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APPLICATION OF CLOUD COMPUTING FOR THE INTERNAL STAKEHOLDERS' COLLABORATIVE INVOLVEMENT IN THE CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

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ABSTRACT

The significant challenge in the construction project is the efficient collaborative involvement of the stakeholders since the stakeholders are coming from multidisciplinary and working together to achieve a particular goal. Consequently, at present, the construction industry has started to move on to Cloud-based technologies for the collaboration of the stakeholders, Cloud-Computing (CC) is one of those technologies. Although the stakeholders' collaboration through cloud-computing provides many benefits for the enhancement of project performance of the industry, the stakeholders rarely utilise the cloud-based applications and technologies during their day-to-day activities of the construction process. Accordingly, practical enhancement of the stakeholder collaborative involvement through CC in the construction industry needs to be re-analysed. Accordingly, there is a requirement to review the involvement ways of internal stakeholders through the CC for the collaboration and enhancement of the project performance. Hence, this paper highlights the literature findings on the collaborative involvement of stakeholders through CC. Also, this study discusses the benefits and limitations of the usage of the CC. The findings revealed that contract management, design management and drawing, real-time management, and document management are the collaborative involvement features of

internal stakeholders through CC in the construction process. Real-time monitoring, low maintenance cost, and high collaboration were found as major benefits of the CC. Moreover, a higher requirement of computer resources, high implementation cost, data security and protection, and lack of awareness of the stakeholders were identified as significant limitations of cloud-based Building Information Modelling (BIM) collaborative involvement of internal stakeholders in the construction process.

Keywords: Construction industry; Cloud computing; Cloud-Based BIM; Stakeholder's involvement, Stakeholder collaboration

INTRODUCTION

The construction industry has been growing, and it plays a considerable role in the Gross Domestic Product (GPD) of a country (Fathi, Rawai, & Abedi, 2012). The most significant factor in the construction industry is the interrelation and communication methods among the parties within a project to improve their relationship (Frederick & Nancy, 2003). Normally, the construction industry is fully personalized with the information and the people, who are involved in the process of delivery (Afolabi et al., 2018). In addition, proper management of internal and external resources, and information are essential factors for making better decisions in order to

overcome the challenges of construction projects in various stages (Shi & Halpin, 2003). In the current situation, the generated information in the construction industry should be more accurate and on time for the increment of stakeholders' performance (Afolabi et al., 2018). Thus, the collaboration of the stakeholders is an important thing for the communication and awareness of the project activities to complete the project in an effective way (Barthelme, 2003). Moreover, the construction industry is fully based on the projects, and many construction firms assess the performance of the organisation based on the completed/ongoing projects (Tatari, Lacouture, & Skibniewski, 2008).

Presently, the construction firms are more towards Information Technology (IT) in most of the prime activities of the construction industry, so the construction firms can exchange information with the help of the internet from many servers at one time (Kumar et al., 2010; Hayes, 2008). Cloud Computing (CC) is a pattern, that is unique and suitable for the access of the network at any time and anywhere, and it acts as a puddle to share the computer resources (Mell & Grance, 2011). The implementation of CC in the construction industry is one of the innovative tools for collaboration, and there is a requirement to analyse the innovative collaboration through CC (Fathi et al., 2012). As well, in the construction industry, the stakeholder can use cloud-based applications in many ways to get the construction process effectively, but the stakeholder rarely utilizes the usage of cloud-based applications and technologies during the day-to-day activities of the construction process (Afolabi et al., 2018). Further, the researchers need to focus on the involvement of construction stakeholders through CC for the efficient outcome of the construction process (Chu, Matthews, & Love, 2018). Meanwhile, there have been some disagreements regarding the collaborative involvement of stakeholders

through CC in the construction industry. Accordingly, there is a requirement to review the involvement ways of internal stakeholders through the cloud-based technology for the collaboration and enhancement of the project performance. Hence, this paper highlights the literature findings on collaborative involvement ways, benefits, and limitations of internal stakeholders through the CC collaboration in the construction industry.

The structure of this paper begins with the methods used to achieve the aim of this study which is to enhance the stakeholder collaborative involvement through cloud-based BIM. To achieve the objectives such as identify the involvement ways and benefits of internal stakeholders through the Cloud-Based BIM collaboration, and identify the involvement level of the internal stakeholders through the Cloud-Based BIM. along with the literature synthesis linked to key concepts. Finally, it presents the conclusions of the study.

Research Method

This study was developed based on a comprehensive literature review of the research gap on the collaborative involvement of the stakeholder through cloud-computing. "Cloud Computing", "Stakeholders of Construction" & "Cloud-Computing", "Collaboration" & "Cloud-Computing", "Application" & "Cloud-Computing" have been used as the keywords to find out relevant academic articles. through popular search engines namely "Google Scholar", "Emerald Insight", "Academica", "Science Direct" and "Research Gate". The literature review was focused on the concept of CC, a cloud-based application available in the industry, the involvement ways and benefits for the collaboration of stakeholders, and also the limitations for the involvement of stakeholders through cloud-computing. A total of 122 articles were chosen after the first round of evaluation, which involved scanning

article titles. Further to refine the set of articles in terms of relevance, articles were selected by reading the abstracts and conclusions, 97 were then refined in the next round.

LITERATURE SYNTHESIS

Introduction to cloud computing

Industry 4.0 is an emerging technology in the whole industry and it has several features, that help to automate the industry such as CC, big data, robotics (Lasi et al., 2014; Oesterreich & Teuteberg, 2016). CC is a model for enabling, ubiquitous, convenient, on-demand network access to a shared pool of configurable computer resources through the internet (Mell & Grance, 2011). In addition to that, CC helps to manage the information and data through the cloud and provides a significant impact on the information system of the business firm and business developers (Pozin et al., 2017; Jadeja & Modi, 2012). CC is the combination of software, data access, storage facility, no need for a physical location, and wireless technology (Diakaisos et al., 2009; Somani & Dadhich, 2013). Accordingly, CC is much better than previous technology and it facilitates to provide better collaboration, interoperable, and easy delivery method (Jadeja & Modi, 2012), also, efficient utilization among the stakeholders, pay as services, on-demand usage, flexibility, vast storage, and store data in the cloud. Scalable, interoperable, service quality, delivery method, easy maintenance, no need to install, efficient utilization, sharing the hardware resources, better security, and easy accessibility are some of the characteristics of CC, (Ashktorab, Taghizadeh, & Zamanifar, 2012). Moreover, the technology side characteristics of CC are the client's preferred operation systems, firewalls for security, compatibility support with already running application, flexibility,

scalable, automatically update, adoption of new requirements, technical supports throughout the operation period (Al-Johani & Youssef, 2013). Furthermore, CC has some specific characteristics such as sharing of infrastructure, vast storage, dynamic resource allocation, software automation, accessibility, hardware pooling, scalable, no need for a physical location, flexible, on-demand services, low cost (Cegielski, Jones-Farmer, Wu, & Hazen, 2012). Accordingly, it could be concluded that CC is a more flexible and efficient technology in the industry.

Applications of cloud computing

In the construction industry, the stakeholders tried to move comprehensive applications for the construction process or managing tasks (Chong, Wong, & Wang, 2014). There are many applications available in the market to deliver the services through CC, especially for the project and document management, and the application can run on the desktop and mobile devices with or without the installation of software in the desktop or mobile devices (Chong et al., 2014; Ma et al., 2018). Industry 4.0 pointed out some technologies which are used in the construction industry such as Building Information Modelling (BIM), CC, Internet of Things (IoT), Internet of Services (IOS) (Oesterreich & Teuteberg, 2016).

BIM is an innovative technology in the construction industry, which helped to encourage collaboration among the stakeholders to increase performance (Onungwa & Olugu, 2017; Ma et al., 2018). Also, BIM uses to collaborate with the stakeholders within the project or organisation, and it allows them to change the design and construction process during the construction period (Onungwa & Olugu, 2017). BIM is getting into the construction industry step-by-step to improve the capability of the construction project practices in the design,

procurement, prefabrication, construction, and post-construction stages (Cao et al., 2017; He et al., 2017). Moreover, cloud-based BIM is the key technology in the construction industry in the field of CC (Abanda, Mzyece, Oti, & Manjia, 2018), and it significantly contributes to the development among the construction industry stakeholders through creating opportunities and real-time communication among the stakeholders (Wong, Wang, Li, Chan, & Li, 2014). Further, the combination of BIM with CC in the construction industry is much better than using BIM as a single product. The adoption of cloud-based BIM is one of the emergent technologies to involve the stakeholder collaboratively to improve the productivity of the construction industry (Ibem & Laryea, 2014; Chu et al., 2018).

There are several cloud-based BIM systems available in the construction industry such as Revit Server, Revit Cloud, and general-purpose cloud services. These help for effective decision-making in construction tasks (Zhang & Issa, 2012; Du et al., 2018). Additionally, BIMX is a feature of BIM, and it can be installed in the computer to develop the functions in the cloud (Chong et al., 2014). Further, the authors stated as Autodesk has been developed from the platform of BIM in the cloud and the product comes out from Autodesk 36 that combines the cloud, CADD Force and BIM9. Furthermore, some BIM applications, which are integrated with the cloud for stakeholder collaboration in the construction industry such as Autodesk BIM 360, BIM Server, BIMX, CADD Force, Onuma System, Autodesk Revit, Archi CAD, CBIM, and Ruska (Alreshidi, Mourshed, & Rezgui, 2016b; Onungwa & Olugu, 2017). CC and BIM integration is developed for the improvement of information exchange during the construction process, and it helped to reduce the technical-based solution in the construction process (Chu et al., 2018).

Involvement ways of stakeholders through cloud computing in the construction industry

The construction industry is fully gathered of information through the presence of stakeholders during the life cycle of the construction project (Teizer, 2013; Hooper & Ekholm, 2010; Alreshidi et al., 2016a). It becomes complicated when the required information increased and it's fragmented due to a large number of stakeholders involved in the construction process (Oh et al., 2015; Grover & Froese, 2016). Thus, this construction industry wants to improve the transfer of information in a digital format, and it helps to manage the activities of stakeholders during the construction process (Behazadan, Aziz, Anumba, & Kamat, 2008). The cloud-based technology is the best option for the construction industry to manage the projects and to provide the information in digitization format during the construction process (Zeeshan et al., 2004; Chu et al., 2018). Currently, several organisations in the construction industry are adopting new emerging technologies for improving the productivity of organisations (Williams, Bernold, & Lu, 2007). The CC provides an open-door collaboration among the construction stakeholders with the cloud-based application (Abedi, Fathi, & Rawai, 2012). It can be used for the stakeholders' day-to-day activities, and there are several platforms available for helping the stakeholders to use CC in the construction industry (Abd Elmonem, Nasr, & Gheith, 2017). Additionally, several applications allow collaborating with the stakeholder through CC (Aziz, Anumba, & Penamora, 2009).

The involvement of the stakeholders is an important part of the improvement of the effectiveness of construction projects, and the quality is dependent on the stakeholder's involvement since construction projects are different from every project (Heravi, Coffey, &

Trigunarysyah, 2015). The stakeholders provide various services during the construction process for the success of the projects (Meng, 2012; Sutterfield et al., 2006). The authors divided stakeholders into two categories according to the services such as internal and external stakeholders. In a construction project, the internal stakeholders are the members of construction projects, and the construction projects can not survive without the involvement of these stakeholders (Clarkson, 1995). Internal stakeholders are the members who financed the project and support completing the construction projects on time efficiently and effectively (Winch & Bonke, 2002; Newcombe, 2003; Olander & Landin, 2005). Also, the internal stakeholders are the responsible persons to share the risk of construction

projects during the construction process stages (Grillo & Goncalves, 2011). The internal stakeholders of the construction industry include several benefits such as clients, designers/architects, project managers, subcontractors, suppliers, contractors, consultants (Newcombe, 2003; Zhang et al., 2014; Grillo & Goncalves, 2011). Thus, stakeholder management in the construction industry is a very critical thing (Vinten, 2000). Further, the authors stated that each activity of the internal stakeholder becomes more complex, so the project manager wants to analyse each stakeholder and type projects for the stakeholder collaboration (Olander S., 2007). Table 1 demonstrates the internal stakeholder involvement ways through CC in construction projects.

Table 1: Internal Stakeholder Involvement Ways through Cloud-Computing in Construction Process.

Authors	Stakeholders	Responsibilities
(Aapaoja, Haapasalo, & Soderstrom, 2013)	Client	Fulfill and put their needs in practice, and they should map the needs in the early stage
	Consultant /project manager	Help with his / her experience through the project and provide solutions for the client's needs and also provide better coordination between the client and contractors for the better project management
	Architect	Complete the design and the project according to the client's needs and find economical solutions in the early phases of the project and be responsible for the designs.
	Main contractors	Construct the project successfully with the experience get gained in the early stages of the project and greatest responsibility in the practical implementation of the project
(Ma, Cai, Yang, Feng, & Wang, 2018)	Client	Recheck and double recheck the work respectively by the specifications
	Consultant	Recheck and double recheck the work respectively by the specifications
	Contractor	Check the work by the specifications
(Heravi et al., 2015)	Client	Establish the project, develop the project and process, and control and operation
	Consultant	Establish the project, develop the project and process, and control and operation

	Architect	Establish the project, develop the project and process, and control and operation
	Contractor	Establish the project, develop the project and process, and control and operation
(Fulford & Standing, 2014)	Client	Initiate the project and Responses for the bidding construction organisations, design and estimation, progress measures, and payments
	Consultants	Responses for the bidding construction organisations, design and estimation, progress measures, and payments
	Contractor	Responsible for the construction phase
(Li & Ma, 2016)	Client	Conflict decision making, data management, authority management
	Architect	Feasibility of the design scheme
	Consultant	Participate in review the planning, designing drawings, construction programme
	Contractor	Implement the construction with the programme
	Client, Architect, Consultant & Contractor	Involve in the project planning and participate through the whole construction process
(Oesterreich & Teuteberg, 2016)	Client	Involve in the briefing, designing, planning, construction, and maintenance stage of the construction activities.
	Architect	Involve in designing, planning, and construction activities
	Consultant	Involve in the briefing, planning, construction activities
	Contractor	Involve in the planning, tendering, and construction activities

In another way, collaboration is the agreement among the several parties, who involve in the project to share the handling capacity, available data, information, and knowledge, aiming of the tasks defined by the client or the stakeholders (Hu et al., 2016; Hughes et al., 2012; Matthews et al., 2018). In the construction industry, the time based and accurate information are needed during the construction phase to success a particular project, because stakeholders involve from the multiple organisation. Real-time and effective information generates the knowledge to make the decisions efficiently (Cheng et al., 2012; Cao et al., 2017). In construction projects, there is a need for the collaboration of stakeholders or various organisations to deliver the projects successfully (Abanda et al.,

2018). Many researchers stated that the collaboration of stakeholders helped to share the information, communicate among them, and coordinate the stakeholders to achieve a particular thing (Alreshidi et al., 2016b).

Benefits for the adoption of cloud computing

The conventional method of collaboration is paper-based or verbal communication among the stakeholder to communicate and share information (Teizer, 2013; Hu, 2008). Further, the authors commented that only a few stakeholders are working efficiently through the conventional method of collaboration in the construction industry (Ma et al., 2018). Two third of the construction problems are arisen by the inadequate exchange of information data

transferring, and the inefficiency of information in the conventional method (Hu W. , 2008). Table 2 elaborates on the

drawbacks of the conventional collaboration of stakeholders in the construction industry.

Table 2: Drawbacks of Conventional Involvement Method of Internal Stakeholder in the Construction Process

No	Drawbacks	Authors													
		Hu, 2008	Xue et al., 2007	Xuan & Yuanzhang, 2007	Peanspap & Walker, 2006	Alarcon et al., 2013	Thomas & Thomas, 2005	Ng,et al., 2006	Nikas & Poulymenakou, 2006	Teizer, 2013	Kim et al., 2013	Afolabi et al., 2018	Matthews et al., 2018	Dallasega et al., 2018	Zhang et al., 2017
01	Inadequate exchange of information	*	*	*	*	*	*	*	*	*	*	*	*	*	*
02	Inefficiency of data	*						*			*	*	*	*	
03	Poor coordination		*			*	*	*							*
04	Low transparency		*					*			*				
05	Limited communication		*	*	*	*	*	*	*			*	*	*	
06	Decision-making path critical			*	*			*	*						*
07	Collaboration among stakeholder very low				*			*	*	*	*	*	*	*	*

CC with BIM collaboration is helped to overcome these issues in the conventional collaboration of construction stakeholders, and it reduces the risk of the construction management (Beach et al., 2013; Oraee et al., 2017; Ma et al., 2018).

Collaborative Features through Cloud- Computing

CC collaboration in the construction industry facilitates many ways in the construction process (Hu W., 2008). The cloud-based collaboration in the construction activities changes the nature of the collaboration, and it introduces a new trend for managing many people at the same time with the stakeholders from the scattered locations (Oraee, Hosseini, Papadonikolaki, Palliyaguru, &

Arashpour, 2017). Table 3 illustrates the collaborative involvement features of

internal stakeholders through cloud-based BIM in the construction process.

Table 3: Collaborative Involvement Features of Internal Stakeholder through Cloud Computing in the Construction Process

No	Collaborative features	Authors											
		(Hu W., 2008)	(Beach, Rana, Rezgui, & Parashar, 2013)	(Chong et al., 2014)	(Zhang, Liu, Yu, Hu, & Zhao, 2014)	(Alreshidi et al., 2016)	(Zhang, Pan, Wang, Sun, & Wang, 2017)	(Ma et al., 2018)	(Hassan & Yolles, 2009)	(Wong et al., 2014)	(Oesterreich & Teuteberg, 2016)	(Chu et al., 2018)	(Du, Shi, Zou, & Zhao, 2018)
01	Document management	*	*	*	*	*	*			*		*	
02	Contract management	*	*	*	*	*	*	*	*	*	*	*	*
03	Design management and drawing	*	*	*	*		*		*	*	*	*	
04	Real-time management	*		*		*	*	*			*	*	*
05	Project life cycle management	*		*	*	*			*	*		*	
06	Efficient communication			*		*	*	*	*		*	*	
07	Supply chain management	*		*	*	*							
08	Finance management				*				*		*	*	
09	Tracking features	*							*		*		
10	Sophisticated reporting	*		*									*
11	Task assignment	*				*					*		*
12	Procurement	*		*								*	
13	Time management	*									*		*

14	Scheduling			*				*		*		
15	Tender management	*		*								

Thus, the adoption of Cloud-based BIM in the construction stakeholder for the collaborative involvement provides more benefits such as improve productivity, high collaboration, real-time monitoring, and efficient communication among

stakeholders (Oesterreich & Teuteberg, 2016; Dallasega, et al., 2018). Table 4 shows the benefits of the collaborative involvement of internal stakeholders through cloud-based BIM in the construction process.

Table 4: Benefits of Collaborative Involvement of Internal Stakeholder through Cloud Computing In The Construction Process

No	Benefits	Authors									
		Afolabi, et al., 2018	Fathi, et al., 2012	Oesterreich & Teuteberg,	Alreshidi, et al., 2016	Du, et al., 2018	Li & Ma, 2016	Zhang, et al., 2017	Amarnath, et al., 2011	Wong, et al., 2014	Abanda, et al., 2018
01	Easy communication	*		*						*	*
02	High storage capacity	*									
03	Backup and recovery				*	*			*		
04	High collaboration	*	*	*	*	*				*	
05	Real-time monitoring	*	*	*	*	*			*	*	*
06	No need for a physical location	*								*	
07	Data transfer quality and productivity improvement			*			*	*			*
08	Trust development				*	*					
09	Low cost	*	*	*	*	*	*	*			*
10	Resource sharing	*		*			*	*			

The construction stakeholders are rarely involved in the construction process through CC (Afolabi, et al., 2018). The

following Table 5 explains the limitations for the involvement of stakeholders through CC.

Table 5: Limitations for the involvement of stakeholders through cloud computing

No	Limitation	Authors							
		Oesterreich & Teuteberg, 2016	Smith, 2014	Davis & Sharp, 2014	Alreshidi, et al., 2016	Wong, et al., 2014	Meza, et al., 2014	Onungwa & Ologu, 2017	Du, et al., 2018
01	Hesitation	*	*	*					
02	High implementation cost	*	*	*	*				
03	Changing of organization culture	*	*	*					
04	Data security and protection	*	*	*	*				
05	Legal uncertainty	*	*	*					
06	Higher requirement of computer resources	*	*	*				*	*
07	Unpredictability of performance				*				
08	Trust related issues				*				
09	The limited size of document sharing				*				
10	Data ownership					*	*		
11	Lack of awareness					*	*	*	*

CONCLUSIONS

This study is assessed the CC concept and its importance for the construction sector. Based on the findings from the literature review, the conclusion was made that, the CC is an innovative technology in the construction industry to improve the performance of the construction project with the better collaboration of the stakeholders through CC. There are several challenges faced by the

stakeholders due to the paper-based collaboration and some main challenges are inadequate exchange of information, poor coordination, decision-making path critical, and limited communication. Also, this paper was found that the collaborative ways of stakeholders through cloud-based BIM, the benefits come through the stakeholder collaboration and the limitations for the stakeholder collaboration through cloud-based BIM in the construction industry. Considering the

Sri Lankan construction industry, cloud-based BIM technology is an innovative technology for investors, who are coming from foreign. Moreover, this study is beneficial for developing countries for the process of involving stakeholders through the cloud-based BIM during the construction process, because most of the investors for the construction sector in developing countries are foreigners. So, the investors can observe the progress of the project without visiting to the countries, where they have invested. In addition to that, stakeholder involvement through the cloud-based application is more beneficial for the pandemic situation like Covid-19, because there are many restrictions to traveling from one place to another place. According to this, stakeholder involvement through the cloud-based application is more effective than paper-based collaboration in the industry.

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