Factors Influencing the Adoption of Automated Data Collection Technologies by Building Contractors in Kenya

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***Abstract*: Despite the fact that automated data collection (ADC) technologies come with new avenues of opportunities to reckon with that can be relevant for establishment of effective and efficient management approaches, studies indicate that construction industry has lagged behind in adopting and implementing these technologies. In the Kenyan construction industry, the current application of the information communication technology (ICT) platforms is on the conventional technologies like cameras, Smart phones & tablets applications and Radio Frequency Identification (RFID). However the use of more advanced ICT platforms like Global positioning systems (GPS) and wireless sensor networks remains highly unexploited in the construction industry. This paper seeks to establish factors which affect the adoption of automated data collection technologies by building contractors in Kenya. A Descriptive research survey design was used and structured questionnaires issued. The target population in this study comprised of Building works contractors in categories National Construction Authority (NCA) 1 to NCA3 operating within Nairobi County. Stratified systematic sampling was then used to draw the sample size from the population of 300 with a return of response rate of 63%. The study concluded that: the level of adoption of automated data collection (ADC) technologies by local building contractors in Kenya is significantly influenced by the cost of technology, availability of technology, management commitment, size of the firm and human resource capacity. The study recommends that construction firms should have competent planning and strategy teams to deal with innovation adoption. There is also the need for the government to improve the information communication technology infrastructure and through bodies like NCA introduce training programs on an industry level on the emerging technologies that can be applied in the construction sector.**

***Keywords*: Automated data collection technologies, hardware, software, data, internet, GPS**

I. INTRODUCTION

Technological advancement in the field of data collection technologies have made the running of construction projects more effective by providing accurate, timely and reliable data (Omar & Nehdi, 2018). The use automated data collection technologies in construction sites provides accurate and timely information in order to compare the as built and as planned status of the project (Majrouhi, 2012). This facilitates the decision making on most appropriate corrective measures in order to avoid reworks. Despite the fact that automated data collection technologies come with new avenues of opportunities to reckon with that can be relevant for establishment of effective and efficient management approaches, studies indicate that construction industry has lagged behind in adopting and implementing these technologies (Majrouhi, 2015).

Most developed countries have successfully exploited automation in their construction sectors paving them the opportunity to accomplish quality projects within the set parameters (Lu et al., 2013). The need for developing nations to adopt the automated technologies in its construction industry cannot be ignored (Oesterreich & Teuteberg, 2016). In the Kenya, the current application of the automated data collection technologies platforms is on the conventional technologies like cameras ,Smart phones & tablets applications and Radio Frequency Identification (RFID, however the use more advanced ICT platforms like Global positioning systems (GPS) and wireless sensor networks(WSN) remains highly unexploited (Nyaga, 2015).

According to Gachungi 2017, studies should be carried out to determine ways to improve the adoption of more advanced ICT platforms like Global positioning systems (GPS) by building contractors in Kenya. Therefore this paper seeks to establish the factors which affect the adoption of automated data collection technologies by building contractors in Kenya, in order to determine ways to increase their level of adoption.

II. TYPES OF AUTOMATED DATA COLLECTION TECHNOLOGIES

According to Srewil & Scherer (2013) automated data collection technologies are advanced and automated data capture and storage technologies which are used in identifying, collecting, storing, transmitting and presenting the information captured from various construction operations. Automated data collection technologies can be categorized depending on their mode of operation including 3D imaging technologies, geospatial technologies and enhanced IT technologies (Omar and Nehdi, 2018).

A. 3D imaging technologies

3D laser imaging technology utilises laser beams in the collection of details of an object and the environment (Guo & Wang, 2019). The digital images created are used to generate information about particular objects in the constructions site

and the information presented in a 3-dimensional format (Omar & Nehdi 2018). Some of the existing 3D imaging technologies include 3D laser scanning and photogrammetry.

B. Geospatial Technologies

Geospatial technologies are technologies that collect and process information about the geographical location of objects, in construction sites they are mostly utilised in construction projects to share data between on-site personnel and managers or other construction project stakeholders (Ebrahim et.al, 2016). Some of the existing geospatial technologies for use in the construction industry include global positioning system (GPS) and ultra-wideband (UWB)

C. Enhanced IT technologies

These are information communication based platforms which are used to collect and relay information from one individual to another (Omar & Nehdi 2018). Enhanced IT can be categorised into multimedia tools and handheld computing platforms. Multimedia tools includes cameras, digital cameras and video cameras while handheld computing includes laptops, smartphones and smartphone applications.

III. FACTORS THAT INFLUENCE THE ADOPTION OF ADC TECHNOLOGIES

Several studies have been carried out to discuss the adoption of new technologies into construction firms (Dixit et al 2020; Al-Shammary & Ali, 2007; Owolabi & Olufemi, 2018). Certainly there are many factors which influence the adoption of technology into a firm and include cost of technology, aspects of the firm, return on investment and necessary infrastructure availability (Gambatese & Hallowell, 2011). Lal (2007) found that lack of government support and poor infrastructure as major factors affecting Technology adoption by firms in Nigeria. Kuhn et al. (2019) investigated factors which influence adoption of innovation by firms in Germany and found that infrastructure availability and government support are significant factors.

Categorisation of factors influencing technology adoption is done based on the technology investigated, study location or the researcher's desire (Bonabana- Wabbi , 2002). This study grouped the factors into five major categories namely Technology aspects, Management, Size of firm aspects, Cost of the technology aspects and Human resource capacity aspects. These five variables are hypothesized to influence the adoption and use of ADC technologies.

A. Cost of technology aspects

There is a strong correlation between the cost of technology and the level of adoption of technology into firms (Ernst &Young 2011; Gajendran & Brewer, 2007; Frits, 2007). The direct cost of technology includes the acquisition cost, maintenance cost, operation costs and scalability costs whereas the indirect costs includes Cost of training staff and cost of integrating the new technology into the current work operation methods.

Acquisition cost is the cost incurred in purchasing the ADC technology platforms whereas maintenance and operation costs refers to costs associated with the daily system running and maintenance including training of staff. Before adoption of technology, firms should consider the operations and maintenance costs as they are significant to the life cycle cost of the technology platform (Kianian et al., 2019). The cost related to the deployment of new systems influences the attitude of the firms towards the adoption of technology.

Scalability costs are the costs involved in the organization changes in order to successfully implement the new technology. The implementation of the technology into firms involves various structural and human resources changes (Kianian et al., 2019). Technologies which are easily integrated with the new systems gives a lower total cost and are more preferable.

B. Management commitment and ADC adoption

The Management commitment to adoption of ADC technologies refers to the readiness of firm's top management to incorporate the use of these technologies in their operations with a view of their firms gaining a competitive advantage. A firm's management play a major role in steering their firms towards embracing any change that is introduced into their firms (Ahmad et.al, 2014). One of the main failures in the implementation of a new technology is the focus on the technology neglecting the firm within which the technology will be implemented and the people who are likely to steer the change. A study by Hsu et.al (2018), concluded that the firms which had successfully adopted ICT technologies had a management which was willing to support the adoption or had partnered with IT firms which provided the necessary technical expertise.

C. Human resource capacity aspect

The levels of skills of the workers and the availability of capital are two of the most impotent determinants of adoption of a new technology into a firm, this is because the new technology cannot be operationalized without two of them. Any change or introduction of a technology in a firm requires a change in skills (Frits, 2007). Bronwyn & Khan (2003) asserts that generally the rate of adoption of technologies which require high level skills are costly and slow. As a result the level of skills of the intended technology and the manner and cost of acquiring the skills is an important determinant of diffusion of technology. With the deployment and changes in technologies, firms are faced with need for continuous learning for their staff and due to the limited resources, most of the small firms do not easily embrace the new technologies.

D. Technology aspects

Technological aspects includes availability of technology, technical support and necessary infrastructure needed in the operation of the technology. The availability of technology determine kind of technology can be adopted. Lack of awareness on the available technologies affect the adoption of

innovation (Rogers, 2003). ICT infrastructure such as stable internet access is crucial in ensuring successful implementation of a new technology in an organization. The importance of availability of technical support has been noted to affect the usage behavior of any innovation (Venkatesh et al., 2003). The end users gain more confidence to adopt a technology if the necessary support will be availed when needed.

IV. RESEARCH METHODOLOGY

The research design used in the study was a descriptive research survey design. A Descriptive research survey design was used and structured questionnaires issued. The target population in this study comprised of Building works contractors in categories NCA1 to NCA3 operating within Nairobi. This is because, most of the contractors in the lower NCA classes handle small projects which may not require high levels of automated data collection technologies. In addition, according to a report by NCA (2019), Nairobi region had the largest number of construction companies registered under Categories NCA 1 to NCA 3. Bertlett, Kotrilik and Higgins, (2001) Formula was used to obtain the sample size of 300 from the population with a return of a response rate of 63%. This research targeted 100 contractors from each of the three categories namely NCA 1, NCA 2 and NCA 3. Stratified systematic sampling technique was used in the study to draw the sample size from the population. Data collected was entered into MS excel and Statistic Package for Social Sciences (SPSS) version 21 to enable carrying out of data analysis. Descriptive statistics including measures of tendency, measures of frequency and measures of dispersion were used to analyse the data which was presented in tables and graphs. Regression analysis was used to show the relationship among the variables in the study.

V. FINDINGS AND DISCUSSIONS

A. ADC platforms used by building contractors

The focus was on nine different ADC technology platforms identified from the literature review and adopted by building contractors in Kenya. They included: Global positioning systems technology (GPS), smartphones and camera applications, barcodes, Radio Frequency Identification, 3D Laser Scanning, Photogrammetry, Ultra-Wideband and

The results (See table 1) on their level of usage show that smartphones (mean = 4.53) and cameras (mean = 4.44) have the highest level usage among the respondents. According to Esselaar et.al (2006), smartphones and cameras are the most used ICT platforms worldwide in all sectors.

Further, table 1 reveals that there is average use of GPS (mean = 2.43) and barcodes (mean= 2.12) however the building contractors are yet to fully embrace the use of 3D laser Scanning (mean = 1.50), Photogrammetry (Mean = 1.44) and Wireless Sensor Networks (Mean= 1.37). Generally, the rate of adoption of technologies which require high level skills and are costly is slow (Bronwyn & Khan, 2003). In addition, when compared to other sectors, firms in the construction industry are generally reluctant to adopt any new emerging technologies .This can mainly be attributed to perceived high costs of adopting emerging technologies (Frits, 2007) , training needs required (Barthorpe et al., 2003) and unwillingness to change the current working methods (love et. al, 2004).

Table 1 Adc Technologies Used by Local Building Contractors

ADC TECHNOLOGY PLATFORMS	N	MEAN	RII	RANK
GPS	189	2.43	0.63	3
Smart phones & tablets applications	189	4.53	0.84	1
Camera	189	4.44	0.81	2
barcodes	189	2.22	0.59	4
Radio Frequency Identification	189	2.28	0.38	5
3D Laser Scanning	189	1.5	0.26	7
Photogrammetry	189	1.44	0.23	8
Ultra-Wideband	189	2.12	0.23	9
Wireless Sensor Networks	189	1.37	0.26	6

Source: Field data

B. Regression analysis of Cost of Technology on Level of adoption of ADC Technologies.

Table 2 Anova for Cost of Technology and Level of Adoption of Adc Technologies

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.751	1	2.751	7.466	0.007
Residual	68.901	187	0.368		
Total	71.651	188			
$R^2 = 78.2\%$	and	*adjusted* $R^2 = 77.2\%$			

Source: Field data

Table 3 Coefficient Table for Cost of Technology and Level of Adoption Of Adc Technologies

	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	2.707	0.212	12.793	0.000
X1	0.201	0.074	2.732	0.002

Source: Field data

The R square value in Table 2 indicates that 78.2% of variation in the Level of adoption of ADC Technologies is explained by the Cost of Technology.

The model was fitted on the data is given by $Y = 2.707 + 0.201X1$.

The ANOVA table 3 indicates that the model fitted is significant since p = 0.002 is less than 0.05 the level of significance, hence it is concluded that there is a significant effect of the Cost of Technology on Level of adoption of ADC Technologies.

The finding are similar to studies Strukova and Liska (2005) which concluded that the high cost of acquisition and maintenance were the most significant barriers towards the adoption of automation technologies. Cost is a major factor which influences the level of adoption of technology in construction firm (Gambatese & Hallowell, 2011). Results from Table 1 also indicate that technologies which are relatively cheaper namely smartphones (mean = 4.53) and cameras (mean = 4.44) had the highest level usage among the building contractors.

The construction industry mainly consists of a relatively large number of small contractors and subcontractors in which only a few big construction firms can assign large amount of financial resources to test a new technology, thus high initial acquisition costs represents a major barrier in the adoption of technology in the construction (Gajendran & Brewer, 2007).

C. Regression analysis of Human resource capacity on Level of adoption of ADC Technologies.

Table 4 Anova For Human Resource Capacity And Level Of Adoption Of Adc Technologies

	Sum of Squares	df	Mean Square	F	Sig.	
Regression	0.055	1	0.055	0.145	.000[a]	
Residual	71.596	187	0.383			
Total	71.651	188				
$R^2 = 57.2\%$		, and $adjusted - R^2 = 55.2\%$				

Source: Field data

Table 5 Coefficient Table For Human Resource Capacity And Level Of Adoption Of Adc Technologies

Unstandardized Coefficients				t	Sig.
	B		Std. Error		
(Constant) X2	3.35		0.21	15.95	0.704
	0.027		0.071	-0.38	0.000

Source: Field data

The R square value outlined in Table 4 indicates that 57.2% of variation in the Level of adoption of ADC Technologies is explained by the Human resource capacity.

The model was fitted on the data is given by $Y = 3.350 + 0.027X2$.

The ANOVA table 5 indicates that the model fitted is significant since p = 0.000 is less than 0.05 the level of significance, this indicates the existence of a significant relationship between Human resource capacity and Level of adoption of ADC Technologies.

This finding corresponds with studies by Songer et al. (2001) which found that lack appropriate skills and high costs as key barriers in the adoption of IT applications. Further, from the study (See table 1) technologies which require technical expertise to operate like GPS (mean = 2.43) and 3D laser scanning technologies (mean 1.50) had lower adoption compared to Cameras (Mean=4.44) which do not require any specialised expertise to operate. Nyaga (2015) also found out that lack of qualified personnel and high cost of training ICT personnel are major barriers to adoption of ICT in construction firms in Kenya.

The rate of adoption of technologies which require high level skills and are costly is slow (Bronwyn & Khan 2003). In order to bridge the knowledge of existing professionals in the industry there is need for the government through bodies like the National Construction authority (NCA) to continuously hold continuous development programs on the use of the high level ADC technologies

D. Regression analysis of Size of the firm on Level of adoption of ADC Technologies.

Table 6 Anova For Size Of The Firm And Level Of Adoption Of Adc Technologies

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.027	1	0.03	0.07	.003[a]
Residual	71.625	187	0.38		
Total	71.651	188			
$R^2 = 32.8\%$	, and	$adjusted - R^2 = 29.8\%$			

Source: Field data

Table 7 Coefficient Table For Size Of The Firm And Level Of Adoption Of Adc Technologies

Unstandardized Coefficients			t	Sig.
	B	Std. Error		
(Constant)	3.222	0.195	16.5	0.023
X3	0.015	0.058	0.26	0.003

Source: Field data

The R square value outlined in Table 6 shows that that 32.8% of variation in the Level of adoption of ADC Technologies is explained by the Size of the firm.

The model was fitted on the data is given by

$$Y = 3.222 + 0.015X3$$

The ANOVA table 7 indicates that the model fitted is significant since p = 0.003 is less than 0.05 the level of significance, thus it can be interpreted that there exists a positive relationship between the Size of the firm and Level of adoption of ADC Technologies. The size of the firm can be determined by the annual turnover, number of employees of the firm and the size & complexity of the projects handled. Large firms are more likely to invest in the use of technology due to access of more resources.

E. Regression analysis of Management commitment on Level of adoption of ADC Technologies.

Table 8 Anova for Management Commitment On Level of Adoption of Adc Technologies

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.254	1	3.254	8.896	.003[a]
Residual	68.398	187	0.366		
Total	71.651	188			
$R^2 = 7.3\%$	, and $adjusted - R^2 = 6.3\%$				

Source: Field data

Table 9 Coefficient Table for Management Commitment On Level of Adoption of Adc Technologies

Unstandardized Coefficients			t	Sig.
	B	Std. Error		
(Constant)	2.759	0.178	2.446	0.023
X4	0.163	0.055	3.277	0.003

Source: Field data

The R square value outlined in Table 8 indicates that 7.3% of variation in the Level of adoption of ADC Technologies is explained by the Management commitment.

The model was fitted on the data is given by

$$Y = 2.759 + 0.163X4$$

The ANOVA table 9 indicates that the model fitted is significant since p = 0.003 is less than 0.05 the level of significance, thus it can be interpreted that there exists a positive relationship between Management commitment on Level of adoption of ADC Technologies.

In a study by Gambatese and Hallowell (2011) it was concluded that support by the management was one of the main driving force in the adoption of new technologies into construction firms. Owners and top leadership play a major role in steering their firms towards embracing any change that is introduced into their firms by providing the necessary financial (Abrell-Vogel & Rowold 2014). In addition, the management is required to offer the necessary supporting by setting aside the necessary financial and resources allocation for the acquisition and maintenance of ADC technologies. The management should also have a competent planning and strategy teams to deal with the adoption of ADC technologies.

F. Regression analysis of Availability of Technology aspects on Level of adoption of ADC Technologies

Table 10 Anova for Availability of Technology and Level of Adoption of Adc Technologies

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.018	1	0.018	0.048	.000[a]
Residual	71.633	187	0.383		
Total	71.651	188			
$R^2 = 31.5\%$	, and $adjusted - R^2 = 30.8\%$				

Source: Field data

Table 11 Coefficient Table For Availability Of Technology And Level Of Adoption Of Adc Technologies

Unstandardized Coefficients			t	Sig.
	B	Std. Error		
(Constant)	3.224	0.224	14.369	0.000
X5	0.017	0.079	0.219	0.000

Source: Field data

The R square value outlined in Table 10 indicates that 31.5% of variation in the Level of adoption of ADC Technologies is explained by the Availability of Technology.

The model that was fitted on the data is given by

$$Y = 3.224 + 0.017X5$$

The ANOVA table 11 reveals that the model fitted is significant since p = 0.000 is less than 0.05 the level of significance, thus it can be interpreted that there exists a positive relationship between the availability of technology on Level of adoption of ADC Technologies.

Availability of technology is major barrier towards the adoption of automation in construction projects (Strukova & Liska, 2005). Availability of technical support and technology infrastructure availability plays a major role when determining the type of technology to be adopt. Some of the ADC technologies requires high speed internet to perform efficiently. Without high speed internets, some ADC technology tools may not be exploited effectively. Therefore, there is the need for the ICT infrastructure to be improved by

the government in order to increase the adaptability of ADC technologies.

VI. CONCLUSIONS

The study examined factors which influence adoption of ADC technologies by building contractors in Kenya. The study revealed that the Cost of Technology, Human resource capacity, Size of the firm, Management commitment and Availability of technology significantly affect the adoption of ADC technologies by building contractors in Kenya. In order to improve the adoption of new technologies construction firms should allocate enough financial resources, put in place competent ICT planning teams to research and steer the implementation and continually hold training programs for their exiting staff on the emerging technologies. There is also the need for the government to improve the ICT infrastructure and through bodies like National Construction Authority introduce training programs on an industry level on the emerging technologies that can be applied in the construction sector.

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