Assessment of the Linkages and Leakages in a Cloud-Based Computing Collaboration among Construction Stakeholders

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Abstract
The uniqueness of the construction industry can be understood in the large volumes of information in terms of paper works, processes, and communication disseminated daily. The voluminous information requires close coordination which cloud based systems offer. The aim of this research is to assess the linkages and leakages in a cloud-based computing collaboration among construction stakeholders. A purposive sampling technique was used in selecting the participants of the study. A questionnaire based instrument was distributed to eighty (80) construction stakeholder in Lagos State, Nigeria. The data collected was analyzed using SPSS v.21. Statistical tools such as frequencies, stacked bars, mean scores, factor analysis, and analysis of variance (ANOVA) were used in the study. The result of the study revealed that construction stakeholders rarely utilize cloud-based technologies for their construction processes. Construction professionals that access cloud based technologies, do so with their smart mobile phones, laptops, and tablet. The study classified the leakages that exist in the use of cloud-based technologies as security-based factors, cloud-based infrastructure factors, and cloud-based benefits deficiency based factors. In conclusion, the study revealed that the linkages in the use of cloud-based technologies include knowledge sharing, remote access of back-office activities and engendering collaboration among construction stakeholders. It was recommended that construction stakeholders should leverage on the benefits cloud-based technologies has to offer in today's competitive economy. Construction stakeholders should be adequately informed on the available cloud-based computing technologies and the additions it can bring into the construction process. Cloud computing technology vendors should improve on the security and privacy features of the platform for adequate protection of building data.

Keywords: Cloud-based systems; Collaborative technologies; Construction stakeholders; Information sharing; Linkages and leakages.

INTRODUCTION

In today's world, the construction industry is characterized by the information and the people involved in its delivery process. Khan *et al.* (2015) opined that the information flow serves as the backbone for all successful projects across the construction sector. The stakeholders participating in these processes have become more fragmented, multi-cultural and multi-layered. While the information generated and transmitted in the course of project delivery have always been complex, voluminous and intensive. This is in conformity with the study by Beach *et al.* (2013), they stated that the architecture, engineering and construction (AEC) sector is highly fragmented, data intensive, project-based industry depending on a large number of very different professions and firms, with strong data sharing and processing requirements across the lifecycle of its products (primarily buildings).

The information generated in the construction industry needs to be on-time and accurate. Khan *et al.* (2015) noted that this would help reduce errors, rework, delays, the likelihood of contractual claims, disputes and the requirement for change orders during the production stage. Timely information and communication also contributes towards improved health and safety on construction sites (Health and Safety Executive, 2002). It helps in completing projects on time, with reduced costs and improved quality (Titus and Bröchner, 2005). Moreover, Khan *et al.* (2015) noted that information in real time about external factors that influence production, such as inclement weather, or a significant design change being proposed by the client and design team, can help to forward plan activities, so that minimal disruptions are experienced during production. But, the construction industry has suffered associated drawbacks from information and communication lapses based on reliance on the traditional method of paper-based storing, processing and transmission of data. Also, decisions are made and exchanged with various construction stakeholders through informal channels like phones, SMS, and email with post facto documentation leaving an information trail that is monumental and difficult to manage.

Collaboration-enabling technologies have the ability to provide a platform for software collaboration tools that can improve information mobility and the information and data transfer. One of such innovative collaborative ICT tools include the use of cloud-based computing technologies. However, the adoption of the technologies has remained slow, partly because the majority of construction firms are small-to-medium enterprises (SMEs) and, therefore, lack the budget for IT investment (Cheng and Kumar, 2012).

The rise of Cloud Computing (CC) is rapidly changing the landscape of information technology, and ultimately allowing enterprises to start from small scale and dynamically increase their resources simultaneously with the increase of their service demand (Shawish and Salama, 2014). The term “cloud” finds its origins in network diagrams that represented the internet, or various parts of it, as schematic clouds. From here, “Cloud computing” was coined for what happens when applications and services are moved into the internet “cloud.” Cloud Computing (CC) has been attracting a huge amount of interest in the post-dotcom boom and bust and the current web 2.0 information technology world (Kumar *et al.*, 2010). Cloud computing is an emerging application platform and aims to share data, calculations and services among users (Ercan, 2010). Vaquero *et al.* (2009) found more than 20 definitions of cloud computing, among which the definition provided by the National Institute of Standards and Technology (NIST) is the most widely recognized. National Institute of Standards and Technology (NIST, 2009) in the USA defined

Cloud Computing – "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". Ercan (2010) stated that the users of cloud computing do not need any background knowledge of the services. A user on the internet can communicate with many servers at the same time and these servers exchange information among themselves (Hayes, 2008).

Ankeny (2011) opined that several advantages can be derived from implementing cloud computing. These advantages have be referred to as linkages in this study. Linkages are the benefits that can be linked from the use of cloud-based technologies. 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. 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. Needless to say, Kumar *et al.* (2010) pointed out that there are also some adverse issues that the technology proponents need to address before the commercial world at large will be comfortable in its adoption. This study posits that these issues can be referred to as leakages. Leakages are perceived fears characterized from the use of the technology and these fears may in turn reduce the adoption of such technology. Some of these issues are trust, security, interoperability, etc. For example, in a cloud based computing infrastructure, the resources are normally in someone else's premise or network and accessed remotely by the cloud users (Singh and Jangwal, 2012). This sensitivity may call for leakages which this study seeks to find out. The construction industry should take advantage of cloud-based computing collaboration to tackle some of its menacing challenges. The questions in the mind of the researcher are:

- How often do construction stakeholders engage the use of cloud-based technologies in their construction process?
- With what IT infrastructures do construction stakeholders access cloud-based technologies?
- What leakages exist in the use of cloud-based technologies by stakeholders in the construction project delivery process?
- What are the linkages in the use of cloud-based technologies by stakeholders in the construction project delivery process?

METHODS

The study been an attitudinal survey of construction stakeholders on cloud computing collaborative tools used a questionnaire instrument to elicit answers for the research questions. The study sample were selected using a purposive sampling technique due to accessibility to the respondents and willingness to take part in the research. The questionnaire based instrument was distributed to eighty (80) construction stakeholder in Lagos State, Nigeria. The study area was selected due to the high exposure of its construction professionals in the state to ICT tools. Most construction organizations in Nigeria also have their head office in Lagos. The construction stakeholders include architects, builders, quantity surveyors and engineers. Out of the eighty (80) questionnaires distributed, only fifty-eight (58) were returned and free of errors. This represented a response rate of 73% and is deemed adequate for this study. The data collected was analyzed using SPSS v.21. Statistical tools such as frequencies, stacked bars, mean scores, principal component factor analysis and analysis of variance (ANOVA) were used in the study.

RESULT AND DISCUSSION

This section presented the results and implication of the phenomenon observed in the study. This section consists of five (5) main sections which include the background information, rate of using cloud-based technologies, IT infrastructures used for accessing cloud-based technologies, leakages and linkages that exist in the use of cloud-based technologies by stakeholders in the construction project delivery process.

Background Information

This section described the characteristics of the construction stakeholders that participated in the study. The construction stakeholders include architects, builders, quantity surveyors and engineers. Figure 1 showed the background information of construction stakeholders for the study.

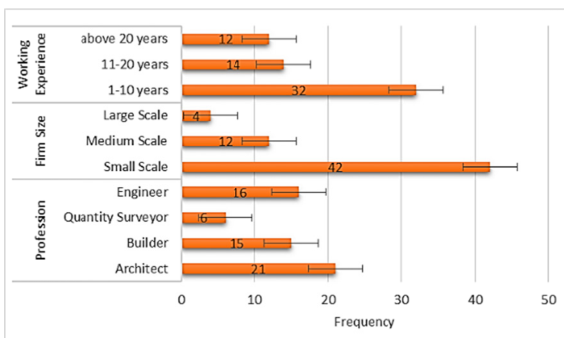

Figure 1 Background information of construction stakeholders

Figure 1 revealed 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 1 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.

Rate of Cloud-based Computing Technologies Usage

Most people are already using the cloud in their daily lives, whether they realize it or not. From any computer, smartphone or tablet as long as it has an internet connection, people access their email services, either Yahoomail, Gmail or Hotmail. These platforms provide cloud services that construction stakeholders have been using to store mails, pictures, videos, documents etc. This section highlighted some crucial construction processes and the application of cloud computing technologies to these processes. Table 1 showed the rate of using cloud-based computing technologies. Table 1 revealed construction stakeholders rarely utilize cloud-based technologies for their construction processes. Although, technologies such as Google Drive and DropBox are often used informally and in an adhoc way between individuals. Beach *et al.* (2013) noted that cloud computing is still an emergent technology that the industry is still trying to adjust to due to concerns over security and the protection of intellectual property. Kumar *et al.* (2010) and Cheng and Kumar (2012) suggested a framework used in the US and the UK whereby propriety software systems can be stored in public cloud for construction staff to access while building data can be kept in a private cloud.

Table 1 Rate of using Cloud-based computing technologies

Construction Process	Mean Score	Ranking Index	Remark
Architectural design	2.98	1st	Rarely Used
Cost estimating	2.94	2nd	Rarely Used
Project planning and control	2.77	3rd	Rarely Used
Structural, HVAC design	2.14	4th	Rarely Used
Procurement management	2.10	5th	Rarely Used
Supply chain management	2.08	6th	Rarely Used
Facility management	2.08	7th	Rarely Used
Others	1.95	8th	Not Used

IT infrastructure for accessing Cloud-based Computing Technologies

This section examined the IT infrastructure in terms of hardware that construction stakeholders use in accessing cloud-based computing technologies. Figure 2 showed the IT infrastructure for accessing cloud-based computing technologies by construction stakeholders. From Figure 2, it is revealed that 89% of construction stakeholders access the cloud via their smart phones, 70% via their laptops, 21% via their tablets and 9% connect via their PCs.

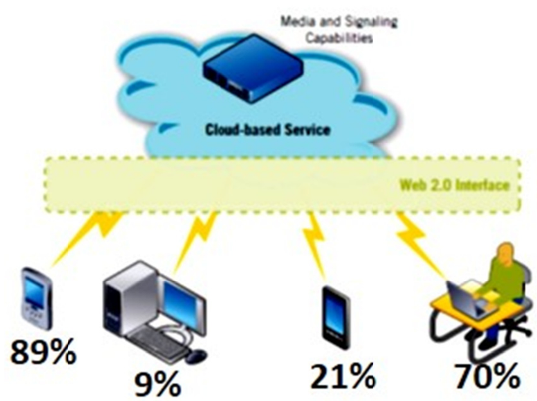

Figure 2 IT infrastructure for accessing Cloud-based Computing Technologies

This means that construction professionals that access cloud based technologies, do so mostly with their smart mobile phones, laptops and tablet. The implication of this is that there is a growing momentum in the use of mobile technologies in the construction industry. Krell (2011) stated that with the proliferation of social media and smart phones (mobile devices), startups and small companies have improved collaboration within their companies. In comparison with the IT survey by Constructech (2011), the smart phone is still one of the most commonly used devices at the jobsite (81%), laptops (69%) and tablets (26%). Given the fast-moving area of mobility, today's business management solutions need to support the highly mobile workforce of the construction industry today and into the future.

Leakages in the use of cloud-based technologies

Although, it is acknowledged that the use of cloud-based computing technologies have several benefits that the construction industry can harness. There are several fears which are referred to as leakages in the use of the technology. The study identified several leakages that were subjected to principal component factor analysis in order to categorize them. To assess the suitability of the data for factor analysis, the KMO measure of sampling adequacy and Bartlett's test of Sphericity was 0.756, which is larger than 0.7, suggesting that the sample was acceptable for factor analysis. The Bartlett's test was 5728.005 and the associated significance level was p-value< 0.001, indicating that the population correlation matrix was not an identity matrix. Both of the tests showed that the obtained data supported the use of factor analysis. With a fixed number of factors to extract at 3, the principal components analysis revealed the presence of three (3) components with eigenvalues exceeding 1, explaining 35.5%, 14.7% and 9.2% of the variance respectively. These three (3) factors explain a total of 59.4 percent of the variance. The three-factor solution with the respective loading scores is shown in Table 2. The factor loading of 0.50 was considered to be the cut-off point.

Table 2 Factor loading for Leakages in the use of cloud-based technologies

	Rotated Component Matrix	Component		
		1	2	3
Security-based leakages	Lack of physical control	0.621		
	Security and data privacy	0.616		
	Ownership of shared data	0.555		
	Compatibility	0.502		
Infrastructure Leakages	Unavailability of IT hardware		0.698	
	High cost of IT investment		0.654	
	Poor/ slow connectivity		0.651	
	Low Service-Provider support		0.520	
Benefit deficiency Leakages	Poor acceptance level			0.590
	Low effective gains/relative advantage			0.583
	Performance unpredictability			0.566
	Time consuming			0.541

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

From the factor analysis, the study posits that the leakages that can exist in the use of cloud-based technologies can be classified as Security-based factors, Cloud-based infrastructure factors and Cloud-based benefits deficiency based factors.

Damodaram and Ravindranath (2010) acknowledged that there are hurdles that need to be scaled for the successful adoption of Cloud at a level where it can be declared mainstream. The most serious question in the mind of people are "can a company entrust a third party (through the cloud) with its business sensitive data" (Kumar *et al.*, 2010). Many potential users are still apprehensive about releasing their in-house data to the datacenter of an external Cloud services provider due to these issues. According to the latest report by McGraw Hill Construction (2014), contractors in many countries have expressed moderate (e.g. Germany, Japan, Brazil, Australia and New Zealand, France, Canada) to high (e.g. Korea, US and UK) levels of concern over the security of cloud technology. Contractual issues, including uncertainty over the ownership of shared data and the inadequacy of contractual relationships, are currently considered to be the main barrier to the adoption and integration of BIM and cloud computing (Redmond *et al.,* 2012). Mahesh *et al.* (2011) argued that cloud security is good, as risks get minimized due to authentication and encryption. Devasena (2011) explained that cloud security is heightened by, for example, monitoring activities, tracking transactions, providing selective access to users, and utilizing strong password.

Since most firms in the construction industry can be categorized from micro to small-to-medium enterprises (SMEs), even in developed countries. Kumar *et al.* (2010) opined that one of the characteristics which appears to drive the slow adoption of IT in the construction industry is the lack of IT infrastructure among the small-to-medium enterprises (SMEs) in the construction sector due to their small size and hence the affordability of these facilities. This study posits that for construction stakeholders to believe that access to cloud-based infrastructure requires huge capital is a big misconception. Martson *et al.* (2011) argued that one of the main benefits of using cloud computing is that it dramatically lowers the cost of entry for small firms who are trying to benefit from computer-intensive business analytics that were previously only accessible by large firms as they are extremely costly. This lowered cost also opens up vast opportunities to third-world countries that may have been left behind in the IT revolution and have no access to these capabilities. 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, 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. Unstable bandwidth and connection 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.

Apart from resources, Kumar *et al.* (2010) noted that some construction stakeholders in small-to-medium enterprises (SMEs) lack of awareness, training and clear understanding of ROIs (Return on Investment) about the uptake of construction IT. Although the fundamental concepts surrounding CC are by no means new, it is the specific advantages that make it an interesting concept for usage with the

Construction IT platform that potential users are unaware about. For example, in the Irish construction industry, the lack of knowledge on cloud computing and, in particular, construction based applications was ranked the highest barrier overall. In that, construction stakeholders had no experience of using collaboration tools or, having availed of them, therefore they found the use of cloud computing to be cumbersome (Redmond *et al.*, 2010).

Linkages in the use of cloud-based technologies

The study identified several linkages in the use of cloud-based technologies in the construction industry while collaborating with other construction stakeholders. Linkages such as reduced implementation and maintenance cost, remote access of back-office activities, flexible and scalable infrastructure, knowledge sharing, collaboration among construction stakeholders, increased mobility, IT department transformation, increased competitive advantage, increased storage and management, virtualized and dynamic, cost-effectiveness and streamlining data resources. These variables were tested using analysis of variance (ANOVA). This statistical tool tested the mean differences among the construction stakeholders. Table 3 showed the significant linkages in the use of cloud-based technologies.

Table 3. ANOVA of Linkages in the use of cloud-based technologies

		Sum of Squares	df	Mean Square	F	P value.	Sig
Knowledge Sharing	Between Groups	2.870	3	3.231	1.541	.037	S
	Within Groups	110.348	54	1.815			
	Total	113.218	57				
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

Table 3 revealed that there is no significant difference in linkages such as knowledge sharing (0.037), remote access of back-office activities (0.015) and engendering collaboration among construction stakeholders (0.033) in the use of cloud-based technologies. This is inferred from their p-value which is less than 0.05 (5% level of significance); signifying they are significant. This means that there is a common belief among construction stakeholders that the use of cloud-based technologies would bring about linkages in knowledge sharing, remote access of back-office activities and engendering collaboration among construction stakeholders.

The word ‘team’ has taken on a whole new meaning with the introduction of cloud computing. Construction stakeholders are able to work as a team with high levels of transparency and accountability in a central location - ‘the cloud’. Abedi *et al.* (2013) stated that proposing cloud computing implementation in the construction process will provide the opportunity for construction stakeholders to be more cooperative, integrate, improve the productivity and collaborate efficiently compared to the traditional approaches and processes. Devasena (2014) stated that cloud computing upsurges collaboration by allowing all employees to synchronize up and work on documents and shared applications simultaneously from their own place. It even allows them to follow colleagues and records to receive critical updates in real time.

Furthermore, Abedi *et al.* (2013) noted that cloud computing technology will assist the users (businesses and individuals) to access, share and disseminate the data; applications and services from the various servers via the internet on any computer or mobile devices. Devasena (2014) stated that cloud computing allows employees to work from anywhere. This elasticity positively affects knowledge workers' work-life balance and productivity.

With the cloud, construction professionals gain the ability to work from any location – construction site, home, office, or during travel. The construction industry is able to balance back-office functions—billing, paying invoices, running financial reports, payroll, planning logistics—with the physical presence needed on the job site. Remote access allow construction stakeholders to work from any location without being tied to a specific physical location. With the amount of consolidation, decentralization of offices, travel-based positions, and project work being done in different regions of the country or even internationally, being able to offer solid remote access technology to employees is critical for a construction company's success and maintaining competitiveness.

CONCLUSION AND RECOMMENDATION

The study assessed the linkages and leakages in a cloud-based computing collaboration among construction stakeholders. The result of the study revealed that construction stakeholders rarely utilize cloud-based technologies for their construction processes. Construction professionals that access cloud based technologies, do so with their smart mobile phones, laptops and tablet. The study classified the leakages that exist in the use of cloud-based technologies as Security-based factors, Cloud-based infrastructure factors and Cloud-based benefits deficiency based factors. The study revealed that the linkages in the use of cloud-based technologies include knowledge sharing, remote access of back-office activities and engendering collaboration among construction stakeholders. It was recommended that construction stakeholders should leverage on the benefits cloud-based technologies has to offer in today's competitive economy. Construction stakeholders should be adequately informed on the available cloud-based computing technologies and the additions it can bring into the construction process. Cloud computing technology vendors should improve on the security and privacy features of the platform for adequate protection of building data.

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