Suitability of Cloud Computing to the Sri Lankan Construction Industry

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Abstract

Construction industry is growing at a significant rate, while acting as one of the most information-intensive industries. However, project overruns and completion of project objectives are still being discussed as major challenges. To address this issue, cloud computing has become a modern technological solution that enables access to up-to-date and onsite information in the construction industry. However, in the Sri Lankan context, efforts for the application of cloud computing is significantly less, and there is a need for innovative ways to integrate cloud computing to the construction industry. Hence, this research is aimed at investigating the potential development and effectiveness of cloud computing as an ICT application for better communication and collaboration between different parties in construction projects. Preliminary interviews and expert opinion surveys were conducted in a qualitative exploration of the phenomenon. Twelve semi-structured interviews were conducted among experts in the information technology industry and experts in the construction industry. Expert opinion surveys' data was analysed through the content analysis technique. Findings revealed that, out of the three cloud service models (Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS)), only SaaS model was relevant to the Sri Lankan construction industry. Accordingly, several cloud based SaaS applications were identified under 'general purpose applications' and 'construction industry specific applications'. The driving sources for the cloud computing implementation were identified under organizational and technological perspectives. According to the findings,

'business growth' was identified as the most important organizational driving source, while 'cost effectiveness' was identified as the most important technological driving source for the construction industry in Sri Lanka.

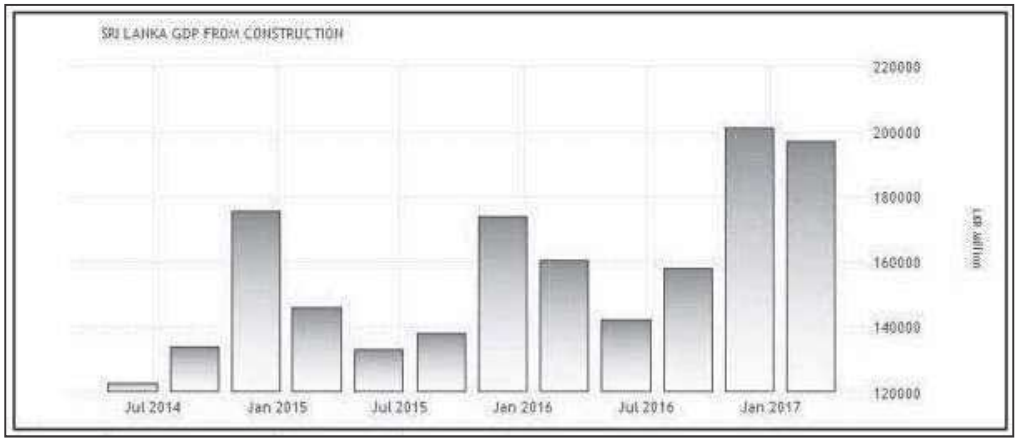
Keywords: *Cloud Computing; Collaboration; Construction Industry; ICT; SaaS*

1. Introduction

Construction industry continues to grow at a significant rate and the projects constantly display higher levels of complexity (Harvey et al., 2015). Simultaneously, the clients have been much more concerned with time, cost and the quality of the projects. Despite these concerns, construction industries in the developing countries are well known for their lack of innovation, sluggish adoption of newer technology, and lesser research and development compared to other industries (Miozzo & Derwick, 2002). Moreover, construction industry is one of the most information-intensive industries, and requires continual dissemination of a vast amount of data and information between numerous project stakeholders and participants. But, construction activities and their processes are dispersed as site locations change from one project to another, and most of the information is communicated and exchanged between the project participants on paper, which is an inefficient and slow medium (Miozzo & Derwick, 2002). Further, Abedi et al. (20013) have argued that inefficient communication of on-site information could hinder the construction personnel from reacting to issues that require quick decisions and actions. Besides, better communication and sharing of information among project participants would minimize errors, delays, cost etc., while improving the productivity and eventually driving the project to a success (Fathi et al., 2012). Accordingly, there is a need for more intelligent and creative methods to improve the collaboration between parties, in order to accommodate the information-intensive and the mobile nature of construction projects (Fathi et al., 2012). Consequently, cloud computing has been highlighted as a rapidly evolved technology that leads to the enhancement of productivity in the construction industry, in terms of integration and collaboration between project stakeholders, when compared to other traditional methods and approaches (Abedi et al., 2013). In Sri Lanka, the construction industry has been a highly booming sector, contributing around 6-7% to the GDP during the last decade; hence, it has a significant impact on the economy of the country (Jayalath & Gunawardhana, 2017). According to the authors, the infrastructure sector has revived, surpassing the building sector, with the end of island's ethnic war in 2009.

However, Reginold (2009) has stated that there is no proper knowledge of the application of cloud computing in the construction industry, and has further stressed that the efforts taken by

Sri Lankan authorities to improve the ICT usage in the Sri Lankan construction industry are not admirable, and that it can badly affect its productivity.



Source: Jayalath and Gunawardhana, 2017

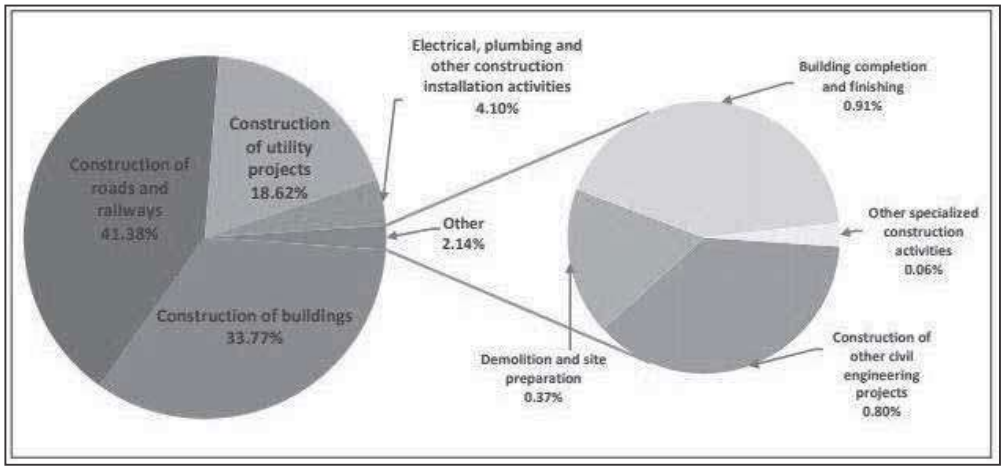


Figure 2: Distribution of Value of Work done by Type of Construction Activity – 2017/18

Source: Department of Census and Statistics, 2020

2. Literature Review

2.1. Significance of ICT in the Construction Industry

Information Communication Technology (ICT) is a comprehensive system that works hand in

hand with technology. It incorporates electronic devices and various applications for processing, storing, transferring and presenting facts, which shows that technology has found its way into the ICT sphere. ICT also relies heavily on efficiency, which is dependent on the rate of transference of raw data into information using state of the art computer systems, and the existence of up-to-date software and hardware which contribute to this process and aid in the analysis and sharing of information (Chong et al., 2014). Today's construction projects seem to use the more up-to-date, digital based information, as opposed to the more traditional paper based predecessor (Ikediashi & Ogwueleka, 2016). According to the authors, this change has paved the way for the incorporation of ICT into today's construction projects. This amalgamation of ICT and construction industry has resulted in the reduction of project costs, shorter project life cycles, and dissolving of non-value added processes in the construction process, which has led to the achievement of higher levels of customer satisfaction (Harvey et al., 2015). The creation of multiple ICT methods enables us to apply ICT to various stages of a project: the development of computer-aided drafting (CAD), spreadsheet and word processors, Building Information Modeling (BIM), internet software, and e-procurement are a few examples (Ikediashi & Ogwueleka, 2016). This proves that ICT is successful in effectively communicating and managing everyday information processes (Xu, Xu, & Ling, 2018). Furthermore, it serves as an integral cog in the successful management of construction projects (Mohamed & Pillutla, 2014).

2.2. Cloud Computing

Cloud computing is considered a major transformational force in the IT and business industries, where software and hardware are hosted and delivered as a service over the internet (Chong et al., 2014). National Institute of Standard and Technology (NIST) (2011) has defined cloud computing as "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". Cloud computing basically shifts the workload from local computers by consolidating and managing the network of computer resources in central locations (Mandicak et al., 2016). Thereby, it moves away the concerns of maintenance, ownership, and operational management of resources in the network, applications, and services from the firm to a third party (Mohamed & Pillutla, 2014). Furthermore, cloud computing enables to expand the capacity and improve the capabilities of the enterprise without having to invest in new hardware, software, infrastructure, and training of new employees. The prime requirements for cloud computing is access to internet or intranet. Therefore, the users can access and use the applications, data and programmes in the cloud via computers, laptops, smart phones, and personal digital assistants (PDA), which makes it more user-friendly and appealing. Additionally, Mohamed & Pillutla (2014) have stated that cloud

computing has shown prodigious implications on improving work, collaboration, and knowledge sharing, since it permits its users to share and use information and applications regardless of their geographical locations.

2.3. Types of available Cloud Service Delivery Model

There are three-main cloud service delivery models: software-as-a-service (SaaS), platform-as-a-service (PaaS) and infrastructure-as-a-service (IaaS) (Senyo et al., 2016). Saas is defined as a software distribution model, whose applications are hosted by the service provider, and who makes them available for customers over the Internet. The service providers for SaaS seek to customise the services to satisfy the customer needs (Senyo et al., 2016). They are responsible to ensure uninterrupted supply of the services to the users [Eg: Google Apps, OneDrive, Dropbox, PlanGrid, FotoIN]. PaaS deals with the renting of hardware, operating systems, storage and network capacity, and other application services via internet (Gupta et al., 2014). This nullifies the necessity to download and install applications on users' computers (Senyo et al., 2016). According to Giessmann and Slabeva, internet-based developments of PaaS offer developers a platform to build applications online (Giessmann & Stanoevska-Slabeva, 2013) [Eg: Google App Engine, Force.com]. IaaS deals with providing the necessary equipment to support different operations like storage, hardware, servers, and networking components via internet (Gupta et al., 2014). The users of IaaS are provided with computing infrastructure, and are not required to purchase them individually [Eg: Amazon Web Service (AWS), GoGrid's Cloud Service].

2.4. Cloud Computing Development Models

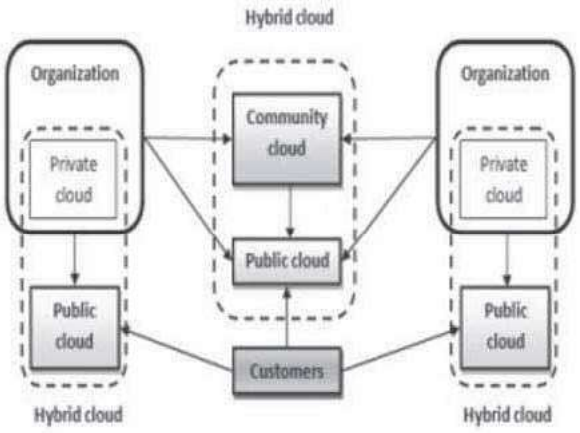


Figure 3: Cloud Service Deployment Models

Source: Fathi et al., 2012

Depending on the need of the organization, cloud computing could be deployed in several models. Private cloud, public cloud, hybrid cloud, and community cloud are a few examples (Fathi et al., 2012). Private clouds are owned by single organizations, and they are not shared with others (Chandrashekhar & Shashikumar, 2017). They are more secure and expensive compared to Public clouds (Fathi et al., 2012). Private clouds can be hosted either externally or within the premises (Rao et al., 2013). Public clouds are the most common type of clouds owned by service providers (Fathi et al., 2012). Users do not have physical access to these servers or locations, and they are shared among different organizations (Chandrashekhar & Shashikumar, 2017). Organzations can use Private clouds to host any of their critical and sensitive data, while using Public clouds to host their non-critical data (Rao et al., 2013). This combination of both Private and Public clouds is defined as Hybrid clouds (Fathi et al., 2012). Community clouds are shared among the organizations of the same community, such as government agencies or non-government agencies. Figure 1 presents cloud service deployment models.

2.5. Application of Cloud Computing in the Construction Industry

Construction industry is a highly fragmented, data intensive, project-based industry that depends on a large number of different professions and firms, who perform their work from disparate locations, with strong data sharing and processing requirements across the lifecycle of its products (Beach et al., 2013). Limitations and challenges that have occurred due to this nature of the industry could be eliminated by achieving the optimum levels of collaboration, coordination, and communication, which are vital for efficient project delivery. Beach et al. (2013), in their study have reported that, cloud computing platforms could provide a more efficient and robust mechanism for individuals within the construction industry to collaborate, and share data more effectively and efficiently. Cloud computing can be applied to the various aspects of the construction industry, including but not limited to architectural design, structural analysis, cost estimating, project planning and control, and procurement management (Adedeji, Rapheal, Olabosipo, & Timothy, 2017). 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 (Adedeji et al., 2017). It has been opined that, the information flow serves as the backbone for all successful projects across the construction sector (Khan et al., 2015). Khan et al. (2015) also 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 contribute towards improved health and safety on construction sites. It helps in completing projects on time with reduced costs and improved quality. Moreover, with

offices being decentralized, projects being dispersed globally, and employees having to travel to various locations, the ability of cloud systems to offer solid remote access to the vital construction information is critical for the success of a construction company (Rawai et al., 2013). In addition to that, BIM and other visualisation technologies continue to evolve the traditional practices of Architecture, Engineering and Construction (AEC) sector; and promising innovations, such as cloud and mobile technologies, are expected to initiate the next wave of technological development, which will transform the construction industry to the next level of technological advancement. Cloud computing is also a very versatile technology, since it could be combined with other new technologies, such as Virtual Reality, Augmented Reality, Radio Frequency Identification (RFID), and Unmanned Ariel Vehicles (UAVs), to further enhance the collaborative working environment.

3. Methods

A comprehensive literature review was carried out to identify the significance of ICT in the construction industry; i.e. cloud computing, cloud service delivery models, cloud computing deployment models and application of cloud computing in the construction industry. Then semi-structured interviews, which included preliminary interviews and expert interviews, were carried out to collect data. The preliminary interviews were conducted to verify the relevance of the findings of the literature survey. Due to the lack of construction industry experts with comprehensive knowledge in cloud technology, experts from both the construction and IT industries were selected to build a correlation between their opinions, and to see if construction industry could also benefit from cloud technology. After collecting the data, an in-depth content analysis was conducted using a computer based content analysis software named Nvivo (version 12). Table 1 presents a brief summary of interview respondents.

Table 1: The Profile of Interviewees

Industry	Type Of Organisation	Designation	Respondent	Years Of Experience
Construction İndustry	Contracting Organisation	Quantity Surveyor - ERP Consultant	C1	7 years
		System Officer	C2	5 years
		Site Engineer	C3	5 years
	Consultant Organization	Senior Quantity Surveyor	C4	10 years
		Senior Engineer	C5	8 years
		Senior Cost Manager	C6	8 years
IT İndustry	Computer Software Company	Senior Software Architect	T1	13 years

	Senior Software Engineer	T2	12 years
	Senior Tech Lead	T3	9 years
	Senior Software Engineer	T4	7 years
Enterprise Software Company	Senior Software Engineer	T5	6 years
	Software Architect	T6	5 years

4. Findings and Analysis

4.1. Significance of Cloud Computing to the Construction Industry in Sri Lanka

Cloud computing can be recognized as an effective collaborative and communication tool for the construction industry, since current projects are highly diverse with multiple parties joining from different geographical locations. All of the respondents were aware of cloud computing, but IT professionals were more conversant with the subject. While analysing the data, the current level of awareness and practice were also considered, since they have a direct impact on the responses given by the experts. Respondent T1 and T2 insisted that cloud computing is vital for companies that have expanded overseas to carry out their business operations successfully. This statement was highlighted with Respondent T3's suggestion; *"if implemented correctly, cloud can provide you with so many benefits in terms of costs, speed, efficiency, and transparency"*. Respondent T4 stressed that, people sometimes use cloud computing without being consciously aware of it, and that every business will operate through cloud in future. This idea has already been established in literature; according to Anzalone (2017), even though most of the online customers use cloud-based apps and sites, they don't realize that they do. Respondent C1 also stated, *"businesses are expanding their activities and now projects and project stakeholders are scattered everywhere in the world. Cloud computing will be a good facilitator for these expansions, as it improves communication and collaboration between parties"*. This further reinforced the statements made by respondents T1 and T3. Respondent C2 also approved the view of respondent T4, and respondent C3 stated, *"everything is getting digitized now, and organizations are moving from paper to electronic media. As a result, cloud computing will play a big part in dealing with this electronic information"*. Respondent C4 added that, cloud computing will relieve companies of IT burdens, allowing them to focus more on their core competencies and business operations.

4.2. Driving Sources for Implementing Cloud Computing

The findings were grouped under two key categories; namely, organisational perspective and technological perspective. Accordingly, support from the top management, business growth, and transparency were identified under the organisational perspective theme, and the technological perspective theme was supported with cost effectiveness, resource availability, efficiency and security. Support from top management has been recognised as an essential need for cloud computing, and convincing the top management of its value and getting approval for implementation were stated as the most difficult tasks by respondent C3. Further, respondent C4 explained that they arranged a number of meetings and demonstrations to get the consent from top management for the newly implemented cloud-based Human Resource Information System (HRIS).

In concert with that opinion, the respondent C5 stated, *"transitioning to cloud computing involves certain operational changes in the company. Therefore, the approval from the top management is mandatory"*. Respondent T1 declared that if the top management is aware of what cloud computing is and its benefits to the organization, the implementation process will be much smoother and more successful. Cloud computing was identified as an added advantage to a business, especially if it is considering investment in foreign projects. In view of that, respondent T4 stated, *"when you are considering cloud computing for the growth of a business, it ultimately boils down to how the business defines its growth"*. Respondent C5 uncovered that as a business continues to grow, there will be simultaneous projects dispersed at several locations, and a strong line of communication is vital. This was emphasized by respondent C6 by stating, *"cloud computing can also be regarded as a solution to the communication requirements between the head office and employees working in remote projects"*. Respondent T5 further added, *"moving to cloud may provide a business, a competitive advantage in the market, due to the many benefits that cloud offers and as ROIs are high with cloud"*. Transparency was suggested as a driving force to implement cloud computing, and respondent T5 mentioned, *"the ability to access information at anytime from anywhere provides the clients and project managers the chance to observe what and how things are being done. It increases the transparency, and may, in the process, decrease the number of corruptions and disputes too"*. Respondent T3 strengthened this point further by stating that when updates or changes are made everyone will be notified instantly if cloud-based applications are used. Respondent C3 also reported the same, *"when contracts, drawings or RFIs are updated, these revisions will be notified to everyone connected to the cloud, and these revisions and notifications can be traced back if needed. So, no one can claim that they were not notified, which is a good solution to construction disputes"*.

All the IT industry experts identified cost as one of the major driving forces that encourages businesses to adopt cloud computing. Respondents T1, T3 and T4 stated that "*pay as you go*" pricing model of cloud computing can greatly reduce the risk of overspending on resources that

a business does not require. It is a payment method, where resources are provided on demand, and the users get charged based on their usage. Furthermore, respondent C3 suggested that cloud computing helps companies to shift from capex (capital expenditure) to opex (operational expenditure) in terms of IT spending. Respondent C3 stated, *"companies now try to find ways to limit their capital expenditure and focus more on operational expenditure when it comes to IT infrastructure, because upfront cost for IT is often made by predicting future needs. Therefore, companies have to pay for underutilized components as well. But you don't have that issue with cloud, as you pay for what you use only"*. Respondent T3 highlighted that implementing cloud computing is not a difficult task, since it needs only a few resources such as an internet connection, computers and mobile devices. Therefore, even smaller companies can adopt cloud computing without large investments. Further, Respondent T3 suggested, "*hybrid cloud solutions are on the rise, which will enable companies that already have on-premise servers to combine them with the cloud*". Respondent C5 recognised that, mobile devices, such as tablets, would be much effective than mobile phones when working with the cloud. Accordingly it was stated, "*cloud computing will be very useful for employees on sites, but I've seen in most of the foreign countries they use tablets on sites, because it is more convenient to work with drawings and other documents using tablets compared to mobile phone,s as they are comparatively smaller in size. But I'm not sure how practical it is to supply each and every employee on sites with tablets*". Efficiency was mentioned as a key driving source by respondents T5 and T6, because that increases the efficiency of work as employees do not have to waste time due to downtimes in on-premise servers. Moreover, respondent T4 indicated that if a company adopts a SaaS cloud solution, all the IT burdens, such as backups, maintenance of servers, security of data, and software updates, can be transferred to the cloud service provider. Respondent C2 also claimed, "*cloud computing will reduce time wastage, idling time, unnecessary paper work, travelling cost etc., which will contribute significantly to the efficiency of the business*". All six IT industry experts suggested security as a key driving source for the adoption of cloud computing in a company, but none of the construction industry experts agreed. Respondent T2 stated that, it is safer to store organisational information in cloud servers than in on-premise servers, because hackers will not be able to pin point and hack data of one specific company. Respondent T1 emphasized, "*it won't be easy to hack cloud servers, because they are well protected by several layers of strong security measures. Also they back up and replicate data, and store them at different server locations, so that the possibility of losing data is very low*".

4.3. Available Applications and their Applicability to the Sri Lankan Construction Industry

The experts were requested to comment on the applicability of the cloud computing delivery models that were identified through the literature review to the Sri Lankan construction

industry. If six or more respondents have marked any of the deployment models as not relevant to the Sri Lankan construction industry, that particular deployment model was removed from the list. The levels of relevance marked by each expert are shown in Table 2.

Table 2: Relevance of Cloud-based Models

Respondent	Cloud Service Model		
	Iaas	PaaS	SaaS
C1	NR	SR	R
C2	NR	NR	R
C3	NR	NR	R
C4	NR	NR	R
C5	NR	SR	SR
C6	NR	NR	SR
T1	NR	NR	R
T2	NR	SR	SR
T3	NR	NR	R
T4	NR	SR	R
T5	NR	NR	R
T6	NR	NR	R

NR Not Relevant SR Somewhat Relevant R Relevant

All Respondents marked IaaS as 'Not Relevant' to the construction industry, as it is more suitable for developers and the IT industry, but not to the construction industry. However, PaaS had a mixture of responses. Respondent T1 clarified, "*in the PaaS model, you still have to develop software, and you have all the required tools to develop them. But still I don't believe PaaS is suitable for the construction industry in Sri Lanka, as it is not one of their competencies*". However, respondent C1 opined that the current ERP system of their organization, which is linked to an on-premise server, was developed with the help of a group of developers. Therefore, the respondent suggested, "*construction industry still can make use of the PaaS model to customize a cloud solution for an organization, such as a cloud based ERP system, but it involves a large investment*". Nevertheless, all the respondents suggested that SaaS model is either 'Relevant' or 'Somewhat Relevant' to the Sri Lankan construction industry, as it offers a significant business opportunity to the companies. Moreover, the experts were expected to mark the relevance of the applications identified in the literature review for the Sri Lankan construction industry and add any further applications, if there were any. Respondent C1 suggested to categorize these applications under two groups as 'General purpose applications' and 'Construction industry specific applications', so that it will be more

useful in arriving at conclusions and recommendations. The relevance levels marked by experts are shown in Table 3.

Table 3: Relevance of Cloud-based Application

Application	C1	C2	C3	C4	C5	C6	T1	T2	T3	T4	T5	T6
IaaS												
General Purpose												
Amazon Web Services (AWS)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
GoGrid cloud server	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
PaaS												
General Purpose												
Google App Engine	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Force.com	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SaaS												
General Purpose												
OneDrive	R	SR	SR	R	R	SR	SR	R	SR	SR	R	R
Dropbox	R	SR	R	R	R	SR	SR	R	SR	SR	SR	R
Google App	NR	SR	SR	SR	SR	SR	SR	R	SR	SR	SR	SR
Construction Industry Specific												
PlanGrid	SR	R	R	R	R	R	R	R	R	R	SR	R
FotoIN	R	SR	R	SR	R	SR	R	SR	SR	R	SR	R

NR Not Relevant SR Somewhat Relevant R Relevant

None of the respondents recommended any IaaS or PaaS applications to the Sri Lankan Construction industry. PlanGrid was the application that got marked as 'Relevant' by the most number of respondents. In fact, respondent C2 stated, "*these applications are most suitable for the employees working on sites. In large projects, drawings get revised a number of times, and these revisions get two to five days to get notified to the employees on sites. PlanGrid has options that could minimize these issues*". Most of the general purpose cloud based applications were marked as 'Somewhat Relevant' by most of the respondents. The main reason according to most of the respondents was that there are better cloud based applications that bring much more value to the businesses than the ones identified through the literature review. Respondent C2 explained, "*having documents in several clouds is not very useful.*

There are cloud based ERP software which I think bring more value compared to the ones identified in the literature review". The new applications which are suitable to the Sri Lankan construction industry, as suggested by the Respondents are listed below in Table 4.

Table 4: New Cloud-based Applications for the Construction Industry in Sri Lanka

SaaS Applications	
General Purpose Applications	Construction Industry Specific Applications
1. Box	1. Procore
2. Salesforce	2. ACONEX
3. SAP	3. Raken

Respondent C4 declared that it is clear that cloud computing could provide a lot of opportunities to a business, and it could enhance the collaboration between parties by a great deal. However, it was further stressed by the respondent that how these different applications could be used to get the best value, and how to integrate these applications to the existing systems are still unclear. This point was supported by respondent T1, "*before using this technology, companies should assess what their current problems and requirements are. Then they can decide what applications will help them to solve their current issues and accomplish their future goals*". However, respondent C3 stated that, it is still too early to adopt cloud computing, since majority of the Sri Lankan construction companies are still not ready. It was further highlighted that cloud computing could be implemented for very large projects, and also for projects that have foreign backgrounds (i.e. foreign contractors or clients).

5. Conclusion

The study analysed the suitability of cloud computing for the construction industry in Sri Lanka. Three cloud service models were identified through the literature review as IaaS, PaaS and SaaS. However, only SaaS model was recognized as relevant to the Sri Lankan construction industry, it was also understood that IaaS and PaaS models suit more to the IT industry. The driving sources for the cloud computing implementation in the Sri Lankan construction industry were identified under organizational and technological perspectives. According to the findings 'business growth' was identified as the most important organizational driving source, while 'cost effectiveness' was identified as the most important technological driving source. It was further expressed that cloud servers are more secure than on-premise servers. It can be concluded that it is important that the construction industry starts using cloud-based applications and other new technologies in its projects to improve their performance and

efficiency. Having an interest and knowledge of new technologies will be vital for even construction industry professionals in future.

References

Abedi, M., Fathi, M.S. and Rawai, N.M., 2013. The impact of cloud computing technology to precast supply chain management. *International journal of construction engineering and management*, 2(4A), 13-16.

Adedeji, A., Rapheal, O., Olabosipo, F., & Timothy, M., 2017. The Economics of Cloud-based Computing Technologies in Construction Project Delivery. *International Journal of Civil Engineering and Technology (IJCIET),* 8(12), 233-242.

Beach, T.H., Rana, O.F., Rezgui, Y. and Parashar, M., 2013. Cloud computing for the architecture, engineering & construction sector: requirements, prototype & experience. *Journal of Cloud Computing: Advances, Systems and Applications*, 2(1), 8.

Chandrashekhar, A. and Shashikumar, 2017. Cloud computing service and deployment models. *International Journal for Research in Applied Science & Engineering Technology*, 5(6), 1083-1088.

Chong, H.Y., Wong, J.S. and Wang, X., 2014. An explanatory case study on cloud computing applications in the built environment. *Automation in Construction*, *44*,152-162.

Department of Census and Statistics, 2020. *Survey of Construction Industries 2017/2018*. Department of Census and Statistics State Ministry of Economic and Policy Development.

Fathi, M.S., Abedi, M., Rambat, S., Rawai, S. and Zakiyudin, M.Z., 2012. Context-aware cloud computing for construction collaboration. *Journal of Cloud Computing*, 1.

Giessmann, A. and Stanoevska-Slabeva, K., 2013, January. What are developers' preferences on platform as a service? An empirical investigation. In *2013 46th Hawaii International Conference on System Sciences*, pp. 1035-1044.

Gupta, N., Chauhan, B., Anand, T. and Dewan, C., 2014. Cloud Computing: Comparison with Previous Technique and Research Challenges. *International Journal of Computer*

Applications, 85(8).

Jayalath, A., & Gunawardhana, T., 2017. Towards Sustainable Constructions: Trends in Sri Lankan Construction Industry - A Review. *International Conference on Real Estate Management and Valuation*, (pp. 137-143). Colombo.

Harvey, B., Frommell, D. and Sturhahn, J., 2015. Growth projected to continue in construction sector. *Colorado Real Estate Journal*, 12-16.

Ikediashi, D.I. and Ogwueleka, A.C., 2016. Assessing the use of ICT systems and their impact on construction project performance in the Nigerian construction industry. *Journal of Engineering, Design and Technology*.

Khan, K., Flanagan, R. and Lu, S. 2015. Managing the complexity of information flow for construction small and medium-sized enterprises (CSMEs) using system dynamics and collaborative technologies. *Proceedings of 31st Annual ARCOM Conference*, 1177-1186. Lincoln, UK,: Association of Researchers in Construction Management.

Mohamed, M. and Pillutla, S., 2014. Cloud computing: a collaborative green platform for the knowledge society. VINE1, 44, 357 - 374.

Miozzo, M., & Derwick, P., 2002. Building competitive advantage: innovation and corporate governance in European construction. *Research Policy*, 989–1008.

Onyegir, I., Nwachukwu, C., & Jamike, O., 2011. Information and communication technology in the construction industry. *American Journal of Scientific and Industrial Research*, 461-468.

Rao, C.C., Leelarani, M. and Kumar, Y.R., 2013. Cloud: computing services and deployment models. *International Journal of Engineering and computer science*, 2(12), 3389-3392.

Rawai, N.M., Fathi, M.S., Abedi, M. and Rambat, S., 2013, January. Cloud computing for green construction management. In *2013 Third International Conference on Intelligent System Design and Engineering Applications*, 432-435.

Reginold, K. D., 2009. Identification of the barriers of information and communication technology implementations in relation to productivity of building construction sector in Sri Lanka (Master's thesis, University of Colombo, Colombo, Sri Lanka). Retrieved

from http://hdl.handle.net/70130/1298

Xu, L., Xu, E., & Ling, L., 2018. Industry 4.0: State of the Art and Future Trends. *International Journal of Production Research*, 56(8), 2941–2962.