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ENHANCE THE COLLABORATIVE INVOLVEMENT OF STAKEHOLDERS THROUGH CLOUD-BASED BIM IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry relies on the collaboration of stakeholders for a successful outcome, as most the stakeholders are from multidisciplinary organisation to achieve a particular goal. In addition, information in the construction industry must be more accurate and on time to increase the project performance. Even though cloud-based collaboration can be a useful tool for working with the stakeholder, is not being used widely yet. Therefore, it is required to analyse the feasibility of collaborative stakeholders' participation on cloud-based Building Information Modelling. Hence, this paper outlines: the level of stakeholder collaborative involvement in cloud-based Building Information Modelling; the benefits of stakeholder collaborative involvement through cloud-based Building Information Modelling; limitation for the cloud-based Building Information Modelling; as well as strategies to overcome these limitations. Findings of the study indicated that even though, the benefits derived from the stakeholder collaboration are high, the collaborative involvement level in cloud-based Building Information Modelling is very low due to several limitations. therefore, this study propose some strategies to overcome the limitations such as: the government can provide training and awareness programmes; formulate regulations allowing for electronic-data processing to lower tax; develop Building Information Modelling execution plans with assistance from the Construction Industry Development Authority; and improve Building Information Modelling Execution plans with the technology.

Keywords: *Building Information Modelling (BIM); Cloud-Based; Construction Industry; Sri Lanka; Stakeholder's Involvement.*

1. INTRODUCTION

The construction sector, which is highly individualised with people and information for the construction process, makes a major contribution to a country's Gross Domestic Product. (GDP). (Fathi, et al., 2012; Afolabi, et al., 2018). Sri Lanka's construction industry generates around 7% of the country's GDP. (Central Bank of Sri Lanka, 2020; Central Bank of Sri Lanka, 2021; Central Bank of Sri Lanka, 2022). The Architecture, Engineering, and Construction (AEC) field is fragmented, covered with a network of data

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and involves a large number of various professionals and organisations throughout the lifetime of the construction outputs (Beach, et al., 2013). As a result, stakeholder might be classified as internal or external depending on their engagement or project scope. (Sutterfield, et al., 2006). Based on this, the primary difficulty in the construction industry is the effective involvement of stakeholders to accomplish specific objective with a substantial impact (Fathi, et al., 2012a). Due to that, many organisation encounter multiple difficulties in managing information safety procedures, and quality of the project for the construction stakeholders (Chung, et al., 2008). Therefore, the efficient collaboration of stakeholders is an important thing for the communication and awareness in the project activities to complete the project in an efficient way (Barthelmess, 2003). Furthermore, stakeholders in the construction industry wants to share the knowledge efficiently and effectively to improve the coordination among the stakeholders (Lang, et al., 2002). In the current world, the generation of information should be more accurate and real-time to get better performance from the construction stakeholder (Afolabi, et al., 2018), the construction firms should move on to the Information Technology (IT) sector to fulfil their day-to-day activities in the construction process (Kumar, et al., 2010). Therefore, the demand for cloud computing (CC) becomes a rapidly changing platform of IT and it allows construction firms to change the resources according to the demand of the construction environment (Shawish and Salama, 2014).

One of the creative techniques for the construction sector to achieve successful stakeholder engagement is the deployment of CC collaboration (Fathi, et al., 2012b). There are several applications (apps) available for stakeholder participation, including;

Building Information Modelling (BIM) is an innovative technology in the construction industry that enables better collaboration among stakeholders during construction processes including design procurement, prefabrication, construction, and post construction (Ma, et al., 2018; Cao, et al., 2017; He, et al., 2017).

In the construction industry, combining BIM and CC is far superior to utilizing BIM as a single product because the integration of BIM and CC provides an excellent platform for the working process and communication. (Wong, et al., 2014; Abanda, et al., 2018). In addition to that, the integration of CC and BIM (here in after Cloud-Based BIM) enables the stakeholder to easily tracking facilities of the building from the design stage to maintenance stage, which covers operations, facility management, energy management and maintenance of the building (Wong, et al., 2014; Amarnath, et al., 2011). Based on that, the development of CC based BIM is an effective and collaborative project management tool (Zhang, et al., 2017; Chu, et al., 2018). In the construction industry, the stakeholder can employ cloud-based applications to get an efficient outcome in the construction process; at the same time, the stakeholder rarely utilises to use the cloud-based applications and technologies during the day-to-day activities in the construction process (Afolabi, et al., 2018). Likewise, the cloud-based BIM collaboration can reduce the issues among the stakeholder collaboration during the construction process, but there is a requirement to check the feasibility of cloud-based BIM collaboration of stakeholders practically (Alreshidi, et al., 2016). Furthermore, there is a shortage of stakeholders' cooperation via cloud-based BIM and future researchers wish to focus the stakeholder involvement level via cloud-based BIM to help the construction stakeholders in obtaining an efficient outcome in the construction process (Wong, et al., 2014; Chu, et al., 2018). According to that, there have been some disagreements regarding the collaborative involvement level of stakeholders through cloud-based BIM, which has been pointed out

by many researchers. So, the gap of this research identified that, the lack of stakeholder involvement through cloud-based BIM in the construction industry.

Hence, this research aims to investigate the stakeholder involvement level and mitigating strategies that accelerate stakeholder involvement in the construction industry. The remainder of this article is structured as the literature review followed by the research methodology. Then, the prime part of the paper is research analysis and findings. Finally, the conclusions and recommendations are provided.

2. LITERATURE REVIEW

This research is a continuation of the prior study (Mohanaraj, et al., 2021). The factors that are required for this study is just summarized and used to further this study. The factors that were used in this study are listed in Table 1.

Table 1: Factors identified from previous research

Drawbacks in the conventional method of stakeholder collaboration	Collaborative Features through cloud-based BIM	Benefits come from the collaborative involvement through cloud-based BIM	Limitation for the collaborative involvement through cloud-based BIM
Inadequate exchange of information	Document management	Easy communication	Hesitation
Inefficiency of data	Contract management	High storage capacity	High implementation cost
Poor coordination	Design management and drawing	Backup and recovery	Changing of organization culture
Low transparency	Real-time management	High collaboration	Data security and protection
Limited communication	Project life cycle management	Real-time monitoring	Legal uncertainty
Decision-making path critical	Efficient communication	No need for a physical location	Higher requirement of computer resources
Collaboration among stakeholder very low	Supply chain management	Data transfer quality and productivity improvement	Unpredictability of performance
	Finance management	Trust development	Trust related issues
	Tracking features	Low cost	The limited size of document sharing
	Sophisticated reporting	Resource sharing	Data ownership
	Task assignment		Lack of awareness
	Procurement		
	Time management		

3. RESEARCH METHODOLOGY

This research aims to investigate the stakeholder involvement level and mitigating strategies to accelerate stakeholder involvement through cloud-based BIM in the Sri Lankan construction industry. This study was developed based on the practical view of the research gap on the stakeholder collaborative involvement level through cloud-based BIM. The data collection was carried out using a mixed-method approach, which was directed in two ways such as questionnaire survey and semi-structured interview. The questionnaire survey was circulated among the fifty (50) professionals in the construction industry to rank the level of involvement through cloud-based BIM. According to the respondent percentage, 76% of respondents responded to the survey. The sample comprised of directors, engineers, architects, project managers, and quantity surveyors, the sample selection was done using the convenience sampling method. They were chosen from both consultant and contractor organisations, although, with the majority of respondents working in consultancy organisations and having experience in the construction industry between eleven to fifteen years. The criteria identified in the literature study were scored using a five-point Likert scale and the survey results were analysed using descriptive statistical analysis method through SPSS V20 software.

According to the findings of the questionnaire survey, the semi-structured interviews were undertaken among the ten (10) interviewees, who are experienced and practice CC and BIM in their day-to-day activities. During the interview, questionnaires were clarified, such as whether or not the collaborative elements in the traditional method and cloud-based BIM technique are the same. The interviewees responded that the Characteristics of any approach are nearly same, with the only variable being the efficiency level. If we employ the most recent approach for the stakeholder participation, the efficiency and accuracy levels increase. The semi-structured interview includes 17 questions divided into two sections for each respondent, and all findings are based on the questionnaire survey for the collaborative involvement through cloud-based BIM as collaborative features, benefits, and limitations for the involvement of stakeholders through cloud-based BIM. The species of the interviews are elaborated in Table 2.

Table 2: Details of the interviewees

Code	Profession	Organisation type	Designation	Experience
I-1	Charted Quantity Surveyor	Contractor	Contract Manager	13 Years
I-2	Charted Architect	Consultancy	Chief Architect	18 Years
I-3	Charted Architect	Consultancy	Project BIM coordinator	14 Years
I-4	Charted Architect	Consultancy	Director	20 Years
I-5	Charted Quantity Surveyor	Consultancy	Director	14 Years
I-6	Structural Engineer	Contractor	Structural Engineer	18 Years
I-7	Quantity Surveyor	Contractor	Project Quantity Surveyor	20 Years
I-8	Charted Architect	Consultancy	Charted Architect	17 Years
I-9	Quantity Surveyor	Consultancy	Project Quantity Surveyor	15 Years
I-10	Engineer	Contractor	Project Manager	23 Years

During the analysis of the factors through SPSS V20, the mean value was used to determine if the factor influence each cluster positively or negatively, ranking was done according to the mean value. According to the thumb rule or general rule, the number three on the five-point Likert scale is regarded ta decision-making point. According to that, values more than three are regarded to positive impact factors, while values less than three are considered negative effect factors.

4. RESEARCH FINDINGS AND DISCUSSION

The section consists of research findings from the questionnaire survey and semi-structured interview.

4.1 QUESTIONNAIRE SURVEY

In addition to the findings from the literature (section 2), some additional factors were identified during data collection and Table 3 elaborates the drawbacks of the conventional collaboration of stakeholders in the construction industry and mention the method of ranking or the basis on which the ranking was done.

Table 3: Drawbacks of the conventional collaboration of stakeholders in the construction industry

Code	Factor	Mean	Rank
A1.	Collaboration among stakeholders	3.82	1
A2.	Decision-making path is critical	3.74	2
A3.	Performance efficiency	3.71	3
A4.	The conflict between the department	3.66	4
A5.	Manipulation of data	3.61	5
A6.	Exchange of information among stakeholders	3.58	6
A7.	The efficiency of handling data	3.55	7
A8.	Coordination among stakeholder	3.53	8
A9.	Communication among stakeholders	3.53	8
A10.	Transparency of data	3.45	10
A11.	Wrong decision-making path	3.26	11
A12.	Security issues	3.26	11

As a result, the ranking order of the factors from the previous studies and the questionnaire survey findings are contradict. For instance, we consider the factor *"exchange of information among the stakeholder*" most authors pointed out that this is a high impact factor the conventional method of collaboration, while respondents stated that, this factor is not very essential the conventional method of collaboration. In this way, we evaluate "*collaboration among stakeholders*" most of the authors indicated that this is not a significant element in the conventional method, respondents highlighted that, this factor has a significant impact on the conventional method of collaboration. Moreover, according to the responses, these elements have a favourable influence on the conventional method of stakeholder collaboration in the construction industry. Those factors also have a positive impact on the conventional method of collaboration.

The collaborative features for the stakeholder involvement through the conventional method and cloud-based BIM found and graded using a literature study. Document

management, contract management, design management, real-time management, project life cycle management, efficient communication, supply chain management, finance management, tracking features, sophisticated reporting, task assignment, procurement, time management, and scheduling are some of the factors to consider (Mohanaraj, et al., 2021). Table 4 depicts the collaborative involvement features available via cloud-based BIM.

Table 4: Collaborative involvement through cloud-based BIM

Code	Factor	Mean	Rank
B1.	Efficient communication	3.05	1
B2.	Tracking features	2.89	2
B3.	Time management	2.89	2
B4.	Finance management	2.82	4
B5.	Document management	2.79	5
B6.	Supply chain management	2.79	5
B7.	Scheduling	2.76	7
B8.	Real-time management	2.66	8
B9.	Sophisticated reporting	2.61	10
B10.	Task assignment	2.55	11
B11.	Project life cycle management	2.53	12
B12.	Design management	2.42	13
B13.	Contract management	2.39	14
B14.	Procurement	2.39	14

According to the findings, collaborative involvement in the cloud-based BIM has a negative impact, indicating that stakeholder rarely use cloud-based BIM to benefit the construction industry. Furthermore, the stakeholder collaborative involvement, features were assessed individually in terms of theory and practice. In this approach, the authors emphasized the significance of collaborative features through cloud-based BIM, however in practice; the intensity of involvement differs from the theory. For instance, the authors claimed that "*contract management*" is an important thing in collaborative involvement, but the respondents pointed out that the involvement level in cloud-based BIM collaboration is too low. In this sense, "*efficient communication*" is not so crucial in the authors' opinion, but respondents claimed that this aspect is extremely important in the collaboration of stakeholders via cloud-based BIM.

Furthermore, the benefits of stakeholder collaborative involvement through cloud-based BIM were discovered and assessed through literature review. Table 5 explains the benefits of collaborative involvement through cloud-based BIM.

As per the findings, all the respondents believed that collaborative involvement through cloud-based BIM had a positive impact on the construction industry. It elaborates that the collaborative involvement of stakeholders through cloud-based BIM is an efficient thing in the construction industry for the stakeholder to make efficient and effective collaboration. However, the significance of the advantages changes from the research review to real situation. For example, while the literature considers real-time monitoring

to be the most essential advantage stakeholder collaborative involvement through cloud-based BIM, in the industry, accuracy is the critical component that comes from the stakeholder collaborative involvement through cloud-based BIM. Through a literature analysis, the limitations for collaborative engagement through cloud-based BIM were discovered and rated appropriately. Table 6 depicts the constraints of stakeholder interaction using cloud-based BIM.

Table 5: Benefits of collaborative involvement through cloud-based BIM

Code	Factor	Mean	Rank
C1.	Accuracy	4.53	1
C2.	Minimise the practical difficulties of design	4.5	2
C3.	High collaboration	4.45	3
C4.	No need for a physical location	4.45	3
C5.	Easy communication	4.39	5
C6.	Backup and recovery	4.39	5
C7.	High storage capacity	4.37	7
C8.	Real-time monitoring	4.32	8
C9.	Transferring of data	4.29	9
C10.	Document handling	4.24	10
C11.	Trust development among the stakeholders	4.24	10
C12.	Data transfer quality and productivity improvement	4.16	12
C13.	Resource sharing	4.13	13
C14.	Project cost reduction	4.11	14

Table 6: Limitation for the collaborative involvement through cloud-based BIM

Code	Factor	Mean	Ranking
D1.	Hesitation	4.08	3
D2.	High implementation cost	4.05`	4
D3.	Changing of organisation culture	4.21	2
D4.	Data security and protection	4.03	5
D5.	Legal uncertainty	3.58	9
D6.	Higher requirement of computer resources	4.26	1
D7.	Unpredictability of performance	2.97	12
D8.	Trust related issues	3.39	10
D9.	Limited size of document sharing	3.71	8
D10.	Data ownership	3.39	10
D11.	Lack of awareness	4.03	5
D12.	Lack of skilled professionals	4.03	5

According to the data survey results, respondents said that the limitations for the stakeholder collaborative involvement through cloud-based BIM in the construction industry had a positive impact. Based on this the conclusion was made that, these limitations have an influence on the collaborative involvement of stakeholders through

cloud-based BIM. When it comes to rating theory vs practice, there is not much of difference in either situation. The amount of stakeholder participation in the construction sector was explored using questionnaire data, and to complete this research, a semi-structured interview was conducted, as will be explained Below.

Based on the findings, which come from the above table 3 the conclusion was made that, the stakeholders face many challenges during the conventional involvement of stakeholder. In addition to that, the collaborative involvement level through cloud-based BIM is considerably negative impact, which was presuming through table 4, as well as Table 5 pointed out that, the collaborative involvement though cloud-based BIM is highly beneficial. In this way, the benefits come from the collaborative involvement through cloud-based BIM has a positive impact, but the involvement level through cloud-based BIM is considerably low. According to that, there is a requirement to analyse the reasons for the negative impact in the stakeholder collaborative involvement through cloud-based BIM.

4.2 SEMI-STRUCTURED INTERVIEWS

The mani goal of semi-structured interviews is to figure strategies for limiting stakeholder collaborative involvement using cloud-based BIM. During the interview, most of the interviewees highlighted some important strategies for reducing the limitation to the collaborative involvement through cloud-based BIM, such as training sessions, initiating BEP plans, changing government regulations and taxes, providing a BIM centre with the help of CIDA and renting it out, and making technical knowledge a piece of key knowledge for employees during the recruiting process. Furthermore, I-1 predicted that, "if the client demand to do the work with the specific set of software, the stakeholders cannot avoid it", while I-5 and I-8 suggested "running pilot project under the overhead cost of organisation and checking whether the project is running properly or not within the particular period with the estimated amount". All except I-1 stated that obtaining government concessions to make a favour and decrease taxes to offer the organization purchasing power to purchase software and resources. In addition to that, I-2 and I-9 suggested to purchasing software rather than individually to avoid high-cost problems, although the collective purchasing have security problem", and I-3, I-4, I-7, and I-9 mentioned strategies such as providing training and awareness programs to improve the awareness of the stakeholders. I-5, I-7, I-10 stated that, once employees are trained, they should be involved in the pilot project within the organisation and see how it works in terms of time, cost, and quality and then prepare a manual and distribute it throughout the organisation to make employees aware of the importance of using technology in their day-to-day activities". I-5, I-7, and I-9 explained, "CIDA and government engage in software purchasing jointly and construct a BIM centre to an open environment for stakeholders to rent and utilize". Accordingly, the following table 6 summarises the strategies to reduce the limitation for As a result, Table 6 summarizes the techniques for reducing the limitations for cloud-based BIM in the construction sector.

Table 6: The strategies to reduce the limitations for cloud-based BIM in the construction industry

Factor	Strategies
Hesitation	• Involvement of the higher management • Client demands the stakeholder to do in a specified system • Government support and purchase power of the organisation • Proper training and awareness programme about the technology • Provide work programme and knowledge sharing programme • Develop a proper framework for the technology • Give education from level 1 for the university students
High initial cost (Implementation cost)	• Provide BIM centre with the help of CIDA, then professional rent it out for their work • Support by the Government by reducing taxes • Purchase power of the organisation • Allocate budget for the purchasing and training the employees
Change organisation culture	• Proper training will reduce this issue • Educate and promote these technologies free of charge • If the organisation reduces the hesitation, then this issue can be shorted out automatically • Develop a proper BIM Execution Plan (BEP) programme within the organisation to interconnect the stakeholders • Recruit the employees with proper technical knowledge
Data security and protection	• Recruit proper Information Technology (IT) concession, people • Regular checking of the system • Develop proper BEP and data security plans within the organisation • Bring proper protection tool which is available in the market and check the system regularly
Legal uncertainty	• Proper BEP plans and amends the contracts to use the technology • Clearly define the rules and regulations for the stakeholders • Government makes laws with the help of CIDA • Relevant authorities implement laws to accept Electronic Data (E-data)

Factor	Strategies
Higher requirement of computer resources	• Development of BIM centre • Use own computer for the work and processing work will be done in the higher speed computer • Purchase power of the organisation • Support by the Government by reducing taxes • Purchase as a group not as individual • Allocate budget within the organisation
Unpredictability of performance	• Make proper BEP plans • Have some backup system to backup data • Under the overhead cost of the organisation run, the pilot project checks its works or not
Trust related issues	• Proper BEP plan and mention the roles and responsibilities for the stakeholders • Define the rules and responsibilities in the supplementary agreement • Provide training programmes • Improve legal background and security background • Provide access for the required person • Maintain data library through the stakeholder system and share with a link through the model
Limited size document sharing	• Purchase power of the organisation again sort out the higher implementation cost it can be sorted out • Purchase space in the cloud for the storage and pay for it annually
Data ownership	• Make proper BEP plans and address responsibilities of the stakeholders clearly and agreed by all of them • Recruit proper IT concession people • Improve the awareness of the stakeholders • Improve the legal background

Factor	Strategies
Lack of awareness	• Make awareness programme • Proper training programme from the university level and Continuous Professional Development (CPD) • Do workshops with the help of the software companies • Based on the top management's decision to give proper education about the system • Allow budget for training the employees • Make the knowledge of the technology a requirement for the employees when recruiting them.
Lack of skilled professionals	• Make awareness programme • Proper training programme from the university level and Continuous Professional Development (CPD) • Do workshops with the help of the software companies • Based on the top management's decision to give proper education about the system • Allow budget for training the employees • Make the knowledge of the technology a requirement for the employees when recruiting them. • Initially train one set of people and evaluate how they work, then they become experts and train another set of people

5. CONCLUSIONS AND RECOMMENDATIONS

This study evaluates the extent of cloud-based BIM involvement in the construction industry as well as mitigation methods to improve the collaborative involvement through cloud-based BIM. According to the data collection findings, the collaborative involvement of stakeholders through cloud-based BIM is at a low level, even though stakeholders encountered several challenges in the conventional method of collaboration and advantages from stakeholder collaborative involvement are high. The key disadvantages of conventional methods include: lack of stakeholder's collaboration, a lack of involvement in crucial decision-making process, and performance inefficiency. At the same time efficient communication, tracking features, time management, money management, and document management have been accomplished through cloud-based BIM in effective and efficient manner. However, several constraints influence the extent of collaborative involvement through cloud-based BIM such as lack of skilled professionals, high implementation cost, hesitation, and data security and protection are some key contraints. Some strategies mentioned by interviewees to increase stakeholder collaborative involvement level through cloud-based BIM are: providing a training session for the staff; collaborating with the government to make regulations and reduce taxes; collaborating with CIDA to provide BIM centre and rent it out to construction firms; making technology knowledge a mandatory thing during the recruitment time; and improving BEP plans to use the technology. Furthermore, the collaborative involvement through cloud-based BIM is not appropriate for smaller-scale projects since the initial cost for cloud-baes BIM is greater than the overall contract sum of the project. When it comes to the Sri Lankan construction industry, cloud-based BIM is a cutting-edge technology and only few construction firms are involving the cloud-based BIM in the early stages or up to a certain point including construction process, however, they cannot use it throughout the entire project. Furthermore, this study suggest that in the Covid-19 pandemic situation, the stakeholder collaboration through cloud-based BIM is beneficial to increase the progress of the project, because of the travel restrictions all over the island and, therefore, it is helpful to the stakeholder to investigate the progress of the project and maintain the records without any issues and anyone can assess and get the detail easily to get a status of the project. According to this, the collaborative involvement through cloud-based BIM is a good approach for stakeholders to involve in the project efficiently and effectively.

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