Adoption and implementation of Building Information Modeling (BIM) application into Sri Lankan construction industry

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Abstract— *As a new paradigm in the sustainable construction industry, BIM has a great potential for professionals. The main objective of this paper evaluates the adoption and implementation of BIM into Sri Lankan construction industry. This study mainly tested the hypothesis whether the effective usage of BIM applications increases the effectiveness and efficiency of service delivery in Sri Lankan construction industry. Data were collected through a designed questionnaire by examining the factors which impact as barriers the implementation of BIM and determine factors which may increase the efficiency and effectiveness of BIM implementation in Sri Lankan construction industry. In this study, a questionnaire survey based on the non-probability sampling was carried out to gather the possible inefficiencies, barriers and driving factors for BIM implementation in Sri Lankan construction industry Further, the relative importance index (RII) formula was used to establish the respondent's ranking on each of the BIM implementation inefficiencies, barriers and driving factors.*

Research findings indicate adoption and implementation of BIM affected by the financial strength of a company. Further, Cost of implementation is high with an RII value of 0.945 which is the most significant challenge to BIM implementation in the Sri Lankan construction Industry. And this study indicated that Enhancing BIM training program with RII of 0.940 and Conducting Seminars, workshops and short courses with RII values of 0.930 are most significant approaches to overcoming the barriers of BIM implementation and adoption in Sri Lanka. Therefore, based on the findings of this study, it can be said that effective usage of BIM applications increases the effectiveness and efficiency of service delivery in Sri Lankan construction industry. Moreover, this study suggests that recommended strategies are required to be undertaken in order to promote the implementation and adoption of BIM applications in Sri Lankan Construction industry.

Keywords— Building Information Modeling (BIM) barriers, Challenges with BIM Adoption and Implementation, BIM adoption on Projects

I. INTRODUCTION

Building Information Modelling (BIM) is an IT enabled technology that allows storage, management, sharing, access, update and use of all the data relevant to a project through the project life -cycle in the form of a data repository. BIM enables improved inter -disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management. Application of BIM is essential and leads to the industry in sustainable construction that emphasizes long-term accessibility, quality and efficiency in general. There is growing awareness and concern among the consultants and the general construction companies on the adoption and implementation of BIM. However, there is a requirement to understand current state of BIM roles and future needs in construction industry. The way of implementing BIM should be planned and implementation could face challenges in construction industries, which must be identified and solved.

Therefore this research is aimed to evaluate the adoption and implementation of BIM into Sri Lankan construction industry. The main objective of this research is to examine the factors which impact as barriers the implementation of BIM applications for construction industries in Sri Lanka and determine factors which may increase the efficiency and effectiveness of BIM implementation in Sri Lankan construction industry.

II. BUILDING INFORMATION MODELING (BIM): AN OVERVIEW

According to Dossicket al. (2009),BIM is an integrated technology process to allow management of efficient services. Moreover, according to Eastman et al. (2008), BIM is the set of technologies process in the construction industry, and the result is a practical perfect model of construction. If fully integrated, the virtual model considers cost, planning, sustainability and health and safety etc for construction project through design, procurement, operations and demolition of the constructed facility.

Systematically BIM is used as the key communication implement in the building procedure. Projects of the planning, designing, constructing use of BIM have confirmed to fully satisfy the customer necessity in terms of cost, quality and time completion (Dossicket al. 2009). BIM is the practical depiction of possibly covering whole evidence needed to construct building as used by the software. Moreover, BIM technologies and processes enable different performance levels or stages of use with a varying degree of integration such as file-based and model-based collaboration which is known as integrated BIM. For the design collaboration file base, projects participants produce BIM models. Based on model collaborative models, all participants work in a synchronized central model that is integrated and can be shared between them in phase of the project.

A. *The benefits of BIM*

The benefits of BIM are time, cost efficiency, visualization, reduce rework, improvisation on work program or planning or productivity and early finding of problems (BSI,2010). Effective and efficient processes in BIM technology information can easily be shared and value-added and used again. Further, according to Ghanem and Wilson (2011) stated that mostly BIM reduce rework as significant benefit. Moreover, documentation output is flexible and utilizes computerization. Digital information can be exploited in downstream processes which is used for developing structural systems. BIM not only reduces cost and time, but also reveals clashes, gaining client confidence and post completion operations and maintenance (M. Mandhar, 2013).

B. *BIM adoption and implementation*

Participants in the building process are constantly challenged to deliver successful projects despite tight budgets, limited manpower, accelerated schedules, and waste (NBS, 2013). The Architecture, Engineering and Construction (AEC) industry has long sought to adopt techniques to decrease project cost, increase productivity and quality, reduce project delivery time, and eliminate waste (Azhar et al. 2008a) One of these techniques is Building Information Modeling (BIM). Azhar et al. (2008b). They said that BIM has recently attained widespread attention in the AEC industry. Moreover, there must be better communication quality, increased coordination through visualization for capabilities of BIM adoption.

i. *Barrier to BIM adoption and implementation:*

Thurairajah and Goucher (2013) identified the main barriers of BIM implementation such as cost, method requirements, lack of knowledge and willingness to culture change. The challenges for adoption of BIM in the Sweden construction project process were personal opinions towards BIM, difficulties in implementation of BIM software, and lack of knowledge (Lahdou and Zetterman, 2011)

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Khosrowshahi and Arayici (2012) recognized the major causes to failure BIM implementation in the UK and Finland are firms are not familiar enough with BIM use, reluctance to initiate new workflows or train staff, benefits from BIM implementation do not outweigh the costs to implement it, benefits of BIM are not tangible enough to warrant its use, lacks the capital to invest in having started with hardware and software, resistance to culture change, and no demand for BIM use. Kassem et al. (2012) observed the barriers to adopt BIM and 4D in the UK civil and building industry. They found that the greatest barriers were shortage of experience within the workforce, and lack of awareness by stakeholders. Crowley (2013) discovered that the possible barriers to BIM implementation are lack of training, lack of client demand, lack of government lead and lack of standards.

Some difficulties for BIM implementation were overall lack of knowledge and understanding of what BIM is, a strong training requirement associated with BIM implementation to gain the full advantages from it, and the need for detailed understanding of cost consultants' challenges during the implementation of 5D BIM in construction projects (Thurairajah and Goucher, 2013).

Further, Aibinu and Venkatesh (2013) reported the barriers to the adoption of BIM were cost of implementation, lack of awareness of the benefits from cost benefit analysis perspective, lack of demand by clients, lack of trust in the integrity of BIM; and adaptation issues, and technology change and ability of firms to adapt to the change from cultural perspective and financial perspective.

ii. Solution for BIM implementation:

The possible solutions are categorized as initiatives and incentives. Need to play biggest roles as driving force such as training the staff on new software, lack of knowledge, setup cost and time, purchase and update new software to ensure BIM technology will be successfully implemented in BIM. However, Solution for BIM implementation will be successful when collaboration of work together. (The IT Construction Forum, 2006).

BIM implementation is present development in the construction industry. However, in this situation construction industries face some barriers. So, every professional needs to overcome their barriers to make their business successful. So, it is needed to improve their knowledge and skills in BIM and apply into their daily practice, providing financial incentives, training staff, and lack of IT knowledge which, are an essential pre-requisite for BIM implementation. In conclusion, literature reviews identify the barriers and driven factors of BIM adoption and implementation. Moreover, open ended questionnaire is also used to validate the findings.

III. Methodology

In this study, an exploratory survey was used to determine and identify the relative importance of the barriers and the driven factors in implementing Building Information Modelling (BIM) in the Sri Lankan construction industry from the perception of Engineers, Architects and contractors. The survey questionnaire consists of four sections. The first section was to identify the respondents' profile. Second section was designed to identify the capabilities of BIM, third section of the questionnaire focused on the barriers factors in implementing BIM and the last section of the questionnaire was designed to identify the relative importance of the driving factors in implementing BIM. In order to identify the relative importance of the barriers in implementing BIM, there was a total of 10 variables used while identifying the relative importance of the driving factors in implementing BIM. There was a total of 10 variables used and among these significant variables, they were grouped into two categories to verify whether two population means are equal or not. All these variables were selected from the literature. The respondents were asked to select their choices through open-ended questions by ticking a column of the relative importance of each of the question. A five-point Likert scale ranging from 1 which represented the least important to 5 which represented the most important was being used to capture the inefficiencies, capabilities of BIM, barriers and the driving factors in implementing Building Information Modelling (BIM) in the Sri Lankan construction industry.

Due to the subjective nature of this research, the non-probability sampling was used. The sample's addresses were obtained from the Sri Lankan Construction Industry. The questionnaire was distributed via email to the 150 potential respondents at all levels in their organisations. These responses were tabulated and analysed using computer software. A total of 130 responses were received from architects, engineers and contractors. 60 responses were from architects and the rest of 70 from Engineers and contractors.

The RII was calculated as:

$$RII = \frac{\sum W}{A*N}, \quad 0 < RII < 1$$

W: the weighting given to each factor by the respondents and range from 1 to 5

A:the highest weight (for example 5 in this case)

N: Total no of Respondents

The RII value had a range from 0 to 1 (0 not inclusive), the higher the value of RII, the more significant factor.

A. *Mann-Whitney U test*

Mann-Whitney U test is same as the independent sample t-test. Mann-Whitney U test is a nonparametric test that is used to compare two population or designation means that come from the same population. It is used to verify whether two population means are equal or not. Thus it is best to compare scores when the dependent variable is not normally distributed and at least of an ordinal scale. In this study, mean rank of Architect was compared with that of Engineer and Contractor. Mann-Whitney U test with Hypothesis is Ho (Null hypothesis) for there is no significant difference between two scores and H1 (Alternate hypothesis) for there is a significant difference between two scores.

IV. Results and Discussion

Moreover, as discussed in the above methodology, this chapter includes comparisons of the findings of the questionnaire survey with the findings of the literature survey which is possible in order to validate the findings

A. *Section One: Respondents details.*

This section mainly elaborates an analysis of four preliminary questions which were included in the questionnaire in order to gather a small amount of background information on the respondents and the current status of BIM application usage in their organizations. Respectively, respondents‟ designation, current employer and work experience.

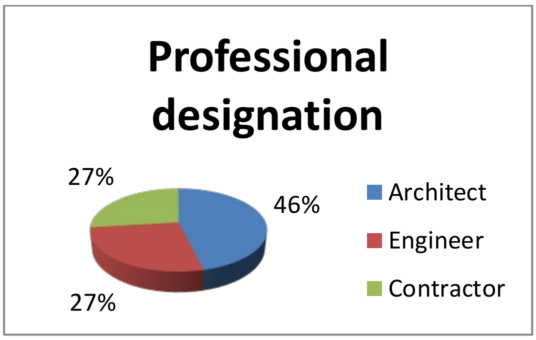

Figure- 1: Respondent's Profession

The aim of the question was to identify the current role of the respondents involved in the questionnaire survey. As has been demonstrated in the Figure 1, the majority of the respondents were represented by Architect (46%). In addition, 27% of contractor and Engineer were involved in this survey.

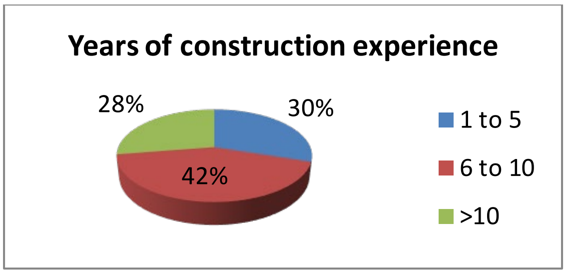

Figure- 2: Composition of years of construction experience

As has been demonstrated in the Figure 2, the majority of the respondents were represented by years of experience ranging 6-10 years (42%). In addition, 30% of respondents having 1-5years of experience and 28% of respondents having >10 years of experience in construction field were involved in this survey.

B. Section two: Inefficiencies and capabilities of BIM

This section mainly explains an analysis of three preliminary questions which were included in the questionnaire in order to identify the most significant issues which may arise as a result of the inefficiencies of the current construction status in Sri Lanka and capabilities of BIM. Furthermore, this section outlines the comparison of the most significant factors identified in the questionnaire survey with the findings of the literature survey.

Inefficiencies		RII	Rank
01	Cost overruns	0.812	1
02	Rework	0.652	5
03	Poor communication and Conflicts.	0.701	4
04	Material Wastages	0.703	3
05	Delays	0.798	2

Table 1: Inefficiencies of the current practice in Sri Lankan construction Industry

As has been demonstrated in the Table 1, the majority of the respondents stated that the "cost overruns" was the most significant issue which arises as a result of inefficiencies of the current construction in Sri Lanka and that was ranked by the respondents with RII of 0.812. In addition, "Delays" with RII of 0.798, "Material wastages" with RII of 0.703 and finally "Poor communication and conflicts" with RII of 0.701 were ranked by the respondents of the questionnaire survey as significant issues. However, "rework" was considered as an insignificant issue, because its RII value ranked below the average of RII value.

Capabilities of BIM		RII	Rank
01	Improve visualization for better understanding	0.842	1
02	Cost checking performs quickly	0.803	2
03	Preliminary cost plans	0.762	4
04	Clash detection reduces design errors and cost estimate revisions	0.782	3

Table 2: Capabilities of BIM

The aim of the question was to identify the most important capabilities of BIM application which may help to enhance the effectiveness and efficiency of Sri Lankan construction industry.

As has been demonstrated in the Table 2, "Improve visualization for better understanding of design" was observed as the highest ranked capability of BIM applications where the majority of respondents of the questionnaire survey stated that with RII of 0.842. Respectively, "Cost checking performs quickly" was ranked second with RII of 0.803, "Clash detection reduces design errors and cost estimate revisions" was ranked third with RII of 0.782 and "Preliminary cost plans" was ranked fourth with RII of 0.762 However, the factors which were below the average of RII values ($RII \leq 0.7972$) were considered as insignificant capabilities of BIM applications.

Therefore, based on the Questionnaire survey, this study established that the "Improve visualization for better understanding of design" and "Cost checking performs quickly" are the most significant capabilities of BIM applications which may help to enhance the effectiveness and efficiency in Sri Lankan construction industry.

C. Section three: barriers of BIM Adoption and implementation of BIM

Practices		RII	Rank
01	Higher cost of hardware and software	0.894	3
02	Software is not user-friendly	0.702	7
03	Lack of client demand	0.882	4

04	Any legal/contractual issues from the use of BIM	0.692	9
05	Aware of the benefits of BIM	0.875	5
06	Aware of how to use BIM	0.875	5
07	Non-availability of market support	0.655	10
08	Costly training requirements in terms of time, persons and money	0.895	2
09	Cost of implementation is high	0.945	1
10	No encouragement from Sri Lankan government to implementation of BIM.	0.700	8

Table 3: barriers of BIM Adoption and implementation

As has been demonstrated in the Table 3, "Cost of implementation is high" was observed as the highest ranked barrier for the adoption of BIM applications where the majority of the respondents of the questionnaire survey stated that with RII of 0.945. Respectively, "Costly training requirements in terms of time, persons and money" was ranked second with RII of 0.895, "Higher cost of hardware and software" was ranked third with RII of 0.894, "Lack of client demand" was ranked fourth with RII of 0.882, "Aware of the benefits of BIM" and "Aware of how to use BIM " were ranked fifth with RII of 0.875. However, the factors which were registered below the average of RII values (RII ≤ 0.815) were considered as insignificant barriers for the adoption BIM applications. Therefore, Cost of implementation is high which was identified as most significant barrier in BIM adoption and implementation in Sri Lankan construction industry.

Most Significant Barriers	**Designation**	**Mean Rank**	**P_Value**
Cost of implementation is high	Architect	65.82	0.425
	Engineer &Contractor	75.65	
Costly training requirements in terms of time, persons and money	Architect	71.78	0.812
	Engineer & Contractor	71.05	
Higher cost of hardware and software	Architect	71.89	0.805
	Engineer & Contractor	71.65	
Lack of client demand	Architect	70.68	0.902
	Engineer & Contractor	70.95	
Aware of the benefits of BIM	Architect	70.45	0.802
	Engineer & Contractor	70.25	
Aware of how to use BIM	Architect	68.52	0.801
	Engineer & Contractor	72.54	

Table 4: The Mann-Whitney U test results

The Mann-Whitney U test results for the top five highest RII values are shown in Table 4. There all the p values are greater than 5% suggesting that Null hypothesis (Ho) i.e., there is no significant difference between two scores is true and Alternate hypothesis (H1) i.e., there is a significant difference between two scores, is false. Thus these results indicate that there is not much difference of opinion between the Architects and the Engineers and Contractors that, the cost of implementing is one of the major challenges in BIM implementation in Sri Lankan construction industry.

D. Section four: Driving factors of BIM implementation and adoption

Driving factors		**RII**	**Rank**
01	Facilitating cost-savings during design	0.8	7
02	Improving cost estimation and control abilities	0.705	10
03	Increasing clients' satisfaction	0.795	8
04	Enhancing quality of the finished product	0.715	9
05	Enhancing collaboration on projects	0.815	6
06	Recognize the benefits and importance of using BIM	0.910	4
07	Encourage staff to use BIM applications	0.825	5
08	Enhancing BIM training program	0.940	1
09	Conducting Seminars, workshops and short courses	0.930	2
10	Support and enforcement in the implementation of BIM by the government	0.928	3

Table 5: Driving factors of BIM implementation and adoption

As has been demonstrated in the above table 5, "Enhancing BIM training program" was observed as the highest ranked strategy required to be taken to promote the adoption and implementation of BIM applications where the majority of the respondents stated that with RII of 0.940. Respectively, "Conducting Seminars, workshops and short courses" was ranked second with RII of 0.930 ,"Support and enforcement in the implementation of BIM by the government" was ranked third with RII of 0.928 and "Recognize the benefits and importance of using BIM" was ranked fourth by with RII of 0.910 by the respondents of the questionnaire survey as significant strategies required to be taken to promote the adoption and implementation of BIM applications in Sri Lankan construction industry. However the factors which registered below the average of RII values (<0.8363) were not considered as the significant strategies.

Most Significant Driving Factors	**Designation**	**Mean Rank**	**P_Value**
Enhancing BIM training program	Architect	75.63	0.825
	Engineer & Contractor	72.15	
Conducting Seminars, workshops and short courses	Architect	69.87	0.915
	Engineer & Contractor	70.25	
Support and enforcement in the implementation of BIM by the government	Architect	72.81	0.725
	Engineer & Contractor	72.49	
Recognize the benefits and importance of using BIM	Architect	71.5	0.705
	Engineer & Contractor	70.25	

Table 6: The Mann-Whitney U test results

The Mann-Whitney U test results for the top four highest RII values are shown in Table 6. There all the p values are greater than 5%. Thus these results indicate that there is not much difference of opinions between the Architects and the Engineers and Contractors that, the cost of implementing is one the major challenge in BIM implementation in Sri Lankan construction industry.

V. Conclusion

Many evidences show that Building Information Modeling (BIM) can enhance the construction performance but the rate of implementation of BIM in the Sri Lankan n construction industry has been at a slow pace. As a result of the findings revealed that the main challenges to the adoption and implementation of BIM were Cost of implementation is high, Costly training requirements in terms of time, persons and money, Higher cost of hardware and software, Lack of client demand, Aware of the benefits of BIM and Aware of how to use BIM. It is recommended for that Enhancing BIM training program, Conducting Seminars, workshops and short courses, Support and enforcement in the implementation of BIM by the government and Recognize the benefits and importance of using BIM. Further, results demonstrated that the effective usage of BIM applications aids to mitigate the above mentioned constraints and also the above discussed significant capabilities of BIM applications help to enhance the effectiveness and efficiency of the Sri Lankan construction industry. It will lead to complete the building construction project by achieving all project goals. Thus, finally following these recommendations should give more effective and efficient project delivery with quality in Sri Lankan construction industry while adopting BIM implementation.

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