APPLICABILITY OF BIM IN CONSTRUCTION WASTE MINIMIZATION OF SRI LANKAN CONSTRUCTION INDUSTRY

H.I.W. Madushanka, H.S. Jayasena and M.K.C.S. Wijewickarma
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The construction industry consumes a larger proportion of natural resources and produces massive volumes of waste. This has become a burden to construction stakeholders, as it leads to extensive overhead costs, project delays, less productivity and additional work. Thus, the construction waste has challenged the successful project performance and sustainable goals. Construction waste can be generated mainly due to design changes during construction. Consequently, in comparison with the other stages, design stage has a wider opportunity to reduce the excessive construction waste. This could be easily achieved through Building Information Modelling (BIM), which allows the construction team to compile, analyze and communicate design information in a collaborative working platform to reach the final sustainable design. However, BIM has achieved only a kindergarten stage in Sri Lankan construction industry. Thus, the research aims to identify the challenges of implementing BIM for waste minimization in Sri Lankan construction industry. In order to achieve the aim, an in-depth documentary survey was conducted. The final conclusion of the research reveals that, BIM can be adopted for construction waste minimization in Sri Lanka. However, this BIM integrated waste minimization process embraces a number of challenges which should be mitigated cautiously for a better consequence.

Keywords: *Building Information Modelling (BIM); Design Stage; Sri Lanka; Waste Minimization.*

1. INTRODUCTION

The construction industry is mounting and emerging unceasingly in all over the world (Vieira *et al*., 2016). Along with this rapid development, greater volumes of construction waste generated and accumulated (Wang *et al*., 2013). This abundant generation of construction waste significantly challenges the sustainable development of entire construction industry (Kulatunga *et al.,* 2006). Therefore, it is important to implement effective procedures, which can minimize the generation of construction waste.

Building Information Modelling (BIM) is a revolutionary paradigm, which espouses modernization to the conventional Architectural, Engineering, Construction and Operations (AECO) industries (Cheng *et al.,* 2015). According to Utiome (2010), BIM holds modest tools and technologies, which enable to design and forecast issues related to the sustainable constructions. Further to him, incorporating BIM into the design stage of a construction project helps to minimize immense generation of construction waste. However, BIM has attained only an infant stage in Sri Lankan construction industry (Jayasena and Weddikkara, 2013). Therefore, it is important to study on, the applicability of BIM in construction waste minimization in Sri Lankan context.

2. CONSTRUCTION WASTE

Modern construction industry has attained a hasty development due to the extensive growth of population and continuous industrialisation (Vieira *et al.,* 2016). As a consequence, greater volumes of construction waste have generated, which adversely affect the serenity of environment and human lifestyle (Wand *et al.,* 2013). According to Harvard Green Campus Initiative (2005), construction waste is abandoned substances generated in the building and infrastructure activities of construction, renovation and demolition. Large number of material waste has become a common sight in current construction sites. Generally, construction waste consists larger number of natural resources, which are removing from sites without grabbing their real essence of value (Wang et *al.,* 2013). According to Roach (as cited in Rameezdeen *et al.,* 2004), construction waste occupies 40 % of total global waste. However, this has

become worse in local context and the percentage has exceeded the global accepted levels (Jayawardane, 1994). Generally, construction waste increases the construction cost and creates unnecessary delays (Koushki and Kartam, 2004). Therefore, it has become a burning issue not only because of its cost efficiency, but also due to its adverse effects on the environment (Rameezdeen *et al.,* 2004). Thus, it is important to implement proper mechanism to minimize the generation of construction waste in modern construction industry.

Ekanayake and Ofori (as cited in Rameezdeen *et al.,* 2004) explicated that, incorporation of design changes during construction, accelerates the rate of generating construction waste in a project. Kulatunga *et al.,* (2006) further confirmed that, changes to the design is the most significant cause of generating construction waste in the industry. As per Liu *et al.,* (2015), 33% of construction waste is generated due to the lapses in design stage decisions. Thus, it is important to distinguish the forces, which motivate the generation of construction waste during design stage of a construction project. According to Kulatunga *et al.,* (2006), better understanding on client's requirements, accurate detailing the documents, understanding the project environment, implementation of approaches required for sustainable construction will lead to less construction waste. Further to them, involvement of human at the pre-contract stage has a great influence for waste minimization. Moreover, Cheng *et al,* (2015) expounded that, incorporation of BIM in a construction project has also created an ideal solution for effective management of construction waste.

3. RESEARCH METHODOLOGY

A comprehensive literature survey was conducted to identify the construction waste generation factors at the design stage. Further, the role of BIM at the design stage was exhaustively identified through literature synthesis. Moreover, the suitability of BIM for waste reduction was explored in advance by identifying its capabilities to overcome the waste generating factors. The literature survey used journals, books, conference proceedings and previous researches to develop an in depth discovery on BIM functions and waste generating factors at design stage separately for the further analytical works. Subsequently, the capability of BIM functions to overcome the waste generating factors and the practical problems which barricade this phenomena were identified through a documentary survey. Documentary survey was accompanied by online discussions at professional networks, personal and company blogs, websites, online forums, online magazines, BIM guidelines and case studies.

4. CONSTRUCTION WASTE GENERATING FACTORS AT DESIGN STAGE

According to Hungu (2013), decisions made during early design stage immensely impact the ultimate project outcomes. Accordingly, the lapses in design stage decisions have a greater impact on construction waste generation. Faniran and Carban (1998) expressed that, 52% of total construction waste has generated due to poor design stage decisions. Thus, it is important to recognize these poor design stage decisions, which encourage the generation of construction waste in advance. The Table 1 clearly illustrates the construction waste generating factors at design stage and their respective literature source.

Table 1: Construction waste generating factors at design stage

	Factor	Sources			
		Naoum and Mustapha (2002)	Jaques (2000)	Sáez *et al.*, (2014)	Wortmann (2014)
1	Changes made to the design while construction is in progress	✓	✓		✓
2	Lack of attention paid to dimensional co-ordination	✓			✓
3	Designer's inexperience in method and sequence of construction	✓			✓
4	Lack of attendance paid to standard sizes available on the market				✓
5	Lack of communication and collaboration between design team		✓	✓	✓
6	Designer's unfamiliarity with alternative products, complexity, errors			✓	✓

	Factor	Sources			
		Naoum and Mustapha (2002)	Jaques (2000)	Sáez *et al.*, (2014)	Wortmann (2014)
7	Incomplete contract documents		✓	✓	
8	Design and construction detail errors		✓	✓	
9	Selection of low quality products		✓	✓	

5. BUILDING INFORMATION MODELLING (BIM)

According to Eastman *et al.*, (2011), building information model is a digital representation of physical and functional characteristics of a facility. It can be introduced as the most innovative technology which dominates the modern AECO industries. As per the definition given by National BIM Standards – United States (NBIMS-US, 2016), "building information model is a shared knowledge resource for information about a facility forming a reliable basis for decision making during its life cycle; from earliest conception to demolition. (para. 1)." Thus, it is an integrated building design, which allows the construction team to communicate, develop and make effective decisions during the whole life cycle of the facility. BIM has provided an operative foundation for construction projects by providing an effective information delivery and data managing module from early inception to completion of a facility. Royal Institute of British Architect (RIBA, 2012) has developed an overlay to identify the different BIM tasks before the construction starts. Accordingly, Liu *et al*. (2015) explicated the different uses of BIM at design stage of construction facility. The Figure 1 shows the functions of BIM generally generate at design stage in a BIM enabled construction project.

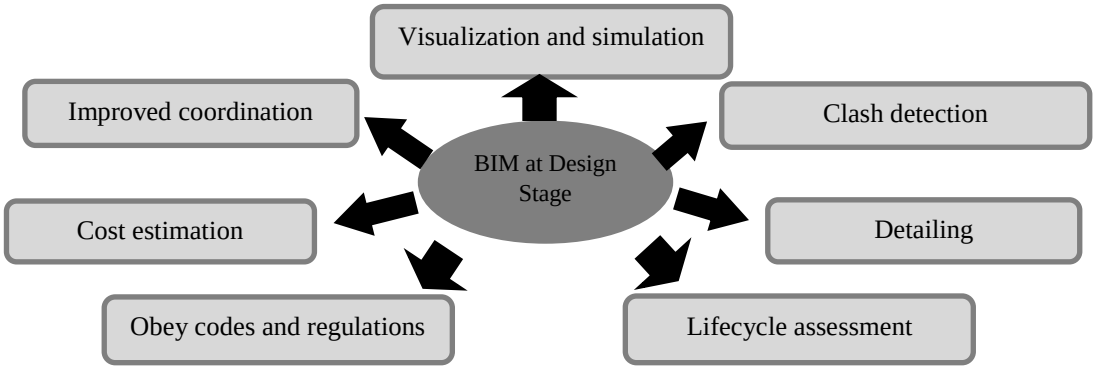

Figure 1: BIM Tasks at Design Stage

Adopted from: Liu *et al*. (2015) and Kreider and Messner (2013)

6. CAPABILITY OF BIM TASKS TO OVERCOME THE CONSTRUCTION WASTE GENERATING FACTORS

The potential ability of the design stage BIM functions to overcome the waste generation causes at the design stage was shown in the table 2. These are critical conclusions derived from extensive analysis of the documentary findings.

Table 2: Capabilities of BIM tasks to overcome the waste factors

Functions of BIM at design stage / Causes for the waste generation at design stage	Visualization and Simulation	Improved coordination and communication	Clash detection	Detailing	Lifecycle assessment	Obey codes and regulations	Cost estimation
Changes made to the design while construction is in progress	×	×	×				
Lack of communication and collaboration between design team	×		×	×			
Lack of attention paid to dimensional co-ordination	×	×					
Design and construction detail errors	×	×	×				
Designer's inexperience in method and sequence of construction	×					×	
Designer's unfamiliarity with alternative products, complexity, errors	×		×				×
Lack of attendance paid to standard sizes available on the market		×		×			
Selection of low quality products					×		×
Incomplete contract documents	×						

Even if, BIM provides an effective solution for waste minimization in construction industry, implementation of BIM is not considered as a smooth process. There are number of challenges which barricade the successful adaptation of BIM in construction waste minimization. Thus, it is important to discover these challenges, in order to develop a successful BIM implementation for waste minimization. The Table 3 clearly exhibits the problems, which challenge the implementation of BIM for waste minimization in local construction industry.

Table 3: Encountered problems, while implementing BIM

BIM Functions at Design stage	Encountered Problems
Changes made to the design while construction is in progress	
• Visualization and simulation	• Unavailability of same configuration in all the local systems of team members • Lack of commitment on BIM for project development
• Improved coordination and communication	• Un identification of centre persons on information management of team
• Clash detection	• Difficulties in identifying the use of model
Lack of communication and collaboration between design team	
• Visualization and simulation	• Difficulties in identifying the ownership of model • Unavailability of same configuration in all the local systems of team members
• Clash detection	• Personal differences in identifying LOD
• Detailing	• Less automation of the data • Inability to overcome from CAD mind-set
Lack of attention paid to dimensional co-ordination	
• Visualization and Simulation	• Inability to Pre-determination of model development method with the architect's support
• Improved coordination and communication	• Call in for new members to the design team at critical points
Design and construction detail errors	
• Clash detection	• Less organizing and maintenance of common folder in good standard • Unavailability of same configuration in all the local systems of team members
• Improved coordination and communication	• Difficulties in identifying the use of model
• Visualization and simulation	• Inability to award the maintenance liability of design at different stages of the project • Less automation of the data

BIM Functions at Design stage	Encountered Problems
Designer's inexperience in method and sequence of construction	
• Visualization and simulation	• Un-defining of the tasks which are required to done by AutoCAD • Less organizing and maintenance of common folder in good standard • Lack of knowledge of team members about BIM • Using single software instead of using multiple
• Obey codes and regulations	• Unable to develop the design according to accepted standard • Not applying the standard sizes of elements • Less practice of designers on project management tools
Designer's unfamiliarity with alternative products, complexity, errors	
• Visualization and simulation	• Unavailability of standard sizes in the market • Assigning a one LOD to entire project
• Clash detection	• Call in for new members to the design team at critical points
• Cost estimation	• Inserting the inaccurate data to the model
Lack of attendance paid to standard sizes available on the market	
• Detailing	• Unavailability of standard sizes in the market
• Improved coordination and communication	• Call in for new members to the design team at critical points
Selection of low quality products	
• Lifecycle assessment	• Difficulties in identifying the ownership of model • Inability to award the maintenance liability of design at different stages of the project
• Cost estimation	• Inaccuracy of manually entered data to quantity take-off
Incomplete contract documents	
• Visualization and simulation	• Lack of commitment on BIM for project development • Difficulties in identifying the ownership of model • Inability to award the maintenance liability of design at different stages of the project • Undefined what weight any BIM model will have contractually

7. CONCLUSION AND RECOMMENDATIONS

Construction waste has become a menace for the development of construction industry. Basically, lapses in design stage decisions contribute for higher percentage of waste accumulation in a construction project. BIM is the most innovative technology in construction industry, which has the capability of eradicating all the design stage causes which encourage the generation of construction waste. BIM has moulded with modern tools and techniques related to Information Technology (IT) and has produced number of tasks to annihilate all the causes, which influence construction waste generation. However, implementation of BIM for waste minimization is not an easy task. There are number of challenges which barricade the successful implementation of BIM for construction waste minimization. Thus, it can be recommended that, for a successful adaptation of BIM for construction waste minimization, all the identified challenges should be mitigated or exterminated.

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