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THE ECONOMICS OF CLOUD-BASED COMPUTING TECHNOLOGIES IN CONSTRUCTION PROJECT DELIVERY

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ABSTRACT

The construction industry is a very traditional sector, albeit one that is embracing new technology faster now than at any time in its past. The purpose of the research is to assess the economics of cloud-based computing technologies in construction project delivery. The study made use of a cross-sectional survey through a questionnaire instrument distributed to construction stakeholders. The surveyed sample size represent a 58% response rate. Statistical tools of Stacked Bars and Analysis of Variance (ANOVA) were used to present the result. The study identified the cloud-based services mostly used by construction stakeholders. The study revealed that economic benefits such as knowledge sharing, remote access of back-office activities and collaboration among construction stakeholders are evident while utilizing cloud-based computing technologies. Although, there are many benefits to the use of this technology, the study identified fear of security and data privacy, poor/slow connection to the internet, lack of physical control and costly data subscription as major threats to the efficient and effective use of cloud-based computing technologies in the construction delivery process.

Key words: Cloud computing, Construction Industry, Economics, Knowledge Sharing, Security and Data Privacy.

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1. INTRODUCTION

The construction industry is fuelled daily by 'big data' information which produced and transmitted by numerous construction stakeholders. The unique characteristics of involving several professions, skilled and unskilled at fragmented stages of project delivery through the lifecycle of the product means that it must be sustained through efficient and effective information and communication. The type of information that is required from the inception to handover of construction products must be accurate, timely, easily accessed and adequately stored for easy recall (Afolabi and Dada, 2014; Afolabi et al., 2017).

However, the construction industry has suffered from poor information generation, flow and storage. This has led to challenges such as cost overrun, time overrun and delay, abandonment of projects, litigation, unresolved dispute and client dissatisfaction. Studies have revealed that information that is adequately cared for can reduce most of these unnecessary challenges (Health and Safety Executive, 2002; Titus, 2005; Khan et al., 2015; Oyeyipo et al., 2017). The poor information experienced by the industry has been largely hinged on the heavy reliance on paper-based channels of transmitting and storing construction information. Notwithstanding, the construction industry makes use of diverse information and communication technologies (ICTs) that has made it to function faster and efficiently that the earlier traditional methods. The positive experiences of using ICTs in the sector has made it embrace new technologies faster now than at any time in its past. Information and communication technologies (ICTs) such as electronic transactions, enterprise systems, building information modelling (BIM) and web-based technologies are transforming the landscape of the construction industry.

One of the new Information and communication technologies (ICTs) promising tremendous change in the construction industry is cloud-based computing technologies. The technology is not new to construction stakeholders, has they have utilized it in one way or the other, informally or formally. Examples of Google drive, Google Doc, Microsoft Office Live and Dropbox are commonplace to construction professionals. The fast adoption of the technology can be traced to the numerous benefits and user friendliness of the technology. Consumers of cloud computing do not need any background knowledge of the services (Ercan, 2010). Ankeny (2011) opined that several advantages can be derived from implementing cloud computing. Benefits such as greater flexibility, no up-front cost, increased collaboration, automatic software update, document control, vast storage capacity, work elasticity, environmentally friendly, disaster recovery and competitiveness. Furthermore, Abedi et al. (2013) added that cloud computing technology assists users (businesses and individuals) to access, share and disseminate the data; applications and services from the various servers via the internet. Moreover, it assists the users to implement the applications with no concerns regarding to the installation which allows them on accessing to their various data through the internet on any computer or mobile devices. This brings to fore the question, what specific contributions does cloud-based computing engender to the construction industry and its stakeholders? Therefore the aim of this study is to assess the economics of cloud-based computing technologies in construction project delivery. The objectives of the study are to:

- Identify the cloud-based computing technologies utilized by construction stakeholder in their construction processes?
- Assess the economics of utilizing cloud-based computing technologies in project delivery by construction stakeholders?
- Examine the possible threats to cloud-based computing technologies in project delivery experienced by construction stakeholders?

2. THE CONCEPT OF CLOUD COMPUTING

Kumar et al. (2010) stated that CC can be applied to the construction industry in various aspects, including but not limited to architectural design, structural analysis, cost estimating, project planning and control, and procurement management. The most important aspect is that the organization should know one's team, know one's required solutions, and finally, understand how the Cloud vendor can benefit one's existing business situation. Figure 1 showed the results of a survey that have been completed in 2009 on the use of cloud

computing in several industrial sector and services. The Figure did not depict the usage in the construction industry.

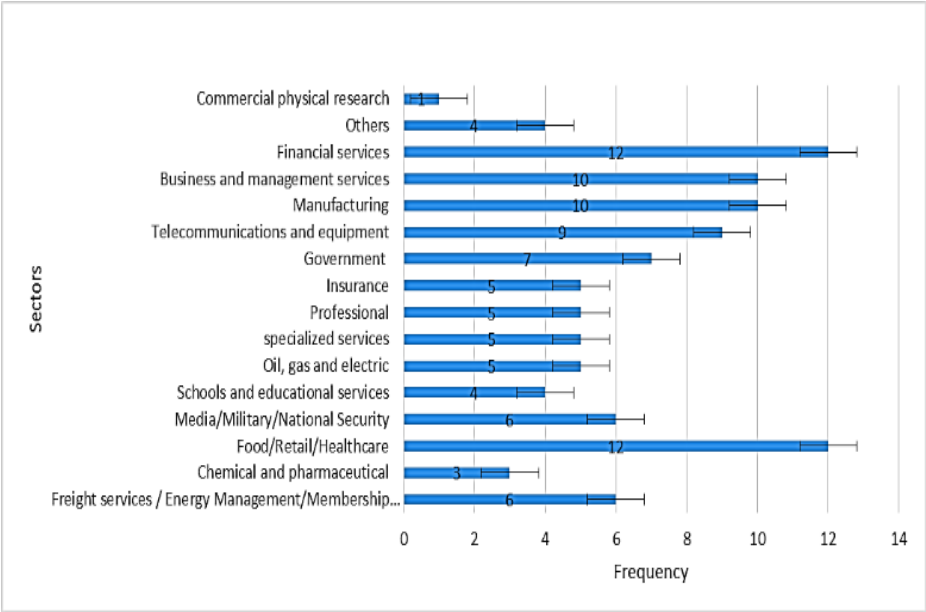

Figure 1 Cloud usage in different industrial sectors and services

Source: Adapted from Gartner (2009)

Cloud computing has been successfully utilized in several industries. Damodaram and Ravindranath (2010) carried out an empirical study of adaptability of cloud computing model for apparel and garment manufacturers to achieve collaboration among the supply chain partners to manage the supply chain. In education, cloud computing has been identified as a key trend that allows access to online services anywhere with improved scalability and availability that is cost-effective Mircea and Andreescu (2011). Ercan (2010) argued that cloud computing is an excellent alternative for educational institutions which are especially under budget shortage in order to operate their information systems effectively without spending any more capital for the computers and network devices. Today's "cloud" platforms such as "Microsoft" and "Google" are providing free services to students and staff at educational institutions which include email, contact lists, calendars, document storage, creation and sharing documents and the ability to create websites (Sclater, 2009).

Klug and Bai (2015) noted that there are factors affecting cloud computing adoption among universities and colleges in the United States and Canada. Khmelevsky and Voytenko (2010) developed an infrastructure prototype for using cloud computing in university education and research. In the study by Kaushik and Kumar (2013), they argued that cloud computing technology is offering great advantages for libraries to connect their services not only promptly but also in new formats with the flexibilities such as pay as you use model, access anywhere any time and so on. Nowadays libraries are using cloud computing technology for enhancing the services by adding more values, attracting the users and cost effectiveness. Regarding the use of cloud computing in the health care sector, Stein (2010) opined that the time was right for genome informatics to migrate to the cloud. Rolim et al. (2010) suggested using cloud computing to collect patient data in health care institutions, while Doukas et al. (2010) suggested that the data could also be managed by cloud computing. Li et al. (2013) suggested sharing personal health records and Rosenthal et al. (2010) proposed that information could be shared among the biomedical informatics community via cloud computing.

3. METHODOLOGY

In this research a cross-sectional survey of stakeholders on construction projects highlighted the use, economics and threats to cloud-based computing. The respondents were selected among registered and unregistered construction professionals on construction projects in South-Western Nigeria, specifically in Lagos State. The area is selected due to the high volume of construction works in the state and its high adoption of ICT in various construction organization within the state. The study made use of a questionnaire instrument which was distributed to the construction stakeholders. The sample size was selected through a purposive sampling technique based on the characteristics of the construction professionals. Out of one hundred (100) questionnaires that were distributed, a total of fifty-eight (58) questionnaires were retrieved and scrutinized to be free of errors, this was used for the study. This represented a response rate of 58% and is deemed adequate for the study based on the area selected and the subject matter of cloud computing. The construction stakeholders include architects, builders, quantity surveyors and engineers. The data collected was analyzed using SPSS v.21 and presented using statistical tools such as frequencies, bar charts and analysis of variance (ANOVA) were utilized for presenting the data obtained in this study.

4. RESULT AND DISCUSSION

This section consists of four (4) main sections; the background information of the construction stakeholders, the cloud-based computing technologies utilized, the economics of utilizing cloud-based computing and the threat to cloud-based computing.

4.1. Background Information

The background information of the construction stakeholders are presented in this section. Figure 2 showed a combined data of the background information of the respondents. that a cross-section of 21 (36.2%) architects, 15 (25.9%) builders, 6 (10.3%) quantity surveyors and 16 (27.6%) engineers participated in the study. The figure revealed that 42 (72.4%) of the construction stakeholders worked in small scaled firms while 12 (20.7%) worked in medium scaled firms and 4 (6.9%) worked in large scale sized firms. This is adequate for the study, in that, more that 90% of construction firms are small to medium scaled firms globally. Figure 2 indicated that 32 (55.2%) of the construction stakeholders had 1-10 years working experience in the construction field, while 14 (24.1%) had 11-20 years working experience and 12 (20.7%) had above 20 years working experience.

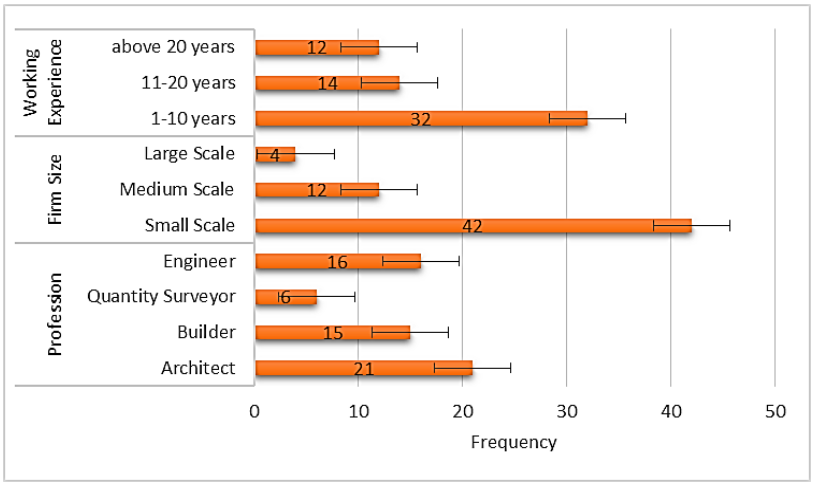

Figure 2 Summary of Background Information

4.2. Cloud-based computing technologies utilized

This section showed the cloud-based computing technologies that are utilized by construction stakeholders in their construction project delivery processes. Figure 3 showed the percentage of utilizing each cloud-based computing technologies. Figure 3 revealed that 84% of construction stakeholders make use of Google App engines, 53% make use of Dropbox in Yahoo mail, 42% make use of Microsoft Office Live, 16% make use of Amazon web services while 5% make use of some other forms of public/private cloud services. The Google App component consist of the Gmail account and the Google Drive; file storage systems used by construction professionals. The Google Drive component allows users to store filed in the cloud and can synchronize files across different user's devices. This encompasses Google Docs, Sheets and Slides including photos. Google Drive platforms offer users with up to 15GB free Drive storage space, this has endeared users to the platform.

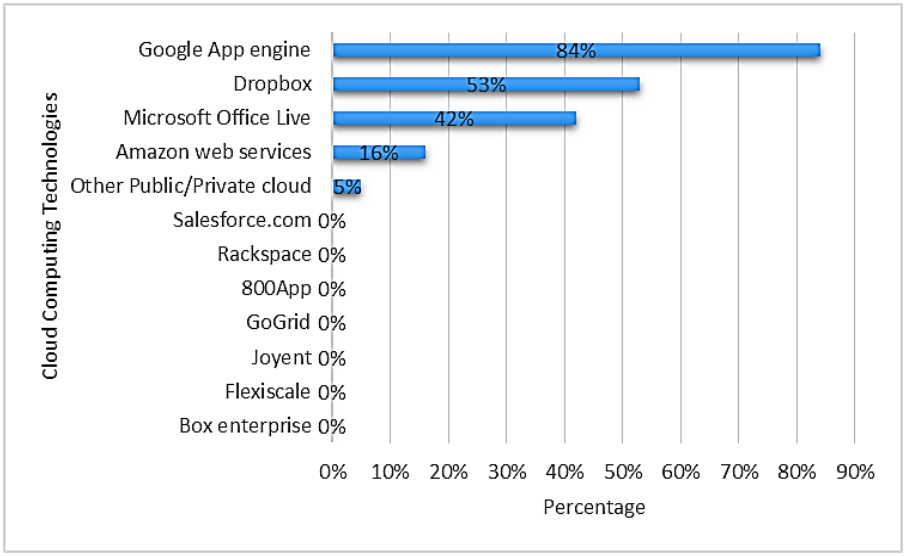

Figure 3 Cloud-based computing technologies utilized

The result revealed that most construction stakeholders use their email services such as Gmail or Yahoo mail services in order to use the cloud. These are public cloud services. Public clouds are ideal for small and medium sized businesses or businesses that have fluctuating demands. The essential advantages are that it incorporates the speed with which one can send IT assets and the capacity to pay just for the server assets that is utilized. By spreading infrastructure costs over various clients, each can exploit a minimal effort, pay-as-you-go way to deal with IT provisioning. Figure 3 revealed that there were little or no use for cloud-based computing technologies such as 800App, GoGrid, Joyent, Flexiscale, Box enterprise, Rackspace and Salesforce.com. Wong et al. (2014) noted that users can choose the right combination that suits their needs when moving to the cloud environment, as the service models and deployment models have different advantages and drawback. National Bureau of Statistics (2015) noted that the Nigerian construction industry is made up of 95% small and medium scale construction firms. Zhang et al. (2010) explained that most small businesses use the service model of Software as a Service (SaaS). SaaS is a service that allows users to use a software application over the internet by connecting to the service provider through a browser. Examples of SaaS include Salesforce.com, Rackspace, Google Doc, Google app, Yahoo mail and Microsoft Office Live (Bhardwaj et al., 2010; Zhang et al., 2010; McGraw Hill Construction, 2014). SaaS is suitable for small businesses as the service provider maintains and manages the software and hardware – storage, virtualization and processing capacity (Zhang et al., 2010).

4.3. Economics of cloud-based computing technologies

The economics portrayed in this section are the benefits that construction stakeholder perceive that cloud-based computing can engender in the construction project delivery process. Various benefits were identified from literature and tested using analysis of variance (ANOVA) to identify any significant differences among the construction stakeholders. Table 3 revealed the ANOVA test of significance of the economics of cloud-based computing technologies. The table indicated that there is no significant difference in variables such as knowledge sharing, remote access of back-office activities and collaboration among construction stakeholders. This is inferred from their p-value which is less than 0.05 (5% level of significance); signifying they are significant. This means that construction stakeholders are in agreement that use of cloud-based technologies would bring about profits in knowledge sharing, remote access of back-office activities and engendering collaboration among construction stakeholders.

Table 3 ANOVA of Benefits in the use of cloud-based technologies

		Sum of Squares	df	Mean Square	F	P value.	Sig.
Reduced implementation and maintenance cost	Between Groups	5.917	2	4.111	1.824	0.06	**NS
	Within Groups	117.450	55	0.867			
	Total	123.367	57				
Flexible and scalable infrastructure	Between Groups	2.832	3	1.909	2.309	0.331	**NS
	Within Groups	122.241	54	0.613			
	Total	125.073	57				
IT department transformation	Between Groups	1.942	2	2.699	0.444	0.084	**NS
	Within Groups	132.009	56	0.816			
	Total	133.951	58				
Knowledge Sharing	Between Groups	2.870	3	3.231	1.541	.037	*S
	Within Groups	110.348	54	1.815			
	Total	113.218	57				
Increased competitive advantage	Between Groups	5.828	5	3.554	2.910	0.106	**NS
	Within Groups	133.621	52	1.935			
	Total	139.449	57				
Secure storage and management	Between Groups	5.627	5	2.571	0.807	0.334	**NS
	Within Groups	131.067	51	1.982			
	Total	136.694	56				
Cost-effectiveness	Between Groups	3.990	1	1.105	1.047	0.09	**NS
	Within Groups	128.645	57	1.062			
	Total	132.635	58				
Remote access to back-office activities	Between Groups	8.292	3	1.418	0.781	.015	*S
	Within Groups	132.510	53	1.674			
	Total	140.802	56				
Collaboration among construction stakeholders	Between Groups	5.343	3	1.972	1.134	.033	*S
	Within Groups	139.563	54	1.696			
	Total	144.906	57				

*S = Significant; **NS = Not Significant

This is supported by Abedi et al. (2013), they stated that the implementation of cloud computing in construction project delivery will give the chance to develop construction

partners to be more helpful, united and enhance the profitability of working together effectively which is in contrast with the conventional methodologies and procedures. By collaborating together on cloud platforms, construction stakeholders can store and receive construction data in real time. The construction industry is such that requires adequate and concise management strategies, therefore, the need to employ innovative tools that deliver excellence on construction projects (Ogunde et al., 2017). There are several benefits that can be obtained from collaboration especially for small and medium scale enterprises (SMEs). These SME construction firms may need to share knowledge in the construction industry thereby leading to more contracts and exchange of technology, which is critical for their growth. A lot of back-office activities are also carried out in the construction industry. Construction staff in the office or in any location can access construction site information and act on them accordingly. Back-office functions such as billing, paying invoices, running financial reports, payroll, planning logistics that may have required physical presence on construction sites are made possible using cloud computing. With remote access, construction sites are decentralized, while workers can work from various areas of the nation or even globally.

4.4. Threats to cloud-based computing technologies

This section identified threats that may hinder the efficient adoption of cloud-based computing technologies in construction project delivery. The variables were presented using bar chart as indicated by Figure 4. Figure 4 showed the threats to cloud-based computing technologies perceived by construction stakeholders. Figure 4 revealed that Fear of security and data privacy had a mean score (MS) of 4.30, Poor/slow connection to the internet had a mean score (MS) of 4.13, Lack of physical control had a mean score (MS) of 3.98 and Costly data subscription had a mean score (MS) of 3.93. The result revealed that all the threats are above average implying that construction stakeholders find them significant to hindering the successful integration in the construction process.

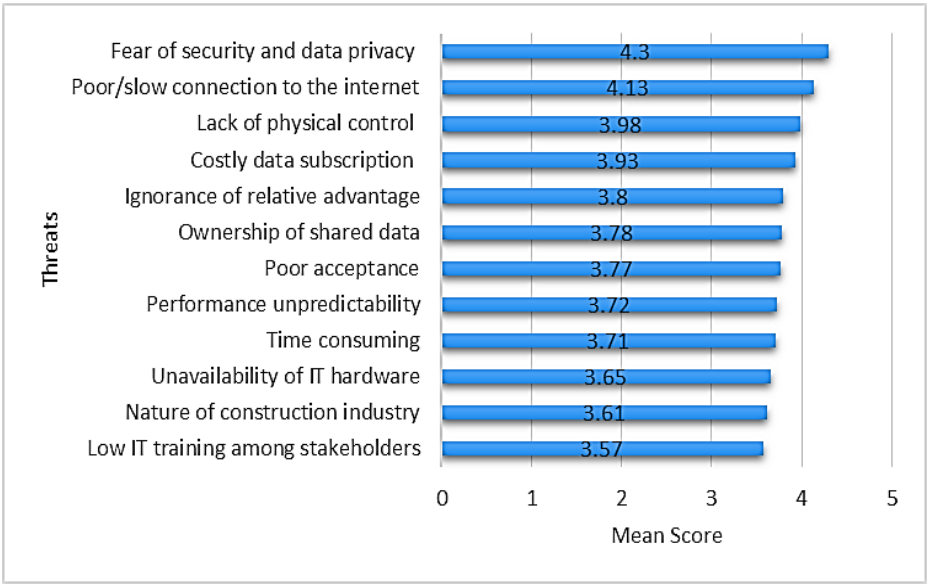

Figure 4 Threats to cloud-based computing technologies

The main threats to the use of cloud-based computing technologies can be categorized into security threats and connectivity threat. Numerous potential clients of the cloud platform are as yet uneasy about discharging their in-house project information to the datacenter of an external cloud administration's supplier because of security and data privacy vulnerability. As

indicated by the most recent report by McGraw Hill Construction (2014), construction contractors in developed countries have expressed moderate to high levels of concern over the security of cloud technology. The performance and availability of cloud services is another issue pointed out by Cheng and Kumar (2012). This depends on the service providers, the geographical locations of the service providers and users, cost of mobile data and the computational complexity of the services. In construction, people on the site may have limited internet access and their mobile devices poor signal reception. Unsteady transfer speed to the web adversely affect the performance and availability of cloud-based systems and applications. Data inconsistency may even happen if operation and data transmission are interrupted due to connection problems. But hopefully with advancements of the web technologies and satellite coverage, availability and stability of web connection will be enhanced in the future, even in rural and tough environments such as construction sites. The pressure of costly mobile data for uploading and retrieving data from cloud services is also an issue. The PwC report (2016) showed that mobile data prices need to drop significantly as only 43% of the world can afford 500 megabytes (500MB) per month. In fact, prices in Nigeria need to drop by 97% to become affordable for the majority of the country's 180 million people.

5. CONCLUSION AND RECOMMENDATION

The study assessed the economics of cloud-based computing technologies in construction project delivery. The study revealed that construction stakeholders mostly used Google App engines and Dropbox cloud services in their construction delivery processes. These cloud services are mostly for small and medium scale firms mainly because of the flexibility and pay-as-you-use offer that it offers by connecting to the internet. The study revealed that economic benefits such as knowledge sharing, remote access of back-office activities and collaboration among construction stakeholders are evident among construction stakeholders while utilizing cloud-based computing technologies. Although, there are many benefits to the use of this technology, the study identified fear of security and data privacy, poor/slow connection to the internet, lack of physical control and costly data subscription as major threats to the efficient and effective use of cloud-based computing technologies in the construction delivery process. The study recommended that cloud service administrators need to tighten the security features of cloud services in order to strengthen the resolve of construction stakeholders to rely on the use of the technology. Cloud services should be more encrypted and introduction of multi-factor authentication features to make it harder for hackers to steal stored data in the technology. Cloud technology requires uninterrupted and fast internet connection, therefore, Telcos in developing countries should help increase the speed of connectivity to the internet and reduce the cost of mobile data subscription in order to increase the use of cloud-based technologies and the number of internet users.

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