE3	BDA can help improve productivity
PE4	BDA can help improve overall performance
PE5	BDA offers easy access the clients need
PE6	BDA offers the use of quality information for organisational growth
PE7	BDA offers valuable information on clients
	Effort Expectancy
EE1	BDA is easy to understand
EE2	BDA is easy to use
EE3	BDA is easy to learn
EE4	Generating valuable data will be easy using BDA
	Social Influence
SI1	BDA is used by our competitors
SI2	BDA offers a better competitive advantage
SI3	BDA offers innovativeness
SI4	Using BDA will improve the status of our organisation
	Facilitating conditions
FC1	Availability of technology needed
FC2	Availability of technical knowledge required
FC3	Compatibility with other organisations activities
FC4	Availability of trained staff to handle BDA
	Resistance to Use
RU1	Resistance to change in method of data analysis in the organisation
RU2	Resistance to change in using BDA for decision making

Table 1. continued

Code	Factors
RU3	Resistance to change in using BDA as a means of interaction among professionals
RU4	Resistance to change in using BDA to change the method of service delivery
	Perceived Risk
PR1	Investment risk
PR2	Privacy risk
PR3	Performance risk
PR4	Time risk
PR5	Psychological risk

The result in Table 2 shows the mean score, chi-square (χ^2) and p-value derived from the K-W test, the α-value, and the weighting for each factor assessed. FSE in this study was done in three levels starting from level three to level one. Level three evaluates the different sub-variables, while level two determined the criticality of the latent factors. The first level shows the overall index of the factors influencing organisations intention to adopt BDA. In developing the suitable weightings for the factors (6) and their sub-variables (28), equation one was adopted, and the results are presented in Table 2.

$$W_i = \frac{M_j}{\sum_{i=1}^{5} M_j} \quad (1)$$

Where:

W_i is the weightings of each dimension or sub-attributes

M_j is the mean rating of each dimension or sub-attributes

ΣM_j is the summation of mean ratings of all dimensions or sub-attributes

Using performance expectancy as an example, this factor has a total mean of 29.28. The first variable, PE1, has a mean score of 4.15. To derive the suitable weighting for this variable, equation two was adopted. This same approach was adopted for all other variables assessed.

$$W_{PE1} = \frac{4.15}{4.15+4.24+4.22+4.21+4.21+4.14+4.12} = \frac{4.15}{29.28} = 0.14 \quad (2)$$

The total weight for each main factor can also be derived using a similar approach, as seen in equation three.

$$W_{PE} = \frac{29.28}{29.28+16.27+16.73+6.78+16.20+20.23} = \frac{29.28}{115.49} = 0.25 \quad (3)$$

After determining the suitable weightings, the next step in the FSE was to determine the membership function of the main factors and sub-variables. Following the Xu, et al. (2010) submission, the basic factors can be written as $f = \{f_1, f_2, f_3, \ldots, \ldots, \ldots, f_{28}\}$, while the grading alternatives are $E = \{1,2,3,4,5\}$ based on the 5-point Likert scale adopted. Equation 4 shows how the different membership function seen in Table 3 were computed. Still using the performance expectancy and the first sub-variables as an example, the percentage response shows that while only 3% of the respondents believe that the sub-variable 'BDA is

Table 2. Kruskal-Wallis, mean ratings and weightings of the factors influencing construction organisations intention to adopt BDA

Main factors	Sub-variables	χ^2	Sig.	α	Mean	Weighting	Total Mean	Total Weighting
Performance Expectancy	PE1	0.991	0.803	0.903	4.15	0.14	29.28	0.25
	PE2	2.579	0.461		4.24	0.14		
	PE3	1.335	0.721		4.22	0.14		
	PE4	4.433	0.218		4.21	0.14		
	PE5	1.633	0.652		4.21	0.14		
	PE6	0.747	0.862		4.14	0.14		
	PE7	3.544	0.315		4.12	0.14		
Effort Expectancy	EE1	10.107	0.018**	0.863	3.99	0.25	16.27	0.14
	EE2	4.776	0.189		4.02	0.25		
	EE3	6.606	0.086		4.14	0.25		
	EE4	0.181	0.981		4.13	0.25		
Social Influence	SI1	5.077	0.166	0.834	4.07	0.24	16.73	0.14
	SI2	0.780	0.854		4.19	0.25		
	SI3	1.559	0.669		4.22	0.25		
	SI4	3.030	0.387		4.25	0.25		
Facilitating conditions	FC1	1.769	0.622	0.837	4.32	0.26	16.78	0.15
	FC2	0.531	0.912		4.28	0.26		
	FC3	3.824	0.281		4.14	0.25		
	FC4	1.036	0.793		4.05	0.24		
Resistance to Use	RU1	2.064	0.559	0.870	4.06	0.25	16.20	0.14
	RU2	10.450	0.015**		4.02	0.25		
	RU3	4.475	0.215		4.03	0.25		
	RU4	1.256	0.740		4.09	0.25		
Perceived Risk	PR1	2.810	0.422	0.899	4.04	0.20	20.23	0.18
	PR2	1.361	0.715		4.11	0.20		
	PR3	1.370	0.713		4.05	0.20		
	PR4	3.333	0.343		4.07	0.20		
	PR5	3.174	0.366		3.95	0.20		
Total							115.49	1.00

Note: ** Significant at $p < 0.05$

useful to carry out the tasks of our organisations (PE1)' has very low influence, 52% noted that it has a very high influence in their organisation's intention to adopt BDA. Thus, the membership function of this factor can be calculated, as seen in equation four. This membership function can be expressed as (0.03, 0.04, 0.05, 0.52, 0.36) as evident in Table 3.

$$PE1 = \frac{0.03}{Very\ low} + \frac{0.04}{Low} + \frac{0.05}{Average} + \frac{0.52}{High} + \frac{0.36}{Very\ High} = \frac{0.03}{1} + \frac{0.04}{2} + \frac{0.05}{3} + \frac{0.52}{4} + \frac{0.36}{5} \quad (4)$$

Table 3. Membership function of the factors influencing construction organisations intention to adopt BDA

Main factors	Sub-variables	Weighting	Membership function level 3	Membership function level 2
Performance Expectancy	PE1	0.14	(0.03, 0.04, 0.05, 0.52, 0.36)	(0.02, 0.03, 0.07, 0.50, 0.38)
	PE2	0.14	(0.01, 0.03, 0.06, 0.52, 0.38)	
	PE3	0.14	(0.03, 0.02, 0.07, 0.47, 0.41)	
	PE4	0.14	(0.01, 0.04, 0.06, 0.52, 0.37)	
	PE5	0.14	(0.03, 0.03, 0.06, 0.47, 0.41	
	PE6	0.14	(0.02, 0.05, 0.09, 0.47, 0.37)	
	PE7	0.14	(0.03, 0.03, 0.09, 0.51, 0.35)	
Effort Expectancy	EE1	0.25	(0.02, 0.05, 0.16, 0.45, 0.32)	(0.02, 0.05, 0.13, 0.44, 0.36)
	EE2	0.25	(0.03, 0.03, 0.14, 0.46, 0.33)	
	EE3	0.25	(0.03, 0.05, 0.12, 0.35, 0.45)	
	EE4	0.25	(0.02, 0.04, 0.10, 0.49, 0.35)	
Social Influence	SI1	0.24	(0.02, 0.05, 0.11, 0.47, 0.35)	(0.02, 0.04, 0.09, 0.47, 0.39)
	SI2	0.25	(0.01, 0.03, 0.11, 0.47, 0.38)	
	SI3	0.25	(0.02, 0.05, 0.03, 0.49, 0.41)	
	SI4	0.25	(0.02, 0.02, 0.10, 0.43, 0.44)	
Facilitating conditions	FC1	0.26	(0.02, 0.03, 0.05, 0.44, 0.47)	(0.02, 0.04, 0.07, 0.44, 0.42)
	FC2	0.26	(0.02, 0.03, 0.04, 0.49, 0.43)	
	FC3	0.25	(0.04, 0.05, 0.06, 0.43, 0.42)	
	FC4	0.24	(0.03, 0.06, 0.12, 0.42, 0.37)	

Table 3. continued

Main factors	Sub-variables	Weighting	Membership function level 3	Membership function level 2
Resistance to Use	RU1	0.25	(0.02, 0.07, 0.12, 0.41, 0.38)	(0.02, 0.07, 0.13, 0.42, 0.36)
	RU2	0.25	(0.02, 0.07, 0.14, 0.42, 0.35)	
	RU3	0.25	(0.01, 0.07, 0.14, 0.45, 0.34)	
	RU4	0.25	(0.03, 0.05, 0.12, 0.43, 0.38)	
Perceived Risk	PR1	0.20	(0.04, 0.03, 0.12, 0.50, 0.32)	(0.03, 0.06, 0.10, 0.45, 0.36)
	PR2	0.20	(0.02, 0.05, 0.11, 0.46, 0.36)	
	PR3	0.20	(0.02, 0.08, 0.10, 0.43, 0.37)	
	PR4	0.20	(0.04, 0.07, 0.09, 0.38, 0.42)	
	PR5	0.20	(0.04, 0.08, 0.10, 0.45, 0.33)	

Having evaluated the sub-variables in level three and the criticality of the main factors in level two, the next step was to determine the model that best explains the factors influencing the intention to adopt BDA among construction organisations. Past studies have explored different model approaches with unique characteristics in the fuzzy environment. Xu, et al. (2010) and Chan, et al. (2011) suggested that the most suitable model can be adopted when many factors are being considered, and the difference in their weight is minimal is given below in equation five.

$$M(\cdot, \oplus), bj = \min\left(1, \textstyle\sum_{i=1}^{m} wi \times rij\right) \forall bj \in B \quad (5)$$

Where w_i = the weighting of a factor affecting smart city attainment

r_{ij} = the membership function of a factor affecting smart city attainment

$\oplus$ = the sum of the product of weighting and membership function

Using the above equation, level one which gives the overall index of the factors influencing construction organisations decision to adopt BDA can be attained by:

(0.25x0.02+0.14x0.02+0.14x0.02+0.15x0.02+0.14x0.02+0.18x0.03,
0.25x0.03+0.14x0.05+0.14x0.04+0.15x0.04+0.14x0.07+0.18x0.06,
0.25x0.07+0.14x0.13+0.14x0.09+0.15x0.07+0.14x0.13+0.18x0.10,
0.25x0.50+0.14x0.44+0.14x0.47+0.15x0.44+0.14x0.42+0.18x0.45,
0.25x0.38+0.14x0.36+0.14x0.039+0.15x0.42+0.14x0.36+0.18x0.36) =
(0.02 0.05, 0.09, 0.46, 0.38).

Therefore, the membership function of the factors influencing construction organisations adoption of BDA at level one can be expressed as (0.02 0.05, 0.09, 0.46, 0.38). Using this result, the overall impact of the identified factors on organisations' intentions to adopt can be derived using equation six.

$$\text{OIL} = \textstyle\sum_{k=1}^{5} (W \times R_k) \times L \quad (6)$$

Where;

OIL = Overall impact level

W = the weighting of each factor assessed

R = the degree of membership function of each factor assessed

L = is the linguistic variable (1=Very low, 2=Low, 3=Average, 4=High, 5=Very High)

Therefore OIL = 0.02x1 + 0.05x2 + 0.09x3 + 0.46x4 + 0.38x5 = 4.13

The impact shows that the identified six factors and 26 variables will have a high influence (4.13) on construction organisations' intention to adopt BDA. This same approach can be used to calculate each factor's level of impact to derive the impact level in Figure 1. The figure further shows that the six different factors will individually highly influence the adoption of BDA. Chief of these factors are variables relating to facilitating conditions (4.20), performance expectancy (4.18), and social influence (4.18). However, issues surrounding effort expectancy (4.07), resistance to use (4.05) and perceived risk (4.05) cannot be overlooked as they also have high impact levels.

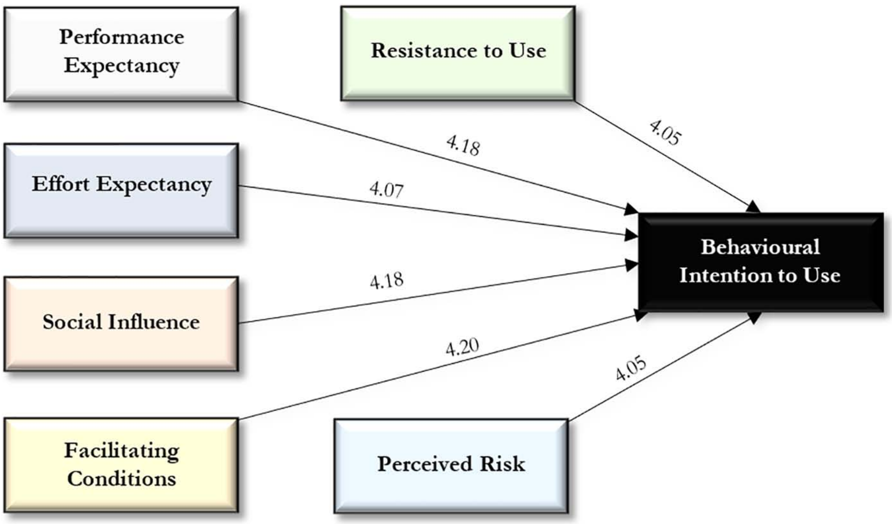

Figure 1. Level of the impact of each factor on the behavioural intention of construction organisations to use BDA.

Discussion

This study has revealed that the six dimensions of the UTAUT highly impact construction organisation's intention to adopt BDA. More critical is the facilitating conditions such as the availability of technology, technical knowledge, trained staff to handle BDA, and compatibility with other organisation activities. These findings resonate with past submissions that have noted that the facilitation conditions within any organisation will significantly influence the behavioural intention and actual usage of new technologies (Alharbi, 2014; Cabrera-Sánchez and Villarejo-Ramos, 2019; Ayaz and Yanartas, 2020). Therefore, having the right technologies and the right expertise is needed to shape their intention to use BDA. This aspect needs to be given significant attention as construction organisations have been described as lacking in technology availability and technical knowledge shortage (Windapo and Cattell, 2010; Elkhalifa, 2016; Aghimien, et al., 2018; Oke, et al., 2018).

Also, performance expectancy and social influence must be given adequate attention as they also contribute significantly to shaping the intention of construction organisations to use BDA. By showcasing the importance of BDA in improving construction organisations' performance and ensuring the development of the industry, the behavioural intention of these organisations can be shaped from the proof of effective delivery of products and services emanating from the adoption of BDA. This is because past studies have averred that performance expectancy plays a crucial role in how organisations or individuals will perceive the usefulness of technology and whether they will be encouraged to adopt it or not (Afonso, et al., 2012; Chauhan and Jaiswal, 2016; Cabrera-Sánchez and Villarejo-Ramos, 2019). Similarly, competitors' role cannot be overemphasised as organisations have been observed to adopt new technologies while mimicking their competitors whilst staying ahead or within the competition (Awa, Ojiabo, and Orokor, 2017; Quinton, et al., 2018). The use of BDA by competitors and complementors might go a long way in influencing construction organisations' behavioural intention to use this technology. Hence, the social influence on the use of BDA on construction organisations should be carefully considered by any organisations hoping to gain a better competitive advantage through BDA (Venkatesh et al., 2003; Afonso, et al., 2012).

Conclusion

This study assessed the factors influencing construction organisations behavioural intention to adopt BDA using South Africa as a case study. By adopting the UTAUT, the study concludes that the intention to use BDA in construction organisations is impacted significantly by the facilitation conditions available within the organisation, the organisation's performance expectations, and the societal influence. However, consideration must also be given to effort expectancy, perceived risk, and resistance to use. They also play a crucial part in the behavioural intention of construction organisations to use BDA. The question today is not about whether to adopt technology but how to go about it, as technological advancement has been noted to offer solutions to long-term construction problems. Therefore, top management within construction organisations must be willing to invest in BDA, its ancillary technologies, and the training of staff to handle these technologies, if the inherent benefits of BDA are to be derived. Proper enlightening of construction participants and organisations regarding the usefulness of BDA to their service delivery is also essential for improving their performance expectations. Technology companies and professional bodies can drive this awareness through a series of workshops, seminars and conferences. Regulatory bodies such as the CIDB can drive the use of BDA and other technologies through legislation and supports for construction organisations that may not fund these technologies or acquire the expertise needed. Government support through the provision of incentives for the use of BDA on public projects can also go a long way in encouraging adoption since the government is the biggest client of the construction industry.

Practically, this study provides insight into the factors that could influence construction organisations behavioural intention to adopt BDA. Construction organisations can benefit from the understanding of the factors they need to consider if they are to derive the positive outcomes of adopting BDA in their organisation. Theoretically, the study provides an excellent background for future research on BDA adoption. The submission of the study hopes to further the discourse on the digital transformation of the construction industry through the use of innovations such as BDA by drawing from the perspective of a developing country like South Africa where such studies are practically non-existent. However, the study's findings are limited by factors such as the geographical scope and the methodology adopted. While the study was conducted in Gauteng province, the findings cannot be generalised for the entire country as several constraints within individual locality may influence the outcome of the study in other provinces. Therefore, further studies can be done in other provinces to get a more comprehensive view of the factors under assessment. Also, further studies can be conducted to assess the level of adoption of BDA across the different sizes of construction organisations (small, medium and large), as the size of the organisation might influence their level of capability to handle BDA. Other methodologies such as qualitative or mixed-method approaches can also be used to get interpretivist and pragmatic perspectives. Furthermore, this study adopted FSE to ascertain the factors influencing construction organisations' behavioural intention to adopt BDA. The significant impact of each factor on the actual usage of this technology can be conducted using other analytical approaches such as multiple linear regression analysis and structural equation modelling.

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APPENDIX 1: Questionnaire sample

QUESTIONNAIRE ON THE FACTORS INFLUENCING THE INTENTION TO ADOPT BIG DATA ANALYTICS AMONG CONSTRUCTION ORGANISATIONS IN SOUTH AFRICA

INSTRUCTION: Please answer the following questions by crossing (x) on the appropriate block

SECTION A - BACKGROUND INFORMATION

This section of the questionnaire refers to background information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. Once again, we assure you that your response will remain anonymous. Your co-operation is appreciated.

1. ***What is your highest academic qualification?***

Matric certificate (Grade 12) [ ], Diploma [ ], Bachelor's Degree [ ], Master's Degree [ ], Doctorate [ ]

2. ***What is your Professional role in the construction sector?***

Architect [ ], Construction Manager [ ] Construction Project Manager [ ], Engineer [ ],
Quantity Surveyor [ ]

3. ***How many years of experience do you have in the construction industry?***

1 – 5 years [ ], 6 –10 years [ ], 11– 15years [ ], 16-20 years [ ], Above 20 years [ ]

4. ***What is your company's primary role in the construction sector?***

Contractor [ ], Generalist subcontractor [ ], Specialist subcontractor [ ]

SECTION B: FACTORS INFLUENCING THE INTENTION TO ADOPT BIG DATA ANALYTICS AMONG CONSTRUCTION ORGANISATIONS IN SOUTH AFRICA

Definition: Big Data Analytics (BDA) involves gathering and processing large and complex datasets known as Big Data through the use of appropriate technology to derive useful information for effective decision-making.

5. ***Based on your understanding of BDA, what is the current level of its usage within your organisation?***
Never [ ], Rarely [ ], Sometimes [ ], Often [ ], Always [ ]

6. ***To what extent will the following factors influence the use of BDA in your organisation on a scale of 1 to 5, with 1 being "Very low influence", 2 being "Low influence", 3 being "Average influence", 4 being "High influence" and 5 being "Very high influence."***

Factors	1	2	3	4	5
BDA offers faster delivery of tasks in organisations	1	2	3	4	5
Resistance to change in using BDA for decision making	1	2	3	4	5
BDA can help improve productivity	1	2	3	4	5
BDA can help improve overall performance	1	2	3	4	5
BDA is easy to learn	1	2	3	4	5
BDA offers easy access the clients need	1	2	3	4	5
Performance risk	1	2	3	4	5
BDA offers valuable information on clients	1	2	3	4	5
BDA is easy to understand	1	2	3	4	5
BDA is easy to use	1	2	3	4	5
Resistance to change in using BDA to change the method of service delivery	1	2	3	4	5
Using BDA will improve the status of our organisation	1	2	3	4	5
BDA is used by our competitors	1	2	3	4	5
Psychological risk	1	2	3	4	5
BDA offers innovativeness	1	2	3	4	5
BDA offers the use of quality information for organisational growth	1	2	3	4	5
Time risk	1	2	3	4	5
Availability of technical knowledge required	1	2	3	4	5
Compatibility with other organisations activities	1	2	3	4	5
Availability of trained staff to handle BDA	1	2	3	4	5
Resistance to change in method of data analysis in organisation	1	2	3	4	5
Investment risk	1	2	3	4	5
Resistance to change in using BDA as a means of interaction among professionals	1	2	3	4	5
BDA is useful to carry out tasks in organisations	1	2	3	4	5
Availability of technology needed	1	2	3	4	5
Privacy risk	1	2	3	4	5
Generating valuable data will be easy using BDA	1	2	3	4	5
BDA offers better competitive advantage	1	2	3	4	5

Thank you for taking the time to complete this survey.